General Information for the Rules and Regulations for the Classification of Ships

July 2014

Lloyd's Register

General Information

1. The 2014 edition of the Rules and Regulations for the Classification of Ships is a complete reprint of the 2013 edition, consisting of 8 books.

Part 1	Regulations
Rules for the Manufacture, Testing and Certification of Materials	
Part 3	Ship Structures (General)
Part 4	Ship Structures (Ship Types)
Part 5	Main and Auxiliary Machinery
Part 6	Control, Electrical, Refrigeration and Fire
Part 7	Other Ship Types and Systems
Part 8	Rules for Ice and Cold Operations

2. A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e., Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right hand digits may be added or omitted depending on the degree of precision required:
   (a) In same Chapter, e.g., *see* 2.1.3 (i.e., down to paragraph).
   (b) In same Part but different Chapter, e.g., *see* Ch 3,2.1 (i.e., down to sub-Section).
   (c) In another Part, e.g., *see* Pt 5, Ch 1,3 (i.e., down to Section).

   The cross-referencing for Figures and Tables is as follows:
   (a) In same Chapter, e.g., as shown in Fig. 2.3.5 (i.e., Chapter, Section and Figure Number).
   (b) In same Part but different Chapter, e.g., as shown in Fig. 2.3.5 in Chapter 2.
   (c) In another Part, e.g., *see* Table 2.7.1 in Pt 3, Ch 2.

3. The primary changes from the 2013 edition of the Rules are identified in the Summary of Changes. The effective dates of the indicated changes are 1 July 2013, 1 August 2013, 1 September 2013, 1 January 2014, 1 March 2014.

4. Until the next edition of the Rules and Regulations for the Classification of Ships is published, Rule change Notices and/or Corrigenda, as necessary, will be published on the LR Webstore — www.webstore.lr.org – and will be available for downloading free of charge. It is not intended at this time to publish hard copies of future Rule Notices to Existing Rules.

5. In this publication, a shortened version of the Notices has been reproduced listing all the paragraphs that have been altered since the last edition of the Rules. It is followed by a comprehensive Contents list of all books in the set, showing all the titles down to Section level.

Notice – Summary of Changes

Summary of Changes from the 2013 Rules

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 1					**Effective Date 1 August 2013**
2	2	2.8.3	Character of classification and class notations	Paragraph amended	2

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 1					**Effective Date 1 September 2013**
2	2	Table 2.2.2	Character of classification and class notations	Table amended	4
2	2	2.3.17 to 2.3.19	Character of classification and class notations	Paragraphs amended	3
2	2	2.8.4	Character of classification and class notations	Paragraph amended	4
2	2	2.8.5	Character of classification and class notations	New paragraph added	4
2	2	2.8.5	Character of classification and class notations	Paragraph renumbered	4
3	2	2.2.40	Annual Surveys – Hull and machinery requirements	Paragraph amended	4
3	2	2.2.41 & 2.2.42	Annual Surveys – Hull and machinery requirements	New paragraphs added	4
3	2	2.2.41	Annual Surveys – Hull and machinery requirements	Paragraph renumbered	4
3	5	5.3.19	Special Survey – General – Hull requirements	Paragraph amended	4

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 1					**Effective Date 1 January 2014**
2	2	2.8.3	Character of classification and class notations	Paragraph amended	6
2	3	3.5.13	Surveys – General	Paragraph amended	5
2	3	3.5.16	Surveys – General	Paragraph amended	5
3	1	1.5.19	General	Paragraph amended	3
3	1	Table 3.1.1	General	New Table added	3
3	6	6.2.1	Special Survey – Bulk carriers – Hull requirements	Paragraph amended	5
3	7	7.2.1	Special Survey – Oil tankers (including ore/oil ships and ore/bulk/oil ships) – Hull requirements	Paragraph amended	5
3	8	8.2.1	Special Survey – Chemical tankers – Hull requirements	Paragraph amended	5

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 1					**Effective Date 1 March 2014**
3	9	Table 3.9.3	Ships for liquefied gases	Table amended	8
3	17	17.2.2 to 17.2.4	Screwshafts, tube shafts and propellers	Paragraphs amended	8
3	17	17.2.6	Screwshafts, tube shafts and propellers	New paragraph added	8

Notice – Summary of Changes

Ch	Section	Para	Section Title	Status	Notice
Part 1					**Effective Date 1 July 2014**
2	2	Table 2.2.1	Character of classification and class notations	Table amended	9
2	2	Table 2.2.4	Character of classification and class notations	Table amended	9
2	2	2.3.21	Character of classification and class notations	Paragraph amended	9
2	2	2.3.21	Character of classification and class notations	Reference amended	10
2	2	2.4.2	Character of classification and class notations	Paragraph amended	9
2	2	2.6.2	Character of classification and class notations	Reference amended	10
2	2	2.8.7	Character of classification and class notations	New paragraph added	9
2	3	3.5.29	Surveys – General	Reference amended	9
2	3	3.8.4	Surveys – General	Paragraph amended	9
2	3	3.8.14	Surveys – General	Paragraph amended	9
3	1	1.5.18	General	Paragraph amended	9
3	1	1.6.5	General	Paragraph amended	9
3	1	1.6.11	General	New paragraph added	9
3	1	1.6.11	General	Paragraph renumbered	9
3	1	2.2.10	General	Paragraph amended	9
3	2	2.2.26	Annual Surveys – Hull and machinery requirements	Reference amended	10
3	5	5.3.5	Special Survey – General – Hull requirements	Paragraph amended	9
3	6	6.3.2	Special Survey – Bulk carriers – Hull requirements	Reference amended	9
3	7	7.3.2	Special Survey – Oil tankers (including ore/oil ships and ore/bulk/oil ships) – Hull requirements	Reference amended	9
3	7	7.5.1	Special Survey – Oil tankers (including ore/oil ships and ore/bulk/oil ships) – Hull requirements	Paragraph amended	9
3	7	7.5.2	Special Survey – Oil tankers (including ore/oil ships and ore/bulk/oil ships) – Hull requirements	New paragraph added	9
3	8	8.3.2	Special Survey – Chemical tankers – Hull requirements	Reference amended	9
3	8	8.5.1	Special Survey – Chemical tankers – Hull requirements	Paragraph amended	9
3	8	8.5.2	Special Survey – Chemical tankers – Hull requirements	New paragraph added	9
3	9	9.7.6	Ships for liquefied gases	Paragraph amended	9
3	14	14.2.4	Electrical equipment	New paragraph added	9
3	14	14.2.4 & 14.2.5	Electrical equipment	Paragraphs renumbered	9
3	14	14.2.6	Electrical equipment	Paragraph renumbered & amended	9
3	14	14.2.8 & 14.2.9	Electrical equipment	Paragraphs renumbered	9
3	14	14.2.10	Electrical equipment	Paragraph renumbered & amended	9
3	14	14.2.11 & 14.2.12	Electrical equipment	Paragraphs renumbered	9
3	14	14.2.12	Electrical equipment	Reference amended	10
3	14	14.3.1	Electrical equipment	Reference amended	9

Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Rules for the Manufacture, Testing and Certification of Materials				**Effective Date 1 August 2013**	
8	1	1.9.1	Plates, bars and sections	Paragraph amended	1

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Rules for the Manufacture, Testing and Certification of Materials				**Effective Date 1 January 2014**	
3	3	Table 3.3.1	Higher strength steels for ship and other structural applications	Table amended	2
3	3	Table 3.3.3	Higher strength steels for ship and other structural applications	Table heading amended	2
3	3	Tables 3.3.4 & 3.3.5	Higher strength steels for ship and other structural applications	Tables amended	2
3	3	Table 3.3.7	Higher strength steels for ship and other structural applications	Table amended	2
9	1	Table 9.1.1	Castings for propellers	Table amended	2
9	1	1.8.2	Castings for propellers	Paragraph amended	2
9	1	Fig. 9.1.2	Castings for propellers	Figure amended	2
9	1	Table 9.1.4	Castings for propellers	Table amended	2
11	1	Table 11.1.1	General	Table amended	2
11	3	Table 11.3.1	Electrodes for manual and gravity welding	Table amended	2
11	3	Table 11.3.2	Electrodes for manual and gravity welding	Table amended	2
11	3	3.3.4	Electrodes for manual and gravity welding	Paragraph amended	2
11	3	Table 11.3.3	Electrodes for manual and gravity welding	Table amended	2
11	4	Tables 11.4.1 & 11.4.2	Wire-flux combinations for submerged-arc automatic welding	Tables amended	2
11	4	4.4.2	Wire-flux combinations for submerged-arc automatic welding	Paragraph amended	2
11	4	Table 11.4.3	Wire-flux combinations for submerged-arc automatic welding	Table amended	2
11	5	Table 11.5.1	Wires and wire-gas combinations for manual, semi-automatic and automatic welding	Table amended	2
11	7	Table 11.7.1	Consumables for use in one-side welding with temporary backing materials	Table amended	2
12	2	–	Welding Procedure Qualification Tests for Steels	Section title amended	2
12	2	Table 12.2.3	Welding Procedure Qualification Tests for Steels	Table title amended	2
12	2	Table 12.2.3	Welding Procedure Qualification Tests for Steels	Table amended	2

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Rules for the Manufacture, Testing and Certification of Materials				**Effective Date 1 July 2014**	
1	3	3.1.3	Certification of materials	Paragraph amended	3
1	5	5.2.1	Non-destructive examination	Paragraph amended	3
1	6	Table 1.6.1	References	Table amended	3
2	3	Table 2.3.1	Impact tests	Table deleted	3
2	3	Table 2.3.1	Impact tests	New Table added	3
3	9	9.9.1	Bars for welded chain cables	New paragraph added	3
3	9	9.9.1 to 9.9.5	Bars for welded chain cables	Paragraphs renumbered	3
3	9	9.11.1	Bars for welded chain cables	Paragraph amended	3
4	8	Tables 4.8.1 & 4.8.2	Stainless steel castings	Tables amended	3
`4	8	8.5	Stainless steel castings	Sub-Section title amended	3

Notice – Summary of Changes

Ch	Section	Para	Section Title	Status	Notice
Rules for the Manufacture, Testing and Certification of Materials *(Continued)*				**Effective Date 1 July 2014**	
4	8	8.5.1 & 8.5.2	Stainless steel castings	Paragraphs amended	3
4	9	9.8.1	Steel castings for container corner fittings	Paragraph amended	3
5	9	–	Austenitic stainless steel forgings	Section title amended	3
5	9	9.1.1	Austenitic stainless steel forgings	Paragraph amended	3
5	9	9.1.3	Austenitic stainless steel forgings	Paragraph deleted	3
5	9	9.2	Austenitic stainless steel forgings	Sub-Section renumbered	3
5	9	9.2.1	Austenitic stainless steel forgings	Paragraph renumbered & amended	3
5	9	9.2	Austenitic stainless steel forgings	New sub-Section added	3
5	9	9.3	Austenitic stainless steel forgings	Sub-Section renumbered	3
5	9	9.3	Austenitic stainless steel forgings	New sub-Section added	3
5	9	9.4	Austenitic stainless steel forgings	Sub-Section title amended	3
5	9	9.4	Austenitic stainless steel forgings	Sub-Section renumbered & amended	3
5	9	9.4.1 & 9.4.2	Austenitic stainless steel forgings	Paragraphs deleted	3
5	9	9.7.1 & 9.7.2	Austenitic stainless steel forgings	New paragraphs added	3
5	9	Tables 5.9.1 & 5.9.2	Austenitic stainless steel forgings	New Tables added	3
5	9	Table 5.9.1	Austenitic stainless steel forgings	Table renumbered	3
7	1	1.1.1 & 1.1.2	General requirements	Paragraphs amended	3
7	1	1.7.2	General requirements	Paragraph amended	3
7	1	1.9.3	General requirements	Paragraph amended	3
7	3	Table 7.3.1	Spheroidal or nodular graphite iron castings	Table amended	3
7	4	–	Compacted or vermicular graphite iron castings	New Section added	3
7	4	–	Iron castings for crankshafts	Section renumbered	3
7	4	4.1	Scope	Sub-Section renumbered	3
7	4	4.1.2	Scope	Paragraph renumbered & amended	3
10	1	1.10.3 & 1.10.4	Anchors	Paragraphs amended	3
10	2	2.1.1 & 2.1.2	Stud link chain cables for ships	Paragraphs amended	3
10	2	2.7.6	Stud link chain cables for ships	Paragraph deleted	3
10	2	2.10.4	Stud link chain cables for ships	Paragraph amended	3
10	2	2.11	Stud link chain cables for ships	New sub-Section added	3
10	2	2.11	Stud link chain cables for ships	Sub-Section renumbered & amended	3
10	2	2.12	Stud link chain cables for ships	Sub-Section deleted	3
10	2	2.12.1 to 2.12.10	Stud link chain cables for ships	Paragraphs deleted	3
10	2	2.13.5	Stud link chain cables for ships	Paragraph amended	3
10	2	2.13.17	Stud link chain cables for ships	New paragraph added	3
10	2	2.13.17	Stud link chain cables for ships	Paragraph renumbered & amended	3
10	2	2.15	Stud link chain cables for ships	Sub-Section deleted	3
10	2	2.15.1 to 2.15.11	Stud link chain cables for ships	Paragraphs deleted	3
10	2	2.16 & 2.17	Stud link chain cables for ships	Sub-Sections renumbered	3
10	2	2.17.2	Stud link chain cables for ships	Paragraph renumbered & amended	3
10	2	Figs. 10.2.4 to 10.2.8	Stud link chain cables for ships	Figures renumbered	3
10	3	3.3.6	Stud link mooring chain cables	Paragraph amended	3
10	3	Fig.10.3.2	Stud link mooring chain cables	Figure title amended	3
10	3	Fig.10.3.3	Stud link mooring chain cables	Figure deleted	3
10	3	Figs. 10.3.4 to 10.3.6	Stud link mooring chain cables	Figures renumbered	3
10	4	4.4.2	Studless mooring chain cables	New paragraph added	3
10	4	Fig. 10.4.1	Studless mooring chain cables	New Figure added	3
10	6	6.5.2	Steel wire ropes	Paragraph deleted	3
12	6	–	Qualificaton of friction stir welding of aluminium alloys	New Section added	3
13	1	1.11.1 & 1.11.2	General welding requirements	Paragraphs amended	3
13	9	–	Friction stir welding requirements for aluminium alloys	New Section added	3

Notice – Summary of Changes

Ch	Section	Para	Section Title	Status	Notice
Part 3				**Effective Date 1 August 2013**	
1	1	1.2.2	Rule application	Paragraph amended	2
1	8	8.3	Inspection and workmanship	Sub-Section re-written	2
1	9	–	Procedures for testing tanks and tight boundaries	New Section added	2
11	4	4.2.30	Hatch cover securing arrangements and tarpaulins	Reference amended	2
11	9	9.2.1	Watertight doors in bulkheads below the freeboard deck	Reference amended	2
11	9	9.2.8	Watertight doors in bulkheads below the freeboard deck	Reference amended	2
13	2	2.6.7	Rudders	Reference amended	2
13	3	3.2.7	Fixed and steering nozzles	Reference amended	2

Ch	Section	Para	Section Title	Status	Notice
Part 3				**Effective Date 1 September 2013**	
4	8	8.4.1	Loading guidance information	New sub-Section added	4
9	7	–	Freight container securing arrangements	Section deleted	4
9	8	–	Bottom strengthening for loading and unloading aground	Section renumbered	4
9	9	–	Strengthening for regular discharge by heavy grabs	Section renumbered	4
14	–	–	Cargo Securing Arrangements	Chapter re-written	4
16	3	3.1	Fatigue design assessment	Sub-Section title amended	3
16	3	3.1.1	Fatigue design assessment	Paragraph amended	3
16	3	3.1.2	Fatigue design assessment	Reference amended	3

Ch	Section	Para	Section Title	Status	Notice
Part 3				**Effective Date 1 January 2014**	
2	3	3.2.6	Corrosion protection	Paragraph amended	5
9	3	Table 9.3.1	Decks loaded by wheeled vehicles	Table amended	7
10	2	2.2.2 & 2.2.3	Welding	Paragraphs amended	7
10	5	5.6.4	Structural details	Paragraph amended	7
16	11	11.1	Safe return to port and orderly evacuation	New sub-Section added	6

Ch	Section	Para	Section Title	Status	Notice
Part 3				**Effective Date 1 July 2014**	
2	1	1.3.1	Materials of construction	Paragraph amended	9
2	2	2.1.2	Fracture control	Paragraph amended	9
2	2	Table 2.2.1	Fracture control	Table amended	9
2	2	Table 2.2.3	Fracture control	Table amended	9
6	7	7.6	Sternframes and appendages	New sub-Section added	9
6	7	7.6	Sternframes and appendages	Sub-Section renumbered	9
6	7	Fig. 6.7.8	Sternframes and appendages	New Figure added	9
6	7	7.4.2	Sternframes and appendages	Paragraph deleted	9
6	7	7.4.2 & 7.4.3	Sternframes and appendages	New paragraphs added	9
6	7	7.4.3 to 7.4.6	Sternframes and appendages	Paragraphs renumbered	9
6	7	7.4.8	Sternframes and appendages	New paragraph added	9
6	7	7.5.1	Sternframes and appendages	New paragraph added	9
6	7	7.5.1	Sternframes and appendages	Paragraph renumbered & amended	9
6	7	7.5.2 & 7.5.3	Sternframes and appendages	Paragraphs renumbered	9
6	7	7.5.4	Sternframes and appendages	Paragraph deleted	9
6	7	7.5.5	Sternframes and appendages	New paragraph added	9
6	7	7.5.5	Sternframes and appendages	Paragraph renumbered	9

Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 3 *(Continued)*					**Effective Date 1 July 2014**
9	2	2.1.2	Timber deck cargoes	References amended	9
9	2	2.3	Timber deck cargoes	Title amended	9
9	2	2.3.1	Timber deck cargoes	Paragraph amended	9
9	2	2.3.2	Timber deck cargoes	Paragraph deleted	9
9	2	2.3.2 & 2.3.3	Timber deck cargoes	New paragraphs added	9
9	2	2.3.3	Timber deck cargoes	Paragraph renumbered	9
9	2	2.3.4	Timber deck cargoes	New paragraph added	9
9	2	2.5	Timber deck cargoes	New sub-Section title added	9
9	2	2.5	Timber deck cargoes	Sub-Section renumbered	9
9	2	2.6	Timber deck cargoes	New sub-Section title added	9
9	2	2.6	Timber deck cargoes	Sub-Section renumbered	9
9	2	2.7	Timber deck cargoes	New sub-Section added	9
9	2	2.7	Timber deck cargoes	Sub-Section renumbered	9
9	2	2.8	Timber deck cargoes	New sub-Section title added	9
9	2	2.8	Timber deck cargoes	Sub-Section renumbered	9
9	2	2.3.4 & 2.3.5	Timber deck cargoes	Paragraphs renumbered	9
9	2	2.3.6	Timber deck cargoes	Paragraph deleted	9
9	2	2.3.8	Timber deck cargoes	New paragraph added	9
9	2	2.4.2	Timber deck cargoes	Paragraph amended	9
9	2	2.4.3	Timber deck cargoes	Paragraph renumbered & amended	9
9	2	2.4.4	Timber deck cargoes	Paragraph deleted	9
9	2	2.4.5	Timber deck cargoes	Paragraph renumbered & amended	9
9	2	2.4.6 to 2.4.8	Timber deck cargoes	Paragraphs renumbered	9
9	2	2.4.9 & 2.4.10	Timber deck cargoes	Paragraphs renumbered & amended	9
9	2	2.4.11	Timber deck cargoes	Paragraph deleted	9
9	2	2.4.12	Timber deck cargoes	Paragraph renumbered & amended	9
9	2	2.4.13 & 2.4.14	Timber deck cargoes	Paragraphs deleted	9
9	2	2.4.15 & 2.4.16	Timber deck cargoes	Paragraphs renumbered & amended	9
9	2	2.4.17	Timber deck cargoes	Paragraph deleted	9
9	2	2.4.18	Timber deck cargoes	Paragraph renumbered & amended	9
9	2	2.4.19 & 2.4.20	Timber deck cargoes	Paragraphs renumbered	9
9	2	2.4.21 & 2.4.22	Timber deck cargoes	Paragraphs deleted	9
9	2	2.5.2	Timber deck cargoes	New paragraph added	9
9	2	2.6.4 to 2.6.8	Timber deck cargoes	New paragraphs added	9
9	2	2.6.10 to 2.6.17	Timber deck cargoes	New paragraphs added	9
9	2	2.8.1	Timber deck cargoes	New paragraph added	9
11	1	1.1.11	General	Reference amended	9
11	2	2.4.2	Steel hatch covers	Paragraph amended	9
12	5	5.2.1 & 5.2.2	Air pipes, ventilator pipes and their securing devices located on the exposed fore deck	Paragraphs amended	9
16	2	2.1.2	Structural design assessment	Paragraph amended	9

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 4					**Effective Date 1 August 2013**
2	8	2.8.1	Bow doors and inner doors	Table amended	2

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 4					**Effective Date 1 January 2014**
2	8	2.8.1	Bow doors and inner doors	Table amended	7
8	2	2.3	Materials	New sub-Section added	5

Notice – Summary of Changes

Ch	Section	Para	Section Title	Status	Notice
Part 4					**Effective Date 1 July 2014**
2	4	4.2.1	Shell envelope plating	Paragraph amended	9
5	8	—	Void spaces	New Section added	9
8	1	1.1.2	General	Paragraph deleted	9
8	1	1.1.3 & 1.1.4	General	Paragraphs renumbered	9
8	1	1.1.5	General	Paragraph renumbered & amended	9
8	1	1.1.6 & 1.1.7	General	Paragraphs renumbered	9
8	1	1.3.3	General	Paragraph amended	9
8	3	—	Longitudinal strength	Section re-written	9
8	14	—	Direct calculation	Section re-written	9
8	15	—	Combined stress calculations	Section re-written	9
9	12	12.4.1	Cargo temperatures	Paragraph amended	9

Ch	Section	Para	Section Title	Status	Notice
Part 5					**Effective Date 1 July 2013**
15	7	7.9.10	Inert gas systems	Paragraph amended	1

Ch	Section	Para	Section Title	Status	Notice
Part 5					**Effective Date 1 August 2013**
2	17	17.1.3	Type testing – General	Paragraph amended	2
2	17	17.2.3	Type testing – General	Paragraph amended	2

Ch	Section	Para	Section Title	Status	Notice
Part 5					**Effective Date 1 January 2014**
12	9	9.6.1	Piping for LPG/LNG carriers, gas fuelled ships and classed refrigeration systems	New paragraph added	6
12	9	9.6.1	Piping for LPG/LNG carriers, gas fuelled ships and classed refrigeration systems	Paragraph renumbered	6
13	12	12.7.1	Air, overflow and sounding pipes	Paragraph amended	6
13	12	12.7.9	Air, overflow and sounding pipes	Paragraph amended	6
19	6	6.1.1	Emergency power	Paragraph amended	6
23	1	1.1.3	General	New paragraph added	6
23	1	1.1.3	General	Paragraph renumbered	6
23	1	1.1.4	General	Paragraph renumbered & amended	6
23	1	1.1.5	General	Paragraph renumbered	6
23	1	1.1.6	General	New paragraph added	6
23	3	—	Qualitative failure analysis for propulsion, steering and essential services	Section title amended	6
23	3	3.1.6	Qualitative failure analysis for propulsion, steering and essential services	Paragraph deleted	6
23	5	5.1.1 & 5.1.2	Verification, testing and trials	Paragraphs amended	6
23	5	5.1.3 & 5.1.4	Verification, testing and trials	New paragraphs added	6
23	5	5.2.1	Verification, testing and trials	Paragraph amended	6

Ch	Section	Para	Section Title	Status	Notice
Part 5					**Effective Date 1 July 2014**
2	4	4.2.2	Electronically controlled engines	References amended	10
2	10	10.8.8	Safety arrangements	Reference amended	10
2	12	12.3.1	Component tests	Paragraph amended	10
2	16	16.2.2	Air compressors	Reference amended	10

Notice – Summary of Changes

Ch	Section	Para	Section Title	Status	Notice
Part 5 *(Continued)*					**Effective Date 1 July 2014**
5	3	3.7.1	Design	Paragraph amended	10
7	3	3.2.5	Design	Paragraph amended	10
7	5	Table 7.5.1	Control and monitoring	Reference amended	10
8	2	2.1.2	Torsional vibration	Paragraph amended	10
9	8	8.2.7	Control engineering systems	Reference amended	10
10	18	Table 10.18.1	Control and monitoring	Reference amended	10
10	18	18.3.3	Control and monitoring	Reference amended	10
12	1	1.6.2	General	Paragraph amended	10
12	1	Table 12.1.2	General	Table amended	10
12	2	Table 12.2.8	Carbon and low alloy steels	Table amended	10
12	2	2.8.1	Carbon and low alloy steels	Paragraph amended	10
12	2	2.8.4	Carbon and low alloy steels	New paragraph added	10
12	2	2.9.1	Carbon and low alloy steels	Paragraph amended	10
12	2	2.9.4	Carbon and low alloy steels	New paragraph added	10
12	2	2.9.4	Carbon and low alloy steels	Paragraph renumbered	10
12	2	2.9.5	Carbon and low alloy steels	Paragraph renumbered & reference amended	10
12	2	2.9.6 & 2.9.7	Carbon and low alloy steels	Paragraphs renumbered	10
12	2	2.14	Carbon and low alloy steels	New sub-Section added	10
14	8	8.7.3	Lubricating oil systems	New paragraph added	10
14	10	10.3.1	Low pressure compressed air systems	Reference amended	10
14	12	—	Control, alarm and safety systems of machinery	Section title amended	10
14	12	12.3	Control, alarm and safety systems of machinery	Sub-Section deleted	10
14	12	12.4	Control, alarm and safety systems of machinery	Sub-Section renumbered	10
14	12	12.4.1	Control, alarm and safety systems of machinery	References amended	10
14	12	12.5	Control, alarm and safety systems of machinery	Sub-Section renumbered	10
14	12	Table 14.12.1	Control, alarm and safety systems of machinery	Reference amended	10
14	12	Tables 14.12.3 & 14.12.4	Control, alarm and safety systems of machinery	Tables renumbered	10
14	12	12.5.1	Control, alarm and safety systems of machinery	References amended	10
15	4	4.4.3	Cargo tank venting, purging and gas-freeing	Reference amended	10
15	7	7.1.1	Inert gas systems	Reference amended	10
15	7	7.1.7	Inert gas systems	Reference amended	10
15	7	7.5.3	Inert gas systems	References amended	10
15	7	7.7	Inert gas systems	New sub-Section added	10
15	7	7.7	Inert gas systems	Sub-Section renumbered	10
15	7	7.7.1 & 7.7.2	Inert gas systems	Paragraphs renumbered	10
15	7	7.7.3	Inert gas systems	Paragraph renumbered & reference amended	10
15	7	7.7.4	Inert gas systems	Paragraph renumbered & references amended	10
15	7	7.7.5	Inert gas systems	Paragraph renumbered	10
15	7	7.7.6 & 7.7.7	Inert gas systems	Paragraphs renumbered & references amended	10
15	7	7.7.8	Inert gas systems	Paragraph renumbered & amended	10
15	7	7.7.9 to 7.7.14	Inert gas systems	Paragraphs renumbered & references amended	10
15	7	7.7.15	Inert gas systems	Paragraph renumbered	10
15	7	7.8	Inert gas systems	Sub-Section renumbered	10
15	7	7.8.1	Inert gas systems	New paragraph added	10
15	7	Table 15.7.1	Inert gas systems	New Table added	10
15	7	7.8.2	Inert gas systems	New paragraph added	10
15	7	7.9	Inert gas systems	Sub-Section renumbered	10
15	7	7.9.2 to 7.9.5	Inert gas systems	Paragraphs renumbered	10

Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 5 *(Continued)*					**Effective Date 1 July 2014**
15	7	7.9.6	Inert gas systems	Paragraph renumbered & reference amended	10
15	7	7.9.7 & 7.9.8	Inert gas systems	Paragraphs renumbered	10
15	7	7.9.9	Inert gas systems	Paragraph renumbered & reference amended	10
15	7	7.9.10 to 7.9.14	Inert gas systems	Paragraphs renumbered	10
15	7	7.9.15 to 7.9.18	Inert gas systems	Paragraphs renumbered & references amended	10
15	7	7.10	Inert gas systems	Sub-Section renumbered	10
15	7	7.10.2	Inert gas systems	New paragraph added	10
15	7	7.10.2 & 7.10.3	Inert gas systems	References amended	10
15	7	Table 15.7.2	Inert gas systems	New Table added	10
15	7	7.10.19	Inert gas systems	References amended	10
23	2	2.1.2	Safe return to port	Reference amended	10
24	9	9.1.7	Electrical and control equipment	Paragraph amended	10
24	9	Table 9.1.9	Electrical and control equipment	Table amended	10

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 6					**Effective Date 1 January 2014**
1	3	3.6.3	Ergonomics of control stations	Paragraph amended	7
2	1	1.3.4	General requirements	Paragraph amended	7
2	1	1.6.5 & 1.6.6	General requirements	Paragraphs amended	7
2	1	1.19.1	General requirements	Paragraph amended	7
2	5	5.2.1	Supply and distribution	Paragraph amended	7
2	5	5.9.4	Supply and distribution	Paragraph amended	7
2	7	7.1.1	Switchgear and controlgear assemblies	Paragraph amended	7
2	7	7.3.1	Switchgear and controlgear assemblies	Paragraph amended	7
2	7	7.5.1	Switchgear and controlgear assemblies	Paragraph amended	7
2	7	Table 2.7.1	Switchgear and controlgear assemblies	Table amended	7
2	7	7.5.3	Switchgear and controlgear assemblies	Paragraph amended	7
2	7	Table 2.7.2	Switchgear and controlgear assemblies	Table amended	7
2	7	7.5.4 to 7.5.6	Switchgear and controlgear assemblies	Paragraphs amended	7
2	7	7.16.5	Switchgear and controlgear assemblies	Paragraph amended	7
2	7	7.18.5	Switchgear and controlgear assemblies	Paragraph amended	7
2	7	7.19.1	Switchgear and controlgear assemblies	Paragraph amended	7
2	9	9.1.1	Rotating machines	Paragraph amended	7

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 6					**Effective Date 1 July 2014**
1	1	1.1.2	General requirements	Paragraph amended	10
1	1	1.1.3 to 1.1.7	General requirements	Paragraphs deleted	10
1	1	1.1.8	General requirements	Paragraph renumbered	10
1	1	1.1.9	General requirements	Paragraph renumbered & reference amended	10
1	1	1.2	General requirements	Title amended	10
1	1	1.2.1	General requirements	Paragraph amended	10
1	1	1.2.2	General requirements	References amended	10
1	1	1.2.4	General requirements	New paragraph added	10
1	1	1.2.4	General requirements	Paragraph renumbered	10
1	1	1.2.5	General requirements	Paragraph renumbered & amended	10

Notice – Summary of Changes

Ch	Section	Para	Section Title	Status	Notice
Part 6 *(Continued)*					**Effective Date 1 July 2014**
1	1	1.2.6	General requirements	Paragraph amended	10
1	1	1.2.7	General requirements	Paragraph renumbered & amended	10
1	1	1.2.8	General requirements	Paragraph renumbered	10
1	1	1.2.9	General requirements	Paragraph deleted	10
1	1	1.3.1	General requirements	Paragraph amended	10
1	1	1.3.3	General requirements	Reference amended	10
1	1	1.3.4 & 1.3.5	General requirements	Paragraphs amended	10
1	1	1.4.2	General requirements	Paragraph amended	10
1	1	1.4.3	General requirements	New paragraph added	10
1	1	1.4.3	General requirements	Paragraph renumbered	10
1	1	1.5.4 to 1.5.11	General requirements	New paragraphs added	10
1	2	2.1.1	Essential features for control, alarm and safety systems	Paragraph deleted	10
1	2	2.1.2	Essential features for control, alarm and safety systems	Paragraph renumbered	10
1	2	2.2.8	Essential features for control, alarm and safety systems	Paragraph deleted	10
1	2	2.3.1	Essential features for control, alarm and safety systems	Paragraph deleted	10
1	2	2.3.2 to 2.3.20	Essential features for control, alarm and safety systems	Paragraphs renumbered	10
1	2	2.4.1	Essential features for control, alarm and safety systems	Paragraph deleted	10
1	2	2.4.2	Essential features for control, alarm and safety systems	Paragraph renumbered	10
1	2	2.4.3 & 2.4.4	Essential features for control, alarm and safety systems	Paragraphs renumbered & references amended	10
1	2	2.4.5 to 2.4.12	Essential features for control, alarm and safety systems	Paragraphs renumbered	10
1	2	2.4.13	Essential features for control, alarm and safety systems	Paragraph renumbered & reference amended	10
1	2	2.5.1	Essential features for control, alarm and safety systems	Paragraph deleted	10
1	2	2.5.2 to 2.5.5	Essential features for control, alarm and safety systems	Paragraphs renumbered	10
1	2	2.5.6	Essential features for control, alarm and safety systems	Paragraph renumbered & amended	10
1	2	2.5.7 & 2.5.8	Essential features for control, alarm and safety systems	Paragraphs renumbered	10
1	2	2.6.1	Essential features for control, alarm and safety systems	Paragraph deleted	10
1	2	2.6.2 to 2.6.4	Essential features for control, alarm and safety systems	Paragraphs renumbered	10
1	2	2.6.5	Essential features for control, alarm and safety systems	Paragraph renumbered & amended	10
1	2	2.6.6 to 2.6.9	Essential features for control, alarm and safety systems	Paragraphs renumbered	10
1	2	2.10.8	Essential features for control, alarm and safety systems	Reference amended	10
1	2	2.10.10	Essential features for control, alarm and safety systems	Reference amended	10
1	2	2.10.16	Essential features for control, alarm and safety systems	Paragraph amended	10
1	2	2.10.20	Essential features for control, alarm and safety systems	Paragraph amended	10
1	2	2.11.7	Essential features for control, alarm and safety systems	Reference amended	10
1	2	2.14.3	Essential features for control, alarm and safety systems	Reference amended	10
1	2	2.14.5	Essential features for control, alarm and safety systems	Paragraph amended & references amended	10

Notice – Summary of Changes

Ch	Section	Para	Section Title	Status	Notice
Part 6 *(Continued)*					**Effective Date 1 July 2014**
1	3	3.3.1	Ergonomics of control stations	Paragraph amended	10
1	3	3.3.9	Ergonomics of control stations	Paragraph amended	10
1	3	3.5.12	Ergonomics of control stations	New paragraph added	10
1	3	3.6.2	Ergonomics of control stations	Paragraph amended	10
1	6	6.1.2 & 6.1.3	Integrated computer control – ICC notation	Paragraphs amended	10
1	7	7.1.3	Integrated computer control – ICC notation	Reference amended	10
2	1	1.1.7	General requirements	Reference amended	10
2	1	1.9.3	General requirements	Paragraph amended	10
2	1	1.11.4	General requirements	Paragraph amended	10
2	1	1.16.5	General requirements	Paragraph amended	10
2	4	4.1.5	External source of electrical power	Reference amended	10
2	5	5.3.8	Supply and distribution	Paragraph amended	10
2	5	5.4.3	Supply and distribution	Paragraph amended	10
2	5	5.5.7	Supply and distribution	Paragraph amended	10
2	6	6.1.4	System design – Protection	Paragraph amended	10
2	6	6.3.2	System design – Protection	Paragraph amended	10
2	6	6.5.4	System design – Protection	Paragraph amended	10
2	7	7.1.1	Switchgear and controlgear assemblies	Paragraph amended	10
2	7	7.3.1	Switchgear and controlgear assemblies	Paragraph amended	10
2	7	7.4.1	Switchgear and controlgear assemblies	Paragraph amended	10
2	7	7.5.1	Switchgear and controlgear assemblies	Paragraph amended	10
2	7	Table 2.7.1	Switchgear and controlgear assemblies	Table amended	
2	7	7.5.2 & 7.5.3	Switchgear and controlgear assemblies	Paragraphs amended	10
2	7	Table 2.7.2	Switchgear and controlgear assemblies	Table amended	
2	7	7.5.4	Switchgear and controlgear assemblies	Paragraph amended	10
2	7	7.5.5 & 7.5.6	Switchgear and controlgear assemblies	Paragraphs deleted	10
2	7	7.8.2	Switchgear and controlgear assemblies	Paragraph amended	10
2	7	7.9.1	Switchgear and controlgear assemblies	Paragraph amended	10
2	7	7.16.5	Switchgear and controlgear assemblies	Paragraph amended	10
2	7	7.18.5	Switchgear and controlgear assemblies	Paragraph amended	10
2	7	7.19.1	Switchgear and controlgear assemblies	Paragraph amended	10
2	9	9.1.1	Rotating machines	Paragraph amended	10
2	9	9.1.6	Rotating machines	Paragraph amended	10
2	9	9.1.14	Rotating machines	Paragraph amended	10
2	9	9.8.6	Rotating machines	Paragraph amended	10
2	10	10.1.2	Converter equipment	Paragraph amended	10
2	10	10.2.1 to 10.2.3	Converter equipment	Paragraphs amended	10
2	10	10.3.2	Converter equipment	Paragraph amended	10
2	10	10.3.8	Converter equipment	Paragraph amended	10
2	11	Table 2.11.1	Electric cables, optical fibre cables and busbar trunking systems (busways)	Table amended	10
2	11	11.2.1	Electric cables, optical fibre cables and busbar trunking systems (busways)	Paragraph amended	10

Notice – Summary of Changes

Ch	Section	Para	Section Title	Status	Notice
Part 6 *(Continued)*					**Effective Date 1 July 2014**
2	11	11.5.3	Electric cables, optical fibre cables and busbar trunking systems (busways)	Paragraph amended	10
2	11	11.8.10	Electric cables, optical fibre cables and busbar trunking systems (busways)	Paragraph amended	10
2	11	11.13.7	Electric cables, optical fibre cables and busbar trunking systems (busways)	Paragraph amended	10
2	12	12.3.10	Batteries	Paragraph amended	10
2	14	14.1.5	Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts	Paragraph deleted	10
2	14	14.2.1	Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts	Paragraph amended	10
2	14	14.2.4	Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts	Paragraph amended	10
2	14	14.2.6	Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts	Paragraph amended	10
2	14	14.2.9	Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts	Paragraph amended	10
2	14	14.3.5	Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts	Paragraph amended	10
2	14	14.4.1	Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts	Paragraph amended	10
2	14	14.5.1 to 14.5.4	Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts	Paragraphs amended	10
2	14	14.9.5	Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts	Paragraph amended	10
2	14	14.10.1	Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts	Paragraph amended	10
2	14	14.13.1	Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts	Paragraph amended	10
2	14	14.14.2 & 14.14.3	Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts	Paragraphs amended	10

Notice – Summary of Changes

Ch	Section	Para	Section Title	Status	Notice
Part 6 *(Continued)*				**Effective Date 1 July 2014**	
2	14	14.15	Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts	New sub-Section added	10
2	16	16.2.2	Electric propulsion	Reference amended	10
2	16	Table 2.16.1	Electric propulsion	Reference amended	10
2	18	18.4.4	Crew and passenger emergency safety systems	Paragraph amended	10
2	19	19.2.9	Ship safety systems	Paragraph amended	10
2	20	20.1.1	Lightning conductors	Paragraph amended	10
3	1	1.1.4	General requirements	Reference amended	10

Ch	Section	Para	Section Title	Status	Notice
Part 7				**Effective Date 1 August 2013**	
5	3	3.1.7	Ship structure	Reference amended	2
10	6	6.1.1	Hold access and maintenance access arrangements	Reference amended	2

Ch	Section	Para	Section Title	Status	Notice
Part 7				**Effective Date 1 January 2014**	
2	1	1.1.1	Introduction	Paragraph amended	6
11	3	3.1.1	Supplementary characters	Paragraph amended	7
15	1	1.1.1	Requirements for machinery and engineering systems of unconventional design	Paragraph amended	7

Ch	Section	Para	Section Title	Status	Notice
Part 7				**Effective Date 1 July 2014**	
3	3	3.1.4	Fire-extinguishing	Paragraph amended	9
3	4	4.2.4	Fire protection	Paragraph amended	9
9	1	1.2.1	General requirements	Reference amended	10
9	3	3.1.12	Workstations	Paragraph amended	10
9	4	4.3.1	Systems	Reference amended	10
11	1	1.1.2	General requirements	Paragraph amended	10
11	1	1.3	General requirements	New sub-Section added	10
11	1	1.3	General requirements	Sub-Section renumbered	10
11	1	1.3.1	General requirements	Paragraph renumbered & amended	10
11	1	1.4 & 1.5	General requirements	Sub-Sections renumbered	10
11	1	1.4.1 & 1.4.2	General requirements	References amended	10
11	2	—	Minimum requirements	Section title amended	10
11	2	2.1.6	Minimum requirements	Paragraph amended	10
11	2	2.7.11	Minimum requirements	Paragraph amended	10
11	3	3.12.2	Supplementary characters	Paragraph amended	10
11	3	3.14.1	Supplementary characters	Paragraph amended	10
11	3	3.15.3	Supplementary characters	Paragraph amended	10
11	4	4.1.1	Survey requirements	Paragraph amended	10
11	4	4.1.3	Survey requirements	Paragraph amended	10
11	4	4.2.5	Survey requirements	New paragraph added	10
11	4	4.3.2	Survey requirements	Paragraph amended	10
12	—	—	Integrated Fire Protection (IFP) Systems	Whole Chapter deleted	10
13	—	—	Passenger and Crew Accommodation Comfort	Chapter renumbered	10
13	1	1.1.2	General requirements	Paragraph amended	10
13	1	1.1.4	General requirements	New paragraph added	10

Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 7 *(Continued)*					**Effective Date 1 July 2014**
13	1	1.1.4	General requirements	Paragraph renumbered	10
13	1	1.1.5	General requirements	New paragraph added	10
13	1	1.1.5 to 1.1.7	General requirements	Paragraphs renumbered	10
13	1	1.2.4	General requirements	Paragraph amended	10
13	2	Tables 12.2.3 & 12.2.4	Noise	Tables renumbered & amended	10
13	2	2.3.2	Noise	Paragraph amended	10
13	2	2.4.2	Noise	Paragraph amended	10
13	2	Table 12.2.5	Noise	Table renumbered & amended	10
13	3	Tables 12.3.1 & 12.3.2	Vibration	Tables renumbered & amended	10
13	3	3.1.5	Vibration	Paragraph deleted	10
13	3	3.2.2	Vibration	Paragraph amended	10
13	4	4.2.1	Testing	Paragraph amended	10
13	4	4.3.1	Testing	Paragraph amended	10
13	4	4.4.1	Testing	Paragraph amended	10
13	4	4.5.1	Testing	Paragraph amended	10
13	5	5.2.1	Noise and vibration survey reporting	Paragraph amended	10
13	5	5.3.1	Noise and vibration survey reporting	Paragraph amended	10
13	5	5.3.1	Noise and vibration survey reporting	Sub-paragraphs renumbered	10
13	7	7.1.1	Referenced standards	Paragraph amended	10
13	7	7.2.1	Referenced standards	Paragraph amended	10
14	—	—	On-shore Power Supplies	Chapter renumbered	10
14	2	2.1.6	Essential features	Paragraph amended	10
14	3	Tables 14.3.1 to 14.3.3	Electrical connection	Tables deleted	10
14	3	3.3.1 & 3.3.2	Electrical connection	Paragraphs amended	10
14	3	3.3.3 to 3.3.5	Electrical connection	Paragraphs deleted	10
14	3	3.3.6	Electrical connection	Paragraph renumbered & amended	10
14	3	3.3.7	Electrical connection	Paragraph deleted	10
14	3	3.3.8 to 3.3.10	Electrical connection	Paragraphs renumbered & amended	10
15	—	—	Requirements for Machinery and Engineering Systems of Unconventional Design	Chapter renumbered	10
16	—	—	Refrigeration Systems and Equipment Serving Provision Stores and Air-Conditioning Installations	Chapter renumbered	10

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 8					**Effective Date 1 July 2014**
2	1	1.1.4	Strengthening requirements for navigation in ice – Application of requirements	Paragraph amended	9
2	2	2.1.10	General hull requirements for navigation in ice – All Ice Classes	New paragraph added	9
2	6	6.4.1	Hull requirements for first-year ice conditions – Ice Classes 1AS FS, 1 A FS, 1 B FS, 1 C FS and 1D	Paragraph amended	9
2	12	12.1.1	Requirements for Icebreaker (+)	Paragraph amended	9
2	12	12.1.2	Requirements for Icebreaker (+)	New paragraph added	9
2	12	12.2.1	Requirements for Icebreaker (+)	Paragraph amended	9
2	12	12.2.2	Requirements for Icebreaker (+)	Paragraph deleted	9
2	12	12.2.3	Requirements for Icebreaker (+)	Paragraph renumbered & amended	9
2	12	12.3.1	Requirements for Icebreaker (+)	Paragraph amended	9

Notice – Summary of Changes

Ch	Section	Para	Section Title	Status	Notice
Part 8 *(Continued)*					**Effective Date 1 July 2014**
2	12	12.3.2	Requirements for Icebreaker (+)	New paragraph added	9
2	12	12.3.2	Requirements for Icebreaker (+)	Paragraph renumbered & amended	9
2	12	12.3.3 to 12.3.5	Requirements for Icebreaker (+)	New paragraphs added	9
2	12	12.4.1	Requirements for Icebreaker (+)	Paragraph amended	9
2	12	12.5	Requirements for Icebreaker (+)	New sub-Section added	9
2	12	12.5	Requirements for Icebreaker (+)	Sub-Section renumbered	9
2	12	12.5.1	Requirements for Icebreaker (+)	Paragraph renumbered & amended	9
2	12	12.6	Requirements for Icebreaker (+)	Sub-Section renumbered & amended	9
2	12	12.6.1	Requirements for Icebreaker (+)	Paragraph renumbered & amended	9
2	12	12.6.2	Requirements for Icebreaker (+)	New paragraph added	9
2	12	12.6.2	Requirements for Icebreaker (+)	Paragraph renumbered & amended	9
2	12	12.7	Requirements for Icebreaker (+)	Title amended	9
2	12	12.7	Requirements for Icebreaker (+)	Sub-Section deleted	9
2	12	12.7.1 & 12.7.2	Requirements for Icebreaker (+)	Paragraphs deleted	9
2	12	12.7.2	Requirements for Icebreaker (+)	New paragraph added	9
2	12	12.7.3	Requirements for Icebreaker (+)	Paragraph deleted	9
2	12	12.7.3	Requirements for Icebreaker (+)	New paragraph added	9
2	12	Fig. 2.12.1	Requirements for Icebreaker (+)	New Figure added	9
2	12	12.7.4	Requirements for Icebreaker (+)	Paragraph deleted	9
2	12	12.7.4 to 12.7.6	Requirements for Icebreaker (+)	New paragraphs added	9
2	12	12.7.8	Requirements for Icebreaker (+)	New paragraph added	9
2	12	12.8 to 12.10	Requirements for Icebreaker (+)	New sub-Sections added	9
2	12	2.12.1	Requirements for Icebreaker (+)	Table amended	9

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Rules and Regulations for the Classification of Ships

Part 1
Regulations
July 2014

Lloyd's Register

A guide to the Rules

and published requirements

Rules and Regulations for the Classification of Ships

Introduction

The Rules are published as a complete set; individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Numbering and Cross-References

A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e., Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right hand digits may be added or omitted depending on the degree of precision required:

(a) In same Chapter, e.g., *see* 2.1.3 (i.e., down to paragraph).
(b) In same Part but different Chapter, e.g., *see* Ch 3,2.1 (i.e., down to sub-Section).
(c) In another Part, e.g., *see* Pt 5, Ch 1,3 (i.e., down to Section).

The cross-referencing for Figures and Tables is as follows:

(a) In same Chapter, e.g., as shown in Fig 2.3.5 (i.e., Chapter, Section and Figure Number).
(b) In same Part but different Chapter, e.g., as shown in Fig. 2.3.5 in Chapter 2.
(c) In another Part, e.g., *see* Table 2.7.1 in Pt 3, Ch 2.

Rules updating

The Rules are generally published annually and changed through a system of Notices. Subscribers are forwarded copies of such Notices when the Rules change.

Current changes to Rules that appeared in Notices are shown with a black rule alongside the amended paragraph on the left hand side. A solid black rule indicates amendments and a dotted black rule indicates corrigenda.

Rules programs

LR has developed a suite of Calculation Software that evaluates Requirements for Ship Rules, Special Service Craft Rules and Naval Ship Rules. For details of this software please contact LR.

Direct calculations

The Rules require direct calculations to be submitted for specific parts of the ship structure or arrangements and these will be assessed in relation to LR's own direct calculation procedures. They may also be required for ships of unusual form, proportion or speed, where intended for the carriage of special cargoes or for special restricted service and as supporting documentation for arrangements or scantlings alternative to those required by the Rules.

July 2014

CLASSIFICATION OF SHIPS

Rules and Regulations

July 2014

UPDATE NOTES

1. The July 2014 version of these Rules and Regulations incorporates those changes contained in the Notices to the July 2013 version.

2. Changes approved by the Board.

3. Editorial amendments have also been incorporated.

4. The July 2014 version of these Rules and Regulations supersedes the July 2013 version.

CLASSIFICATION

The following explanatory note is offered to assist those concerned in the application of these Rules and Regulations.

Explanatory Note

Ship classification may be regarded as the development and worldwide implementation of published Rules and Regulations which, in conjunction with proper care and conduct on the part of the Owner and operator, will provide for:

1. the structural strength of (and where necessary the watertight integrity of) all essential parts of the hull and its appendages;

2. the safety and reliability of the propulsion and steering systems; and

3. the effectiveness of those other features and auxiliary systems which have been built into the ship in order to establish and maintain basic conditions on board whereby appropriate cargoes and personnel can be safely carried whilst the ship is at sea, at anchor, or moored in harbour.

Lloyd's Register (LR) maintains these provisions by way of the periodical visits by its Surveyors to the ship as defined in the Regulations in order to ascertain that the vessel currently complies with those Rules and Regulations. Should significant defects become apparent or damages be sustained between the relevant visits by the Surveyors, the Owner and operator are required to inform LR without delay. Similarly any modification which would affect Class must receive prior approval by LR.

A ship is said to be in Class when the Rules and Regulations which pertain to it have, in the opinion of LR, been complied with, or when special dispensation from compliance has been granted by LR.

It should be appreciated that, in general, classification Rules and Regulations do not cover such matters as the ship's floatational stability, life-saving appliances, and structural fire protection, detection and extinction arrangements where these are covered by the *International Convention for the Safety of Life at Sea, 1974, its Protocol of 1978*, and the amendments thereto. Nor do they cover pollution prevention arrangements where these are covered by the *International Convention for the Prevention of Pollution from Ships, 1973*, its protocol of 1978, and the amendments thereto. Nor do they protect personnel on board from dangers connected with their own actions or movement around the ship. This is because the handling of these aspects is the prerogative of the National Authority with which the ship is registered. A great many of these authorities, however, delegate such responsibilities to the Classification Societies who then undertake them in accordance with agreed procedures.

Chapter Contents Part 1

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■ *Section 1*

1.1 Lloyd's Register Group Limited is a registered company under English law, with origins dating from 1760. It was established for the purpose of producing a faithful and accurate classification of merchant shipping. It now primarily produces classification Rules.

1.2 Classification services are delivered to clients by a number of other members subsidiaries and affiliates of Lloyd's Register Group Limited, including but not limited to: Lloyd's Register EMEA, Lloyd's Register Asia, Lloyd's Register North America, Inc., and Lloyd's Register Central and South America Limited. Lloyd's Register Group Limited, its subsidiaries and affiliates are hereinafter, individually and collectively, referred to as 'LR'.

■ *Section 2*

2.1 Lloyd's Register Group Limited is managed by a Board of Directors (hereinafter referred to as 'the Board').

The Board has:

appointed a Classification Committee and determined its powers and functions and authorised it to delegate certain of its powers to a Classification Executive and Devolved Classification Executives;
appointed Technical Committees and determined their powers, functions and duties.

2.2 LR has established National and Area Committees in the following:

Countries:
Australia (via Lloyd's Register International)
Canada (via Lloyd's Register North America, Inc.)
China (via Lloyd's Register Asia)
Egypt (via Lloyd's Register EMEA)
Federal Republic of Germany
(via Lloyd's Register EMEA)
France (via Lloyd's Register EMEA)
Italy (via Lloyd's Register EMEA)
Japan (via Lloyd's Register Group Limited)
New Zealand (via Lloyd's Register International)
Poland (via Lloyd's Register (Polska) Sp zoo)
Spain (via Lloyd's Register EMEA)
United States of America (via Lloyd's Register North America, Inc.)

Areas:
Benelux (via Lloyd's Register EMEA)
Central America (via Lloyd's Register Central and South America Ltd)
Nordic Countries (via Lloyd's Register EMEA)
South Asia (via Lloyd's Register Asia)
Asian Shipowners (via Lloyd's Register Asia)
Greece (via Lloyd's Register EMEA)

■ *Section 3*

3.1 LR's Technical Committee is at present composed of a maximum of 80 members which includes:
Ex officio members:
- Chairman and Chief Executive Officer of Lloyd's Register Group Limited ....
- Chairman of the Classification Committee of Lloyd's Register Group Limited ....

Members Nominated by:

• Technical Committee	
• Royal Institution of Naval Architects	2
• Institution of Engineers and Shipbuilders in Scotland	2
• Institute of Marine, Engineering, Science and Technology	2
• Institute of Materials, Minerals and Mining	1
• Honourable Company of Master Mariners	2
• Institution of Engineering and Technology	1
• Institute of Refrigeration	1
• Welding Institute	1
• Shipbuilders' and Shiprepairers' Association	2
• The Society of Consulting Marine Engineers and Ship Surveyors	1
• Community of European Shipyards Associations	1
• Society of Maritime Industries	2
• European Marine Equipment Council	1
• Chamber of Shipping	1
• Greek Shipping Co-operation Committee	1
• International Association of Oil and Gas Producers	1

3.2 In addition to the foregoing:
(a) Each National or Area Committee may appoint a representative to attend meetings of the Technical Committee.
(b) A maximum of five representatives from National Administrations may be co-opted to serve on the Technical Committee. Representatives from National Administrations may also be elected as members of the Technical Committee under one of the categories identified in 3.1.
(c) Further persons may be co-opted to serve on the Technical Committee by the Technical Committee.

3.3 All elections are subject to confirmation by the Board.

3.4 The function of the Technical Committee is to consider:
(a) any technical issues connected with LR's marine business;
(b) any proposed alterations in the existing Rules;
(c) any new Rules for classification;
Where changes to the Rules are necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies these may be implemented by LR without consideration by the Technical Committee.

3.5 The term of office of the Chairman and of all members of the Technical Committee is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of office of the Chairman may be extended with the approval of the Board.

3.6 In the case of continuous non-attendance of a member, the Technical Committee may withdraw membership.

3.7 Meetings of the Technical Committee are convened as often and at such times and places as is necessary, but there is to be at least one meeting in each year. Urgent matters may be considered by the Technical Committee by correspondence.

3.8 Any proposal involving any alteration in, or addition to, Part 1, Chapter 1 of Rules for Classification is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification other than Part 1, Chapter 1, will following consideration and approval by the Technical Committee either at a meeting of the Technical Committee or by correspondence, be recommended to the Board for adoption.

3.9 The Technical Committee is empowered to:
(a) appoint sub-Committees or panels; and
(b) co-opt to the Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

■ *Section 4*

4.1 LR's Naval Ship Technical Committee is at present composed of a maximum of 50 members and includes:
Ex officio members
- Chairman and Chief Executive Officer of Lloyd's Register Group Limited

Member nominated by:
- Naval Ship Technical Committee;
- The Royal Navy and the UK Ministry of Defence;
- UK Shipbuilders, Ship Repairers and Defence Industry;
- Overseas Navies, Governments and Governmental Agencies;
- Overseas Shipbuilders, Ship Repairers and Defence Industries;

4.2 All elections are subject to confirmation by the Board.

4.3 All members of the Naval Ship Technical Committee are to hold security clearance from their National Authority for the equivalent of NATO CONFIDENTIAL. All material is to be handled in accordance with NATO Regulations or, for non-NATO countries, an approved equivalent. No classified material shall be disclosed to any third party without the consent of the originator.

4.4 The term of office of the Naval Ship Technical Committee Chairman and of all members of the Naval Ship Technical Committee Chairman is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of the Chairman may be extended with the approval of the Board.

4.5 In the case of continuous non-attendance of a member, the Naval Ship Technical Committee may withdraw membership.

4.6 The function of the Naval Ship Technical Committee is to consider technical issues connected with Naval Ship matters and to approve proposals for new Naval Ship Rules, or amendments to existing Naval Ship Rules.

4.7 Meetings of the Naval Ship Technical Committee are convened as necessary but there will be at least one meeting per year. Urgent matters may be considered by the Naval Ship Technical Committee by correspondence.

4.8 Any proposal involving any alteration in, or addition to, Part 1, Chapter 1 of Rules for Classification of Naval Ships is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification of Naval Ships, other than Part 1, Chapter 1, will following consideration and approval by the Naval Ship Technical Committee, either at a meeting of the Naval Ship Technical Committee or by correspondence, be recommended to the Board for adoption.

4.9 The Naval Ship Technical Committee is empowered to:
(a) appoint sub-Committees or panels; and
(b) co-opt to the Naval Ship Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

■ *Section 5*

5.1 LR has the power to adopt, and publish as deemed necessary, Rules relating to classification and has (in relation thereto) provided the following:
(a) Except in the case of a special directive by the Board, no new Regulation or alteration to any existing Regulation relating to classification or to class notations is to be applied to existing ships.
(b) Except in the case of a special directive by the Board, or where changes necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies are concerned, no new Rule or alteration in any existing Rule is to be applied compulsorily after the date on which the contract between the ship builder and shipowner for construction of the ship has been signed, nor within six months of its adoption. The date of 'contract for construction' of a ship is the date on which the contract to build the ship is signed between the prospective shipowner and the ship builder. This date and the construction number (i.e. hull numbers) of all the vessels included in the contract are to be declared by the party applying for the assignment of class to a newbuilding. The date of 'contract for construction' of a series of sister ships, including specified optional ships for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective shipowner and the ship builder. In this section a 'series of sister ships' is a series of ships built to the same approved plans for classification purposes, under a single contract for construction. The optional ships will be considered part of the same series of sister ships if the option is exercised not later than 1 year after the contract to build the series was signed. If a contract for construction is later amended to include additional ships or additional options, the date of 'contract for construction' for such ships is the

date on which the amendment to the contract is signed between the prospective shipowner and the ship builder. The amendment to the contract is to be considered as a 'new contract'. If a contract for construction is amended to change the ship type, the date of 'contract for construction' of this modified vessel, or vessels, is the date on which the revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder. Where it is desired to use existing approved ship or machinery plans for a new contract, written application is to be made to LR. Sister ships may have minor design alterations provided that such alterations do not affect matters related to classification, or if the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective owner and the ship builder or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to LR for approval.

(c) All reports of survey are to be made by surveyors authorised by members of the LR Group to survey and report (hereinafter referred to as 'the Surveyors') according to the form prescribed, and submitted for the consideration of the Classification Committee.

(d) Information contained in the reports of classification and statutory surveys will be made available to the relevant owner, National Administration, Port State Administration, P&I Club, hull underwriter and, if authorised in writing by that owner, to any other person or organisation.

(e) Notwithstanding the general duty of confidentiality owed by LR to its client in accordance with the LR Rules, LR clients hereby accept that, LR will participate in the IACS Early Warning System which requires each IACS member to provide its fellow IACS members and Associates with relevant technical information on serious hull structural and engineering systems failures, as defined in the IACS Early Warning System (but not including any drawings relating to the ship which may be the specific property of another party), to enable such useful information to be shared and utilised to facilitate the proper working of the IACS Early Warning System LR will provide its client with written details of such information upon sending the same to IACS Members and Associates.

(f) Information relating to the status of classification and statutory surveys and suspensions/withdrawals of class together with any associated conditions of class will be made available as required by applicable legislation or court order.

(g) A Classification Executive consisting of senior members of LR's Classification Department staff shall carry out whatever duties that may be within the function of the Classification Committee that the Classification Committee assigns to it.

■ *Section 6*

6.1 No LR Group employee is permitted under any circumstances, to accept, directly or indirectly, from any person, firm or company, with whom the work of the employee brings the employee into contact, any present, bonus, entertainment or honorarium of any sort whatsoever which is of more than nominal value or which might be construed to exceed customary courtesy extended in accordance with accepted ethical business standards.

■ *Section 7*

7.1 LR has the power to withhold or, if already granted, to suspend or withdraw any ship from class (or to withhold any certificate or report in any other case), in the event of non-payment of any fee to any member of the LR Group.

■ *Section 8*

8.1 When providing services LR does not assess compliance with any standard other than the applicable LR Rules, international conventions and other standards agreed in writing.

8.2 In providing services, information or advice, LR does not warrant the accuracy of any information or advice supplied. Except as set out herein, LR will not be liable for any loss, damage or expense sustained by any person and caused by any act, omission, error, negligence or strict liability of LR or caused by any inaccuracy in any information or advice given in any way by or on behalf of LR even if held to amount to a breach of warranty. Nevertheless, if the Client uses LR services or relies on any information or advice given by or on behalf of LR and as a result suffers loss, damage or expense that is proved to have been caused by any negligent act, omission or error of LR or any negligent inaccuracy in information or advice given by or on behalf of LR then LR will pay compensation to the client for its proved loss up to but not exceeding the amount of the fee (if any) charged for that particular service, information or advice.

8.3 LR will print on all certificates and reports the following notice: Lloyd's Register Group Limited, its affiliates and subsidiaries and their respective officers, employees or agents are, individually and collectively, referred to in this clause as 'Lloyd's Register'. Lloyd's Register assumes no responsibility and shall not be liable to any person for any loss, damage or expense caused by reliance on the information or advice in this document or howsoever provided, unless that person has signed a contract with the relevant Lloyd's Register entity for the provision of this information or advice and in that case any responsibility or liability is exclusively on the terms and conditions set out in that contract.

8.4 Except in the circumstances of section 8.2 above, LR will not be liable for any loss of profit, loss of contract, loss of use or any indirect or consequential loss, damage or expense sustained by any person caused by any act, omission or error or caused by any inaccuracy in any information or advice given in any way by or on behalf of LR even if held to amount to a breach of warranty.

8.5 Any dispute about LR services is subject to the exclusive jurisdiction of the English courts and will be governed by English law.

Section

■ *Section 1* Conditions for classification

1.1 General

1.1.1 Ships referred to in this Chapter are defined in Parts 3, 4 and 7 of these Rules. Machinery referred to in this Chapter is defined in Parts 5 and 6 of these Rules. Systems referred to in this Chapter are defined in Part 7 of these Rules. Materials are referred to in the *Rules for the Manufacture and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.1.2 Ships built in accordance with Lloyd's Register Group Limited's Rules and Regulations, or in accordance with requirements equivalent thereto, will be assigned a class in the *Register Book* and will continue to be classed as long as they are found, upon examination at the prescribed surveys, to be maintained in accordance with the requirements of the Rules. Classification will be conditional upon compliance with LR's requirements for both hull and machinery and with the Certification Requirements of 1.1.

1.1.3 The Classification Committee, in addition to requiring compliance with LR's Rules, may require to be satisfied that ships are suitable for the geographical or other limits or conditions of the service contemplated.

1.1.4 Loading conditions and any other preparations required to permit a ship with a class notation specifying some service limitation to undertake a sea-going voyage, either from port of building to service area or from one service area to another, are to be in accordance with arrangements agreed by LR prior to the voyage.

1.1.5 Any damage, defect, breakdown grounding, serious deficiency, detention or, arrest or refusal of access, which could invalidate the conditions for which a class has been assigned, is to be reported to LR without delay.

1.1.6 The Rules are framed on the understanding that ships will be properly loaded and handled. They do not, unless stated or implied in the class notation, provide for special distributions or concentrations of loading. The Classification Committee may require additional strengthening to be fitted in any ship which, in their opinion, would otherwise be subjected to severe stresses due to particular features in the design, or where it is desired to make provision for exceptional loaded or ballast conditions. In such cases, particulars are to be submitted for consideration.

1.1.7 When longitudinal strength calculations have been required, loading guidance information is supplied to the Master by means of a Loading Manual and in addition, when required, by means of a loading instrument.

1.1.8 The Rules are framed on the understanding that ships will not be operated in environmental conditions more severe than those agreed for the design basis and approval, without the prior agreement of LR.

1.1.9 For ships, the arrangements and equipment of which are required to comply with the requirements of the:
- Load Line Convention;
- *International Convention for the Safety of Life at Sea, 1974* and its Protocol of 1978;
- *International Convention for the Prevention of Pollution from Ships, 1973*, as modified by the Protocol of 1978 relating thereto;
- *International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk* (IBC Code);
- *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* (IGC Code);

and applicable Amendments thereto, the Classification Committee requires the applicable Convention Certificates to be issued by a National Administration, or by LR, or by an IACS Member when so authorised. Safety Management Certificates in accordance with the provisions of the *International Safety Management Code* (ISM Code) may be issued by an organisation complying with IMO Resolution A.739(18) and authorised by the National Authority with which the ship is registered. Cargo Ship Radio Certificates may be issued by an organisation authorised by the National Administration with which the ship is registered. In the case of dual-classed ships, Convention Certificates may be issued by the other Society with which the ship is classed provided this is recognised in a formal Dual Class Agreement with LR and provided the other Society is also authorised by the National Administration. In the event of a National Administration withdrawing any ship's Convention Certificate (referred to in this section) then the Classification Committee may suspend the ship's class. If a ship is removed from the National Administration's Registry for the non-compliance with the Conventions or Classification Requirements referred to herein then the Classification Committee will suspend the ship's class. In the event of ISM Code certification being withdrawn from a ship or Operator then the Classification Committee will suspend the ship's class.

1.1.10 Where an onboard computer system having longitudinal strength computation capability, which is required by the Rules, is provided on a new ship, or newly installed on an existing ship, then the system is to be certified in respect of longitudinal strength in accordance with LR's document entitled *Approval of Longitudinal Strength and Stability Calculation Programs*, *see also* Pt 3, Ch 4,8.

1.1.11 Where an onboard computer system having stability computation capability is provided on a new ship, then the system is to be certified in respect of stability aspects in accordance with LR's document entitled, *Approval of Longitudinal Strength and Stability Calculation Programs*. When provided, an onboard computer system having stability computation capability is to carry out the calculations and checks necessary to assess compliance with all the stability requirements applicable to the ship on which it is installed.

1.1.12 Where a ship has been detained by Port State Control the Owner is to advise LR immediately in order to arrange the attendance of a Surveyor.

1.2 Advisory services

1.2.1 The Rules do not cover certain technical characteristics, such as stability, trim, hull vibration, etc., but advice may be given on such matters without any assumption of responsibility for such advice.

■ *Section 2* Character of classification and class notations

2.1 Definitions

NOTE
For the purpose of class notations, the definitions given in 2.1.1 to 2.1.11 will apply.

2.1.1 **Clear water**. Water having sufficient depth to permit the normal development of wind generated waves.

2.1.2 **Fetch**. The extent of clear water across which a wind has blown before reaching the ship.

2.1.3 **Sheltered water**. Water where the fetch is six nautical miles or less.

2.1.4 **Reasonable weather**. Wind strengths of force six or less in the Beaufort scale, associated with sea states sufficiently moderate to ensure that green water is taken on board the ship's deck at infrequent intervals only or not at all.

2.1.5 **Type notation**. A notation indicating that the ship has been arranged and constructed in compliance with particular Rules intended to apply to that type of ship. Type notations that may be assigned are listed in Table 2.2.1.

Table 2.2.1 Type notations

Dry cargo	Tanker	Passenger
Anchor handler AHTS (Anchor Handler Tug Ship) Barge Bulk carrier Container ship Diving support ship Dredger Escort tug Fire fighting Fishing vessel Hopper barge Hopper dredger Icebreaker Icebreaker(+) Launch Livestock carrier Offshore supply Offshore tug Offshore well stimulation Ore carrier Pipe laying Pontoon Reclamation ship Refrigerated cargo ship Research Roll on-Roll off cargo ship Shipborne barge Standby ship Stern trawler Split hopper barge Split hopper dredger Trawler Tug Vehicle carrier	Chemical tanker Double hull oil tanker Liquefied gas carrier Liquefied gas tanker Oil barge Oil or bulk carrier Oil recovery ship Oil tanker Ore or oil carrier	Passenger ferry Passenger/vehicle ferry Passenger ship Passenger yacht Roll on-Roll off passenger ship Sailing passenger ship

2.1.6 **Cargo notation.** A notation indicating that the ship has been designed, modified or arranged to carry one or more particular cargoes, e.g., sulphuric acid. Ships with one or more particular cargo notations are not thereby prevented from carrying other cargoes for which they are suitable.

2.1.7 **Special duties notation**. A notation indicating that the ship has been designed, modified or arranged for special duties other than those implied by the type and cargo notations, e.g., research. Ships with special duties notations are not thereby prevented from performing any other duties for which they may be suitable.

2.1.8 **ShipRight notation**. A notation indicating that one or more of LR's **ShipRight** procedures have been satisfactorily followed. Class notations or descriptive notes will be assigned according to whether the ShipRight procedures are applied on a mandatory or voluntary basis, i.e.:

(a) The procedures relating to the design and construction of the hull are mandatory for the classification of large and structurally complex ships. In such cases, the associated **ShipRight** notation is assigned as a class notation and will appear in column 4 of the *Register Book*, *see* 2.3.17. When these procedures are applied on a voluntary basis, then the associated **ShipRight** notation is assigned as a descriptive note and will appear in column 6 of the *Register Book*, *see* 2.7.

(b) The remaining ShipRight procedures are voluntary for the purposes of classification, and are assigned as descriptive notes and will appear in column 6 of the *Register Book*, *see* 2.8.3.

2.1.9 **Special features notation**. A notation indicating that the ship incorporates special features which significantly affect the design, *see* Table 2.2.2.

2.1.10 **Service restriction notation**. A notation indicating that a ship has been classed on the understanding that it will be operated only in suitable areas or conditions which have been agreed by the Classification Committee, e.g., protected waters service.

2.1.11 **Linked** means connected, while in operation, to an attendant ship (which may be on shore, submerged or afloat) by a restraining line, suspension cable or umbilical cord.

2.1.12 **Laid-up notation**. A ship not under repair or not actively employed may be assigned the laid-up notation in order to maintain the ship in class subject to agreement by the Classification Committee. A general examination of the hull and machinery is to be carried out in lieu of the Annual Survey. An Underwater Examination (UWE) is to be carried out in lieu of the Special Survey. *See* Ch 3,1.1.2, 2.1.5, 5.1.6 and 11.1.2.

2.2 Character symbols

2.2.1 All ships, when classed, will be assigned one or more character symbols as applicable. For the majority of ships, the character assigned will be **100A1**, **✠100A1** or **✠̇100A1**.

2.2.2 A full list of character symbols for which ships may be eligible is as follows:

✠ This distinguishing mark will be assigned, at the time of classing, to new ships constructed under LR's Special Survey, in compliance with the Rules, and to the satisfaction of the Classification Committee.

✠̇ This distinguishing mark, will be assigned to ships built under supervision of another IACS member society and later assigned class with LR. For such ships the class notations will be reviewed separately and equivalent notations will be assigned.

100 This character figure will be assigned to all ships considered suitable for sea-going service.

A This character letter will be assigned to all ships which have been built or accepted into class in accordance with LR's Rules and Regulations, and which are maintained in good and efficient condition.

1 This character figure will be assigned to:

(a) Ships having on board, in good and efficient condition, anchoring and/or mooring equipment in accordance with the Rules.

(b) Ships classed for a special service, having on board, in good and efficient condition, anchoring and/or mooring equipment approved by the Classification Committee as suitable and sufficient for the particular service.

N This character letter will be assigned to ships on which the Classification Committee has agreed that anchoring and mooring equipment need not be fitted in view of their particular service.

T This character letter will be assigned to ships which are intended to perform their primary designed service function only while they are anchored, moored, towed or linked, and which have, in good and efficient condition, adequately attached anchoring, mooring, towing or linking equipment which has been approved by the Classification Committee as suitable and sufficient for the intended service.

2.2.3 For classification purposes, the character figure **1**, or either of the character letters **N** or **T**, is to be assigned.

2.2.4 In cases where the anchoring and/or mooring equipment is found to be seriously deficient in quality or quantity, the class of the ship will be liable to be withheld.

Table 2.2.2 Special features notations (*see continuation*)

Special features notation	Description	*See also*
BC	Assigned to bulk carriers of length 150 m or above	Pt 4, Ch 7,1.4.2
Bottom Strengthened for (Operating Aground) (Loading and Unloading Aground)	Assigned where the bottom structure has been additionally strengthened for loading and unloading aground	Pt 3, Ch 9,8 and Pt 4, Ch 12,1.3.4
BLS	Bow Loading System. Assigned to tankers equipped with bow loading arrangements to facilitate the transfer of cargo oil from offshore loading terminals	Pt 7, Ch 6,1.2.1
BoxMax	Where a container ship has an approved onboard container lashing program which is installed and maintained in accordance with the requirements of the Rules, the special features notation **BoxMax** may be assigned on application from Owners. In conjunction with the notation **BoxMax**, the following supplementary characters may be assigned and are to be shown consecutively in brackets; **V** may be assigned where, in addition to the requirements for **BoxMax**, the onboard lashing program is capable of performing calculations specific to defined sea areas, and the weather-dependent factors for these areas have been supplied by LR; **W** may be assigned where, in addition to the requirements for **BoxMax(V)**, the onboard lashing program is capable of performing calculations specific to defined sea areas and seasons, and the weather-dependent factors for these areas and seasons have been supplied by LR	Pt 3, Ch 4 and Ch 14
Cargo Loading on (Tank Top/ Tween/ Deck (s) Plating/ Hatch cover(s)) limited to .... tonnes/m^2	Assigned where cargo loading on tank tops, decks and/or hatch covers are limited to a specified maximum value which is less than the normal Rule loading	—
Carriage of Oils with a F.P. not exceeding 60°C	Assigned to non-oil tankers where the ship is suitably constructed and arranged for the carriage of oils with a flash point not exceeding 60°C (closed cup test)	Pt 4, Ch 9 Pt 4, Ch 10
Carriage of Oils with a F.P. exceeding 60°C	Assigned where only the carriage of oils having a flash point exceeding 60°C (closed cup test) is contemplated	Pt 4, Ch 9,1.1.5
(Specified Cargo(es)) only	Assigned where arrangements have been approved for the carriage of a specific product(s)	Pt 4, Ch 9,1.1.7
c.c.	Assigned where structures are fitted with an approved corrosion control system	Chapter 3
CCSA	Certified Container Securing Arrangements. Assigned where freight container securing arrangements are fitted, and the design and construction of the system is in accordance with LR Rules and loose fittings are supplied	Pt 3, Ch 14
CG	Cargo Gear. Assigned where cargo gear is included in class at the Owner's request	Pt 3, Ch 9,6
CL	Cargo Lift(s). Assigned where cargo lift(s) are included in class at the Owner's request	Pt 3, Ch 9,6
CR	Cargo Ramp(s). Assigned where cargo ramp(s) are included in class at the Owner's request	Pt 3, Ch 9,6
CRC –/– –kW –%/–%	Carriage of refrigerated containers. The **CRC** notation may be applied to any ship which has the ability to carry refrigerated containers operating at their design condition with a 24-hour average external ambient air temperature of 35°C The following descriptive notations may be appended, giving details of electrical power and type of cargo: –/– No. of hold-stowed refrigerated containers/No. of deck-stowed refrigerated containers e.g. 230/140 –kW Power generating capacity dedicated to supplying the container plug-in points, e.g., 2,800 kW –%/–% Stowage ratio of deep frozen and chilled cargoes, e.g., 60%/40%	Pt 7, Ch 10,1.1
Container Cargoes in (((all) Hold (No(s)))(and on Upper Deck)((and on (all) Hatch Cover(s) (No(s))...)	Assigned where general cargo ships carry container cargoes.	Pt 3, Ch 4

Table 2.2.2 Special features notations (*continued*)

Special features notation	Description	*See also*
Deck No(s) ... Strengthened for Carriage of Roll on-Roll off Cargoes	Assigned where it is proposed either to stow wheeled vehicles on the deck or to use wheeled vehicles for cargo handling and the deck and supporting structure has been specially considered	Pt 3, Ch 9,3
DSPM4	Dual Single Point Mooring. Assigned to a ship provided with a dual mooring line arrangement at a single-point mooring	Pt 3, Ch 13,8
Fire-Fighting Ship 1, 2, 3 (with water spray)	Designed where fire protection and fire-fighting equipment is provided. Type 1, 2 or 3 signifies the capacity of the fire-fighting equipment. The total discharge capacity of the monitors in m^3/h is shown in brackets. 'With water spray' signifies that a ship is provided with a water spray system which will provide an effective cooling spray of water	Pt 7, Ch 3
Hatch Covers omitted in Hold (No(s)) ...	Assigned where the omission of hatch covers have been specially considered based upon the model tests or alternative means to determine the quantity of water likely to ingress the cargo holds and the means by which it is effectively and safely discharged	Pt 4, Ch 8,11.4
Heavy Deck Loads	Assigned where decks are strengthened for loading in excess of Rule basic minimum, e.g. 'Upper deck aft of Fr. 50 strengthened for load of 10 tonnes/m^2'	Pt 3, Ch 6
Helicopter Landing Area	Assigned where a helicopter landing area is provided	Pt 3, Ch 9,5
Hold (No(s)) ... may be empty at draughts not (less than) (exceeding) ...m	Assigned where particular loading arrangements have been specially considered	Pt 4, Ch 7
Ice Class	Assigned where a ship is strengthened to navigate in specific ice conditions. Supplementary Ice Class notations are given in Table 2.2.3	Pt 8, Ch 1 and Ch 2
Icebreaker	Assigned designed for icebreaking duties	Pt 8, Ch 1 and Ch 2
LA	Mandatory Lifting Appliance(s). Assigned where the lifting appliance is considered to be an essential feature, e.g., cranes on crane barges, lifting arrangements for diving on diving support ships, and is mandatory	Pt 3, Ch 9,6
LFPL	Low Flashpoint liquids. Assigned to offshore supply ships intended for the carriage of liquids with flashpoint below 60°C (closed cup test) in bulk	Pt 4, Ch 4
For Liquefaction and Storage of (Methane, etc.) in Independent Gas Tanks (Type B, etc.), Maximum Vapour Pressure ( ) bar, Minimum Temperature Minus ( ) °C	Assigned where ships of Category 1B or 2 which have process plants installed solely for the purposes of the physical liquefaction of impure feedstock gases at low temperature and the storage of the purified liquefied gases (where the chemical treatment of the impurities is an incidental process)	Pt 7, Ch 2,2.2
Marpol 20.1.3	Assigned to double hull oil tankers not meeting the Rule minimum double side width requirements but which comply with MARPOL Annex 1, Regulation 20.1.3	Pt 4, Ch 9,1.4.3
Marpol 21.1.2	Assigned to double hull oil tankers of less than 5000 tonnes deadweight which have a complete double hull in accordance with MARPOL Annex I, Regulation 21.1.2	Pt 4, Ch 9,1.4.4
Movable Decks	Assigned where all movable decks comply with LR requirements. Movable decks other than those specifically indicated in LR Rule requirements are not a classification item	Pt 3, Ch 9,4
Oil Recovery	Assigned when a ship is equipped for oil recovery operations	Pt 7, Ch 5,2
Petrol in Hold (No(s))...	Assigned to ships that can carry motor vehicles with fuel in their tanks for self-propulsion, in specified locations. It does not apply to ships that are designed primarily for the carriage of motor vehicles Specific requirements will be advised upon request	–
PL	Passenger Lift(s). Assigned where the passenger lift(s) are included in class at the Owner's request	Pt 3, Ch 9,6
PM T1 [or T2 or T3] encircled	For ships fitted with a positional mooring system (PM). The supplementary notation T1 [or T2 or T3] encircled may be applied if the system is thruster-assisted. The encircled numeral defines the thruster allowance	Pt 7, Ch 8,1.2.1
PMC T1 [or T2 or T3] encircled	For ships fitted with a positional mooring system for mooring in close proximity to other ships or installations (PMC). The supplementary notation T1 [or T2 or T3] encircled may be applied if the system is thruster-assisted. The encircled numeral defines the thruster allowance	Pt 7, Ch 8,1.2.1

Table 2.2.2 Special features notations (*conclusion*)

Special features notation	Description	*See also*
RD	Relative Density. Assigned where a ship has tanks appraised for a maximum permissible relative density greater than 1,025	Pt 4, Ch 1 Pt 4, Ch 4
Self-Discharging (Unloading)	Assigned where a ship fitted with self-unloading equipment whose structural aspect has been specially approved	Pt 4, Ch 12,1
SLS	Stern Loading System. Assigned to tankers equipped with stern loading arrangements to facilitate the transfer of cargo oil from offshore loading terminals	Pt 7, Ch 6,1
Specialised for the Carriage of ...	Assigned to a vessel which has been designed for the carriage of specified cargo other than that applied by the type notation	Pt 4, Ch 4,1
SPM4	Single Point Mooring. Assigned to a ship provided with a single mooring line arrangement at a single point mooring	Pt 3, Ch 13,8
Strengthened for Heavy Cargoes ((any) Hold (No(s)) .... may be empty)	Assigned to a bulk carrier of less than 150 m in length or a ship designed for the carriage of heavy cargoes. If only certain holds are strengthened for heavy cargoes, they will be specified	Pt 4, Ch 1 and Pt 4, Ch 7,1
HNLS	Hazardous and noxious liquids system. Assigned to ships complying with the requirements for the transport and handling of limited amounts of hazardous and noxious liquid substances in bulk	Pt 4, Ch 4,8.1.6
Hold No(s) ... Strengthened for Regular Discharge by Heavy Grabs	Assigned to bulk carriers where cargoes are regularly discharged by heavy grabs and the thickness of the plating of the hold inner bottom, hopper and transverse bulkhead bottom stool is increased	Pt 3, Ch 9,9
Submersible to a depth of ...m below Upper Deck in Harbour only	Assigned to a ship that is designed so that it can be submersed to a specified depth in harbour only	—
Timber Deck Cargoes	Assigned where a cargo of timber is carried on an uncovered part of the freeboard or superstructure deck (does not include wood pulp or similar cargo) and the requirements of the 1966 Load Line Convention concerning timber deck cargoes or other National Regulations are complied with	Pt 3, Ch 9,2
TLS	Submerged Turret Loading System. Assigned to tankers equipped with submerged turret loading systems to facilitate the transfer of cargo oil from offshore loading to terminals	Pt 7, Ch 6,1
Winterisation	Assigned to a ship that is intended to navigate in cold climates and may be exposed to low temperatures that may cause equipment to freeze due to ice accretion from atmospheric icing or sea spray or due to freezing of liquid within a system. Protection measures are provided and operational procedures are specified to ensure that equipment is suitably protected to enable operation in low temperatures. Supplementary Winterisation notations are given in Table 2.2.3	Pt 8, Ch 1 and Ch 2
WDL(+)	Weather Deck Load. Assigned where the weather deck load scantlings have been approved for a loading greater than a design head of 3,5 m	Pt 4, Ch 1 and Ch 4

Table 2.2.3 Notations for ice and cold operations

Notation	Description	Conditions	Application	*See also*
Ice Class 1E	For offshore supply vessels	Light and very light ice conditions	Hull, Machinery	Pt 8, Ch 2,4 and Pt 8, Ch 2,5
Ice Class 1D	Hull strengthening in forward region only			
Ice Class 1C FS	Finnish Swedish Ice Class Rules	Ice Class 1C; ships with such structure, engine output and other properties that they are capable of navigating in light ice conditions, with the assistance of icebreakers when necessary;	Hull, Machinery	Pt 8, Ch 2,6 and Pt 8, Ch 2,7
Ice Class 1B FS		Ice Class 1B; ships with such structure, engine output and other properties that they are capable of navigating in moderate ice conditions, with the assistance of icebreakers when necessary		
Ice Class 1A FS		Ice Class 1A; ships with such structure, engine output and other properties that they are capable of navigating in difficult ice conditions, with the assistance of icebreakers when necessary		
Ice Class 1AS FS		Ice Class 1A Super; ships with such structure, engine output and other properties that they are normally capable of navigating in difficult ice conditions without the assistance of icebreakers		
Ice Class 1C FS(+)	Finnish Swedish Ice Class Rules with enhanced engine power for icebreaking capability	Ice Class 1C; ships with such structure, engine output and other properties that they are capable of navigating in light ice conditions, with the assistance of icebreakers when necessary	Hull, Machinery	Pt 8, Ch 2,8 and Pt 8, Ch 2,9
Ice Class 1B FS(+)		Ice Class 1B; ships with such structure, engine output and other properties that they are capable of navigating in moderate ice conditions, with the assistance of icebreakers when necessary		
Ice Class 1A FS(+)		Ice Class 1A; ships with such structure, engine output and other properties that they are capable of navigating in difficult ice conditions, with the assistance of icebreakers when necessary		
Ice Class 1AS FS(+)		Ice Class 1A Super; ships with such structure, engine output and other properties that they are normally capable of navigating in difficult ice conditions without the assistance of icebreakers		
Ice Class PC7	IACS Polar Ship Rules	Summer/autumn operation in thin first-year ice which may include old ice inclusions	Hull, Machinery	Pt 8, Ch 2,10 and Pt 8, Ch 2,11
Ice Class PC6		Summer/autumn operation in medium first-year ice which may include old ice inclusions		
Ice Class PC5		Year-round operation in medium first-year ice which may include old ice inclusions		
Ice Class PC4		Year-round operation in thick first-year ice which may include old ice inclusions		
Ice Class PC3		Year-round operation in second-year ice which may include multi-year ice inclusions		
Ice Class PC2		Year-round operation in moderate multi-year ice conditions		
Ice Class PC1		Year-round operation in all Polar waters		
Winterisation H(*t*)	Hull construction materials	Low temperature operations	Hull, materials	Section 2 of the *Provisional Rules for the Winterisation of Ships*
Winterisation C(*t*)	Short duration		Equipment and systems	Section 3 of the *Provisional Rules for the Winterisation of Ships*
Winterisation B(*t*)	Seasonal duration			
Winterisation A(*t*)	Prolonged duration			

2.3 Class notations (hull)

2.3.1 When considered necessary by the Classification Committee, or when requested by an Owner and agreed by the Classification Committee, a class notation will be appended to the character of classification assigned to the ship. This class notation will consist of one of, or a combination of: a type notation, a cargo notation, a special duties notation, a special features notation and/or a service restriction notation, e.g., '✠**100A1** Oil Tanker F.P. exceeding 60°C in No. 4 tanks ESP Baltic Service Ice Class 1B'.

2.3.2 Details of the ship types and particular cargoes for which special Rules apply are given in those Chapters of Parts 3, 4 and 7 which apply to such ships and cargoes.

2.3.3 Details of the more common special features and the conditions relevant to the assignment of special features notations, together with the form of such notations, are incorporated in Parts 3, 4 and 7 as applicable.

2.3.4 Service restriction notations will generally be assigned in one of the forms shown in 2.3.6 to 2.3.10, but this does not preclude Owners or Shipbuilders requesting special consideration for other forms in unusual cases.

2.3.5 Where a service notation is applicable, certain exemptions may be granted. Where these affect statutory requirements, such as Load Lines, the Owner or shipbuilder is to obtain the authorisation of the Flag State. Such exemptions are to be recorded on the Class certificate and any applicable statutory certificate.

2.3.6 **Protected waters service**. Service in sheltered waters adjacent to sand banks, reefs, breakwaters or other coastal features, and in sheltered waters between islands, e.g., 'Protected Waters Service at Storebaelt Bridge'.

2.3.7 **Extended protected waters service**. Service in protected waters and also for short distances (generally less than 15 nautical miles) beyond protected waters in 'reasonable weather', e.g., 'Extended Protected Waters Service from the Port of Lagos'.

2.3.8 **Specified coastal service**. Service along a coast, the geographical limits of which will be indicated in the *Register Book*, and for a distance out to sea generally not exceeding 21 nautical miles, unless some other distance is specified for 'coastal service' by the Administration with which the ship is registered, or by the Administration of the coast off which it is operating, as applicable, e.g., 'Indonesian coastal service'.

2.3.9 **Specified route service**. Service between two or more ports or other geographical features which will be indicated in the *Register Book*,
e.g., 'London to Rotterdam service'
'London, Rotterdam and Hamburg service'.

2.3.10 **Specified operating area service**. Service within one or more geographical area(s) which will be indicated in the *Register Book*,
e.g. 'Pacific Tropical Zone service'.
'Great Lakes and St.Lawrence to Pt. du Monts service'
'Red Sea, Eastern Mediterranean and Black Sea service'.

2.3.11 ***IWS**. This notation (In-water Survey) may be assigned to a ship where the applicable requirements of LR's Rules and Regulations are complied with, *see* Ch 3,4.3; Pt 3, Ch 1,5.2 and 5.3; Pt 3, Ch 2,3.5; Pt 3, Ch 13,2.8 and Pt 5, Ch 6,3.12. This notation will be withdrawn for **ESP** ships upon reaching 15 years of age.

2.3.12 **ESP**. This notation (Enhanced Survey Programme) will be assigned to oil tankers, combination carriers, chemical tankers, bulk carriers and ore carriers, as defined in Ch 3,1.5 which are subject to an enhanced survey programme as detailed in Ch 3, Sections 3, 6, 7 and 8.

2.3.13 **CSR**. This notation will be assigned to bulk carriers and double hull oil tankers compliant with the *IACS Common Structural Rules*, *see* Pt 4, Ch 7,1.2.1 and Ch 9,1.2.1. Additional mandatory and non-mandatory class notations for CSR bulk carriers are given in 2.3.14

2.3.14 **Class notations for CSR bulk carriers**. In general, CSR bulk carriers less than 150 m in length are to comply with the requirements of Pt 4, Ch 7,1.4 and the IACS *Common Structural Rules for Bulk Carriers* (CSR) and will be eligible for one of the following mandatory class notations:

{any holds may be empty} This class notation is normally assigned to a ship designed to carry dry bulk cargoes of cargo density 1,0 tonne/m^3 and above, with an approved arrangement of loaded holds such that any hold may be empty at the maximum draught.

{holds a, b, ... may be empty} This class notation is normally assigned to a ship designed to carry dry bulk cargoes of cargo density 1,0 tonne/m^3 and above with specified holds empty at maximum draught.

In general, CSR bulk carriers equal to or greater than 150 m in length are to comply with the requirements of Pt 4, Ch 7,1.4 and the IACS *Common Structural Rules for Bulk Carriers* (CSR) and will be eligible for one of the following mandatory class notations:

BC-A, {holds a, b, … may be empty} This class will be assigned for bulk carriers designed to carry dry bulk cargoes of cargo density 1,0 tonne/m^3 and above with specified holds empty at maximum draught.

BC-B This class will be assigned for bulk carriers designed to carry dry bulk cargoes of cargo density 1,0 tonne/m^3 and above with all cargo holds loaded.

BC-C This class will be assigned for bulk carriers designed to carry dry bulk cargoes of cargo density less than 1,0 tonne/m^3 with all cargo holds loaded.

The following additional notations and annotations are to be provided giving further detailed description of limitations to be observed during operation as a consequence of the design loading condition applied during the design:

(maximum cargo density (in tonnes/m^3)) For notations **BC-A** and **BC-B** if the maximum cargo density is less than 3,0 tonnes/m^3

(no MP) For all notations when the vessel has not been designed for loading and unloading in multiple ports in accordance with the conditions specified in IACS *Common Structural Rules for Bulk Carriers* (CSR) Ch 4,7.3.3;

GRAB [X] Where the net thickness of plating of inner bottom, hopper tank sloping plate, transverse lower stool, transverse bulkhead plating and inner hull up to a height of 3,0 m above the lowest point of the inner bottom, excluding bilge wells comply with IACS *Common Structural Rules for Bulk Carriers* (CSR) Ch 12,1 for **BC-A** and **BC-B**, *see* CSR Ch 1,1;

(allowed combination of specified empty holds) Annotation for notation **BC-A**.

2.3.15 **ESN**. This notation (Enhanced Survivability Notation) will be assigned to non-**CSR** bulk carriers which are designed to withstand the individual flooding of all cargo holds, *see* Pt 4, Ch 7,1.3.2.

2.3.16 **LI**. This notation will be assigned where an approved loading instrument has been installed as a classification requirement.

2.3.17 **ShipRight notations**. The following notations are associated with LR's ShipRight procedures and may be assigned in conjunction with the **ShipRight** notation as considered appropriate by the Classification Committee, on application from the Owners. The requirements pertaining to these notations and the ShipRight procedures are given in Pt 3, Ch 16.

ShipRight ACS The ShipRight Anti-Corrosion System notation will be assigned when a specified area or areas of the ship have been protected against corrosion in accordance with ShipRight procedures. The **ShipRight ACS** notation with the extension of one or more of the following associated characters shown in brackets, detailing the specified protected area or areas, may be assigned;

- **B** for protective coating system of water ballast tanks;
- **D** for protective coating system of double-side skin spaces;
- **C** for protective coating system of cargo oil tanks;
- **C*** when corrosion resistant steel has been used in cargo oil tanks;
- **V** for protective coating system of void spaces.

ShipRight SDA This notation (Structural Design Assessment) will be assigned when direct calculations in accordance with the ShipRight procedures have been applied.

ShipRight FDA This notation (Fatigue Design Assessment) will be assigned when an appraisal has been made of the fatigue performance of the hull structure in accordance with the ShipRight FDA procedures.

ShipRight FDA plus This notation (Fatigue Design Assessment plus) may be assigned upon request when an appraisal has been made for a higher level of fatigue performance than that made for the assignment of **ShipRight FDA**.The appraisal may be made based upon a specific trading pattern, which is to be expressed in terms of either a Worldwide trading route, as defined in the **ShipRight FDA** procedure, or a North Atlantic trading route (that utilises the wave data from IACS Recommendation 34). The notation **ShipRight FDA plus** is to be followed by the number of years that the vessel has been assessed for the specific trading pattern for either the Worldwide or North Atlantic trading routes, denoted by **WW** and **NA** respectively, e.g., **ShipRight FDA plus (25, NA)**.

ShipRight FDA ICE This notation (Fatigue Design Ice) will be assigned when an appraisal has been made for the fatigue performance of the ship structure when navigating in ice.

ShipRight CM This notation (Construction Monitoring), which complements the **ShipRight SDA, ShipRight FDA**, **ShipRight FDA plus** and **ShipRight FDA ICE** notations, will be assigned when the controls in construction tolerances detailed in the ShipRight procedures have been applied and verified.

2.3.18 When **ShipRight SDA**, **ShipRight FDA**, **ShipRight FDA plus** or **ShipRight FDA ICE** are assigned, the precise technical conditions of the appraisal will be made available to Owners.

2.3.19 Where LR's **ShipRight SDA** procedure has been applied individually or where **ShipRight SDA**, **ShipRight FDA** or **ShipRight FDA plus**, or **ShipRight FDA ICE** and **ShipRight CM** procedures have all been applied, whether on a voluntary or mandatory basis, these particular class notations will appear in column 4 of the *Register Book*.

2.3.20 **EU notations**. The following notations may be assigned to passenger ships that comply with the requirements of the European Council Directive 98/18/EC of 17 March 1998 on safety Rules and Standards for passenger ships, and subsequent revisions:

EU(A) This class notation will be assigned to a passenger ship engaged on domestic voyages other than voyages covered by Classes B, C and D.

EU(B) This class notation will be assigned to a passenger ship engaged on domestic voyages in the course of which it is at no time more than 20 miles from the line of coast, where shipwrecked persons can land, corresponding to the medium tide height.

EU(C) This class notation will be assigned to a passenger ship engaged on domestic voyages in sea areas where the probability of exceeding 2,5 m significant wave height is smaller than 10 per cent over a one-year period for all-year-round operation, or over a specific restricted period of the year for operation exclusively in such a period (e.g., summer period operation), in the course of which it is at no time more than 15 miles from a place of refuge, nor more than 5 miles from the line of coast, where shipwrecked persons can land, corresponding to the medium tide height.

EU(D) This class notation will be assigned to a passenger ship engaged on domestic voyages in sea areas where the probability of exceeding 1,5 m significant wave height is smaller than 10 per cent over a one-year period for all-year-round operation, or over a specific restricted period of the year for operation exclusively in such a period (e.g., summer period operation), in the course of which it is at no time more than 6 miles from a place of refuge, nor more than 3 miles from the line of coast, where shipwrecked persons can land, corresponding to the medium tide height.

2.3.21 The following notations may be assigned to ships that comply with standards for noise and vibration levels in different spaces at the time of delivery and during the ship's life if substantial changes to the machinery installation or interior arrangements are made.

PAC Passenger Accommodation Comfort. This notation indicates that the passenger accommodation meets the acceptance criteria.

CAC Crew Accommodation Comfort. This notation indicates that the crew accommodation and work areas meet the acceptance criteria.

PCAC Passenger and Crew Accommodation Comfort. This notation indicates that the passenger and crew spaces both meet the acceptance criteria.

Following the **PAC** or **CAC** notation, numerals 1, 2 or 3 will indicate the acceptance criteria to which the noise and vibration levels have been assessed. In the case of the **PCAC** notation, two numerals will be assigned. The first will indicate the acceptance criteria for passenger accommodation, whilst the second will indicate the crew comfort criteria. These notations are optional and are primarily intended to apply to passenger ships. Spaces that comply with the minimum Rule requirement for noise levels indicated in Pt 7, Ch 12, will meet the requirements of section 4 of IMO Resolution MSC.337(91), when measured in accordance with the requirements of Chapters 2 and 3 of that Resolution.

2.3.22 The notation **EPN** (escort performance numeral) may be assigned to escort tugs which carry out full-scale performance trials in accordance with the requirements of Pt 4, Ch 3,9.3. **(F,B,V,C)** may be appended to the notations where:

F Maximum steering force, in tonnes.

B Maximum braking force, in tonnes.

V Speed, in knots, at which F and B are determined.

C Time, in seconds, required for the escort tug in manoeuvring from maintained oblique position of the tug giving it a maximum steering force on one side of the assisted vessel to a mirror position on the other side.

2.4 Class notations (machinery)

2.4.1 The following class notations are associated with the machinery construction and arrangement, and may be assigned as considered appropriate by the Classification Committee, *see also*, Table 2.2.4:

✠ LMC This notation will be assigned when the propelling and essential auxiliary machinery, *see* 2.9.1, have been constructed, installed and tested under LR's Special Survey and in accordance with LR's Rules and Regulations for the classification of Ships, *see* 3.2.

[✠] LMC This notation will be assigned when;

- the propelling arrangements for propellers, propulsion shafting and multiple input/output gearboxes, steering systems, pressure vessels and electrical equipment for essential systems have been constructed, installed and tested under LR's Special Survey and are in accordance with LR's Rules and Regulations, *see* 3.2.
- other items of machinery and gearing arrangements for propulsion and electrical power generation and other auxiliary machinery for essential services are in compliance with LR Rules and supplied with the Manufacturer's certificate, *see* 2.9.2.
- the system arrangements of propelling and essential auxiliary machinery, *see* 2.9.1, are appraised and found to be acceptable to LR.

✠LMC This notation will be assigned to existing ships in service that will be accepted or transferred into LR class when:

- the propelling and essential auxiliary machinery, *see* 2.9.1, have neither been constructed nor installed under LR's Special Survey.
- the existing machinery installation and arrangement have been tested and found to be acceptable to LR.

MCH This notation will be assigned when the:

- propelling and essential auxiliary machinery, *see* 2.9.1, has been installed and tested under LR's survey and found to be acceptable to LR.
- propelling and essential auxiliary machinery has been supplied with a Manufacturer's certificate, *see* 2.9.3.
- system arrangements of propelling and essential auxiliary machinery, *see* 2.9.1, are appraised and found to be acceptable to LR.

IGS This notation will be assigned when a ship intended for the carriage of oil in bulk, or for the carriage of liquid chemicals in bulk, is fitted with an approved system for producing gas for inerting the cargo tanks.

2.4.2 The following class notations are associated with the machinery control and automation, and may be assigned as considered appropriate by the Classification Committee:

UMS This notation may be assigned when the arrangements are such that the ship can be operated with the machinery spaces unattended. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

CCS This notation may be assigned when the arrangements are such that the machinery may be operated with continuous supervision from a centralised control station. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

ICC This notation may be assigned when the arrangements are such that the control and supervision of ship operational functions are computer based. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

IP This notation may be assigned to a ship classed with LR when the arrangements of the machinery are such that the propulsion equipment and all the essential auxiliary machinery is integrated with the power unit for operation under all normal sea-going and manoeuvring conditions. The system is to be bridge controlled and the propulsion equipment is to incorporate an emergency means of propulsion in the event of failure in the prime mover. It also denotes that the machinery and control equipment have been arranged, installed and tested in accordance with LR's Rules.

2.4.3 The following class notations are associated with dynamic positioning arrangements, and may be assigned as considered appropriate by the Classification Committee:

DP(CM) This notation may be assigned when a ship is fitted with centralised remote manual controls for position keeping and with position reference system(s) and environmental sensor(s). It denotes that the machinery and control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

DP(AM) This notation may be assigned when a ship is fitted with automatic main and manual standby controls for position keeping and with position reference system(s) and environmental sensor(s). It denotes that the machinery and control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

DP(AA) This notation may be assigned when a ship is fitted with automatic main and automatic standby controls for position keeping and with position reference system(s) and environmental sensor(s). It denotes that the machinery and control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

DP(AAA) This notation may be assigned when a ship is fitted with automatic main and automatic standby controls for position keeping, together with an additional/emergency automatic control unit located in a separate compartment and with position reference systems and environmental sensors. It denotes that the machinery and control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

Table 2.2.4 Machinery Class Notations

Machinery Notations
See 2.4, 2.5, 2.6

✠ LMC
Propulsion and essential machinery

[✠] LMC
Propulsion and essential machinery

✠̇LMC
Propulsion and essential machinery

MCH
Propulsion and essential machinery

IGS
Inert Gas System

UMS
Unattended Machinery Spaces

CCS
Centralised Control Station

ICC
Integrated Computer Control

IP
Integrated Propulsion

DP(CM)
Dynamic Position
(Centralised Remote Manual Controls)

DP(AM)
Dynamic Position (Automatic main and Manual standby Controls)

DP(AA)
Dynamic Position (Automatic main and Automatic standby Controls)

DP(AAA)
Dynamic Positioning (Automatic main and Automatic standby controls with additional/emergency Automatic control)

PCR()()
Performance Capability Rating

NAV1
Navigation Equipment

IBS
Integrated Bridge System

OPS
Operation of Services by connection to an external electrical Power Supply

PM
Positional Mooring System

PMC
Positional Mooring System for mooring in Close proximity to other vessels or installations

GF
Natural Gas Fuelled Ships

PMR
Propulsion System Redundancy

PSMR
Propulsion and Steering System Redundancy

PSMR*
Propulsion and Steering System Redundancy in Separate Compartments

PMRL
Propulsion System Redundancy with Limited Capacity

PMRL*
Propulsion System Redundancy in Separate Compartments with Limited Capacity

SMRL
Steering System Redundancy with Limited Capacity

SMRL*
Steering System Redundancy in Separate Compartments with Limited Capacity

PSMRL
Propulsion and Steering System Redundancy with Limited Capacity

PSMRL*
Propulsion and Steering System Redundancy in Separate Compartments with Limited Capacity

CAC1(1 or 2 or 3)
Crew Accommodation Comfort

PAC1 (or 2 or 3)
Passenger Accommodation Comfort

PCAC1 (or 2 or 3), 1 (or 2 or 3)
Passenger and Crew Accommodation

✠ Lloyd's RMC
Refrigerated Machinery

Lloyd's RMC
Refrigerated Machinery

‡ Double Dagger – Suitable for carriage of fruit

✠Lloyd's RMC (LG)
Reliquefaction and/or refrigeration equipment is fitted

Lloyd's RMC (LG)
Reliquefaction and/or refrigeration equipment is fitted

✠Lloyd's RMC (BC)
Refrigerated Chemical tanker

Lloyd's RMC (BC)
Refrigerated Chemical Tanker

TC
Chemical Tanker temperature Control Systems

(**CA**)
Controlled Atmosphere

CA (%O_2, %CO_2)
Controlled Atmosphere

RH
Relative Humidity

PCR()() This rating supplements the **DP()** notation. This rating indicates the calculated percentage of time that a unit is capable of holding heading and position under a standard set of environmental conditions (North Sea).
Two rating numerals are calculated:
- The first numeral represents the percentage of time that the ship can remain on station when subjected to a set of standard environmental conditions (North Sea fully developed) with all thrusters operating.
- The second numeral represents the percentage of time that the ship can remain on station when subjected to a set of standard environmental conditions (North Sea fully developed) with the most effective thruster being inoperative.
- A typical rating might be (95),(70).

The foregoing dynamic positioning notations may be supplemented with a Performance Capability Rating (PCR). This rating indicates the calculated percentage of time that a ship is capable of holding heading and position under a standard set of environmental conditions (North Sea), *see* Pt 7, Ch 4.

2.4.4 The following class notations are associated with navigation safety, and may be assigned as considered appropriate by the Classification Committee:

NAV1 This notation will be assigned when the bridge layout and level of equipment are such that the ship is considered suitable for safe periodic operation under the supervision of a single watchkeeper on the bridge. It denotes that the navigational installation has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

IBS This additional notation will be assigned where an integrated bridge system is fitted to provide electronic chart display, track planning and automatic track following, centralised navigation information display, and bridge alarm management. It denotes that the integrated bridge system has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto. For assignment of this notation, in addition to satisfying LR Rules, or equivalent thereto, for navigational function integration:

(a) the layout of the bridge and the equipment located on the bridge is to satisfy the requirements of a relevant international or national ergonomic or human-centred design standard, or an acceptable equivalent, to the satisfaction of LR; or
(b) the notation **NAV1** is also to be assigned; or
(c) where the bridge is not intended to operate a periodic one man watch, the layout of the bridge and the equipment on the bridge are to satisfy the requirements for the assignment of the notation **NAV1** to the satisfaction of LR with the exception of requirements identified by LR Rules that may be relaxed in such cases.

2.4.5 Machinery class notations will not be assigned to ships the hulls of which are not classed or intended to be classed with LR.

2.4.6 The notations ✠ **LMC**, **[✠]LMC**, **✠LMC** and **MCH** will in general not be assigned to non-propelled craft, but individual cases will be considered on their merits.

2.5 Class notations (machinery special features)

2.5.1 The following class notation is associated with onshore power supply arrangements and may be assigned as considered appropriate by the Classification Committee, upon application from the Owners:

OPS Assigned when the machinery, electrical and control engineering arrangements installed on board to permit continued operation of services by connection to an external electrical power supply have been assessed.

2.5.2 The following class notations are associated with positional mooring systems, or thruster-assisted positional mooring systems, and may be assigned as considered appropriate by the Classification Committee:

PM Assigned when a positional mooring system is fitted. It is not intended to apply to vessels which have station-keeping capabilities, but which are not required to remain on station in adverse weather conditions. This notation can be supplemented by a Thrust-Assisted notation **T1** [or **T2** or **T3**].

PMC Assigned when a positional mooring system for mooring in close proximity to other vessels or installations is fitted. It is not intended to apply to vessels which have station-keeping capabilities, but which are not required to remain on station in adverse weather conditions. This notation can be supplemented by a Thrust-Assisted notation **T1** [or **T2** or **T3**].

GF Assigned to ships other than LNG carriers, where the main propelling and/or auxiliary machinery is designed to operate on natural gas as fuel, or a combination of natural gas and oil fuel. The notation also indicates that the gas-fuelled machinery has been installed and tested in accordance with LR's Rules and Regulations.

2.5.3 The following class notations are associated with machinery redundancy and may be assigned as considered appropriate by the Classification Committee:

PMR This notation will be assigned where the main propulsion systems are arranged such that, in the event of a single failure in equipment, the ship will retain not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems. It also denotes that the installation has been arranged, installed and tested in accordance with LR Rules.

PMR* This notation will be assigned where the main propulsion systems are arranged such that, in the event of a single failure in equipment, the ship will retain not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems and where the machinery is installed in separate compartments such that, in the event of the loss of one compartment, the ship will retain availability of propulsion power. It also denotes that the installation has been arranged, installed and tested in accordance with LR Rules.

SMR This notation will be assigned where the steering systems for manoeuvring are arranged so that steering capability will continue to be available in the event of a single failure in the steering gear equipment or loss of power supply or control system for any steering system. It also denotes that the installation has been arranged, installed and tested in accordance with LR's Rules.

SMR* This notation will be assigned where the steering systems for manoeuvring are arranged so that steering capability will continue to be available in the event of a single failure in the steering gear equipment or loss of power supply or control system for any steering system and where the steering systems are installed in separate compartments such that, in the event of the loss of one compartment, steering capability will continue to be available. It also denotes that the installation has been arranged, installed and tested in accordance with LR's Rules.

PSMR This notation will be assigned where the main propulsion and steering systems are configured such that, in the event of a single failure in equipment, the ship will retain not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems and retain steering capability. It also denotes that the installation has been arranged, installed and tested in accordance with LR's Rules.

PSMR* This notation will be assigned where the main propulsion and steering systems are configured such that, in the event of a single failure in equipment, the ship will retain not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems and retain steering capability. The propulsion and steering arrangements are to be installed in separate compartments such that, in the event of the loss of one compartment, the ship will retain availability of propulsion power and manoeuvring capability. It also denotes that the installation has been arranged, installed and tested in accordance with LR's Rules.

The foregoing machinery redundancy notations may be supplemented with the additional **L** character which indicates a limited capability.

2.5.4 The following class notations are associated with comfort control and may be assigned as considered appropriate by the Classification Committee:

CAC1 (or **2** or **3**)
Assigned when noise and vibration levels in crew accommodation and work areas have been assessed. Numerals **1** or **2** or **3** indicate the acceptance criterion to which the noise and vibration levels have been assessed. Primarily intended to apply to passenger ships. If requested, however, any ship can be assessed for compliance.

PAC1 (or **2** or **3**)
Assigned when noise and vibration levels in passenger accommodation have been assessed. Numerals **1** or **2** or **3** indicate the acceptance criterion to which the noise and vibration levels have been assessed. Primarily intended to apply to passenger ships. If requested, however, any ship can be assessed for compliance.

PCAC1 (or **2** or **3**), (**1** or **2** or **3**)
Assigned when noise and vibration levels in passenger and crew spaces have been assessed. Numerals **1** or **2** or **3** indicate the acceptance criterion to which the noise and vibration levels have been assessed. Two numerals will be assigned, the first for the acceptance criteria for passenger accommodation, the second for crew comfort criteria. Primarily intended to apply to passenger ships. If requested, however, any ship can be assessed for compliance.

2.6 Class notations (refrigerated cargo installations (RMC), controlled atmosphere (CA) systems and carriage of refrigerated containers (CRC))

2.6.1 The following class notations may be assigned as considered appropriate by the Classification Committee, on application from the Owners:

✠ Lloyd's RMC This notation will be assigned when a refrigerated cargo installation has been constructed, installed and tested under LR's Special Survey and in accordance with the relevant requirements of the Rules.

Lloyd's RMC This notation will be assigned when the arrangements of the refrigerated cargo installation have been found to be equivalent to Rule requirements, and the installation has been tested in accordance with the relevant requirements of the Rules.

‡ This symbol will be assigned to installations considered suitable for the carriage of fruit. It indicates that the following parameters have been assessed and found satisfactory:

(a) The rate of air circulation and the air refreshing arrangements through the refrigerated spaces or chambers, or to containers.

(b) The temperature controls and monitoring arrangements.

(c) The installation's capability to cool down a complete cargo of fruit to its carrying temperature within a specified time. The symbol will also be assigned to fishing vessels that have the refrigerating capacity to freeze down their catch.

✠ Lloyd's RMC (LG) This notation will be assigned to a classed liquefied gas carrier or tanker, in which reliquefaction or refrigeration equipment is approved and fitted for cargo temperature and pressure control where the equipment has been constructed, installed and tested in accordance with the relevant requirements of the Rules.

Lloyd's RMC (LG) This notation will be assigned to a classed liquefied gas carrier or tanker, in which reliquefaction or refrigeration equipment is fitted for cargo temperature and pressure control, where the equipment has been found equivalent to Rule requirements and tested in accordance with the relevant requirements of the Rules.

✠ Lloyd's RMC (BC) Assigned to a classed chemical tanker in which refrigeration equipment has been constructed, installed and tested, in accordance with the relevant requirements of the Rules.

Lloyd's RMC (BC) Assigned to a classed chemical tanker where the equipment has been found equivalent to Rule requirements and tested in accordance with the relevant requirements of the Rules.

TC Assigned to a classed chemical tanker where the temperature control systems have been found equivalent to Rule requirements and tested in accordance with the relevant requirements of the Rules.

2.6.2 The following class notations are associated with controlled atmospheres and may be assigned as considered appropriate by the Classification Committee, on application from Owners, *see also* Pt 7, Ch 1:

(CA) This notation may be assigned when a ship is fitted with arrangements for maintaining airtightness in CA zones and for the ready connection to a gas system in accordance with the relevant requirements of the Rules.

CA (%O_2, %CO_2) This notation may be assigned when a ship is provided with a CA system which will achieve and maintain specified ranges of oxygen and carbon dioxide levels in accordance with the relevant requirements of the Rules.

RH This notation may be assigned when a ship can maintain a specified relative humidity in the CA zones.

RPA Assigned to ships where the Refrigeration Machinery for Provision Stores and Air-conditioning comply with the applicable requirements of Pt 7, Ch 15.

Before assignment of any of the above notations it is a prerequisite that the refrigeration installation is assigned an **RMC** class notation.

2.6.3 The following class notation is associated with the carriage of refrigerated cargo containers and may be assigned as considered appropriate by the Classification Committee, on application from Owners, *see also* Pt 7, Ch 10:

✠CRC This notation may be assigned when a ship is provided with a ventilation system which is approved, installed and tested in accordance with the relevant requirements of the Rules.

2.6.4 The class notation assigned will additionally specify the temperature conditions and other relevant characteristics for which the equipment has been approved, *see* Pt 6, Ch 3.

2.6.5 The class notation assigned will be maintained as long as the installation is found, at the prescribed Periodical Surveys, to be in a fit and efficient condition, and in accordance with the requirements of the Rules.

2.6.6 The Classification Committee will give consideration to ships engaged on voyages of short duration, to installations of small capacity, or to other special circumstances. In such cases the class may include a service limitation or other restriction.

2.6.7 Refrigerating installations designed to supply refrigerated air to insulated containers in ships' holds aboard container ships, are eligible for classification. The installation is to include the refrigerating machinery, supply and return air ducting, and the flexible couplings between containers and the duct system. Where the arrangements are such that cell air conditioning is essential to the carriage of the containers, the air conditioning equipment and/or insulation of the hold, deckheads, sides and tank tops are to be included in the classification.

2.6.8 Other methods of carrying refrigerated cargoes in containers aboard container ships will be considered for classification on application.

2.7 Class notations (Environmental Protection)

2.7.1 The following class notations are associated with the design and operation of a ship and may be assigned as considered appropriate by the Classification Committee, on application from the Owners:

ECO This notation will be assigned when a ship is designed and operated in accordance with the relevant requirements of the Rules.

ECO(TOC) This notation will be assigned when the environmental protection arrangements are in accordance with the requirements of another recognised classification society and are essentially equivalent to Rule requirements and the ship is operated in accordance with the relevant requirements of the Rules.

2.8 Descriptive notes

2.8.1 In addition to any class notations, an appropriate descriptive note may be entered in column 6 of the *Register Book* indicating the type of ship in greater detail than is contained in the class notation, and/or providing additional information about the ship's design and construction. This descriptive note is not an LR class notation and is provided solely for information.

2.8.2 Where evidence exists that supporting calculations have been performed in accordance with hull structural finite element and fatigue analysis procedures of a recognised Classification Society, then, on application from Owners, the descriptive note **ShipRight (E)** may be entered in column 6 of the *Register Book*.

2.8.3 Where LR's ShipRight procedures for the following have been applied on a voluntary basis, a descriptive note will, at the Owner's request, be entered in column 6 of the *Register Book*, preceded by the word **ShipRight** (*see also ShipRight Procedures Overview,* Pt 3, Ch 16 and Pt 5, Ch 21):

ES Enhanced Scantlings

PCWBT(date) Protection Coatings in Water Ballast Tanks

SEA(HSS-n) Ship Event Analysis (Hull Surveillance Systems) for monitoring of the ship's hull girder stresses and motions.

SEA(ICE) Ship Event Analysis for monitoring of the ship's hull girder stresses and local ice loads when the ship is navigating in ice.

SERS Ship Emergency Response Service

SRtP Safe Return to Port and Orderly Evacuation. To be applied where the design appraisal and survey of vessel has been performed in accordance with the ShipRight Procedure where vessels are required to comply with Safe Return to Port and Orderly Evacuation.

SCM Screwshaft Condition Monitoring
This descriptive note will be assigned where an Owner adopts the requirements for monitoring of the screwshaft. The descriptive note will indicate that equipment and procedures are in place to determine the physical and operational condition of that equipment.

TCM Main Steam Turbine Condition Monitoring
This descriptive note will be assigned where an Owner adopts the requirements for monitoring of the main steam turbine. The descriptive note will indicate that equipment and procedures are in place to determine the physical and operational condition of that equipment.

MCM Machinery Condition Monitoring
This descriptive note will be assigned where an Owner operates an approved Planned Maintenance Scheme as part of the Continuous Survey Machinery (CSM) cycle, and monitoring techniques and equipment are used to record the condition against agreed acceptable limits. The descriptive note will indicate that equipment, procedures and documentation are in place to monitor, control and record the physical and operational condition of the equipment on the ship and control the maintenance routines accordingly. For the design and installation of machinery condition monitoring systems which form part of a machinery planned maintenance scheme approved by LR for the assignment of the descriptive note, the requirements of Pt 5,Ch 21 are applicable.

MPMS Machinery Planned Maintenance Scheme
This descriptive note will be assigned where an Owner operates an approved Machinery Planned Maintenance Scheme as part of the Continuous Survey Machinery (CSM) cycle. The descriptive note will indicate that procedures and documentation are in place to control and record the inspection and maintenance routines of all machinery and equipment in the ship.

MCBM This descriptive note will be assigned where an Owner operates an approved Planned Maintenance Scheme based on the use of Condition-based Maintenance as part of the Continuous Survey Machinery (CSM) cycle. The descriptive note will indicate that procedures and documentation are in place to control and record the inspection and maintenance routines of all surveyable machinery and equipment. The Scheme is to be based on acceptable and applicable modes of failure analysis and risk assessment approved by LR. For the design and installation of

machinery condition monitoring systems which form part of a Machinery Condition-based Maintenance scheme approved by LR for the assignment of the descriptive note, the requirements of Pt 5, Ch 21 are applicable.

RCM Reliability Centred Maintenance
This descriptive note will be assigned where an Owner operates an approved Planned Maintenance Scheme based on the use of Reliability Centred Maintenance as part of the Continuous Survey Machinery (CSM) cycle. The descriptive note will indicate that procedures and documentation are in place to control and record the inspection and maintenance routines of all machinery and equipment in the ship, and that they are based on acceptable and applicable methodology.

BWMP Ballast Water Management Plan

DIST(M,AB,I,IG) Machinery suitable for operation on distillate fuels
M = main engine(s)
AB = auxiliary engines and boiler
I = incinerator
IG = inert gas generator
This notation will be assigned where the specified machinery items are suitable for operation on distillate fuel.
For example, the note **DIST(AB,IG)** will indicate that the auxiliary engines, auxiliary boiler and IG system are suitable for operation on distillate fuels.

IHM Inventory of Hazardous Materials

VECS Vapour Emission Control System
This notation will be assigned to a ship that has a vapour emission control system fitted which has been designed and constructed in accordance with the requirements of USCG 46, CFR 39 or the IMO Standards for Vapour Emission Control Systems (MSC Circular 585).

VECS-L Vapour Emission Control System – Lightering
This notation will be assigned to a ship that has a vapour emission control system that complies with the requirements for the **VECS** Descriptive Note and which has also been designed and constructed to meet the requirements for vapour balancing in accordance with USCG 46, CFR 39.40 for service vessels. If a ship has been assigned the **ECO** notation then it will not be eligible for the **VECS-L** Descriptive Note. Instead, **VECS** for lightering will be referenced in the **ECO** notation, i.e., **ECO(VECS-L)**.

2.8.4 Where an approved loading instrument is provided as an Owner's requirement, a descriptive note **LI** may be entered in column 6 of the Register Book, *see also* 2.3.16.

2.8.5 Where container securing arrangements are designed and constructed in accordance with Pt 3, Ch 14, but where the Initial and Periodical Survey requirements for loose fittings are not requested, the ship will be eligible to be assigned the descriptive note **CSA** (container securing arrangement) and for an entry to be made in column 6 of the *Register Book*.

2.8.6 **EDD**. Vessel is eligible for the Owner/Operator to apply to the Flag Administration for the vessel to be placed on a pilot Extended Dry-Docking regime. The relevant Flag Administration may elect to impose requirements additional to those defined as per this descriptive note. Vessels are to comply with the LR Guidance notes on Extended Dry-Dockings.

2.8.7 **STV**. Where a sailing vessel is used for the offshore training of cadets or trainee seamen, a sailing training vessel **STV** descriptive note may be entered in column 6 of the *Register Book*.

2.9 Application notes

2.9.1 **Propelling and essential auxiliary machinery** includes machinery, equipment and systems installed for the ship to be under seagoing conditions and that are necessary for the following:

(a) Maintaining the watertight and weathertight integrity of the hull and spaces within the hull.
(b) The safety of the ship, machinery and personnel on board.
(c) The functioning and dependability of propulsion, steering and electrical systems.
(d) The operation and functioning of control engineering systems for the monitoring and safety of propulsion and steering systems.
(e) The operation and functioning of emergency machinery and equipment.

2.9.2 **Manufacturer's certificate** for assignment of the **[✠]LMC** notation. Acceptance of the manufacturer's certificate for items of machinery for propulsion (including propulsion gearing with single input/output arrangements) and for electrical power generation and for other auxiliary machinery for essential services is subject to the following:

(a) The ship is a cargo ship of less than 500 gross tonnage or is a ship of 500 gross tonnage or greater and is not required to comply with international conventions applicable to a ship with unrestricted service.
(b) Propulsion power is provided by oil engines or gas turbines which have been type approved in accordance with LR requirements for marine application.
(c) Electrical power is provided by generators driven by oil engines or gas turbines which have been type approved in accordance with LR requirements for marine application.
(d) The design and manufacture standards for all machinery and associated engineering systems are the applicable LR Rules.

(e) The machinery and equipment is manufactured under a recognised quality control system.
(f) Propellers, propulsion shafting and multiple input/output gearboxes are not included within the scope of propulsion arrangements for acceptance of a manufacturer's certificate.

2.9.3 **Manufacturer's certificate** for assignment of the **MCH** notation. Acceptance of the manufacturer's certificate for propelling and essential auxiliary machinery is subject to the following:
(a) The ship is a cargo ship of less than 500 gross tonnage or is a ship of 500 gross tonnage or greater and is not required to comply with the international conventions applicable to a ship with unrestricted service.
(b) Propulsion power is provided by oil engines or gas turbines which have been type approved in accordance with LR requirements for marine application.
(c) Electrical power is provided by generators driven by oil engines or gas turbines which have been type approved in accordance with LR requirements for marine application.
(d) The power of any prime mover is less than 2,250 kW and the cylinder bore or any diesel engine is not greater than 300 mm.
(e) The design and manufacture standards for machinery and associated systems are the applicable LR Rules or other marine standards acceptable to LR.
(f) The machinery and equipment is manufactured under a recognised quality control system in accordance with the requirements of LR's *Rules for the Manufacture, Testing, and Certification of Materials*.
(g) Individual components manufactured under (f) are to be delivered with a manufacturer's statement confirming that the scantlings comply with the applicable LR Rule requirements.

■ *Section 3* **Surveys – General**

3.1 Statutory surveys

3.1.1 The Classification Committee will act, when authorised on behalf of Governments, in respect of National and International statutory safety and other requirements for passenger and cargo ships.

3.1.2 The Classification Committee will also act, when authorised, in respect of National Safety and other requirements relating to ships used for offshore mineral exploration and exploitation.

3.2 New construction surveys

3.2.1 When it is intended to build a ship for classification with LR, constructional plans and all necessary particulars relevant to the hull, equipment and machinery, as detailed in the Rules, are to be submitted for approval before the work is commenced. Any subsequent modifications or additions to the scantlings, arrangements or equipment shown on the approved plans are also to be submitted for approval.

3.2.2 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of the Classification Committee, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be assigned.

3.2.3 The materials used in the construction of hulls and machinery intended for classification are to be of good quality and free from defects and are to be tested in accordance with the requirements of the Rules for Materials. The steel is to be manufactured by an approved process at an approved works. Alternatively, tests will be required to demonstrate the suitability of the steel.

3.2.4 New ships intended for classification are to be built under LR's Special Survey. From the commencement of the work until the completion of the ship, the Surveyors are to be satisfied that the materials, workmanship and arrangements are satisfactory and in accordance with the Rules. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be unsatisfactory, are to be rectified.

3.2.5 For compliance with 3.2.4, LR is prepared to consider methods of survey and inspection for hull construction which formally include procedures involving the shipyard management, organisation and quality systems. The minimum requirements for the approval of any such proposed Quality Assurance methods are laid down in Pt 3, Ch 15.

3.2.6 Each offshore supply ship, offshore tug/supply ship, dredger, hopper dredger, sand carrier, hopper barge or reclamation craft, proceeding to sea is to comply with the draught and stability requirements of the National Authority and is to have on board sufficient stability data to enable it to be properly loaded and handled, or, where appropriate, to be properly towed. This data is to take full account of any intended special distribution or concentration of loading. In the case of an unmanned ship under tow, the data is to be made available to the tug master.

3.2.7 Copies of approved plans (showing the ship as built), essential certificates and records, required loading and other instruction manuals are to be readily available for use when required by the attending Surveyors, and may be required to be kept on board.

3.2.8 When the machinery is constructed under LR's Special Survey, this survey is to relate to the period from the commencement of the work until the final test under working conditions. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be unsatisfactory, are to be rectified.

3.2.9 When arrangements are such that essential machinery can be operated by remote and/or automatic control equipment, the control equipment is to be arranged, installed and tested in accordance with LR's Rules and Regulations.

3.2.10 The date of completion of the Special Survey during construction of ships built under LR's inspection will normally be taken as the date of build to be entered in the *LR Publication Record*. If the period between launching and commissioning is, for any reason, unduly prolonged, the dates of launching and completion or commissioning may be separately indicated in the *LR Publications*.

3.2.11 When a ship, upon completion, is not immediately commissioned but is laid-up for a period, the Classification Committee, upon application by the Owner, prior to the ship proceeding to sea, will direct an examination to be made by the Surveyors which may include a survey in dry-dock. If, as the result of such a survey, the hull and machinery be reported in all respects in accordance with applicable Rule requirements, the subsequent Special Survey and Complete Survey of the machinery will date from the time of such examination.

3.3 Existing ships

3.3.1 **Classification of ships not built under survey.** The requirements of the Classification Committee for the classification of ships which have not been built under LR's Survey are indicated in Ch 3,19. Special consideration will be given to ships transferring class to LR from another recognised Classification Society.

3.3.2 Reclassification. When reclassification or class reinstatement is desired for a ship for which the class previously assigned by LR has been withdrawn or suspended, the Classification Committee will direct that a survey, appropriate to the age of the ship and the circumstances of the case, be carried out by the Surveyors. If, at such a survey, the ship be found or placed in a condition in accordance with the requirements of the Rules and Regulations, the Classification Committee will be prepared to consider reinstatement of the original class or the assignment of such other class as may be deemed necessary.

3.3.3 A similar arrangement will apply in the case of reclassification of refrigerated cargo installations.

3.3.4 The Classification Committee reserves the right to decline an application for classification or reclassification where the prior history or condition of the ship indicates this to be appropriate.

3.3.5 **Unscheduled surveys**. Where the Classification Committee has concern about the condition of a ship and/or the equipment an unscheduled survey may be required at any time to determine the actual condition.

3.4 Damages, repairs and alterations

3.4.1 All repairs to hull, equipment and machinery which may be required in order that a ship may retain her class, (*see* 1.1.5), are to be carried out to the satisfaction of the Surveyors. When repairs are effected at a port, terminal or location where the services of a Surveyor to LR are not available, the repairs are to be surveyed by one of the Surveyors at the earliest opportunity thereafter.

3.4.2 When, at any survey, the Surveyors consider repairs to be immediately necessary, either as a result of damage, or wear and tear, they are to communicate their recommendations at once to the Owner, or his representative. When such recommendations are not complied with, immediate notification is to be given to the Classification Committee by the Surveyors.

3.4.3 Where repairs are to be carried out by a riding crew during a voyage then these must be planned in advance. A complete repair procedure, including the extent of proposed repair and the need for Surveyor's attendance during the voyage, is to be submitted reasonably in advance to the Surveyor for agreement. Failure to notify LR in advance of the repairs may result in the class of the ship being specially considered by the Classification Committee. Where emergency repairs are effected immediately due to an emergency circumstance, the repairs should be documented in the ship's log and submitted thereafter to LR for use in determining further survey requirements.

3.4.4 When, at any survey, it is found that any damage, defect or breakdown (*see* 1.1.5) is of a nature that does not require immediate permanent repair, but is sufficiently serious to require rectification by a prescribed date in order to maintain class, a suitable condition of class is to be imposed by the Surveyors and recommended to the Classification Committee for consideration.

3.4.5 If a ship which is classed with LR is to leave harbour limits or protected waters under tow, the Owner is to advise LR of the circumstances prior to her departure.

3.4.6 If a ship which is classed with LR is taken in tow whilst at sea, the Owner is to advise LR of the circumstances at the first practicable opportunity.

3.4.7 Plans and particulars of any proposed alterations to the approved scantlings and arrangements of hull, equipment, or machinery are to be submitted for approval, and such alterations are to be carried out to the satisfaction of the Surveyors.

3.4.8 Where a complete replacement or addition of a major portion of the ship is involved, as defined in 3.4.9, consideration may be given to assignment of a separate date of build for the new structure. The Survey requirements shall be based on the date of build associated with each major portion of the ship. Special Survey due dates may be aligned at the discretion of the Committee.

3.4.9 A major portion of the ship may include a complete forward or after section, a complete main cargo section (which may include a complete hold/tank of a cargo ship), a complete block of deck structure of a passenger ship or a structural modification of a single hull to a double hull ship.

3.5 Existing ships – Periodical Surveys

3.5.1 Annual Surveys are to be held on all ships within three months, before or after each anniversary of the completion, commissioning or Special Survey in accordance with the requirements given in Chapter 3. The date of the last Annual Survey will be recorded on the ClassDirect Live website.

3.5.2 Intermediate Surveys are to be held on all ships instead of the second or third Annual Survey after completion, commissioning or Special Survey. The Intermediate Survey may be commenced at the second Annual Survey and progressed with completion at the third Annual Survey. The date of the last Intermediate Survey will be recorded on the ClassDirect Live website. The concurrent crediting of items towards both Intermediate Survey and Special Survey is not permitted.

3.5.3 The Owner should notify LR whenever a ship can be examined in dry dock or on a slipway. A minimum of two Docking Surveys is to be held in each five-year Special Survey period and the maximum interval between successive Docking Surveys is not to exceed three years. One of the two Docking Surveys required in each five-year period is to coincide with the Special Survey. Consideration may be given in exceptional circumstances to an extension of the Docking Survey, not exceeding three months, provided the interval between successive surveys does not exceed 36 months. A definition of 'exceptional circumstances' is given in 3.5.9. The Classification Committee may accept an In-water Survey in lieu of the intermediate docking between Special Surveys, *see* Ch 3,4.3.

An In-water Survey shall not be permitted for ships of 15 years of age and over that are assigned the notation **ESP**. A Docking Survey is considered to coincide with the Special Survey when held within the 15 months prior to the due date of the Special Survey.

Where the Special Survey of the hull is carried out on a Continuous Survey basis, as given in 3.5.14, the survey in dry dock may be held at any time within the five-year cycle.

3.5.4 The interval between dry-dockings for ships operating in fresh water and for certain non-self-propelled craft may be greater than that given in 3.5.3.

3.5.5 Attention is to be given to any relevant statutory requirements of the National Authority of the country in which the ship is registered.

3.5.6 The date of the last examination in dry-dock or on a slipway will be recorded on the ClassDirect Live website.

3.5.7 As an alternative to Annual Surveys and Docking Surveys, according to 3.5.1 and 3.5.3 respectively, ships classed '100A1 shipborne barge' may be subjected to Intermediate Surveys. These surveys become due 30 months after the previous Special Survey. The survey is to be in accordance with the requirements given in Ch 3,2, as applicable. Intermediate Surveys are to be completed within three months of the due date.

3.5.8 Survey requirements for In-water Surveys are given in Ch 3,4.3. The date of the last In-water Survey will be recorded on the ClassDirect Live website.

3.5.9 All ships classed with LR are also to be subjected to Special Surveys in accordance with the requirements given in Chapter 3. These Surveys become due at five-yearly intervals, the first one five years from the date of build or date of Special Survey for Classification as recorded in the *Register Book*, and thereafter five years from the date recorded for the previous Special Survey. Consideration may be given at the discretion of the Committee to any exceptional circumstances justifying an extension of the hull classification to a maximum of three months beyond the fifth year. If an extension is agreed, the next period of hull classification will start from the due date of the Special Survey before the extension was granted. In this context 'exceptional circumstances' means unavailability of dry-docking facilities, repair facilities, essential materials, equipment or spare parts or delays incurred by action taken to avoid severe weather conditions.

3.5.10 Where, on shipborne barges, Intermediate Surveys are permitted as an alternative to Annual and Docking Surveys, Special Surveys become due five years after the previous Special Survey.

3.5.11 Special Surveys may be commenced at the fourth Annual Survey after completion, commissioning, or previous Special Survey, and be progressed during the succeeding year with a view to completion by the due date of the Special Survey.

3.5.12 When Special Surveys are commenced prior to the fourth Annual Survey, the entire survey is to be completed within 15 months if such work is to be credited towards the Special Survey.

3.5.13 Ships which have satisfactorily passed a Special Survey will have a record entered in the *Register Book* indicating the date and the notation **ESP** if this is applicable, *see* 2.3.12. Where the Special Survey is completed more than three months before the due date, the new record of Special Survey will be the final date of survey.

(a) In all other cases, with the exception of (b), the date recorded will be the fifth anniversary of the previous Special Survey.
(b) For ships registered with Flag Administrations that have neither implemented the International Convention for the Safety of Life at Sea (SOLAS 1974) Harmonised System of Survey and Certification (HSSC) under the Protocol of 1988, nor adopted HSSC under IMO Resolution A.883 (21) – *Global and Uniform Implementation of the Harmonised System of Survey and Certification*, where the Special Survey is completed before the due date, the new record will be the final date of survey.

3.5.14 At the request of an Owner, it may be agreed that the Special Survey of the hull, for ships other than general dry cargo ships, bulk carriers, combination carriers, chemical tankers and oil tankers, be carried out on the Continuous Survey basis, all compartments of the hull being opened for survey and testing, in rotation, with an interval of five years between consecutive examinations of each part. In general, approximately one fifth of the Special Survey is to be completed each year and all the requirements of the particular hull Special Survey must be completed at the end of the five year cycle. For examination of items listed in Ch 3,2.2.24 to 2.2.25, 2.2.29 and Ch 3,3.2.6, 3.2.7 and

3.2.9, the intervals for inspection will require to be specially agreed. For ships more than 10 years of age, an examination of the ballast tanks is to be carried out twice in each five year cycle, i.e., once within the scope of the Intermediate Survey and once within the scope of the Continuous Survey. Ships which have satisfactorily completed the cycle will have a record entered in ClassDirect Live indicating the date of completion which will not be later than five years from the last assigned date of Complete Survey of the hull. The agreement for surveys to be carried out on Continuous Survey basis may be withdrawn at the discretion of the Classification Committee.

3.5.15 Machinery is to be submitted to the surveys detailed in Ch 3,11 to 17.

3.5.16 Complete Surveys of machinery become due at five-yearly intervals, the first one five years from the date of build or date of first classification as recorded in ClassDirect Live, and thereafter five years from the date recorded for the previous Complete Survey. Consideration can be given at the discretion of the Classification Committee to any exceptional circumstances justifying an extension of machinery class to a maximum of three months beyond the fifth year. If an extension is agreed, the next period of machinery class will start from the due date of Complete Survey of machinery before extension was granted. Surveys which are commenced prior to their due date are not to extend over a period greater than 15 months, except with the prior approval of the Classification Committee. Where the survey is completed more than three months before the due date, the recorded date of completion will be the final date of survey.

(a) In all other cases, with the exception of (b), the date recorded will be the fifth anniversary of the previous Complete Survey of machinery.
(b) For ships registered with Flag Administrations that have neither implemented the International Convention for the Safety of Life at Sea (SOLAS 1974) Harmonised System of Survey and Certification (HSSC) under the Protocol of 1988, nor adopted HSSC under IMO Resolution A.883 (21) – *Global and Uniform Implementation of the Harmonised System of Survey and Certification*, where the Survey is completed before the due date, the new record will be the final date of survey.

3.5.17 Upon application by an Owner, the Classification Committee may agree to an extension of the survey requirements for main engines, which, by the nature of the ship's normal service, do not attain the number of running hours recommended by the engines' manufacturer for major overhauls within the survey periods given in 3.5.16.

3.5.18 If it is found desirable that any part of the machinery should be examined again before the due date of the next survey, a certificate for a limited period will be granted in accordance with the nature of the case.

3.5.19 When, at the request of an Owner, it has been agreed by the Classification Committee that the Complete Survey of the machinery may be carried out on the Continuous Survey basis, the various items of machinery are to be opened for survey in rotation, as far as practicable, to ensure that the interval between consecutive examinations of each item will not exceed five years. In general, approximately one-fifth of the machinery is to be examined each year.

3.5.20 If any examination during Continuous Survey reveals defects, further parts are to be opened up and examined as considered necessary by the Surveyor, and the defects are to be made good to his satisfaction.

3.5.21 Upon application by an Owner, the Classification Committee may agree to an arrangement whereby, subject to certain conditions, some items of machinery may be examined by the Chief Engineer of the ship at ports where LR is not represented, or, where practicable, at sea, followed by a limited confirmatory survey carried out at the next port of call where an Exclusive Surveyor is available. Particulars of this arrangement may be obtained from LR. Where an approved planned maintenance scheme is in operation, the confirmatory surveys may be held at annual intervals, at which time the records will be checked and the operation of the scheme verified. Particulars of this arrangement may be obtained from any LR Office.

3.5.22 Where condition monitoring equipment is fitted, the Classification Committee, upon application by the Owner, will be prepared to amend applicable Periodical Survey requirements where details of the equipment are submitted and found satisfactory. Where machinery installations are accepted for this method of survey, it will be a requirement that an Annual Survey be held, at which time monitored records will be analysed and the machinery examined under working conditions. An acceptable lubricating oil trend analysis programme may be required as part of the condition monitoring procedures.

3.5.23 Boiler Surveys, examination of steam pipes and Screwshaft Surveys are to be carried out as stated in Ch 3,15 to 17.

3.5.24 Where any inert gas system is fitted for the protection of cargo tanks on board a ship intended for the carriage of oil or liquid chemicals in bulk, the system is to be surveyed annually in accordance with the requirements of Ch 3,2.2.32. In addition, on ships to which an **IGS** notation has been assigned, a Special Survey of the inert gas plant is to be carried out at intervals not exceeding five years, in accordance with the requirements of Ch 3,18.

3.5.25 Where the ship is fitted with a dynamic positioning system, the system is to be examined and tested annually in accordance with the requirements of Ch 3,2.2.23. In addition, a Special Survey is to be carried out at intervals not exceeding five years in accordance with Ch 3,11.2.10.

3.5.26 Where the ship is fitted with a classed refrigerated cargo installation, the installation is to be surveyed annually in accordance with the requirements of Ch 3,20.1. In addition, a Special Survey is to be carried out at intervals not exceeding five years in accordance with the requirements of Ch 3,20.2. At the request of the Owner, consideration will be given to the Survey of the installation being carried out on the Continuous Survey basis.

3.5.27 Where the ship is fitted with a classed refrigerated cargo installation, a Loading Port Survey, as detailed in Ch 3,20.4, may be carried out at the request of the Owner. On completion, a certificate will be issued recording, in addition to other details, the temperatures in the various refrigerated spaces at the time of the survey. The certificate issued by LR is not in respect of the cargo to be loaded or the manner in which it is to be stowed. A Loading Port Survey is not mandatory for classification, but may be carried out concurrently with the Annual, Continuous or Special Surveys if so desired.

3.5.28 At the request of an Owner, the Classification Committee may give special consideration to the application of the periodical survey requirements given in Chapter 3 to military ships or commercial ships owned or chartered by Governments, which are utilised in support of military operation or service.

3.5.29 Where the ship has been assigned an **OPS** notation, the on-shore power supply arrangements are to be examined annually in accordance with the requirements of Ch 3,2.2.26. In addition, a Special Survey is to be carried out at intervals not exceeding five years in accordance with Ch 3,14.2.13.

3.5.30 Where the Committee has agreed to an Owner's request to assign the notation 'laid-up', the ship may be retained in class provided a satisfactory general examination of the hull and machinery is carried out at the Annual Survey due date and in addition an Underwater Examination (UWE) is carried out at the Special Survey due date. The general examination may be carried out within three months before or after the Annual Survey due date.

3.6 Certificates

3.6.1 When the required reports, on completion of the survey of new or existing ships which have been submitted for classification, have been received from the Surveyors and classification has been agreed by the Classification Executive a Certificate of Classification may be issued by an authorised surveyor. After approval by the Classification Committee, a certificate of First Entry of Classification, signed by LR's Chairman or the Chairman of the Classification Committee, will be issued to Builders or Owners.

3.6.2 A Certificate of Class valid for five years subject to endorsement for Annual and Intermediate Surveys will also be issued to the Owners.

3.6.3 LR's Surveyors are permitted to issue provisional (interim) certificates to enable a ship classed with LR to proceed on her voyage (or to continue her service in the case of a fixed or tethered ship) provided that in their opinion it is in a fit and efficient condition. Such certificates will embody the Surveyors' recommendations for continuance of class, but in all cases are subject to confirmation by the Classification Committee.

3.6.4 The full class notation and abbreviated descriptive notes shall be stated on the Certificate of Class and provisional (interim) certificate.

3.7 Notice of surveys

3.7.1 It is the responsibility of the Owners to ensure that all surveys necessary for the maintenance of class are carried out at the proper time and in accordance with the instructions of the Classification Committee. Information is available to Owners on the ClassDirect Live website.

3.7.2 LR will arrange timely notice to an Owner about forthcoming surveys by means of a letter or a computer printout of a ship's Scheduled Surveys, Condition(s) of Class and Memoranda. The omission of such notice, however, does not absolve the Owner from his responsibility to comply with LR survey requirements for maintenance of class, all of which are available to Owners on the ClassDirect Live website.

3.8 Withdrawal/Suspension of class

3.8.1 When the class of a ship, for which the Regulations as regards surveys on hull, equipment and machinery have been complied with, is withdrawn by the Classification Committee in consequence of a request from the Owner the notation 'Class withdrawn at Owner's request' (with date) will be assigned.

3.8.2 When the Regulations as regards surveys on hull, equipment or machinery have not been complied with and the ship is thereby not entitled to retain class, the class will be suspended or withdrawn, at the discretion of the Classification Committee, and a corresponding notation will be assigned.

3.8.3 Class will be automatically suspended and the Certificate of Class will become invalid if the Annual or Intermediate Survey is not completed within three months of the due date of the survey.

3.8.4 Class will be automatically suspended from the expiry date of the Certificate of Class in the event that the Special Survey has not been completed by the due date and an extension has not been agreed (*see* 3.5.9), or is not under attendance by the Surveyors with a view to completion prior to resuming trading.
Classification will be reinstated from suspension of class upon satisfactory completion of the surveys due. The surveys to be carried out are to be based upon the survey requirements at the original date due and not on the age of the ship when the survey is carried out. Such surveys are to be credited from the date originally due. However, the ship's Class remains suspended from the date of suspension until the date Class is reinstated.

3.8.5 When, in accordance with 3.4.4 of the Regulations, a condition of class is imposed, this will be assigned a due date for completion and the ship's class may be suspended if the condition of class is not dealt with, or postponed by agreement, by the due date.

3.8.6 When it is found, from the reported condition of the hull equipment machinery or arrangements of a ship, that an Owner has failed to comply with 1.1.5, 1.1.9, 3.4.1 or 3.4.6, the class will be suspended or withdrawn, at the discretion of the Classification Committee, and a corresponding notation assigned. When it is considered that an Owner's failure to comply with these requirements is sufficiently serious, the suspension or withdrawal of class may be extended to include other ships controlled by the same Owner, at the discretion of the Classification Committee.

3.8.7 When the Classification Committee is satisfied that a ship proceeded to sea with less freeboard than that approved by the Classification Committee, or that the freeboard marks are placed higher on the sides of the ship than the position assigned or approved by the Classification Committee, or, in cases of ships where freeboards are not assigned, the draught is greater than that approved by the Classification Committee, the ship's class will be withdrawn or suspended in relation to the above voyage(s) concerned.

3.8.8 When the Classification Committee is satisfied that a specialised ship has been operated in a manner contrary to that agreed at the time of classification, or is being operated in environmental conditions which are more onerous or in areas other than those agreed by the Classification Committee, the ship's class will be withdrawn or suspended in relation to those operations.

3.8.9 Where a ship has been:
- detained following a Flag State or Port State Control inspection on one or more occasions with serious deficiencies found, or
- been subject to an unscheduled survey (*see* 3.3.5) with serious deficiencies found,

then class will be liable to be suspended or withdrawn, at the discretion of the Classification Committee, and a corresponding notation will be assigned. In these cases, a period of notice, but not exceeding 3 months, may be given prior to any suspension or withdrawal of class.

3.8.10 When a client fails to pay all undisputed portions of invoices for the services by the contractual due date then class will be liable to be suspended or withdrawn at the discretion of the Classification Committee and a corresponding notation will be assigned. In these cases, a period of notice not exceeding 3 months may be given, prior to any suspension or withdrawal of class.

3.8.11 In all instances of class withdrawal or suspension, the assigned notation, with date of application, will be published by members of the LR Group. In cases where class has been suspended by the Classification Committee and it becomes apparent that the Owners are no longer interested in retaining LR's class it will be withdrawn.

3.8.12 When a ship is intended for a demolition voyage with any Periodical Survey overdue, the ship's class suspension may be held in abeyance and consideration may be given to allow the ship to proceed on a single direct ballast voyage from the lay up or final discharge port to the demolition yard, provided the attending Surveyor finds the ship in a satisfactory condition to proceed for the intended voyage, at the discretion of the Classification Committee.

3.8.13 When a ship is intended for a single voyage from 'laid-up' position to repair yard with any Periodical Survey overdue, the ship's class suspension may be held in abeyance and consideration may be given to allow the ship to proceed on a single direct ballast voyage from the site of lay up to the repair yard, upon agreement with the Flag Administration, at the discretion of the Classification Committee. This is provided the ship is found in a satisfactory condition by surveys, the extent of which are to be based on surveys overdue and duration of lay-up.

3.8.14 For reclassification and reinstatement of class, *see* 3.3.2 and 3.8.4.

3.9 Appealing against Surveyors' recommendations

3.9.1 If the recommendations of the Surveyors are considered in any case to be unnecessary or unreasonable, an appeal may be made to the Classification Committee, who may direct a Special Examination to be held.

3.10 Force majeure

3.10.1 If due to circumstances reasonably beyond the Owner's or LR's control, as defined below, the ship is not in a port when surveys become overdue the Classification Committee may allow the ship to sail, in class, directly to an agreed discharge port and then, if necessary, in ballast to an agreed repair facility at which the survey can be completed. In this context 'Force Majeure' means damage to the ship, unforeseen inability of Surveyors to attend the ship due to governmental restrictions on right of access or movement of personnel, unforeseen delays in port or inability to discharge cargo due to unusually lengthy periods of severe weather, strikes, civil strife, acts of war or other force majeure.

3.11 Ownership details

3.11.1 It is the responsibility of the Owner to inform a member of the LR Group in writing of any change to its contact details and in the event of a ship sale to supply details of the new Owners. If the new Owner of a ship cannot be properly identified and the contact details established then the class of that ship will be specially considered by the Classification Committee. It is the responsibility of the new Owner to inform a member of the LR Group in writing of their contact details and that they are now responsible for the ship, if they fail to do so then the class of that ship will be specially considered by the Classification Committee.

■ *Section 4*
IACS and EMSA Audits and Assessments

4.1 Audit of surveys

4.1.1 The surveys required by the Regulations may be subject to audit or assessment in accordance with the requirements of the International Association of Classification Societies and European Maritime Safety Agency requirements.

■ *Section 5*
Approval/Type Testing/Quality Control System

5.1 LR Type Approval – Marine Applications

5.1.1 LR Type Approval is an impartial certification system that provides independent third-party Type Approval Certificates attesting to a product's conformity with specific standards or specifications. It is based on design review and type testing or where testing is not appropriate, a design analysis.

5.1.2 The LR Type Approval System is a process whereby a product is assessed in accordance with a specification, standard or code to check that it meets the stated requirements and through selective testing demonstrates compliance with specific performance requirements. The testing is carried out on a prototype or randomly selected product(s) which are representative of the manufactured product under approval. Thereafter, the producer is required to use Quality Control procedures and processes to ensure that each item delivered is in conformity with that which has been Type Approved.

5.1.3 The selective testing required by 5.1.2 is to include environmental testing applicable to the product's installation on board a ship classed or intended to be classed with LR.

5.1.4 LR Type Approval does not remove the requirements for inspection and survey procedures required by the Rules for equipment to be installed in ships classed or intended to be classed with LR. Also, LR Type Approval does not remove the requirement for plan appraisal of a system that incorporates Type Approved equipment where required by the Rules.

5.1.5 LR Type Approval is subject to the understanding that the producer's recommendations and instructions for the product and any relevant requirements of the Rules for the Classification of Ships are fulfilled.

5.1.6 The producer supplying equipment or components under Quality Control procedures and processes is to have a recognised quality management system certified by an IACS member or Notified Body. The Quality Control procedures and processes are to address the production of the product consistent with 5.3.

5.1.7 Where equipment or components have been Type Approved in accordance with specifications and procedures other than LR's, details of the product, certification and testing are to be submitted for consideration where appropriate.

5.2 Type testing

5.2.1 Type testing is an impartial process that provides independent third-party verification that an item of machinery or equipment has satisfactorily undergone a functional type test.

5.2.2 Type testing is carried out against defined performance and test standards for a defined period of time with test conditions varying between minimum and maximum declared design conditions.

5.2.3 Type testing is carried out on a prototype or randomly selected product(s) which are representative of the manufactured product under assessment.

5.2.4 After type testing, mechanical equipment is to be opened out and inspected for damage or excessive wear.

5.2.5 On application from the manufacturer, type tests may be waived for equipment and machinery that has been proven to be reliable in marine service and where compliance with the current applicable standards can be demonstrated. Equipment and machinery that has been previously type tested with satisfactory testing evidence and certification need not have the type tests repeated where previous testing is in accordance with current testing standards.

5.2.6 The acceptance of type testing certification is subject to the understanding that the manufacturer's recommendations and instructions for the product and any relevant requirements of the applicable Rules are fulfilled.

5.3 Quality Control System

5.3.1 A quality control system for the purposes of LR acceptance of materials and machinery refers to a scheme that covers the operational techniques and activities that is used to demonstrate that the quality requirements for a product are in accordance with declared standards.

5.3.2 The quality control system for a particular product extends to all parties involved in the supply chain from manufacture and testing through to delivery of the product.

5.3.3 LR acceptance of machinery and equipment manufactured under a quality control scheme is dependent on the scheme being maintained through a traceable process involving planned audits and spot inspections at the discretion of LR Surveyors. The purpose of the audits and spot inspections is to ensure that the procedures for manufacture and quality control are being maintained in a satisfactory manner.

5.3.4 The use of a quality control system does not remove the requirements for inspection processes that may be required by the Rules applicable to the equipment being supplied with a manufacturer's certificate. Also the use of a quality control system does not remove the requirement for plan appraisal of equipment or systems where required by the Rules.

■ *Section 6* Classification of machinery with [✠]LMC or MCH notation

6.1 General

6.1.1 After delivery of machinery and equipment with the manufacturer's certificate to the shipyard, Survey at the Shipyard and Periodical Surveys are to be in accordance with the requirements for ships built or accepted into class with the ✠**LMC** notation.

6.2 Appraisal and records

6.2.1 To facilitate survey and compilation of classification records, plans and information required for a ship being accepted into class with the ✠**LMC** notation are to be submitted for appraisal and information. Plans are not required where machinery and equipment has previously been type approved; in these cases it is only necessary to submit details of the machinery and equipment together with details of previous approval.

6.3 Survey and inspection

6.3.1 The manufacturer's certificate for acceptance of machinery and equipment for assignment of the [✠]**LMC** or **MCH** notation is to be in the English language and include the following information:

(a) Design and manufacturing standard(s) used.
(b) Materials used for construction of key components and their sources.
(c) Details of the quality control system applied during design, manufacture and testing and of any software maintenance.
(d) Details of any type approval or type testing.
(e) Details of installation and testing recommendations for the machinery or equipment.

The manufacturer is to have a recognised quality management system certified by an IACS member or a Notified Body.

6.3.2 The installation and testing of machinery and equipment at the build yard which has been supplied with a manufacturer's certificate is to be in accordance with the requirements applicable to a ship having the ✠**LMC** notation.

■ *Section 1* General

1.1 Frequency of surveys

1.1.1 The requirements of this Chapter are applicable to the Periodical Surveys set out in Ch 2,3.5. Except as amended at the discretion of the Committee, the periods between such surveys are as follows:

(a) Annual Surveys, as required by Ch 2,3.5.1.
(b) Intermediate Surveys, as required by Ch 2,3.5.2.
(c) Docking Surveys, as required by Ch 2,3.5.3 and 3.5.4.
(d) When ships classed **100A1 shipborne barge** are subjected to Intermediate Surveys, those surveys become due 30 months after the previous Special Survey, *see* Ch 2,3.5.7.
(e) Special Surveys at five-yearly intervals, *see* Ch 2,3.5.9. For alternative arrangements, *see also* Ch 2,3.5.10, 3.5.11, 3.5.12 and 3.5.14.
(f) Complete Surveys of machinery at five-yearly intervals, *see* Ch 2,3.5.16.

1.1.2 For ships assigned the notation 'laid-up', in order to maintain the ship in class a general examination of the hull and machinery is to be carried out in lieu of the Annual Survey and in addition an Underwater Examination (UWE) is to be carried out in lieu of the Special Survey, *see* 2.1.5, 5.1.6 and 11.1.2.

1.1.3 When it has been agreed that the complete survey of the hull and machinery may be carried out on the Continuous Survey basis, all compartments of the hull and all items of machinery are to be opened for survey in rotation to ensure that the interval between consecutive examinations of each part will not exceed five years, *see* Ch 2,3.5.14 and 3.5.19.

1.1.4 For the frequency of surveys of boilers, steam pipes, screwshafts, tube shafts, propellers and inert gas systems, *see* Sections 15 to 18.

1.1.5 For the requirements for surveys of refrigerated cargo installations, *see* Pt 6, Ch 3.

1.1.6 In general, the periodical survey requirements contained in Chapter 3 also apply to ships built in accordance with the IACS Common Structural Rules (CSR). Where a requirement does not apply to CSR ships, or where a specific requirement applies only to CSR ships, this will be clearly stated.

1.2 Surveys for damage or alterations

1.2.1 At any time when a ship is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g., if any part of the main or auxiliary machinery, including boilers, insulation or fittings, is removed for any reason, the steel structure in way is to be carefully examined by the Surveyor, or when cement in the bottom or covering on decks is removed, the plating in way is to be examined before the cement or covering is relaid.

1.3 Unscheduled surveys

1.3.1 In the event that Lloyd's Register (hereinafter referred to as LR) has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull and machinery as well as the applicable statutory requirements whether or not the appropriate statutory certificate has been issued by LR.

1.3.2 In the event of significant damage or defect affecting any ship, LR serves the right to perform unscheduled surveys of the hull or machinery of other similar ships classed by LR and deemed to be vulnerable.

1.4 Surveys for the issue of Convention Certificates

1.4.1 Surveys are to be held by LR when so appointed, or by the Exclusive Surveyors to a National Administration or by an IACS Member when so authorised by the National Authority, or, in the case of Cargo Ship Safety Radio Certificates or Safety Management Certificates, by any organisation authorised by the National Authority. In the case of dual classed ships, Convention Certificates may be issued by the other Society with which the ship is classed provided this is recognised in a formal Dual Class Agreement with LR and provided the other Society is also authorised by the National Authority.

1.5 Definitions

1.5.1 An **Oil Tanker** is a sea going self-propelled ship which is constructed generally with integral tanks and is intended primarily to carry oil in bulk and includes ship types such as combination carriers (ore/oil and ore/bulk/oil ships, etc.). Where referred to in this Chapter, it shall also include double hull oil tankers as well as tankers with alternative structural arrangements, e.g., mid-deck designs, except where specified. Single hull oil tankers and combination carriers are not covered by the IACS Common Structural Rules (CSR).

1.5.2 A **Double Hull Oil Tanker** is a sea going self-propelled ship which is constructed primarily for the carriage of oil in bulk, where the cargo tanks are protected by a double hull extending for the entire length of the cargo area, consisting of double side and double bottom spaces for the carriage of salt-water ballast.

1.5.3 A **Bulk Carrier** is a sea going self-propelled ship which is constructed generally with single deck, double bottom, topside tanks and hopper side tanks and with single side skin construction in the cargo length area, and is intended primarily to carry dry cargo in bulk and includes ship types such as ore carriers. Where referred to in this Chapter, it shall also include double skin bulk carriers except where specified.

1.5.4 A **Double Skin Bulk Carrier** is a sea going self-propelled ship which is constructed generally with single deck, double bottom, topside tanks and hopper side tanks and with double side skin construction in the cargo length area (regardless of the width of the wing space), and is intended primarily to carry dry cargo in bulk and includes such types as ore carriers.

1.5.5 An **Ore Carrier** is a sea going self-propelled ship which is constructed generally with single deck, two longitudinal bulkheads and a double bottom throughout the cargo length area and intended primarily to carry ore cargoes in the centre holds only. Ore carriers are not covered by the IACS Common Structural Rules (CSR).

1.5.6 A **Chemical Tanker** is a sea going self-propelled ship constructed generally with integral tanks and being single or double hull construction, or having alternative structural arrangements, used primarily for the carriage in bulk of any liquid product listed in Chapter 17 of the *International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, IBC Code*.

1.5.7 A **Gas Carrier** is a cargo ship constructed or adapted and used for the carriage in bulk of any liquefied gas or other products of flammable nature listed in Chapter 19 of the *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk*.

1.5.8 A **Ballast Tank** is a tank which is used solely for the carriage of salt-water ballast. For bulk carriers, a space which is used for both cargo and salt-water ballast will be treated as a salt-water ballast tank when substantial corrosion has been found in that space. For double skin bulk carriers, the double side tank is to be considered as a separate tank even if it is connected to either the topside or hopper side tank. For oil tankers and chemical tankers, a combined tank which is used for both cargo and salt-water ballast as a routine part of the ship's operation will be treated as a ballast tank. A cargo tank which in exceptional cases may carry salt-water water ballast during severe weather conditions and is not designated as a combined cargo/ballast tank will be treated as a cargo tank.

1.5.9 **Spaces** are separate compartments such as holds, tanks, cofferdams and void spaces bounding cargo holds, decks and the outer hull.

1.5.10 An **Overall Survey** is a survey intended to report on the overall condition of the hull structure and to determine the extent of additional Close-up Surveys.

1.5.11 A **Close-up Survey** is a survey where the details of structural components are within the close visual inspection range of the Surveyor, i.e., normally within reach of hand.

1.5.12 A **Transverse Section** includes all longitudinal members such as plating, longitudinals and girders at the deck, side, bottom, inner bottom, inner side, hopper side, top wing side and longitudinal bulkhead, where fitted. For transversely framed ships, a transverse section includes adjacent frames and their end connections in way of transverse sections.

1.5.13 **Representative Spaces** are those which are expected to reflect the condition of other spaces of similar type and service and with similar corrosion prevention systems. When selecting representative spaces, account is to be taken of the service and repair history on board and identifiable Critical Structural Areas.

1.5.14 **Critical Structural Areas** are locations which have been identified from calculations to require monitoring or from the service history of the subject ship or from similar ships or sister ships, if applicable, to be sensitive to cracking, buckling or corrosion which would impair the structural integrity of the ship.

1.5.15 **Substantial Corrosion** is wastage of individual plates and stiffeners in excess of 75 per cent of allowable margins, but within acceptable limits. For ships built in accordance with the Common Structural Rules (CSR), substantial corrosion is an extent of corrosion such that the assessment of the corrosion pattern indicates a gauged (or measured) thickness between t_{ren} + 0,5 mm and t_{ren}. Renewal thickness, t_{ren}, is the minimum allowable thickness, in mm, below which renewal of the structural members is to be carried out.

1.5.16 Steel renewal requirements have been separately determined according to date of contract for construction for:
(a) cargo hold hatch covers and coamings under IACS UR S21 and UR S21A; and
(b) bulk carriers' corrugated transverse watertight cargo hold bulkheads under IACS UR S18. *See* 5.6, 6.7 and 7.7.

In these cases, the net thickness, t_{net}, is the minimum net thickness of the structural member, excluding any corrosion addition, and is defined in Pt 4, Ch 7,12.1.2 for Hatch Covers and Pt 4, Ch 7,10.4.10 for Transverse Bulkheads.

1.5.17 **A Corrosion Prevention System** is normally considered a full hard protective coating. This is usually to be an epoxy coating or equivalent. Other systems with the exception of soft and semi-hard coatings, may be considered acceptable as alternatives provided they are applied and properly maintained in compliance with the manufacturer's specification.

1.5.18 For the application of requirements outlined in Sections 2, 3, 4 and 5, a general dry cargo ship is a self-propelled ship of 500 gross tonnes or above, constructed generally with a 'tween deck and intended to carry solid cargoes, other than:

- bulk carriers;
- ships dedicated to the carriage of containers;
- roll on-roll off ships;
- refrigerated cargo ships;
- dedicated wood chip carriers;
- dedicated cement carriers;
- livestock carriers;
- dock/deck cargo ships;
- general dry cargo ships of double side-skin construction, with double side-skin extending for the entire length of the cargo area, and for the entire height of the cargo hold to the upper deck.

1.5.19 **Coating Condition** is defined as follows:

GOOD: Condition with only minor spot rusting.

FAIR: Condition with local breakdown of coating at edges of stiffeners and weld connections and/or light rusting over 20 per cent or more of areas under consideration, but less than as defined for POOR condition.

POOR: Condition with general breakdown of coating over 20 per cent or more of areas or hard scale at 10 per cent or more of areas under consideration.

These are further clarified as follows, in order to achieve a unified assessment of coating conditions, *see* Table 3.1.1:

GOOD: Condition with spot rusting on less than 3 per cent of the area under consideration without visible failure of the coating. Rusting at edges or welds should be on less than 20 per cent of edges or weld lines in the area under consideration.

FAIR: Condition with breakdown of coating or rust penetration on less than 20 per cent of the area under consideration. Hard rust scale should be less than 10 per cent of the area under consideration. Rusting at edges or welds should be on less than 50 per cent of edges or weld lines in the area under consideration.

POOR: Condition with breakdown of coating or rust penetration on more than 20 per cent or hard rust scale on more than 10 per cent of the area under consideration or local breakdown concentrated at edges or welds on more than 50 per cent of edges or weld lines in the area under consideration.

Further information on coating assessment can be found in the LR document *Thickness Measurement and Close-Up Survey Guidance*.

Table 3.1.1 Assessment of coating conditions

	GOOD[3]	FAIR	POOR
Breakdown of coating or area rusted [1]	< 3%	3–20%	> 20%
Area of hard rust scale [1]	—	< 10%	≥ 10%
Local breakdown of coating or rust on edges or weld lines [2]	< 20%	20–50%	> 50%

NOTES
1. % is the percentage calculated on basis of the area under consideration or of the 'critical structural area'.
2. % is the percentage calculated on basis of edges or weld lines in the area under consideration or of the 'critical structural area'.
3. Spot rusting, i.e., rusting in spot without visible failure of coating.

1.5.20 **Pitting Corrosion**. Pitting corrosion is defined as scattered corrosion spots/areas with local material reductions which are greater than the general corrosion in the surrounding area. Further information on pitting intensity can be found in the LR document *Thickness Measurement and Close-Up Survey Guidance*.

1.5.21 **Edge Corrosion**. Edge corrosion is defined as local corrosion at the free edges of plates, stiffeners, primary support members and around openings. An example of edge corrosion can be found in the LR document *Thickness Measurement and Close-Up Survey Guidance*.

1.5.22 **Grooving Corrosion**. Grooving corrosion is typically local material loss adjacent to weld joints along abutting stiffeners and at stiffener or plate butts or seams. An example of groove corrosion can be found in the LR document *Thickness Measurement and Close-Up Survey Guidance*.

1.5.23 A **Prompt and Thorough Repair** is a permanent repair completed at the time of survey to the satisfaction of the Surveyor, therein removing the need for the imposition of any associated condition of class or recommendation.

1.5.24 Bulk carriers with hybrid cargo hold arrangements are to have single skin cargo holds surveyed in accordance with the requirements for single skin bulk carriers and the double skin cargo holds surveyed in accordance with the requirements for double skin bulk carriers.

1.5.25 **Special consideration** or **specially considered** (in connection with close-up surveys and thickness measurements) means sufficient close-up inspection and thickness measurements are to be taken to confirm the actual average condition of the structure under the coating.

1.5.26 **Air pipe heads** installed on the exposed decks are those extending above the freeboard deck or superstructure decks.

1.5.27 The **Cargo Area** or **Cargo Length Area** is that part of the ship which contains all cargo holds and adjacent areas including fuel tanks, cofferdams, ballast tanks and void spaces. For oil tankers and chemical tankers, the **Cargo Area** is that part of the ship which contains cargo tanks, slop tanks and cargo/ballast pump-rooms, cofferdams, ballast tanks and void spaces adjacent to cargo tanks and also deck areas throughout the entire length and breadth of the part of the ship over the above mentioned spaces.

1.6 Preparation for survey and means of access

1.6.1 In order to enable the attending Surveyor(s) to carry out the survey, provisions for proper and safe access are to be agreed between the Owner and LR. Tanks and spaces are to be safe for access, be gas free and properly ventilated. Prior to entering a tank, void or enclosed space, it is to be verified that the atmosphere in that space is free from hazardous gas and contains sufficient oxygen.

1.6.2 In preparation for survey, thickness measurements and to allow for a thorough examination, all spaces are to be cleaned including removal from surfaces of all loose accumulated corrosion scale. Spaces are to be sufficiently clean and free from water, scale, dirt, oil residues, etc., to reveal corrosion, deformation, fractures, damages or other structural deterioration, as well as the condition of the protective coating. However, those areas of structure whose renewal has already been decided by the owner need only be cleaned and descaled to the extent necessary to determine the limits of renewed areas.

1.6.3 Sufficient illumination is to be provided to reveal corrosion, deformation, fractures, damages or other structural deterioration.

1.6.4 Means are to be provided to enable the Surveyor to examine the structure in a safe and practical way. Where the provisions of safety and required access are determined by the Surveyor not to be adequate, then the survey of the space(s) involved is not to proceed.

1.6.5 For surveys, including close-up survey where applicable, in cargo spaces and ballast tanks, one or more of the following means of access is to be provided:

(a) Permanent staging and passages through structures.
(b) Temporary staging and passages through structures.
(c) Hydraulic arm vehicles such as conventional cherry pickers, lifts and movable platforms.
(d) Portable ladders, *see* Note.
(e) Boats or rafts.
(f) Other equivalent means.

Note
Portable ladders may be used, at the discretion of the Surveyor, for survey of the hull structure of single skin bulk carriers, except for the close-up survey of cargo hold shell frames, *see* 1.6.6 and 1.6.7.

1.6.6 For close-up surveys of the cargo hold shell frames of single skin bulk carriers with a deadweight less than 100,000 tonnes, one or more of the following means of access is to be provided:

(a) Permanent staging and passages through structures.
(b) Temporary staging and passages through structures.
(c) Portable ladder restricted to not more than 5 m in length may be accepted for surveys of the lower section of a shell frame including bracket.
(d) Hydraulic arm vehicles such as conventional cherry pickers, lifts and movable platforms.
(e) Boats or rafts, provided the structural capacity of the hold is sufficient to withstand static loads at all levels of water.
(f) Other equivalent means.

1.6.7 For close-up surveys of the cargo hold shell frames of single skin bulk carriers with a deadweight equal to or greater than 100,000 tonnes the use of portable ladders is not accepted and one or more of the following means of access, is to be provided:

(a) At Annual Surveys, Intermediate Surveys held before the ship is 10 years old and Special Survey I:
    (i) Permanent staging and passages through structures.
    (ii) Temporary staging and passages through structures.

(iii) Hydraulic arm vehicles such as conventional cherry pickers, lifts and movable platforms.
(iv) Boats or rafts, provided the structural capacity of the hold is sufficient to withstand static loads at all levels of water.
(v) Other equivalent means.

(b) At Special Survey II and all subsequent surveys:
(i) Either permanent or temporary staging and passage through structures for close-up survey of at least the upper part of hold frames.
(ii) Hydraulic arm vehicles such as conventional cherry pickers for surveys of lower and middle part of shell frames as alternative to staging.
(iii) Lifts and movable platforms.
(iv) Boats or rafts, provided the structural capacity of the hold is sufficient to withstand static loads at all levels of water.
(v) Other equivalent means.

(c) Notwithstanding the above requirements, for single skin bulk carriers greater than 10 years old, at Annual Survey the use of a portable ladder fitted with a mechanical device to secure the upper end of the ladder is acceptable for when the close-up survey of cargo hold shell frames is required.

1.6.8 Survey at sea or anchorage may be undertaken when the Surveyor is fully satisfied with the necessary assistance from the personnel onboard and provided the foregoing preparations for survey, as applicable, have been met. In addition, the following conditions and limitations are to be applied:

(a) A communication system is to be arranged between the survey party in the tank and the responsible officer on deck. This system must include the personnel in charge of ballast pump handling if boats or rafts are to be used.

(b) Surveys of tanks by means of boats or rafts are to be agreed with the attending Surveyor, who is to take into account the safety arrangements provided, including weather forecasting and ship response under foreseeable sea conditions and provided the expected rise of water within the tank does not exceed 0,25 m.
Where it has been agreed to use boats or rafts when carrying out close-up survey, the following conditions are to be observed:
(i) Only rough duty, inflatable rafts or boats, having satisfactory residual buoyancy and stability even if one chamber is ruptured, are to be used.
(ii) The boat or raft is to be tethered to the access ladder and an additional person is to be stationed down the access ladder with a clear view of the boat or raft.
(iii) Appropriate lifejackets are to be available for all participants.
(iv) The surface of water in the tank is to be calm and the water level stationary. On no account is the level of the water to be rising while the boat or raft is in use.
(v) The tank or space must contain clean ballast water only. Even a thin sheen of oil on the water is not acceptable.
(vi) At no time is the water level to be allowed to be within 1 m of the deepest under deck web face flat so that the survey team is not isolated from a direct escape route to the tank hatch. Filling to levels above the deck transverses is only to be contemplated if a deck access manhole is fitted and open in the bay being examined, so that an escape route for the survey party is available at all times. Other effective means of escape to the deck may be considered.
(vii) If the tanks (or spaces) are connected by a common venting system, or Inert Gas system, the tank in which the boat or raft is to be used is to be isolated to prevent a transfer of gas from other tanks (or spaces).

(c) Rafts or boats may be permitted for the survey of the under deck areas of tanks or spaces, if the depth of the under deck web plating is 1,5 m or less. If the depth of the under deck web plating is greater than 1,5 m, then rafts or boats may be permitted only when the coating of the under deck structure is in GOOD condition and there is no evidence of wastage or if a permanent means of access is provided in each bay to allow safe entry and exit. A permanent means of access is considered to mean:
(i) Access direct from the deck via a vertical ladder and a small platform fitted approximately 2 m below the deck in each bay or,
(ii) Access to deck from a longitudinal permanent platform having ladders to the deck at each end of the tank. The platform shall be arranged over the full length of the tank and level with, or above, the maximum water level needed for rafting of the under deck structure. For this purpose, the ullage corresponding to the maximum water level is to be assumed not more than 3 m from the deck plate measured at the midspan of deck transverses and at the mid point of the tank's length.

If neither of the above conditions are met, then staging or another equivalent means is to be provided for the survey of the under deck areas.

1.6.9 Where soft or semi-hard coatings have been applied, safe access is to be provided for the Surveyor to verify the effectiveness of the coating and to carry out an assessment of the conditions of internal structures which may include spot removal of the coating. When safe access cannot be provided, the soft or semi-hard coating is to be removed.

1.6.10 An oxygen-meter, breathing apparatus, lifeline, riding belts with rope and hook and whistles together with instructions and guidelines on their use are to be made available during the survey. For oil tankers and chemical tankers, an explosimeter is to be provided. A safety checklist is also to be provided.

1.6.11 Rescue and emergency response equipment: if breathing apparatus and/or other equipment is used as 'rescue and emergency response equipment', it is recommended that the equipment be suitable for the configuration of the space being surveyed.

1.6.12 For ships assigned the notation **ESP**, the owner is to respond to a Survey Planning Questionnaire and to prepare a Survey Programme, *see* 6.3, 7.3 and 8.3. In such cases, the following requirements are applicable:

(a) The Survey Planning Questionnaire is to be submitted to LR prior to the preparation of a Survey Programme. The response to the Questionnaire is to include information on access provisions for close-up Surveys and thickness measurements; cargo history; the results of inspections carried out by the Owner; a list of reports of Port State Control Inspection containing hull structural deficiencies; a list of Safety Management System non-conformities related to hull maintenance and details of the thickness measurement company.

(b) The Survey Programme is to be submitted prior to the commencement of any part of the Intermediate Survey on ships over 10 years of age and Special Survey. This is to be in a written format and submitted to LR at least six months in advance of the survey. The Survey Programme at Intermediate Survey may consist of the Survey Programme agreed for the previous Special Survey supplemented by the Executive Hull Summary of that Special Survey and later relevant survey reports. The survey will not commence until a Survey Programme has been agreed.

(c) The Survey Programme is to be worked out taking into account any amendments to the survey requirements implemented after the previous Special Survey.

(d) Further information on the Survey Planning Questionnaire and Survey Programme can be found in the *ESP guidance booklets* that have been prepared by LR and are available on the ClassDirect Live website.

(e) Prior to the commencement of any part of the Intermediate Survey and Special Survey, a survey planning meeting is to be held between the attending Surveyor(s), the Owner's representative in attendance, the thickness measurement company operator representative (as applicable) and the Master of the ship or an appropriately qualified representative appointed by the Master or Owner for the purpose of ascertaining that all the arrangements envisaged in the Survey Programme are in place, so as to ensure the safe and efficient conduct of the survey to be carried out. The following is an indicative list of items that are to be addressed in the meeting:
   - (i) Schedule of the ship (i.e., the voyage, docking and undocking manoeuvres, periods alongside, cargo and ballast operations, etc.).
   - (ii) Provisions and arrangements for thickness measurements (i.e., access, cleaning/de-scaling, illumination, ventilation, personal safety).
   - (iii) Extent of the thickness measurements.
   - (iv) Permissible diminution levels.
   - (v) Extent of close-up survey and thickness measurement considering the coating condition and suspect areas/areas of substantial corrosion.
   - (vi) Execution of thickness measurements.
   - (vii) Taking representative readings in general and where uneven corrosion/pitting is found.
   - (viii) Mapping of areas of substantial corrosion.
   - (ix) Communication between attending surveyor(s), the thickness measurement company operator(s) and Owner's representative(s) concerning findings.

(f) Proper preparation and close co-operation between the attending Surveyor(s) and the Owner's representative on board prior to and during the survey are an essential part in the safe and efficient conduct of the survey. During the survey on board safety meetings are to be held regularly.

1.7 Thickness measurement at surveys

1.7.1 This Section is applicable to the thickness measurement of the hull structure where required by Sections 2, 3, 5, 6, 7, 8 and 9.

1.7.2 Prior to the commencement of the Intermediate Survey and Special Survey, a meeting is to be held between the attending Surveyor(s), the Owner's representative in attendance, the thickness measurement company representative and the Master of the ship or an appropriately qualified representative appointed by the Master or Owner, so as to ensure the safe and efficient conduct of the survey and thickness measurements to be carried out.

1.7.3 Thickness measurements are normally to be taken by means of ultrasonic test equipment and are to be carried out by a firm approved in accordance with LR's *Approval for Thickness Measurement of Hull Structure*. For non-**ESP** ships less than 500 gross tons and all fishing vessels, a suitably qualified exclusive Surveyor (where available) may carry out thickness measurements. On all other occasions, an approved firm is to carry out the thickness measurements.

1.7.4 The Surveyor may require to measure the thickness of the material in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality. Attention is to be given to the structure in way of discontinuities. If a corrosion control (**cc**) notation, as defined in the *Register Book*, is assigned, surfaces are to be re-coated as necessary.

1.7.5 Thickness measurements are to be witnessed by the Surveyor. This requires the Surveyor is to be on board, while the measurements are carried out, to the extent necessary to control the process. This also applies to thickness measurements carried out while the ship is at sea.

1.7.6 The Surveyor may extend the scope of thickness measurement if deemed necessary.

1.7.7 Where it is required as part of the survey to carry out thickness measurements for the structural areas subject to Close-up Survey, then these measurements are to be carried out simultaneously with the Close-up Survey.

1.7.8 Thickness measurements are to be taken in the forward and aft areas of all plates. Where plates cross ballast/cargo tank boundaries separate measurements for the area of plating in way of each type of tank are to be reported. In all cases the measurements are to represent the average of multiple measurements taken on each plate and/or stiffener. Where measured plates are renewed, the thicknesses of adjacent plates in the same strake are to be reported.

1.7.9 A report is to be prepared by the approved firm or surveyor carrying out the thickness measurements. The report is to give the location of measurement, the thickness measured as well as the corresponding original thickness. The report is to give the date when measurement was carried out, the type of measuring equipment, names of personnel and their qualifications and is to be signed by the operator.

1.7.10 The thickness measurement report is to be verified and signed by the Surveyor and countersigned by an authorising Surveyor.

1.7.11 In all cases the extent of the thickness measurements is to be sufficient to represent the actual average condition.

1.8 Repairs

1.8.1 Any damage in association with wastage over the allowable limit (including buckling, grooving, detachment or fracture), or extensive areas of wastage over the allowable limits, which affects or, in the opinion of the Surveyor, will affect the ship's structural, watertight or weathertight integrity, is to be promptly and thoroughly repaired. Areas to be considered include, (where fitted):

- side shell frames, their end attachments and adjacent shell plating;
- deck structure and deck plating;
- bottom structure and bottom plating;
- side structure and side plating;
- inner bottom structure and inner bottom plating;
- inner side structure and inner side plating;
- watertight or oiltight bulkheads;
- hatch covers and hatch coamings;
- the weld connection between air pipes and deck plating;
- air pipe heads installed on the exposed decks;
- ventilators, including closing devices.

For locations where adequate repair facilities are not available, consideration may be given to allow the ship to proceed directly to a repair facility. This may require discharging the cargo and/or temporary repairs for the intended voyage.

1.8.2 Additionally, when a survey results in the identification of structural defects or corrosion, either of which, in the opinion of the Surveyor, will impair the ship's fitness for continued service, remedial measures are to be implemented before the ship continues in service.

1.8.3 Where the damage found on structure mentioned in 1.8.1 is isolated and of a localised nature which does not affect the ship's structural integrity, consideration may be given by the Surveyor to allow an appropriate temporary repair to restore watertight or weathertight integrity and impose a Condition of Class with a specific time limi

■ *Section 2*
Annual Surveys – Hull and machinery requirements

2.1 General

2.1.1 Annual Surveys are to be held concurrently with statutory annual or other relevant statutory surveys, wherever practicable.

2.1.2 At Annual Surveys, the Surveyor is to examine the ship and machinery, so far as necessary and practicable, in order to be satisfied as to their general condition.

2.1.3 For additional requirements for ships for liquefied gases, *see* Section 9.

2.1.4 For ships which are required by International Convention to comply with the I*nternational Safety Management Code* (ISM Code), the Surveyor is to review the overall effectiveness of the Code onboard ship. This is to be undertaken regardless of the organisation issuing the Safety Management Certificate (SMC).

2.1.5 For ships assigned the notation 'laid-up', in lieu of the normal Annual Survey requirements a general examination of the hull and machinery is to be carried out.

2.2 Annual Surveys

2.2.1 The survey is to include:

(a) An examination for the purpose of ensuring, as far as practicable, that the hull, hatch covers, hatch coamings, closing appliances, equipment and related piping are maintained in a satisfactory condition.
(b) Examination of weather decks, ship side plating above the waterline, hatch cover and coamings.
(c) Examination of watertight penetrations as far as practicable.
(d) Examination of the weld connection between air pipes, ventilators and deck plating.
(e) External examination of all air pipe heads installed on exposed decks.
(f) Examination of flame screens on air pipes to all bunker tanks.
(g) Examination of ventilators including closing devices, if any.
(h) The Surveyor is to be satisfied regarding the efficient condition of:
    - exposed casings, skylights, flush deck scuttles, deckhouses and companionways, superstructure bulkheads, side, bow and stern doors, side scuttles and deadlights, chutes and other openings, together with all closing appliances.
    - scuppers and sanitary discharges (so far as practicable); valves on discharge lines (so far as practicable) and their controls; guard rails and bulwarks; freeing ports, gangways and life-lines; fittings and appliances for timber deck cargoes.
    - bilge level detection and alarm systems on ships assigned a **UMS** notation.

2.2.2 The following requirements for hatch covers and coamings are applicable:

(a) The Surveyor is to obtain confirmation that no unapproved changes have been made to the hatch covers, hatch coamings and their securing and sealing devices since the previous survey.
(b) Where mechanically operated steel hatch covers are fitted, Surveyors are to confirm the satisfactory condition of:
    - hatch covers;
    - tightness devices of longitudinal, transverse and intermediate cross junctions (gaskets, gasket lips, compression bars, drainage channels);
    - clamping devices, retaining bars, cleating;
    - chain or rope pulleys;

- guides;
- guide rails and track wheels;
- stoppers, etc;
- wires, chains, gypsies, tensioning devices;
- hydraulic system essential to closing and securing;
- safety locks and retaining devices.

(c) Where portable hatch covers, wooden or steel pontoons are fitted, Surveyors are to confirm the satisfactory condition of:
- wooden covers and portable beams, carriers or sockets for the portable beam, and their securing devices;
- steel pontoons;
- tarpaulins;
- cleats, battens and wedges;
- hatch securing bars and their securing devices;
- loading pads/bars and the side plate edge;
- guide plates and chocks;
- compression bars, drainage channels and drain pipes (if any).

(d) The Surveyor is to confirm the satisfactory condition of hatch coaming plating and their stiffeners, where applicable.

(e) The Surveyor is to carry out random checking of the satisfactory operation of mechanically operated hatch covers including:
- stowage and securing in open condition,
- proper fit and efficiency of sealing in closed condition,
- operational testing of hydraulic and power components, wires, chains and link drives.

(f) Where considered necessary by the Surveyor, the effectiveness of sealing arrangements may be proved by hose or chalk testing supplemented by dimensional measurements of seal compressing components.

(g) For **general dry cargo ships** the survey is to include a close-up survey of the hatch covers, hatch coaming and stiffeners.

(h) For **bulk carriers** the following requirements are also applicable:
  (i) The survey is to include a close-up survey of the hatch covers, hatch coaming and stiffeners.
  (ii) A thorough survey of cargo hatch covers and coamings is only possible by their examination in an open and closed position, including verification of the proper opening and closing operation. As such, the hatch cover sets located in the forward 25 per cent of the ship's length and at least one other additional set are to be surveyed open, closed and in operation to the full extent on each direction in accordance with (e) above. When selecting hatch cover sets it should be ensured that all sets are subject to survey at least once in every five-year Special Survey period. The closing of the covers is to include the fastening of all peripheral and cross joint cleats or other securing devices, with particular attention to be paid to the condition of the hatch covers located in the forward 25 per cent of the ship's length, where sea loads are normally greatest.
  (iii) If there are indications of difficulty in operating and securing hatch covers, then additional sets are to be tested in operation at the discretion of the Surveyor.
  (iv) Where the cargo hatch securing system does not function properly, repairs are to be carried out under the supervision of the Surveyor.
  (v) Surveyors are to survey the sealing arrangements of perimeter and cross joints (gaskets for condition of permanent deformation, flexible seals on combination carriers, gasket lips, compression bars, drainage channels and non-return valves).

2.2.3 The Surveyor is to confirm that, where required, an approved loading instrument together with its operation manual is available on board, *see* Pt 3, Ch 4,8. The operation of the loading instrument is to be verified in accordance with LR's certification procedure.

2.2.4 The anchoring and mooring equipment is to be examined so far as practicable.

2.2.5 The watertight doors in watertight bulkheads, their indicators and alarms, are to be examined and tested (locally and remotely), together with an examination of watertight bulkhead penetrations, so far as practicable.

2.2.6 The Surveyor is to examine and test in operation all main and auxiliary steering arrangements including their associated equipment and control systems, and verify that log book entries have been made in accordance with statutory requirements where applicable.

2.2.7 The Surveyor is to be satisfied regarding the freeboard marks on the ship's side.

2.2.8 The Surveyor is to generally inspect the machinery and boiler spaces, with particular attention being given to the propulsion system, auxiliary machinery and to the existence of any fire and explosion hazards. Emergency escape routes are to be checked to ensure that they are free of obstruction.

2.2.9 The means of communication between the navigating bridge and the machinery control positions, as well as the bridge and the alternative steering position, if fitted, are to be tested.

2.2.10 The bilge pumping systems for each watertight compartment, including bilge wells, extended spindles, self-closing drain cocks, valves fitted with rod gearing or other remote operation, pumps and level alarms, where fitted, are to be examined and operated as far as practicable and all confirmed to be satisfactory. Any hand pumps provided are to be included.

2.2.11 Piping systems containing oil fuel, lubricating oil or other flammable liquids are to be generally examined and operated as far as practicable, with particular attention being paid to tightness, fire precaution arrangements, flexible hoses and sounding arrangements.

2.2.12 The Surveyor is to be satisfied regarding the condition of non-metallic joints in piping systems which penetrate the hull, where both the penetration and the non-metallic joint are below the deepest load waterline.

2.2.13 The main propulsion, essential auxiliary and emergency generators including safety arrangements, controls and foundations are to be generally examined. Surveyors are to confirm that Periodical Surveys of engines have been carried out as required by the Rules and that safety devices have been tested.

2.2.14 The boilers, other pressure vessels and their appurtenances, including foundations, controls, high pressure and waste steam piping and insulation and gauges, are to be generally examined. Surveyors should confirm that Periodical Surveys of boilers and other pressure vessels have been carried out as required by the Rules.

2.2.15 For boilers, the safety devices are to be tested, and the safety valves are to be operated using the relieving devices. For exhaust gas heated economisers/boilers, the safety valves are to be tested at sea by the Chief Engineer and details recorded in the log book.

2.2.16 The operation and maintenance records, repair history and feed water chemistry records of boilers are to be examined.

2.2.17 For other pressure vessels, the safety devices are to be examined.

2.2.18 The electrical equipment and cabling forming the main and emergency electrical installations are to be generally examined under operating conditions so far as practicable. The satisfactory operation of the main and emergency sources of power and electrical services essential for safety in an emergency is to be verified; where the sources of power are automatically controlled they should be tested in the automatic mode. Bonding straps for the control of static electricity and earthing arrangements are to be examined where fitted.

2.2.19 The electrical installation in areas which may contain flammable gas or vapour and/or combustible dust is to be examined in order to verify that it is in good condition and has been properly maintained.

2.2.20 For main propulsion, essential auxiliary and emergency machinery control engineering systems, a general examination of the equipment and arrangements is to be carried out. Records of modifications are to be made available for review by the attending Surveyor. The documentation required by Pt 6, Ch 1, including configuration management, are to be reviewed following system modifications to confirm compliance with applicable Rules. Satisfactory operation of the safety devices and control systems is to be verified. For ships having **UMS** or **CCS** notation, a general examination of the control engineering equipment required for these notations is also to be carried out.

2.2.21 For ships fitted with an electronically controlled engine for main propulsion, essential auxiliary or emergency power purposes the following is to be carried out to the satisfaction of the Surveyor:

(a) Verification of evidence of satisfactory operation of the engine and where possible this is to include a running test under load.
(b) Verification of satisfactory operation of the safety devices and control, alarm and monitoring systems.
(c) Verification that any changes to the software or control, alarm, monitoring and safety systems that affect the operation of the engine have been assessed by LR and are under configuration management control

2.2.22 Dead ship starting arrangements for bringing machinery into operation without external aid are to be tested to the Surveyor's satisfaction.

2.2.23 On ships fitted with a dynamic positioning system, the control system and associated machinery items are to be generally examined and tested to demonstrate that they are in good working order.

2.2.24 For ships to which a **PM** or **PMC** notation has been assigned in accordance with Pt 7, Ch 8,1.2.1(b), the thruster assisted positional mooring system, control system and associated machinery items are to be generally examined and tested under operating conditions to an approved Test Schedule.

2.2.25 For ships fitted with positional mooring equipment in accordance with Pt 7, Ch 8, a schedule or rota of moorings to be examined at Annual Survey should be agreed for component parts of the positional moorings.

2.2.26 For ships having an **OPS** notation assigned, a General Examination of on-shore power supply arrangements is to be carried out in accordance with Pt 7, Ch 13.

2.2.27 For ships to which Pt 6, Ch 4 applies, the arrangements for fire protection, detection and extinction are to be examined and are to include:

(a) Verification, so far as practicable, that no significant changes have been made to the arrangement of structural fire protection.
(b) Verification of the operation of manual and/or automatic doors where fitted.
(c) Verification that fire-control plans are properly posted.
(d) Examination, so far as possible, and testing as feasible, of the fire and/or smoke detection and alarm system(s).
(e) Examination of fire main system, and confirmation that each fire pump, including the emergency fire pump can be operated separately so that the two required powerful jets of water can be produced simultaneously from different hydrants.
(f) Verification that fire-hoses, nozzles, applicators and spanners are in good working condition and situated at their respective locations.
(g) Examination of fixed fire-fighting systems controls, piping, instructions and marking, checking for evidence of proper maintenance and servicing, including date of last systems tests.
(h) Verification that all portable and semi-portable fire-extinguishers are in their stowed positions, checking for evidence of proper maintenance and servicing, conducting random checks for evidence of discharged containers.
(j) Verification, so far as practicable, that the remote control for stopping fans and machinery and shutting-off fuel supplies in machinery spaces and, where fitted, the remote controls for stopping fans in accommodation spaces and the means of cutting off power to the galley are in good working order.

(k) Examination of the closing arrangements of ventilators, funnel annular spaces, skylights, doorways and tunnels, where applicable.
(l) Verification that the firemen's outfits are complete and in good condition.

2.2.28 The examination of salt-water ballast tanks is to be carried out as follows:
(a) Salt-water ballast tanks, other than double bottom ballast tanks, on all ships (excluding oil tankers and chemical tankers) where it has been identified at a previous Special Survey or Intermediate Survey that:
 (i) A hard protective coating has not been applied from the time of construction; or
 (ii) A soft or semi-hard coating has been applied; or
 (iii) A hard protective coating is found to be in POOR condition, as defined in 1.5, and the hard protective coating is not repaired to the satisfaction of the Surveyor.
 If the conditions listed above are applicable to double bottom ballast tanks, then these tanks may be subject to examination at the Annual Survey at the discretion of the Surveyor.
(b) Salt-water ballast tanks on oil tankers (including ore/oil and ore/bulk/oil ships) and chemical tankers where it has been identified at a previous Special Survey or Intermediate Survey that:
 (i) A hard protective coating has not been applied from the time of construction; or
 (ii) A soft or semi-hard coating has been applied; or
 (iii) The hard protective coating is found to be in less than GOOD condition, as defined in 1.5, and the hard protective coating is not repaired to the satisfaction of the Surveyor.
(c) The examination of the salt-water ballast tanks, in accordance with the above, is to include thickness measurements to confirm the condition of the hull structure.

2.2.29 The Surveyor is to carry out an examination and thickness measurement of structure identified at the previous Special Survey or Intermediate Survey as having substantial corrosion, as defined in 1.5. This requirement does not apply to cargo tanks of oil tankers and chemical tankers. The extent of thickness measurements is to be in accordance with the appropriate Tables in Sections 5, 6, 7 or 8, as applicable, to determine the full extent of the corrosion pattern. The survey will not be considered complete until these additional thickness measurements have been carried out. For cargo holds and ballast tanks of bulk carriers built in accordance with the IACS Common Structural Rules (CSR), the annual thickness measurement may be dispensed with where a protective coating has been applied in accordance with the coating manufacturer's requirements and is maintained in good condition. Steel renewal requirements have been separately determined according to date of contract for construction for:
(a) cargo hold hatch covers and coamings under IACS UR S21 and UR S21A; and
(b) bulk carriers' corrugated transverse watertight hold bulkheads under IACS UR S18.

Where the gauged thickness is within the range t_{net} + 0,5 mm and t_{net} + 1,0 mm, a coating (applied in accordance with coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. *See* 5.6.7, 6.7.5 and 7.7.4.

2.2.30 For **oil tankers** (including ore/bulk/oil ships and ore/oil ships), in addition to the applicable requirements of 2.2.1 to 2.2.29, the following are to be dealt with where applicable:
(a) Examination of cargo tank openings including gaskets, covers, coamings and screens.
(b) Examination of cargo tank venting arrangements including secondary means of venting, or over/under pressure alarms where fitted, with associated pressure/vacuum valves and flame screens.
(c) Examination of flame screens on vents to all bunker, oily ballast and oily slop tanks and void spaces, so far as practicable.
(d) Examination of cargo, crude oil washing, bunker, ballast and vent piping systems together with flame arrestors and pressure/vacuum valves, as applicable above the upper deck within the cargo tank area, including vent masts and headers.
(e) Verification that no potential sources of ignition such as loose gear, excessive products in the bilges, excessive vapours, combustible materials, etc., are present in or near the cargo pump room and that access ladders are in good condition.
(f) Examination of cargo pump rooms and pipe tunnels (where fitted) and examination of all pump room bulkheads for signs of leakage or fractures and, in particular, the sealing arrangements of all penetrations in these bulkheads.
(g) Verification that the pump room ventilation system is operational, ducting intact, dampers operational and screens are clean.
(h) For ships to which Pt 6, Ch 4 applies, the external examination of the piping and cut-out valves of cargo tank and cargo pump room fixed fire-fighting system.
(j) For ships to which Pt 6, Ch 4 applies, verification that the deck foam system and deck sprinkler system are in good operating condition.
(k) Examination of the condition of all piping systems in the cargo pump room so far as practicable.
(l) Examination, so far as practicable, of cargo, bilge, ballast and stripping pumps for excessive gland seal leakage, verification of proper operation of electrical and mechanical remote operating and shutdown devices and operation of pump room bilge system, and checking that pump foundations are intact.
(m) Verification that installed pressure gauges on cargo discharge lines and level indicator systems are operational.
(n) Verification that at least one portable instrument for measuring flammable vapour concentrations is available, together with a sufficient set of spares and a suitable means of calibration.
(o) Examination of any inert gas system, *see* 2.2.32.

(p) For ballast tanks, in areas where substantial corrosion, as defined in 1.5, has been noted then additional measurements are to be carried out in accordance with Tables 3.7.7 to 3.7.15, as applicable. The survey will not be considered complete until these additional thickness measurements have been carried out.
(q) Verification that any special arrangements made for bow or stern loading and unloading are in good condition.

2.2.31 For **chemical tankers**, in addition to the applicable requirements of 2.2.1 to 2.2.30, the following are to be dealt with, where applicable:
(a) Examination of gauging devices, high level alarms and valves associated with overflow control.
(b) Verification that any devices provided for measuring the temperature of the cargo and any associated alarms are satisfactory.
(c) Examination of the cargo heating/cooling system sampling arrangements where fitted.
(d) Verification that wheelhouse doors and windows, side scuttles and windows in superstructure and deckhouse ends facing the cargo area are in good condition.
(e) Verification that pump discharge pressure gauges fitted outside the cargo pump rooms are satisfactory.
(f) Verification that pumps, valves and pipelines are identified and distinctively marked.
(g) Verification that the remote operation of the cargo pump room bilge system is satisfactory.
(h) Verification that cargo pump room rescue arrangements are in order.
(j) Verification that removable pipe lengths or other approved equipment necessary for cargo separation are available, and satisfactory.
(k) Verification that the ventilation system including portable equipment, if any, of all spaces in the cargo area is operational.
(l) Verification that arrangements are made for sufficient inert/padding/drying gas to be carried to compensate for normal losses and that means are provided for monitoring of ullage spaces.
(m) Verification that arrangements are made for sufficient medium to be carried where drying agents are used on air inlets to cargo tanks.
(n) Verification that suitable protective clothing is available for crew engaged in loading and discharging operations and that suitable storage is maintained.
(o) Verification that the requisite safety equipment and associated breathing apparatus with requisite air supplies and emergency escape respiratory and eye protection, if required, are in good condition and are properly stowed.
(p) Verification that medical first aid equipment including stretchers and oxygen resuscitation is in good condition and that satisfactory arrangements are made for antidotes for cargoes actually carried to be on board.
(q) Verification that decontamination arrangements are operational.
(r) Verification that the requisite gas detection instruments are on board and that satisfactory arrangements are made for the supply of any required vapour detection tubes.
(s) Verification that the cargo sample stowage arrangements are in good condition.
(t) Verification that, if applicable, the provisions made for chemicals which have special requirements listed in Chapter 17 of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquid Chemicals in Bulk* are in order.
(u) For ballast tanks, in areas where substantial corrosion, as defined in 1.5, has been noted then additional measurements are to be carried out in accordance with Tables 3.8.5, 3.8.6, 3.8.7 and 3.8.8. The survey will not be considered complete until these additional thickness measurements have been carried out.

2.2.32 For **inert gas systems**, where fitted, the following are to be dealt with:
(a) External examination of the condition of piping including vent piping above the upper deck in the cargo tank area and overboard discharges through the shell so far as practicable, together with components for signs of corrosion or gas leakage/effluent leakage.
(b) Verification of the proper operation of both inert gas blowers.
(c) Checking the scrubber room ventilation system.
(d) Checking, so far as practicable, of the deck water seal for automatic filling and draining and checking for presence of water carry-over. Checking the operation of the non-return valve.
(e) Testing of all remotely operated or automatically controlled valves including the flue gas isolating valve(s).
(f) Checking the interlocking features of soot blowers.
(g) Checking that the gas pressure regulating valve automatically closes when the inert gas blowers are secured.
(h) Checking, so far as practicable, the following alarms and safety devices of the inert gas system using simulated conditions where necessary:
  (i) high oxygen content of gas in the inert gas main;
  (ii) low gas pressure in the inert gas main;
  (iii) low pressure in the supply to the deck water seal;
  (iv) high temperature of gas in the inert gas main;
  (v) low water pressure to the scrubber;
  (vi) accuracy of portable and fixed oxygen measuring equipment by means of calibration gas.

2.2.33 For **bulk carriers**, in addition to the applicable requirements of 2.2.1 to 2.2.29, the following are to be dealt with, where applicable:
(a) Examination of cargo holds in accordance with Table 3.2.1 is required.
(b) Where substantial corrosion, as defined in 1.5, has been noted then additional measurements are to be carried out in accordance with Tables 3.6.5, 3.6.6, 3.6.7, 3.6.8, 3.6.9 and 3.6.10. The survey will not be considered complete until these additional thickness measurements have been carried out.

For cargo holds and ballast tanks of bulk carriers built in accordance with the IACS Common Structural Rules (CSR), the annual thickness measurement may be dispensed with where a protective coating has been applied in accordance with the coating manufacturer's requirements and is maintained in good condition. Steel renewal requirements have been separately determined according to date of contract for construction for:
(c) cargo hold hatch covers and coamings under IACS UR S21; and
(d) corrugated transverse watertight hold bulkheads under IACS UR S18.

Where the gauged thickness is within the range t_{net} + 0,5 mm and t_{net} + 1,0 mm, a coating (applied in accordance with coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. *See* 5.6.7 and 6.7.5.

(e) For ships fitted with water level detectors in cargo holds, ballast tanks forward of the collision bulkhead and any dry or void space which extends forward of the foremost cargo hold, an examination and a test, at random, of the water ingress detection systems and of their alarms is to be carried out.

(f) For ships fitted with a means for draining and pumping ballast tanks forward of the collision bulkhead and the bilges of dry spaces, any part of which extends forward of the foremost cargo hold, an examination and a test of the draining and pumping systems, including their controls, is to be carried out.

(g) Examination of bunker and vent piping systems, including ventilators.

2.2.34 For **general dry cargo ships**, in addition to the applicable requirements of 2.2.1 to 2.2.29, the following are required for ships over 10 years of age:

(a) Overall survey of one forward and one after cargo hold and their associated 'tween deck spaces.

(b) When considered necessary by the Surveyor, thickness measurement is to be carried out. If the results of thickness measurement indicate substantial corrosion, the extent of thickness measurement is to be in accordance with Table 3.5.6 in Section 5. The survey will not be considered complete until these additional thickness measurements have been carried out. Steel renewal requirements have been separately determined according to date of contract for construction for cargo hold hatch covers and coamings under IACS UR S21A. Where the gauged thickness is within the range t_{net} + 0,5 mm and t_{net} + 1,0 mm, a coating (applied in accordance with coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. *See* 5.6.7.

2.2.35 For **general dry cargo ships**, in addition to the applicable requirements of 2.2.1 to 2.2.29, the following are required for ships over 15 years of age:

(a) Overall survey of all cargo holds and 'tween deck spaces.

(b) Close-up Survey of at least 25 per cent of shell frames, including their end attachments and adjacent shell plating in a forward lower cargo hold and one other selected lower cargo hold. Close-up Survey is to include the lower one third length of the shell frames.

(c) Where the survey reveals the need for remedial measures, then the survey is to be extended to include the Close-up Survey of all shell frames and adjacent shell plating in those cargo holds and associated 'tween deck spaces, as well as a Close-up Survey of sufficient extent of all remaining cargo holds and 'tween deck spaces.

(d) Where the protective coatings in cargo holds are found in GOOD condition, as defined in 1.5, the extent of Close-up Survey may be specially considered.

(e) When considered necessary by the Surveyor, thickness measurement is to be carried out. If the results of thickness measurement indicate substantial corrosion, the extent of thickness measurement is to be in accordance with Table 3.5.6 in Section 5. The survey will not be considered complete until these additional thickness measurements have been carried out. Steel renewal requirements have been separately determined according to date of contract for construction for cargo hold hatch covers and coamings under IACS UR S21A. Where the gauged thickness is within the range t_{net} + 0,5 mm and t_{net} + 1,0 mm, a coating (applied in accordance with coating manufacturer's requirements)

Table 3.2.1 Bulk carriers – Annual Surveys

Ships less than 10 years old	Ships between 10 and 15 years old	Ships greater than 15 years old
An Overall Survey of the forward cargo hold and an aft cargo hold on single skin ships *See* Note 1	(a) Overall Survey of (i) all cargo holds on single skin ships (ii) two selected cargo holds on double skin ships (b) Close-up Survey of at least 25 per cent of the cargo hold side shell frames, their lower end attachments and adjacent shell plating in the forward cargo hold on single skin ships. (c) Examination of all piping and penetrations in cargo holds including overboard piping. *See* Notes 2, 3, 4 and 5.	(a) Overall Survey of all cargo holds (b) Close-up Survey of at least 25 per cent of the cargo hold side shell frames, their lower end attachments and adjacent shell plating in the forward cargo hold and one other selected cargo hold on single skin ships (c) Examination of all piping and penetrations in cargo holds including overboard piping. *See* Notes 2, 3, 4 and 5.

NOTES
The requirements in this Table apply to both single skin and double skin ships, unless stated otherwise.
1. Where the Survey reveals the need for remedial measures, then the Survey is to be extended to include all cargo holds.
2. Close-up Survey is required within the area of the lower one-third of the length of the cargo hold side shell frames.
3. Where the Survey reveals the need for remedial measures, the Survey is to be extended to include a Close-up Survey of all of the cargo hold side shell frames and adjacent shell plating of that cargo hold, as well as a Close-up Survey of sufficient extent of all remaining cargo holds.
4. When considered necessary by the Surveyor, thickness measurement is to be carried out. If the results of thickness measurement indicate substantial corrosion, the extent of thickness measurement is to be in accordance with Section 6, Tables 3.6.5, 3.6.6, 3.6.7, 3.6.8, 3.6.9 and 3.6.10 as applicable. The survey will not be considered complete until these additional thickness measurements have been carried out.
5. Where protective coatings are found in GOOD condition, as defined in 1.5, the extent of the Close-up Survey may be specially considered. When considered necessary by the Surveyor, thickness measurement is to be carried out. However, prior to any coating or recoating of cargo holds, scantlings are to be confirmed by thickness measurement with the Surveyor in attendance.

or annual gauging may be adopted as an alternative to steel renewal. *See* 5.6.7.

2.2.36 For **ship-borne barges** where surveys are permitted in accordance with Pt 1, Ch 2,3.5.7, *see* Section 3.

2.2.37 For **roll on-roll off ships** (i.e., those that utilise a loading ramp which enables wheeled vehicles to be rolled on and rolled off the ship), in addition to the requirements of 2.2.1, the requirements of Section 22 are to be complied with, as applicable. For ships other than roll on-roll off ships, fitted with bow doors, inner doors, side doors and stern doors, in addition to the requirements of 2.2.1, the following are to be satisfactorily dealt with, as applicable:

(a) Verification of the freedom of movement of doors, and operation of their power units.
(b) Examination of the door structure and surrounding ship structure.
(c) Examination of the door sealing arrangements including gaskets and retaining bars.
(d) Examination of the door cleating, locking and securing arrangements.
(e) Examination of the door hinging arrangements.
(f) Verification of the local and/or remote control of the securing devices/cleats.
(g) Examination of all equipment associated with the opening, closing and securing of the door, e.g., wire ropes, chains, sheaves, rollers, guides, shackles, etc.
(h) Verification of the tightness of the doors.
(j) Examination and testing of remote control panels and associated indicator lights, closed circuit television systems, water leakage indicator lights and alarm systems.
(k) Examination of the required notice boards and verification of log entries.
(l) Verification of the satisfactory testing of the bilge systems for the space between the inner and outer bow doors and of the vehicle deck.
(m) Verification that the approved Operation and Maintenance Manual is on board and satisfactorily maintained.

2.2.38 For **navigational arrangements for periodic one man watch** and **integrated bridge systems**, Annual Surveys are to be carried out in accordance with the approved test schedule as required by Pt 7, Ch 9,1.2.1 to ascertain that the equipment and arrangements required for the applicable class notation(s) are being maintained in good working order. At the time of the survey, relevant statutory certificates may be accepted as evidence of satisfactory operation.

2.2.39 For **liquefied gas ships**, *see also* Section 9.

2.2.40 The Surveyor is to examine the fixed cargo securing fittings as far as necessary and practicable in order to be satisfied as to their general condition, *see* Pt 3, Ch 14,10.

2.2.41 Where the special features notation **CCSA** (certified container securing arrangements) is assigned, the Surveyor is to examine the securing arrangements including loose fittings so far as necessary and practicable in order to be satisfied as to their general condition, *see* Pt 3, Ch 14,10.

2.2.42 The Surveyor is to confirm that, for container ships which have the special features notation **BoxMax**, the onboard lashing program, together with its operation manual, is available on board, *see* Pt 3, Ch 4,8. The operation of the program is to be verified in accordance with LR's certification procedure.

2.2.43 For single hold general dry cargo ships, other than bulk carriers, fitted with water level detectors in the cargo hold, an examination and a test, at random, of the water ingress detection system and alarms are to be carried out.

Section 3
Intermediate Surveys – Hull and machinery requirements

3.1 General

3.1.1 Intermediate Surveys are to be held concurrently with statutory annual or other relevant statutory surveys wherever practicable.

3.2 Intermediate Surveys

3.2.1 The requirements of Section 2 are to be complied with so far as applicable.

3.2.2 A general examination of salt-water ballast tanks is to be carried out as required by 3.2.6 and 3.2.7. For ships other than oil tankers and chemical tankers, if such examinations reveal no visible structural defects then the examination may be limited to a verification that the protective coating remains in GOOD or FAIR condition as defined in 1.5.

3.2.3 In application of 3.2.12, 3.2.15 and 3.2.17 respectively for **oil tankers** (including ore/oil and ore/bulk/oil ships), **chemical tankers** and **bulk carriers** over 15 years of age a survey in dry-dock is to be a part of the Intermediate Survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of cargo tanks/holds and water ballast tanks are to be surveyed in accordance with the applicable requirements for Intermediate Surveys, if not already surveyed.

3.2.4 For **oil tankers** (including ore/oil and ore/bulk/oil ships) and **chemical tankers**, the condition of the corrosion prevention system identified during the Survey may result in the salt-water ballast tanks being subject to further examination at Annual Surveys, in accordance with 2.2.28.

3.2.5 For salt-water ballast tanks on those ships not listed in 3.2.4, the condition of the corrosion prevention system identified during the Survey may result in the tanks being subject to further examination at Annual Surveys, in accordance with 2.2.28. For double bottom ballast tanks, the examination at Annual Surveys will be at the discretion of the Surveyor.

3.2.6 For ships over 5 years of age and up to 10 years of age, representative salt-water ballast tanks are to be examined. In addition to this, the following requirements are applicable:

(a) For **general dry cargo ships**, an Overall Survey of representative salt-water ballast tanks, as selected by the Surveyor is to be carried out.
(b) For **bulk carriers**, an Overall Survey of representative salt-water ballast tanks, as selected by the Surveyor is to be carried out. The selected tanks are to include the fore peak tank, aft peak tank and a number of other tanks, taking into account the total number and type of ballast tanks.
(c) For **single hull oil tankers** (including ore/oil and ore/bulk/oil ships), an examination of all salt-water ballast tanks is to be carried out. Where considered necessary by the Surveyor, thickness measurement and testing are to be carried out to ensure the structural integrity remains effective.
(d) For **double hull oil tankers** and **chemical tankers**, an Overall Survey of representative salt-water ballast tanks, as selected by the Surveyor is to be carried out. If the survey reveals no visible defects, the examination may be limited to a verification that the hard protective coating remains in GOOD condition, as defined in 1.5.
(e) Where a hard protective coating is found to be in POOR condition, as defined in 1.5, where a soft or semi-hard coating has been applied, where a protective coating was not applied from the time of construction or other defects are found, the survey is to be extended to other ballast tanks of the same type.

3.2.7 For all ships over 10 years of age, the following are required:

(a) All salt-water ballast tanks are to be examined.
(b) The anchors are to be partially lowered and raised using the windlass.

3.2.8 The Surveyor is to carry out an examination and thickness measurement of structure identified at the previous Special Survey as having substantial corrosion, *see also* Sections 5, 6, 7 and 8. In addition, for double hull oil tankers built in accordance with the IACS Common Structural Rules (CSR), the identified substantial corrosion areas are required to be examined and additional thickness measurements are to be carried out in accordance with Tables 3.7.11 to 3.7.15.

3.2.9 For all ships, the electrical generating sets are to be examined under working conditions to verify compliance with Pt 6, Ch 2,2.2.

3.2.10 In addition to the foregoing, in the case of all **oil tankers** (including ore/oil and ore/bulk/oil ships) the following are to be dealt with where applicable:

(a) An examination of cargo, crude oil washing, bunker, ballast, steam and vent piping on the weather decks, as well as vent masts and headers. If upon examination there is any doubt as to the condition of the piping, the piping may be required to be pressure tested, gauged, or both.
(b) A general examination within the zones and spaces deemed as hazardous, such as cargo pump rooms and spaces adjacent to and zones above cargo tanks, for defective and non-certified safe-type electrical equipment, improperly installed, defective and dead-end wiring. An electrical insulation resistance test of the circuits terminating in, or passing through, the hazardous zones and spaces is to be carried out. If the ship is not in a gas free condition the results of previously recorded test readings may be accepted.

3.2.11 For **oil tankers** (including ore/oil and ore/bulk/oil ships), in addition to 3.2.10, the following are required for ships over 10 years of age:

(a) A survey to the same extent as the previous Special Survey (applicable only to ESP surveys, *see* 7.1.2).
(b) Pressure testing of cargo and ballast tanks and the requirements for the longitudinal strength evaluation (*see* 7.7.3) are to be carried out if deemed necessary by the attending Surveyor.

3.2.12 For **chemical tankers**, in addition to the applicable requirements of 3.2.1 to 3.2.9 the following are to be dealt with where applicable:

(a) Examination of vent line drainage arrangements.
(b) Verification that the cargo heating/cooling system is in good condition.
(c) Verification that the ship's cargo hoses are approved and in good condition.
(d) Verification that, where applicable, pipelines and independent cargo tanks are electrically bonded to the hull.
(e) An examination of cargo, cargo washing, bunker, ballast, steam and vent piping on the weather decks, as well as vent masts and headers. If upon examination there is any doubt as to the condition of the piping, the piping may require to be pressure tested, gauged or both.
(f) A General Examination within the zones and spaces deemed as hazardous, such as cargo pump rooms and paces adjacent to and zones above cargo tanks, for defective and non-certified safe-type electrical equipment, improperly installed, defective and dead-end wiring. An electrical insulation resistance test of the circuits terminating in, or passing through, the hazardous zones and spaces is to be carried out. If the ship is not in a gas free condition the results of previously recorded test readings may be accepted.

3.2.13 For **chemical tankers**, in addition to 3.2.12, the following are required for ships over 10 years of age:

(a) A survey to the same extent as the previous Special Survey (applicable only to ESP surveys, *see* 8.1.2).
(b) Pressure testing of cargo and ballast tanks is to be carried out if deemed necessary by the attending Surveyor.

3.2.14 For **bulk carriers**, in addition to the applicable requirements of 3.2.1 to 3.2.9, the following are to be dealt with on ships over five years of age:

(a) Overall Survey, Close-up Survey and thickness measurements of cargo holds in accordance with Table 3.3.1.

(b) For ore carriers, in addition to the requirements of 3.2.7, the examination of salt-water ballast tanks is to include the following:
- (i) All web frame rings in one ballast wing tank.
- (ii) One deck transverse in each remaining ballast wing tank.
- (iii) Both transverse bulkheads in one ballast wing tank.
- (iv) One transverse bulkhead in each remaining ballast wing tank.

(c) Steel renewal requirements have been separately determined according to date of contract for construction for:
- (i) cargo hold hatch covers and coamings under IACS UR S21; and
- (ii) corrugated transverse watertight hold bulkheads under IACS UR S18.

Where the gauged thickness is within the range t_{net} + 0,5 mm and t_{net} + 1,0 mm, a coating (applied in accordance with coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. *See* 5.6.7 and 6.7.5.

(d) For bulk carriers built in accordance with the IACS Common Structural Rules (CSR), the areas identified with substantial corrosion in cargo holds and ballast tanks may be either:
- (i) protected by coating applied in accordance with the coating manufacturer's requirements and examined at Annual Surveys to confirm the coating in way is still in GOOD condition, or alternatively;
- (ii) subject to thickness measurement at Annual Surveys.

3.2.15 For **bulk carriers**, in addition to the applicable requirements of 3.2.1 to 3.2.9, the following is required for ships over 10 years of age:

(a) A survey to the same extent as the previous special Survey (applicable to ESP surveys, *see* 6.1.2).

(b) Pressure testing of all tanks and the internal examination of fuel oil tanks are to be carried out if deemed necessary by the Surveyor.

3.2.16 For ships over 10 years old of age (other than dry cargo ships, general dry cargo ships, ships assigned **ESP** Notation and ships for liquefied gases), in addition to the applicable requirements of 3.2.1 to 3.2.8, an Overall Survey of selected cargo spaces is to be carried out.

3.2.17 For **dry cargo ships** over 15 years old (other than bulk carriers and general dry cargo ships), in addition to the applicable requirements of 3.2.1 to 3.2.8, an Overall Survey of selected cargo holds is to be carried out.

3.2.18 For **general dry cargo ships,** in addition to the applicable requirements of 3.2.1 to 3.2.9, the following is required for ships over 5 years of age:

(a) An overall survey of one forward and one after cargo hold and their associated 'tween deck spaces.

3.2.19 For **general dry cargo ships,** in addition to the applicable requirements of 3.2.1 to 3.2.9, the following are required for ships over 10 years of age:

(a) An overall survey of all cargo holds and 'tween deck spaces.

Table 3.3.1 Bulk carriers – Intermediate Surveys

Ships between 5 and 10 years old	Ships between 10 and 15 years old	Ships greater than 15 years old
(a) Overall Survey of all cargo holds, *see* Notes 1, 2, 3 and 4 (b) Close-up Survey to establish the condition of at least 25 per cent of the cargo hold side shell frames including their upper and lower end attachments, adjacent shell plating and the transverse bulkheads in the forward cargo hold and one other selected cargo hold on single skin hips, *see* Notes 1, 3 and 4.	A survey to the same extent as the previous Special Survey (applicable only to ESP surveys, *see* 6.1.2), *see* Note 3.	A survey to the same extent as the previous Special Survey (applicable only to ESP surveys, *see* 6.1.2), *see* Note 3.

NOTES

The requirements in this Table apply to both single skin and double skin ships, unless stated otherwise.

1. For single skin ships, where considered necessary by the Surveyor as a result of the Overall and Close-up Survey, the Survey is to be extended to include a Close-up Survey of all of the side shell frames and adjacent shell plating of that cargo hold, as well as a Close-up Survey of sufficient extent of all remaining cargo holds.
2. For double skin ships, where considered necessary by the Surveyor as a result of the Overall Survey, the Survey is to be extended to include a Close-up Survey of those areas of structure in cargo holds selected by the Surveyor.
3. Thickness measurement is to be carried out of sufficient extent to determine the level of corrosion of those areas subject to Close-up Survey. If the results of thickness measurement indicate substantial corrosion, the extent of thickness measurement is to be in accordance with Section 6, Tables 3.6.5 to 3.6.10 as applicable. The survey will not be considered complete until these additional thickness measurements have been carried out.
4. For ships between 5 and 10 years old where hard protective coatings in cargo holds are found to be in GOOD condition, as defined in 1.5, the extent of Close-up Survey and thickness measurement may be specially considered but not dispensed with in its entirety. Prior to any coating or recoating of cargo holds, scantlings are to be confirmed by thickness measurement with the Surveyor in attendance.

(b) Where considered necessary by the Surveyor, thickness measurement is to be carried out. If the results of thickness measurement indicate substantial corrosion, the extent of thickness measurement is to be in accordance with Table 3.5.6 in Section 5. The survey will not be considered complete until these additional thickness measurements have been carried out. Steel renewal requirements have been separately determined according to date of contract for construction for cargo hold hatch covers and coamings under IACS UR S21A. Where the gauged thickness is within the range t_{net} + 0,5 mm and t_{net} + 1,0 mm, a coating (applied in accordance with coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. *See* 5.6.7.

3.2.20 For **general dry cargo ships,** in addition to the applicable requirements of 3.2.1 to 3.2.9, the following are required for ships over 15 years of age:

(a) A survey to the same extent as the previous special Survey (applicable only to surveys of the hull structure and piping systems in way of the cargo holds, cofferdams, pipe tunnels and void spaces within the cargo area and all salt water ballast tanks).
(b) Tank testing, survey of automatic air pipe heads and internal examination of fuel oil, lubricating oil and fresh water tanks are to be carried out if deemed necessary by the Surveyor.

3.2.21 For **ship-borne barges**, where Intermediate Surveys are permitted as an alternative to Annual Surveys and Docking Surveys, all the hatch covers are to be hose tested at every survey. The external surfaces of the barges are to be surveyed at these surveys.

3.2.22 For **liquefied gas ships**, *see* Section 9.

■ *Section 4*
Docking Surveys and In-water Surveys – Hull and machinery requirements

4.1 General

4.1.1 At Docking Surveys or In-water Surveys the Surveyor is to examine the ship and machinery, so far as necessary and practicable, in order to be satisfied as to the general condition.

4.1.2 For **oil tankers** (including ore/oil and ore/bulk/oil ships), **chemical tankers** and **bulk carriers** over 15 years of age the intermediate docking between Special Surveys is to be held in dry-dock. Further, this survey is to be held as part of the Intermediate Survey.

4.2 Docking Surveys

4.2.1 Where a ship is in dry-dock or on a slipway it is to be placed on blocks of sufficient height, and proper staging is to be erected as may be necessary, for the examination of the shell including bottom and bow plating, keel, stern, sternframe and rudder. The rudder is to be lifted for examination of the pintles if considered necessary by the Surveyor.

4.2.2 The shell plating is to be examined for excessive corrosion, deterioration due to chafing or contact with the ground and for undue unfairness or buckling. Special attention is to be given to the connection between the bilge strakes and the bilge keels.

4.2.3 The clearances in the rudder bearings are to be measured. Where applicable, pressure testing of the rudder may be required if deemed necessary by the Surveyor.

4.2.4 The sea connections and overboard discharge valves and cocks and their attachments to the hull are to be examined.

4.2.5 The propeller, sternbush and sea connection fastenings and the gratings at the sea inlets are to be examined.

4.2.6 The clearance in the sternbush and the efficiency of the oil glands are to be ascertained.

4.2.7 When chain cables are ranged, the anchors and cables are to be examined by the Surveyor, *see also* 5.3.13, 5.3.14, 5.3.16 and Table 3.5.1.

4.2.8 For electrical equipment survey requirements of oil tankers five years old and over, *see* 14.3.

4.2.9 Where the antifouling system is changed completely, or partial repair is carried out affecting 25 per cent or more of the antifouling system, the coating specification and antifouling system is to be examined by the Surveyor in accordance with IMO Antifouling System Convention.

4.3 In-water Surveys

4.3.1 The Committee will accept an In-water Survey in lieu of the intermediate docking between Special Surveys required in a five year period on ships other than those covered in 4.1.2 and where an ***IWS** notation is assigned, *see* Ch 2,2.3.11.

4.3.2 The Committee may accept an In-water Survey in lieu of the intermediate docking between Special Surveys required in a five year period on ships where suitable protection is applied to the underwater portion of the hull. If requested, and providing that there is suitable access for the taking of rudder pintle and bush clearances and for verifying the security of pintles in their sockets while the vessel is afloat,an ***IWS** notation may be assigned on satisfactory completion of the Survey, provided that the applicable requirements of LR's Rules and Regulations are complied with, *see also* Ch 2,2.3.11.

4.3.3 The In-water Survey is to provide the information normally obtained from the Docking Survey.

4.3.4 When there is no access, special consideration shall be given to ascertaining rudder bearing clearances and sternbush clearances based on a review of the operating history, on board testing and stern bearing oil analysis. These considerations are to be included in the proposals. In-water Surveys which are to be submitted in advance of the survey being required, so that satisfactory arrangements can be agreed with LR.

4.3.5 The In-water Survey is to be carried out at an agreed geographical location under the surveillance of a Surveyor to LR, with the ship at a suitable draught in sheltered waters and with weak tidal streams and currents. The in-water visibility and the cleanliness of the hull below the waterline is to be clear enough to permit a meaningful examination which allows the Surveyor and diver to determine the condition of the plating, appendages and the welding. The Surveyor is to be satisfied that the method of pictorial presentation is satisfactory. There is to be good two-way communication between the Surveyor and the diver.

4.3.6 Prior to commencing the In-water Survey, the equipment and procedures for both observing and reporting the survey are to be agreed between the Owners, the Surveyor and the diving firm

4.3.7 The In-water Survey is to be carried out by a qualified diver employed by a firm approved by LR.

4.3.8 If the In-water Survey reveals damage or deterioration that requires early attention, the Surveyor may require that the ship be dry-docked in order that a fuller survey can be undertaken and the necessary work carried out.

4.3.9 Where a vessel has an ***IWS** notation, the conditions of the high resistant paint is to be confirmed at each dry-docking in order that the ***IWS** notation can be maintained.

4.3.10 Some National Administrations may have requirements additional to those of 4.3.1 to 4.3.9.

■ *Section 5*
Special Survey – General – Hull requirements

5.1 General

5.1.1 The survey is to be of sufficient extent to ensure that the hull and related piping are in satisfactory condition and are fit for the intended purpose for the new period of class of five years to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out as required by the Regulations.

5.1.2 The requirements of Section 2 are to be complied with as applicable for all ships.

5.1.3 Additional requirements for **general dry cargo ships** are given in this Section; **dry bulk cargo ships bulk carriers** in Section 6; **oil tankers** (including ore/oil ships and ore/bulk/oil ships) in Section 7; **chemical tankers** in Section 8; **ships for liquefied gases** in Section 9.

5.1.4 A Docking Survey in accordance with the requirements of Section 4 is to be carried out as part of the Special Survey.

5.1.5 During the Docking Survey, for general dry cargo ships, oil tankers (including ore/oil ships and ore/bulk/oil ships), chemical tankers and bulk carriers, the overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo spaces and ballast tanks are to be carried out as required, if not already surveyed.

5.1.6 For ships assigned the notation 'laid-up', an Underwater Examination (UWE) and general examination of hull and machinery is to be carried out in lieu of the normal Special Survey requirements.

5.1.7 For roll on-roll off ships (i.e., those fitted with a loading ramp which enables wheeled vehicles to be rolled on and rolled off the ship), in addition to the requirements of this Section, the requirements of Section 22 are to be complied with, as applicable.

5.2 Preparation

5.2.1 The ship is to be prepared for Overall Survey in accordance with the requirements of Table 3.5.1. The preparation should be of sufficient extent to facilitate an examination to ascertain any significant corrosion, deformation, fractures, damages and other structural deterioration.

5.3 Examination and testing

5.3.1 All spaces within the hull and superstructure are to be examined.

5.3.2 The requirements for tank internal examination are given in Table 3.5.2.

5.3.3 For **oil tankers** (including ore/oil and ore/bulk/oil ships) and **chemical tankers**, the condition of the corrosion prevention system, where provided, is to be examined in cargo tanks and salt-water ballast tanks. When considered necessary by the Surveyor, thickness measurements are to be carried out. The condition of the corrosion prevention system identified during the Survey may result in the salt-water ballast tanks being subject to further examination at Annual Surveys, in accordance with 2.2.28.

Table 3.5.1 Survey preparation

Special Survey I (Ships 5 years old)	Special Survey II (Ships 10 years old)	Special Survey III (Ships 15 years old)
(1) The holds, 'tween decks, peaks, deep tanks, engine and boiler spaces, and other spaces, are to be cleared and cleaned as necessary, and the bilges and limbers all fore and aft are to be cleaned and prepared for examination. Platform plates in engine and boiler spaces are to be lifted as may be necessary for the examination of the structure below. Where necessary, close and spar ceiling, lining and pipe casings are to be removed for examination of the structure (2) In ships having a single bottom, a sufficient amount of close ceiling is to be lifted all fore and aft on each side from the bottom and bilges to permit the structure below to be examined (3) In ships having a double bottom, a sufficient amount of ceiling is to be removed from the bilges and inner bottom to enable the condition of the plating to be ascertained. If it is found that the plating is clean and in good condition, and free from rust, the removal of the remainder of ceiling may be dispensed with. The Surveyor may waive the removal of heavy reinforced compositions if there is no evidence of leakages, cracking or other faults in the composition (4) Casings, ceilings or linings and loose insulation, where fitted, are to be removed for examination of plating and framing, as required by the Surveyor. Compositions on plating are to be examined and sounded, but need not be disturbed if found to be adhering satisfactorily to the plating. Where structural defects are identified, any applied composition is to be locally removed to enable further examination of the plating and adjacent frames, as required by the Surveyor (5) The steelwork is to be exposed and cleaned and rust removed as may be required for its proper examination by the Surveyor (6) All tanks are to be cleaned as necessary to permit examination, where this is required by Table 3.5.2 (7) Casings or covers of air, sounding, steam and other pipes, spar ceiling and lining in way of the side scuttles are to be removed, as required by the Surveyor	In addition to the requirements for Special Survey I, the following are to be complied with: (1) A sufficient amount of ceiling in the holds and other spaces is to be removed from the bilges and inner bottom to enable the condition of the structure in the bilges, the inner bottom plating, pillar feet, and the bottom plating of bulkheads and tunnel sides to be examined. If the Surveyor deems it necessary, the whole of the ceiling is to be removed (2) In ships having a single bottom, the limber boards and ceiling equal to not less than three strakes, all fore and aft on each side are to be removed, one such strake being taken from the bilges. Where the ceiling is fitted in hatches, the whole of the hatches and at least one strake of ceiling in the bilges are to be removed. If the Surveyor deems it necessary the whole of the ceiling and limber boards are to be removed (3) The chain locker is to be cleaned internally. The chain cables are to be ranged for inspection. The anchors are to be cleaned and placed in an accessible position for inspection	In addition to the requirements for Special Survey II the following are to be complied with: (1) Ceiling in holds is to be removed in order to ascertain that the steelwork is in good condition, free from rust and coated. If the Surveyor is satisfied, after removal of portions of the ceiling then it need not all be removed (2) Portions of wood sheathing, or other covering, on steel decks are to be removed, as considered necessary by the Surveyor, in order to ascertain the condition of the plating **All subsequent Special Surveys** In addition to the requirements for Special Survey III the following are to be complied with: (1) In refrigerated cargo spaces, sufficient insulation is to be removed in each of the chambers to enable the Surveyor to be satisfied as to the condition of the steel structure, and to enable the thickness of the structure to be ascertained as required by 5.6

5.3.4 For those ships not listed in 5.3.3, the condition of the corrosion prevention system, where provided, in salt-water ballast tanks is to be examined. When considered necessary by the Surveyor, thickness measurements are to be carried out. The condition of the corrosion prevention system identified during the Survey may result in the salt-water ballast tanks being subject to further examination at Annual Surveys, in accordance with 2.2.28. For double bottom ballast tanks, the examination at Annual Surveys will be at the discretion of the Surveyor.

5.3.5 Double bottom, deep, ballast, peak and other tanks, including cargo holds assigned also for the carriage of salt water ballast, are to be tested with a head of liquid to the top of air pipes or to near the top of hatches for ballast/cargo holds. Boundaries of oil fuel, lubricating oil and fresh water tanks are to be tested with a head of liquid to the highest point that liquid will rise to under service conditions. Tank testing of oil fuel, lubricating oil and fresh water tanks may be specially considered based upon a satisfactory external examination of the tank boundaries, and a confirmation from the Master stating that the pressure testing has been carried

Table 3.5.2 Tank internal examination requirements

Tank	Special Survey I (Ships 5 years old)	Special Survey II (Ships 10 years old)	Special Survey III (Ships 15 years old)	Special Survey IV and subsequent (Ships 20 years old and over)
(1) Peaks	All tanks	All tanks	All tanks	All tanks
(2) Salt water ballast, *see* Note 5	All tanks	All tanks	All tanks	All tanks
(3 Lubricating oil	None	None	None	One tank
(4) Fresh water	None	One tank	All tanks	All tanks
(5) Oil fuel - in way of				
(i) Engine Room	None	None	One tank	One tank
(ii) Cargo Area	None	One tank	Two tanks, Note 3	50% of tanks – Notes 3 and 4

NOTES
1. The above requirements apply to integral tanks only.
2. Where a selected number of tanks are examined, then different tanks are to be examined at each Special Survey on a rotational basis.
3. To include one deep tank, if any.
4. Where 50% of tanks are to be examined, a minimum of two tanks are required to be examined depending upon the overall number of tanks.
5. The requirements for Salt-water ballast tanks are applicable to Bilge water, Sewage and Grey water tanks.

out according to the requirements with satisfactory results. Surveyors may extend the testing as deemed necessary.
For **oil tankers** (including ore/oil and ore/bulk/oil ships) and **chemical tankers**, the minimum requirements for cargo tank testing are to be in accordance with Sections 7.5 and 8.5, as applicable.

5.3.6 Where repairs are effected to the shell plating or bulkheads, any tanks in way are to be tested to the Surveyor's satisfaction on completion of these repairs.

5.3.7 On ship-borne barges, in lieu of water testing, tanks and cofferdams may be air tested.

5.3.8 In cases where the inner surface of the bottom plating is covered with cement, asphalt, or other composition, the removal of this covering may be dispensed with, provided that it is inspected, tested by beating or chipping, and found sound and adhering satisfactorily to the steel.

5.3.9 All decks, casings and superstructures are to be examined.

5.3.10 Wood decks or sheathing are to be examined. If decay or rot is found or the wood is excessively worn, the wood is to be renewed. When a wood deck, laid on stringers and ties, has worn by 15 mm or more, it is to be renewed. Attention is to be given to the condition of the plating under wood decks, sheathing or other deck covering. If it is found that such coverings are broken, or are not adhering closely to the plating, sections are to be removed as necessary to ascertain the condition of the plating, *see also* 1.2.1.

5.3.11 Mechanically-operated hatch covers are to be tested to confirm satisfactory operation including stowage; and securing in open condition; proper fit and efficiency of sealing in closed conditions; operational testing of hydraulic and power components, wires, chains and link drives. The effectiveness of sealing arrangements of all hatch covers is to be checked by carrying out hose testing or equivalent.

5.3.12 The masts and standing rigging are to be examined.

5.3.13 The anchors are to be examined. If the chain cables are ranged they are to be examined. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 12 per cent or more from its nominal diameter, it is to be renewed. The windlass is to be examined. For equipment forming part of a positional mooring system, *see* 5.3.16.

5.3.14 The chain cables are to be ranged and examined on all ships over five years old.

5.3.15 The Surveyor is to be satisfied that there are suitable mooring ropes when these are a Rule requirement.

5.3.16 On ships fitted with positional mooring equipment in accordance with Pt 7, Ch 8, or wire rope anchor cables in accordance with Pt 3, Ch 13,7, the anchors are to be cleaned and examined. Wire rope anchor cables are to be examined. If cables are found to contain broken, badly corroded or birdcaging wires they are to be renewed. Chain cables are to be ranged and examined. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 12 per cent or more from its nominal diameter it is to be renewed. The windlass(es) or winches are to be examined.

5.3.17 The hand pumps, suctions, watertight doors, air and sounding pipes are to be examined. In addition, the Surveyor is to internally and externally examine air pipe heads in accordance with the requirements of Table 3.5.7.

5.3.18 The Surveyor is to be satisfied as to the efficient condition of the following:
(a) For ships to which Pt 6, Ch 4 applies, means of escape from crew and passenger spaces, and spaces in which crew are normally employed.
(b) Helm indicator, protection of aft steering wheel and gear.

5.3.19 Where the special features notation **CCSA** (certified container securing arrangements) is assigned, the Surveyor is to be satisfied as to the efficient condition of:

(a) Cell guide structure including the connections between vertical cell guides and cross ties.
(b) Cell guide entry devices.
(c) Portable frameworks or other forms of structural restraints.
(d) Fittings attached to the ship structure, with special attention to any signs of leakage in way of tanks or deck and shell plating.
(e) End connecting pieces for lashings, twist locks and other loose fittings, which are to be examined and verified with the Register.
(f) All lashings, rods, wire ropes, and chains, together with turn buckles and other tightening devices, which are to be examined and verified with the Register.
(g) Lashing wire ropes, which are to be renewed where more than five per cent of the wires are broken, worn or corroded in any length of 10 diameters of the wire rope.
(h) Chains, which are to be renewed where worn or damaged.

Where renewals are required, the new item is to be of approved type and manufacture. Where test certificates are not available, the item is to be tested in accordance with Pt 3, Ch 14,3.

5.3.20 All bilge and ballast piping systems are to be examined and operationally tested to working pressure, to the satisfaction of the Surveyor, to ensure that tightness and condition remain satisfactory.

5.3.21 For engine room and machinery space fire dampers the following is applicable:

(a) At Special Survey I, Surveyors are to select and internally examine one engine room fire damper and one machinery space fire damper. Where considered necessary by the Surveyor as a result of the examinations, the extent of examinations may be extended to include other fire dampers.
(b) At each subsequent Special Survey, all engine room and machinery space fire dampers are to be internally examined by the Surveyor.

Note

The examination of fire dampers may be specially considered by the Surveyor where there is satisfactory documented evidence of their replacement within the previous five years.

5.3.22 In refrigerated cargo spaces, the condition of the coating and structure behind the insulation is to be examined at representative locations. Surveyors may limit the examination to the verification that the protective coating remains effective and that there are no visible structural defects. Where POOR coating condition is found, or structural defects are identified, then sufficient insulation is to be removed in each of the chambers in order to assess the condition of the remaining structure, as deemed necessary by the Surveyor. Additionally, where indents, scratches or other defects are identified during the survey of the shell plating from the outside, insulations in way are to be removed to enable further examination of the plating and adjacent frames, as required by the Surveyor

5.4 Overall Survey

5.4.1 The following requirements are applicable to **general dry cargo ships.**

5.4.2 All cargo holds, salt-water ballast tanks including double bottom tanks, pipe tunnels, cofferdams and void spaces bounding cargo holds, decks and outer hull are to be examined, and this is to be supplemented by Close-up Survey, thickness measurement and testing as deemed necessary, to ensure that the structural integrity remains effective.

5.4.3 The examination is to be sufficient to ascertain substantial corrosion, significant deformation, fractures, damages or other structural deterioration and, if deemed necessary by the Surveyor, suitable non-destructive examination may be required.

5.4.4 All piping systems within the tanks and spaces indicated in 5.4.2 are to be examined and operationally tested to working pressure to the satisfaction of the Surveyor, to ensure that conditions remain satisfactory.

5.4.5 Where the salt-water ballast tanks have been converted to void spaces, the survey extent is to be specially considered based upon salt-water ballast tank requirements.

5.4.6 For single hold general dry cargo ships, other than bulk carriers, fitted with water level detectors in the cargo hold, an examination and a test of the water ingress detection system and alarms are to be carried out.

5.5 Close-up Survey

5.5.1 The following requirements are applicable to **general dry cargo ships.**

5.5.2 The minimum requirements for Close-up Survey are given in Table 3.5.4. The Close-up Survey may be extended, as deemed necessary by the Surveyor, after taking into account the maintenance of the spaces under survey, the condition of the corrosion prevention system and where spaces have structural arrangements or details which have suffered defects in similar spaces or on similar ships according to available information.

5.5.3 For areas in tanks and cargo holds where coatings are found to be in GOOD condition, as defined in 1.5, the extent of Close-up Surveys may be specially considered.

5.6 Thickness measurement

5.6.1 The general minimum requirements for thickness measurement are given in Table 3.5.3. For **general dry cargo ships**, the minimum requirements for thickness measurement

Table 3.5.3 Thickness measurement – General

<table>
<tr><th>Special Survey I
(Ships 5 years old)</th><th>Special Survey III
(Ships 15 years old)</th><th>Special Survey IV and subsequent
(Ships 20 years old and over)</th></tr>
<tr><td>(1) Critical areas, as required by the Surveyor</td><td rowspan="3">(1) Within 0,5L amidships;
2 transverse sections in way of two different cargo spaces, see Notes 2, 3 and 4
(2) All cargo hold hatch covers and coamings (plating and stiffeners)
(3) All transverse webs with associated plating and longitudinals, and the transverse bulkhead complete in the fore peak tank and aft peak tank, see Notes 3 and 5
(4) Critical areas, as required by the Surveyor</td><td rowspan="3">(1) Within 0,5L amidships;
a minimum of 3 transverse sections in way of cargo spaces, see Notes 2, 3 and 4
(2) All cargo hold hatch covers and coamings (plating and stiffeners)
(3) All exposed main deck plating over full length of ship
(4) All wind and water strakes over the full length of the ship, port and starboard.
(5) Representative exposed superstructure deck plating (i.e. poop, bridge and forecastle deck)
(6) Lowest strake and strakes in way of ‘tween deck of all transverse bulkheads in cargo spaces together with internals in way, see Note 3
(7) All transverse webs with associated plating and longitudinals, and the transverse bulkhead complete in the fore peak tank and aft peak tank, see Notes 3 and 5
(8) All keel plates over the full length of the ship. Also additional bottom plates in way of cofferdams, machinery space and aft end of tanks
(9) Plating of seachests. Also side shell plating in way of overboard discharges, as considered necessary by the Surveyor
(10) Critical areas, as required by the Surveyor</td></tr>
<tr><th>Special Survey II
(Ships 10 years old)</th></tr>
<tr><td>(1) Within 0,5L amidships;
1 transverse section of deck plating in way of a cargo space
(2) Critical areas, as required by the Surveyor</td></tr>
<tr><td colspan="3">NOTES
1. Thickness measurement locations are to be selected to provide the best representative sampling of areas likely to be most exposed to corrosion, considering cargo and ballast history and arrangement, and condition of protective coatings.
2. A transverse section is to include all longitudinal members such as plating, longitudinals and girders at the deck, sides, bottom, inner bottom, hopper side and longitudinal bulkheads, where fitted.
3. Where the protective coating is in GOOD condition, then the extent of thickness measurements of internals may be specially considered, but not dispensed with in its entirety, at the discretion of the Surveyor.
4. For ships having length L less than 100 m:
(a) the number of transverse sections required at Special Survey III may be reduced to one;
(b) the number of transverse sections required at Special Survey IV and subsequent surveys may be reduced to two;
(c) at Special Survey III, thickness measurements of exposed deck plating within 0,5L amidships may be required.
5. Transverse bulkhead complete including stiffening system.
6. The requirements for thickness measurement for bulk carriers, oil tankers (including ore/oil and ore/bulk/oil ships), chemical tankers and ships for liquefied gases are given in Sections 6, 7, 8 and 9 respectively.</td></tr>
</table>

are given in Table 3.5.5. The Surveyor may extend the thickness measurements as deemed necessary.

5.6.2 Thickness measurements may be carried out in association with the fourth Annual Survey.

5.6.3 In areas where substantial corrosion, as defined in 1.5, has been noted, then additional measurements are to be carried out, as applicable, in accordance with Table 3.5.6 to determine the full extent of the corrosion pattern. The survey will not be considered complete until these additional thickness measurements have been carried out.

5.6.4 Where substantial corrosion is identified and not rectified, this will be subject to examination and thickness measurement at Annual and Intermediate Surveys.

5.6.5 Where considered necessary by the Surveyor, thickness measurements are to be carried out in way of critical areas. These include areas considered prone to rapid wastage.

5.6.6 Where required by LR, a check of the buckling capacity of the upper deck is to be carried out for tankers having a length greater than 90 m.

5.6.7 Steel evaluation of hatch covers on exposed decks and hatch coamings and closing arrangements of cargo holds on ships with contract for construction on or after 1 July 2012 is to be in accordance with IACS UR S21A. Further information is provided in the LR document *Thickness Measurement and Close-Up Survey Guidance*.

Table 3.5.4 Close-up Survey – General dry cargo ships

Special Survey I (Ships 5 years old)	Special Survey II (Ships 10 years old)	Special Survey III (Ships 15 years old)	Special Survey IV and subsequent (Ships 20 years old and over)
(1) Selected shell frames in one forward and one aft cargo hold and associated 'tween deck spaces. (2) One selected cargo hold transverse bulkhead. (3) All cargo hold hatch covers and coamings (plating and stiffeners).	(1) Selected shell frames in all cargo holds and 'tween deck spaces. (2) One transverse bulkhead in each cargo hold, including stiffening system. (3) Forward and aft transverse bulkhead in one side ballast tank, including stiffening system. (4) One transverse web with associated plating and framing in two representative water ballast tanks of each type (i.e. topside, hopper side, side tank or double bottom tank). (5) All cargo hold hatch covers and coamings (plating and stiffeners). (6) Selected areas of all deck plating and underdeck structure inside the line of hatch openings between cargo hold hatches. (7) Selected areas of inner bottom plating.	(1) All shell frames in the forward lower cargo hold and 25% of shell frames in each remaining cargo hold and 'tween deck spaces, including their end attachments and adjacent shell plating. (2) All cargo hold transverse bulkheads, including stiffening system. (3) All transverse bulkheads in ballast tanks, including stiffening system. (4) All transverse webs with associated plating and framing in each water ballast tank. (5) All cargo hold hatch covers and coamings (plating and stiffeners). (6) All deck plating and underdeck structure inside the line of hatch openings between cargo hold hatches. (7) All areas of inner bottom plating.	(1) All shell frames in all cargo holds and 'tween deck spaces, including their end attachments and adjacent shell plating. (2) All cargo hold transverse bulkheads, including stiffening system. (3) All transverse bulkheads in ballast tanks, including stiffening system. (4) All transverse webs with associated plating and framing in each water ballast tank. (5) All cargo hold hatch covers and coamings (plating and stiffeners). (6) All deck plating and underdeck structure inside the line of hatch openings between cargo hold hatches. (7) All areas of inner bottom plating.
NOTES 1. Close-up survey of cargo hold transverse bulkheads to be carried out at the following areas: (i) Immediately above the inner bottom and immediately above the 'tween decks, as applicable. (ii) Mid-height of the bulkhead for holds without 'tween decks. (iii) Immediately below the main deck plating and 'tween deck plating. 2. Ballast tank includes peak tanks.			

5.6.8 Steel renewal is required where the gauged thickness is less than t_{net} + 0,5 mm. For definition of t_{net}, *see* Pt 4, Ch 7,12.1.2.

5.6.9 Where the gauged thickness is within the range t_{net} + 0,5 mm and t_{net} + 1,0 mm, a coating (applied in accordance with coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal.

Table 3.5.5 Thickness measurement – General dry cargo ships

<table>
<tr><th>Special Survey I
(Ships 5 years old)</th><th>Special Survey III
(Ships 15 years old)</th><th>Special Survey IV
and subsequent
(Ships 20 years old and over)</th></tr>
<tr><td>(1) Critical areas, as required by the Surveyor.</td><td rowspan="3">(1) Within 0,5L amidships;
2 transverse sections in way of two different cargo spaces, see Notes 2, 3 and 4.
(2) Measurements for the general assessment and recording of corrosion pattern of those structural members subject to Close-up Survey in accordance with Table 3.5.4, see Note 5.
(3) Within the cargo length area;
(i) Each deck plate outside the line of cargo hatch openings.
(ii) All wind and water strakes.
(4) Selected wind and water strakes outside the cargo length area.
(5) All cargo hold hatch covers and coamings (plating and stiffeners).
(6) All transverse webs with associated plating and longitudinals, and the transverse bulkhead complete in the fore peak tank and aft peak tank, see Notes 3 and 6.
(7) Critical areas, as required by the Surveyor</td><td rowspan="3">(1) Within 0,5L amidships;
a minimum of 3 transverse sections, see Notes 2, 3 and 4.
(2) Measurements for the general assessment and recording of corrosion pattern of those structural members subject to Close-up Survey in accordance with Table 3.5.4, see Note 5.
(3) Within the cargo length area;
(i) Each deck plate outside the line of cargo hatch openings.
(ii) Each bottom plate, including turn of bilge.
(iii) Duct keel or pipe tunnel plating and internals.
(4) All wind and water strakes over the full length of the ship, port and starboard.
(5) All cargo hold hatch covers and coamings (plating and stiffeners).
(6) Remaining exposed main deck plates not considered in item (3) and representative exposed superstructure deck plating (i.e., poop, bridge and forecastle deck).
(7) Lowest strake and strakes in way of ‘tween decks of all transverse bulkheads in cargo spaces together with internals in way, see Note 3.
(8) All transverse webs with associated plating and longitudinals, and the transverse bulkhead complete in the fore peak tank and aft peak tank, see Notes 3 and 6.
(9) All keel plates over the full length of the ship. Also additional bottom plates in way of cofferdams, machinery spaces and aft end of tanks.
(10) Plating of seachests. Also side shell plating in way of overboard discharges, as considered necessary by the Surveyor.
(11) Critical areas, as required by the Surveyor.</td></tr>
<tr><th>Special Survey II
(Ships 10 years old)</th></tr>
<tr><td>(1) Within 0,5L amidships;
1 transverse section of deck plating in way of a cargo space.
(2) Measurements for the general assessment and recording of corrosion pattern of those structural members subject to Close-up Survey in accordance with Table 3.5.4, see Note 5.
(3) Critical areas, as required by the Surveyor.</td></tr>
<tr><td colspan="3">NOTES
1. Thickness measurement locations are to be selected to provide the best representative sampling of areas likely to be most exposed to corrosion, considering cargo and ballast history and arrangement, and condition of protective coatings.
2. A transverse section is to include all longitudinal members such as plating, longitudinals and girders at deck, sides, bottom, inner bottom, hopper side and longitudinal bulkheads, where fitted.
3. Where the protective coating is in GOOD condition, then the extent of thickness measurements of internals may be specially considered, but not dispensed with in its entirety, at the discretion of the Surveyor.
4. For ships having length L less than 100 m:
(a) the number of transverse sections required at Special Survey III may be reduced to one.
(b) the number of transverse sections required at Special Survey IV and subsequent surveys may be reduced to two.
5. For areas in cargo holds and salt-water ballast tanks subject to Close-up Survey, the thickness measurements may be dispensed with provided the Surveyor is satisfied with the Close-up Survey examination, that there is no structural diminution and the protective coating remains effective.
6. Transverse bulkhead complete including stiffening system.</td></tr>
</table>

Table 3.5.6 Thickness measurement – Additional requirements in way of structure identified with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
Plating	Suspect areas and adjacent plates	5 point pattern over 1 m^2
Stiffeners	Suspect areas	3 measurements each in line across web and flange

Table 3.5.7 Air pipe head internal examination requirements (applicable for automatic air pipe heads installed on exposed decks of all ships except passenger ships)

Special Survey I (Ships 5 years old)	Special Survey II (Ships 10 years old)	Special Survey III (Ships 15 years old) and subsequent
(1) Two air pipe heads (one port and one starboard) on exposed decks in the forward 0,25*L*. *See* Notes 1 to 5 (2) Two air pipe heads (one port and one starboard) on the exposed decks, serving spaces aft of 0,25*L*. *See* Notes 1 to 5	(1) All air pipe heads on exposed decks in the forward 0,25*L*. *See* Notes 1 to 5 (2) At least 20% of air pipe heads on exposed decks, serving spaces aft of 0,25*L*. *See* Notes 1 to 5	All air pipe heads on exposed decks. *See* Notes 1 to 6

NOTES
1. Air pipe heads serving ballast tanks are to be selected where available.
2. The Surveyor is to select which air pipe heads are to be examined.
3. Where considered necessary by the Surveyor as a result of the examinations, the extent of examinations may be extended to include other air pipe heads on exposed decks.
4. Where the inner parts of air pipe head cannot be properly examined due to its design, it is to be removed in order to allow an internal examination.
5. Particular attention is to be given to the condition of the zinc coating in heads constructed from galvanised steel.
6. Exemption may be considered for air pipe heads where there is documented evidence of their replacement within the previous five years.

■ *Section 6* Special Survey – Bulk carriers – Hull requirements

6.1 General

6.1.1 The requirements of Sections 2, 4 and 5 are to be complied with as applicable.

6.1.2 In order to maintain and/or assign the **ESP** notation, the following requirements apply to the surveys of the hull structure and piping systems in way of the cargo holds, cofferdam, pipe tunnels, void spaces, topside tanks and double bottom tanks in way of the cargo hold area and all salt-water ballast tanks.

6.2 Documentation

6.2.1 The Owner is to obtain, supply and maintain documentation on board as follows:

(a) A survey file comprising reports of structural surveys, thickness measurement and executive hull summary in accordance with the 2011 ESP Code.

(b) Supporting documentation consisting of:
  - (i) Main structural plans of cargo holds and ballast tanks (for ships built in accordance with the IACS Common Structural Rules (CSR), these plans are to include for each structural element, both the as-built and the renewal thickness. Any thickness for voluntary addition is also to be clearly indicated on the plans. The midship section plan to be supplied on board the ship is to include the minimum allowable hull girder sectional properties for the hold transverse section in all cargo holds).
  - (ii) Previous repair history.
  - (iii) Cargo and ballast history.
  - (iv) Records of inspections by ship's personnel with reference to structural deterioration in general, leakages in bulkheads and piping and the condition of the corrosion prevention systems, if any.
  - (v) Any other Information that may help to identify critical structural areas and/or suspect areas requiring inspection.
  - (vi) Survey Programme as required by 6.3.

The complete documentation in 6.2.1 is to be readily available for examination by the Surveyor and should be used as a basis for survey.

6.2.2 The documentation is to be kept on board for the lifetime of the ship.

6.3 Planning for survey

6.3.1 A Survey Programme is to be submitted by the Owner and is to include the proposals for survey, including the means of providing access for Close-up Survey, thickness measurement and tank testing and should take account of the information detailed in 6.2.1.

6.3.2 Prior to the development of the Survey Programme, a Survey Planning Questionnaire is to be completed and submitted by the Owner, *see* 1.6.12.

6.4 Overall Survey

6.4.1 All cargo holds, salt-water ballast tanks including double bottom tanks, pipe tunnels, cofferdams and void spaces bounding cargo holds, decks and outer hull are to be examined, and this examination is to be supplemented by Close-up Survey, thickness measurement and testing as applicable, to ensure that the structural integrity remains effective.

6.4.2 The examination is to be sufficient to ascertain substantial corrosion, significant deformation, fractures, damages or other structural deterioration and, if deemed necessary by the Surveyor, suitable non-destructive examination may be required.

6.4.3 Where substantial corrosion, as defined in 1.5, is identified and is not rectified, this will be subject to re-examination at Annual and Intermediate Surveys.

6.4.4 All piping systems within the tanks and spaces indicated in 6.4.1 are to be examined and tested under working conditions to ensure that the conditions remain satisfactory.

6.4.5 The extent of survey of combined salt-water ballast cargo holds is to be evaluated based on the records of ballast history, the extent and condition of the corrosion protection system provided, and the extent of structural diminution (corrosion).

6.4.6 Where salt-water ballast tanks have been converted to void spaces the survey extent is to be based upon salt-water ballast tank requirements.

6.4.7 Where provided, in association with a corrosion control (c.c.) notation as defined in the *Register Book*, the condition of the protective coating or corrosion prevention system is to be examined.

6.4.8 For ships fitted with water level detectors in cargo holds, ballast tanks forward of the collision bulkhead and any dry or void space which extends forward of the foremost cargo hold, an examination and a test of the water ingress detection systems and of their alarms is to be carried out.

6.4.9 For ships fitted with a means for draining and pumping ballast tanks forward of the collision bulkhead and the bilges of dry spaces, any part of which extends forward of the foremost cargo hold, an examination and a test of the draining and pumping systems including their controls is to be carried out.

6.5 Testing

6.5.1 The minimum requirements for tank testing, as applicable, are given in 5.3.5. Where required, the Surveyor may extend the tank testing if deemed necessary.

6.6 Close-up Survey

6.6.1 The minimum requirements for Close-up Survey are given in Tables 3.6.1, 3.6.2 and 3.6.3 as applicable.

6.6.2 The Close-up Survey may be extended, as deemed necessary by the Surveyor, after taking into account the maintenance of the spaces under survey, the condition of the corrosion prevention system and where spaces have structural arrangements or details which have suffered defects in similar spaces or on similar ships according to available information.

6.6.3 For areas in tanks and cargo holds where coatings are found to be in GOOD condition, as defined in 1.5, the extent of Close-up Surveys may be specially considered.

6.7 Thickness measurement

6.7.1 The minimum requirements for thickness measurements are given in Table 3.6.4, *see also* 5.6. For ships built in accordance with the IACS Common Structural Rules (CSR), the number and locations of measurements are detailed in the LR document *Thickness Measurement and Close-Up Survey Guidance*.

6.7.2 In areas where substantial corrosion, as defined in 1.5, has been noted then additional measurements are to be carried out, as applicable, in accordance with Tables 3.6.5, 3.6.6, 3.6.7, 3.6.8, 3.6.9 and 3.6.10 to determine the full extent of the corrosion pattern. The survey will not be considered complete until these additional thickness measurements have been carried out. For bulk carriers built in accordance with the IACS Common Structural Rules (CSR), the areas identified with substantial corrosion may be either:

(a) protected by coating applied in accordance with the coating manufacturer's requirements and examined at Annual Surveys to confirm the coating in way is still in GOOD condition, or alternatively;
(b) subject to thickness measurement at Annual Surveys.

6.7.3 Thickness measurement is required to determine both general and local levels of corrosion in salt-water ballast tanks and in the shell frames and their end attachments in all cargo holds. Thickness measurements are also to be carried out to determine the corrosion levels on the transverse bulkhead plating.

Table 3.6.1 Close-up Survey – Single skin bulk carriers

Special Survey I (Ships 5 years old)	Special Survey II (Ships 10 years old)	Special Survey III (Ships 15 years old)	Special Survey IV (Ships 20 years old and over)
(1) 25% of shell frames and their end attachments in the forward cargo hold at representative positions. (2) Selected shell frames and their end attachments in remaining cargo holds. (3) 1 transverse web with associated plating and longitudinals in 2 representative water ballast tanks of each type (i.e. topside or hopper side tank). (4) 2 selected cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted. This is to include the aft bulkhead of the forward hold. (5) All cargo hold hatch covers and coamings (plating and stiffeners).	(1a) For bulk carriers with a deadweight less than 100,000 tonnes, all shell frames in the forward cargo hold and 25% of frames in each of the remaining cargo holds, including their end attachments and adjacent shell plating. (1b) For bulk carriers with a deadweight equal to or greater than 100,000 tonnes, all shell frames in the forward cargo hold and 50% of frames in each of the remaining cargo holds, including their end attachments and adjacent shell plating. (2) 1 transverse web with associated plating and longitudinals in each water ballast tank. (3) Forward and aft transverse bulkhead in 1 side ballast tank, including stiffening system. (4) All cargo hold transverse bulkheads including internal structure of upper and lower stools, where fitted. (5) All cargo hold hatch covers and coamings (plating and stiffeners). 6) All deck plating and underdeck structure inside line of hatch openings between all cargo hold hatches.	(1) All shell frames in the forward and one other selected cargo hold and 50% of frames in each of the remaining cargo holds, including their end attachments and adjacent shell plating. (2) All transverse webs with associated plating and longitudinals in each water ballast tank. (3) All transverse bulkheads in ballast tanks, including stiffening system. (4) All cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted. (5) All cargo hold hatch covers and coamings (plating and stiffeners). (6) All deck plating and underdeck structure inside line of hatch openings between all cargo hold hatches.	(1) All shell frames in all cargo holds, including their end attachments and adjacent shell plating. (2) All transverse webs with associated plating and longitudinals in each water ballast tank. (3) All transverse bulkheads in ballast tanks, including stiffening system. (4) All cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted. (5) All cargo hold hatch covers and coamings (plating and stiffeners). (6) All deck plating and underdeck structure inside line of hatch openings between all cargo hold hatches.

NOTES
The requirements in this Table apply to all single skin bulk carriers unless stated otherwise.
1. Ballast tank includes peak tanks.
2. Close-up Survey of transverse bulkheads to be carried out at four levels:
   - Level (a) Immediately above the inner bottom and immediately above the line of gussets (if fitted) and shedders for ships without lower stool.
   - Level (b) Immediately above and below the lower stool shelf plate (for those ships fitted with lower stools), and immediately above the line of the shedder plates.
   - Level (c) About mid-height of the bulkhead.
   - Level (d) Immediately below the upper deck plating and immediately adjacent to the upper wing tank and immediately below the upper stool shelf plate for those ships fitted with upper stools, or immediately below the topside tanks.

6.7.4 Single skin bulk carriers contracted for construction prior to 1 July 1998 are to undergo a re-assessment and evaluation of their cargo hold shell frames in accordance with the Provisional Rules for Existing Ships. The number of shell frames to be measured is equivalent to number of shell frames subject to Close-up Survey (*see* Table 3.6.1), with representative measurements to be taken at specific areas for each frame. The extent of thickness measurement may be specially considered, but not dispensed with in its entirety, by the Surveyor, provided the structural members indicate no thickness diminution with respect to the Rule thickness and the coating is found in 'as-new' condition (i.e., without breakdown or rusting). Repairs to shell frames are to be based upon the minimum thickness values shown in the evaluation records.

6.7.5 For bulk carriers built in accordance with the IACS Common Structural Rules (CSR), the ship's longitudinal strength is to be evaluated by using the thickness of structural members measured, renewed and reinforced, as appropriate, during the Special Surveys carried out after the ship reaches 15 years of age (or during the Special Survey No. 3, if this is carried out before the ship reaches 15 years) in accordance with the criteria for longitudinal strength of the ship's hull girder for CSR bulk carriers specified in Chapter 13 of CSR. For further details refer to the LR document Thickness Measurement and Close-Up Survey Guidance.

Table 3.6.2 Close-up Survey – Double skin bulk carriers (excluding ore carriers)

Special Survey I (Ships 5 years old)	Special Survey II (Ships 10 years old)	Special Survey III (Ships 15 years old)	Special Survey IV (Ships 20 years old and over)
(1) 1 transverse web with associated plating and longitudinals in 2 representative water ballast tanks of each type. This is to include the foremost topside and double side ballast tanks on either side (2) 2 selected cargo hold transverse bulkheads including internal structure of upper and lower stools, where fitted (3) All cargo hold hatch covers and coamings (plating and stiffeners)	(1) 1 transverse web with associated plating and longitudinals in each water ballast tank (2) Forward and aft transverse bulkheads, including stiffening system, in one complete double side ballast tank on one side of the ship (i.e., port or starboard), *see* Note 1 (3) 25% of ordinary transverse web frames in the foremost double side tanks (4) One transverse bulkhead in each cargo hold including internal structure of upper and lower stools, where fitted (5) All cargo hold hatch covers and coamings (plating and stiffeners) (6) All deck plating and under-deck structure inside line of hatch openings between all cargo hold hatches	(1) All transverse webs with associated plating and longitudinals in each water ballast tank (2) All transverse bulkheads in ballast tanks, including stiffening system (3) 25% of ordinary transverse web frames in all double side tanks (4) All cargo hold transverse bulkheads including internal structure of upper and lower stools, where fitted (5) All cargo hold hatch covers and coamings (plating and stiffeners) (6) All deck plating and under-deck structure inside line of hatch openings between all cargo hold hatches	(1) All transverse webs with associated plating and longitudinals in each water ballast tank (2) All transverse bulkheads in ballast tanks, including stiffening system (3) All ordinary transverse web frames in all double side tanks (4) All cargo hold transverse bulkheads including internal structure of upper and lower stools, where fitted (5) All cargo hold hatch covers and coamings (plating and stiffeners) (6) All deck plating and under-deck structure inside line of hatch openings between all cargo hold hatches

NOTES
1. Complete ballast tank means topside tank, hopper tank, double bottom tank and double side tank, even if these are separate.
2. Ballast Tank includes peak tanks.
3. Close-up survey of transverse bulkheads to be carried out at four levels:
   - Level (a) Immediately above the inner bottom and immediately above the line of gussets (if fitted) and shedders for ships with out lower stool.
   - Level (b) Immediately above and below the lower stool shelf plate (for those ships fitted with lower stools), and immediately above the line of the shedder plates.
   - Level (c) About mid-height of the bulkhead.
   - Level (d) Immediately below the upper deck plating and immediately adjacent to the upper wing tank and immediately below the upper stool shelf plate for those ships fitted with upper stools, or immediately below the topside tanks.

6.7.6 Steel renewal evaluation of corrugated transverse watertight bulkheads on bulk carriers of 150 m in length and above, intending to carry solid bulk cargoes having a density of 1,0 t/m^3 with contract for construction on or after 1 July 1998 is to be in accordance with IACS UR S18. These requirements are not applicable to bulk carriers with class notation ESN Hold 1 and ESN – All Holds, or ships built in accordance with the IACS Common Structural Rules (CSR). Further information is provided in the LR document *Thickness Measurement and Close-Up Survey Guidance*.

6.7.7 Steel renewal is required where the gauged thickness is less than t_{net} + 0,5 mm. For definition of t_{net}, *see* Pt 4, Ch 7,10.4.10.

6.7.8 Where the gauged thickness is within the range t_{net} + 0,5 mm and t_{net} + 1,0 mm, a coating (applied in accordance with coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal.

6.7.9 Hatch covers of cargo holds' steel renewal evaluation of bulk carriers with contract for construction on or after 1 July 1998 is to be in accordance with IACS UR S21. These requirements are not applicable to ships built in accordance with the IACS Common Structural Rules (CSR). Further information is provided in the LR document *Thickness Measurement and Close-Up Survey Guidance.*

Table 3.6.3 Close-up Survey – Ore carriers

Special Survey I (Ships 5 years old)	Special Survey II (Ships 10 years old)	Special Survey III (Ships 15 years old)	Special Survey IV (Ships 20 years old and over)
(1) 1 web frame ring complete including adjacent structural members in a water ballast wing tank. (2) 1 transverse bulkhead lower part including girder system and adjacent structural members in a ballast tank. (3) 2 selected cargo hold transverse bulkheads, including internal structure of upper and lower stools where fitted, *see* Note 2. (4) All cargo hold hatch covers and coamings (plating and stiffeners).	(1) All web frame rings complete including adjacent structural members in a water ballast wing tank. (2) 1 deck transverse including adjacent structural members in each remaining water ballast tank. (3) Forward and aft transverse bulkheads including girder system and adjacent structural members in a ballast wing tank. (4) 1 transverse bulkhead lower part including girder system and adjacent structural members in each remaining ballast tank. (5) 1 transverse bulkhead in each cargo hold, including internal structure of upper and lower stools where fitted, *see* Note 2. (6) All cargo hold hatch covers and coamings (plating and stiffeners). (7) All deck plating and under deck structure inside line of hatch openings between all cargo hold hatches.	(1) All web frame rings complete including adjacent structural members in each water ballast tank. (2) All transverse bulkheads including girder system and adjacent structural members in each ballast tank. (3) 1 web frame ring complete including adjacent structural members in each wing void space. (4) Additional web frame rings including adjacent structural members in void spaces as deemed necessary by the Surveyor. (5) All cargo hold transverse bulkheads, including internal structure of upper and lower stools where fitted, *see* Note 2. (6) All cargo hold hatch covers and coamings (plating and stiffeners). (7) All deck plating and under deck structure inside line of hatch openings between all cargo hold hatches	(1) All web frame rings complete including adjacent structural members in each water ballast tank. (2) All transverse bulkheads including girder system and adjacent structural members in each ballast tank. (3) 1 web frame ring complete including adjacent structural members in each wing void space. (4) Additional web frame rings including adjacent structural members in void spaces as deemed necessary by the Surveyor. (5) All cargo hold transverse bulkheads, including internal structure of upper and lower stools where fitted, *see* Note 2. (6) All cargo hold hatch covers and coamings (plating and stiffeners). (7) All deck plating and under deck structure inside line of hatch openings between all cargo hold hatches.

NOTES
1. Ballast tank includes peak tanks.
2. Close-up Survey of transverse bulkheads to be carried out at four levels:

Level (a) Immediately above the inner bottom and immediately above the line of gussets (if fitted) and shedders for ships without lower stool.
Level (b) Immediately above and below the lower stool shelf plate (for those ships fitted with lower stools), and immediately above the line of the shedder plates.
Level (c) About mid-height of the bulkhead.
Level (d) Immediately below the upper deck plating and immediately adjacent to the upper wing tank and immediately below the upper stool shelf plate for those ships fitted with upper stools, or immediately below the topside tanks.

6.7.10 Steel renewal is required where the gauged thickness is less than t_{net} + 0,5 mm. For definition of t_{net}, *see* Pt 4, Ch 7,12.1.2.

6.7.11 Where the gauged thickness is within the range t_{net} + 0,5 mm and t_{net} + 1,0 mm, a coating (applied in accordance with coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal.

6.7.12 Steel renewal evaluation of hatch covers and hatch coamings of cargo holds on bulk carriers and ore carriers with contract for construction on or after 1 January 2004 is to be in accordance with IACS UR S21. These requirements are not applicable to ships built in accordance with the IACS Common Structural Rules (CSR). Further information is provided in the LR document *Thickness Measurement and Close-Up Survey Guidance*.

Table 3.6.4 Thickness measurement – Single skin and double skin bulk carriers

<table>
<tr><td>Special Survey I
(Ships 5 years old)</td><td rowspan="4">Special Survey III
(Ships 15 years old)

(1) Within the cargo length area:
(a) Each deck plate outside line of cargo hatch openings.
(b) 2 transverse sections, outside line of cargo hatch openings. (A minimum of 1 of the above transverse sections is to be within 0,5L amidships).
(2) Measurement, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey in accordance with Table 3.6.1, Table 3.6.2 or Table 3.6.3.
(3) All wind and water strakes within the cargo length area.
(4) Selected wind and water strakes outside the cargo length area.
(5) All cargo hatch covers and coamings (plating and stiffeners).
(6) All transverse webs with associated plating and longitudinals, and the transverse bulkhead complete in the fore peak tank and aft peak tank, see Notes 1 and 3.
(7) The aft bulkhead of the forward cargo hold on single skin ships, see Note 4.
(8) Cargo hold shell frames on single skin ships, see Note 5.
(9) Critical areas, as required by the Surveyor.</td><td rowspan="4">Special Survey IV and subsequent
(Ships 20 years old and over)

(1) Within the cargo length area:
(a) Each deck plate outside line of cargo hatch openings.
(b) 3 transverse sections, outside line of cargo hatch openings. (A minimum of 2 of the above transverse sections is to be within 0,5L amidships).
(c) Each bottom plate.
(2) Measurement, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey in accordance with Table 3.6.1, Table 3.6.2 or Table 3.6.3.
(3) All wind and water strakes over the full length of the ship, port and starboard.
(4) All cargo hatch covers and coamings (plating and stiffeners).
(5) Remaining exposed main deck plates not considered in item (1) and representative exposed superstructure deck plating (i.e. poop, bridge and forecastle deck).
(6) All transverse webs with associated plating and longitudinals, and the transverse bulkhead complete in the fore peak tank and aft peak tank, see Notes 1 and 3.
(7) All keel plates outside the cargo length area. Also additional bottom plates in way of cofferdams. Machinery space and aft end of tanks.
(8) Plating of seachests. Also side shell plating in way of overboard discharges, as considered necessary by the Surveyor.
(9) The aft bulkhead of the forward cargo hold on single skin ships, see Note 4.
(10) Cargo hold shell frames on single skin ships, see Note 5.
(11) Critical areas, as required by the Surveyor.</td></tr>
<tr><td>(1) Measurement, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey in accordance with Table 3.6.1, Table 3.6.2 or Table 3.6.3.
(2) Critical areas, as required by the Surveyor.</td></tr>
<tr><td>Special Survey II
(Ships 10 years old)</td></tr>
<tr><td>(1) Within the cargo length area:
(a) 2 sections of deck plating outside line of cargo hatch openings.
(2) Measurement, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey in accordance with Table 3.6.1, Table 3.6.2 or Table 3.6.3.
(3) Wind and water strakes in way of the transverse sections considered in item (1).
(4) Selected wind and water strakes outside the cargo length area.
(5) Cargo hold shell frames on single skin ships, see Note 5.
(6) Critical areas, as required by the Surveyor.</td></tr>
<tr><td colspan="3">NOTES
The requirements in this table apply to both single skin and double skin ships unless stated otherwise.
1. For areas in spaces where coatings are found to be in GOOD condition, as defined in 1.5, the extent of thickness measurement may be specially considered, but not dispensed with in its entirety. Prior to any coating or re-coating of cargo holds, scantlings are to be confirmed by thickness measurement with the Surveyor in attendance.
2. Transverse sections should be chosen where the largest reductions are likely to occur, or as revealed by deck plating measurement.
3. Transverse bulkhead complete including stiffening system.
4. For ships assigned notations ESN Hold No1 and ESN All Holds, the corrugated part of the aft transverse bulkhead of the forward cargo hold is to be subject to thickness measurement. This is to include each vertical corrugation at its lower and middle level including shedder plates and gusset plates, where applicable.
5. Single skin bulk carriers contracted for construction prior to 1 July 1998 are to undergo a re-assessment of their cargo hold shell frames in accordance with the Provisional Rules for Existing Ships. The number of shell frames to be measured is equivalent to the number of shell frames subject to Close-up survey (see Table 3.6.1), with representative measurements to be taken at specific areas for each frame.</td></tr>
</table>

6.7.13 Steel renewal is required where the gauged thickness is less than t_{net} + 0,5 mm. For definition of t_{net}, *see* Pt 4, Ch 7,12.1.2.

6.7.14 Where the gauged thickness is within the range t_{net} + 0,5 mm and t_{net} + 1,0 mm, a coating (applied in accordance with coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal.

Table 3.6.5 Thickness measurement – Single skin bulk carriers – Shell plating and stiffening, with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
(1) Bottom and side shell plating	Suspect plate, plus four adjacent plates	5 point pattern for each panel between longitudinals
(2) Bottom/side shell longitudinals	Minimum of three longitudinals in way of suspect areas	3 measurements in line across web and 3 measurements on flange
(3) Side shell frames	Suspect frame and each adjacent	At each end and mid-span: (a) 5 point pattern on both web and flange (b) 5 point pattern within 25 mm of welded attachment to both side shell and hopper sloping plate

Table 3.6.6 Thickness measurement – Single skin bulk carriers – Double bottom and hopper structure, with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
(1) Inner bottom plating	Suspect plate plus all immediately adjacent plates	5 point pattern for each panel between longitudinals over 1 m length
(2) Inner bottom longitudinals	Three longitudinals in way of plates measured	3 measurements in line across web and 3 measurements on flange
(3) Transverse floors and longitudinal girders	Suspect plates	5 point pattern over approximately 1 m^2 of plating
(4) Watertight floors and girders	(a) lower $^1/_3$ of tank (b) upper $^2/_3$ of tank	(a) 5 point pattern over 1 m^2 of plating (b) 5 point pattern alternate plates over 1 m^2 of plating
(5) Transverse web frames	Suspect plate	5 point pattern over 1 m^2 of plating

Table 3.6.7 Thickness measurement – Single skin and double skin bulk carriers – Transverse bulkheads in cargo holds, with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
(1) Lower stool	(a) Transverse band within 25 mm of welded connection to inner-bottom	(a) 5 point pattern between stiffeners over 1 m length
	(b) Transverse band within 25 mm of welded connection to shelf plate	(b) as above
(2) Transverse bulkhead	(a) Transverse band immediately above lower stool shelf plate	(a) 5 point pattern over 1 m length
	(b) Transverse band at approximately mid-height	(b) 5 point pattern over 1 m^2 of plating
	(c) Transverse band at part of bulkhead adjacent to upper deck or below upper stool shelf plate (for those ships fitted with upper stools)	(c) 5 point pattern over 1 m^2 of plating

Table 3.6.8 Thickness measurement – Single skin and double skin bulk carriers – Deck structure including cross strips, main cargo hatchways, hatch covers, coamings and topside tanks, with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
(1) Cross deck strip plating	Suspect cross deck strip plating	5 point pattern between underdeck stiffeners over 1 m length
(2) Underdeck stiffeners	(a) Transverse members	(a) 5 point pattern at each end and mid-span
	(b) Longitudinal member	(b) 5 point pattern on both web and flange
(3) Hatch covers	(a) Each side and end plate 3 locations	(a) 5 point pattern at each location
	(b) Top plate, 3 longitudinal bands – 2 on outboard strakes and 1 on centreline strake	(b) 5 point measurement at each band
(4) Hatch coamings	Each side and end of coaming, one upper and one lower band	5 point measurement at each band
(5) Topside salt water ballast tanks	(a) Watertight transverse bulkheads (i) lower 1/3 of bulkhead (ii) upper 2/3 of bulkhead (iii) stiffeners	 (i) 5 point pattern over 1 m^2 of plating (ii) 5 point pattern over 1 m^2 of plating (iii) 5 point pattern over 1 m length
	(b) Swash transverse bulkheads (i) lower 1/3 of bulkhead (ii) upper 2/3 of bulkhead (iii) stiffeners	 (i) 5 point pattern over 1 m^2 of plating (ii) 5 point pattern over 1 m^2 of plating (iii) 5 point pattern over 1 m length
	(c) 3 representative bays of the topside sloping plate (i) lower 1/3 of tank (ii) upper 2/3 of tank	 (i) 5 point pattern over 1 m^2 of plating (ii) 5 point pattern over 1 m^2 of plating
	(d) suspect longitudinals and adjacent longitudinals	5 point pattern both web and flange over 1 m length
(6) Main deck plating	Suspect plates and 4 immediately adjacent plates	5 point pattern over 1 m^2 of plating
(7) Main deck longitudinals	Minimum of 3 longitudinals where plating measured	5 point pattern on both web and flange over 1 m length
(8) Web frames/transverses	Suspect plates	5 point pattern over 1 m^2 of plating

Table 3.6.9 Thickness measurement – Double skin bulk carriers – Bottom, inner bottom and hopper structure, with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
(1) Bottom, inner bottom and hopper structure plating	(a) Minimum of 3 bays across double bottom tank, including aft bay (b) Measurements around and under all suction bell mouths	5 point pattern for each panel between longitudinals and floors
(2) Bottom, inner bottom and hopper structure longitudinals	Minimum of 3 longitudinals in each bay where bottom plating measured	3 measurements in line across flange and 3 measurements on the vertical web
(3) Bottom girders, including watertight girders	At fore and aft watertight floors and in centre of tanks	Vertical line of single measurements on girder plating with 1 measurement between each panel stiffener, or a minimum of 3 measurements
(4) Bottom floors, including watertight floors	3 floors in the bays where bottom plating measured, with measurements at both ends and middle	5 point pattern over 2 m^2 area
(5) Hopper structure web frame ring	3 floors in bays where bottom plating measured	5 point pattern over 1 m^2 of plating and single measurements on flange
(6) Hopper structure transverse watertight bulkhead or swash bulkhead	(a) lower 1/3 of bulkhead (b) upper 2/3 of bulkhead (c) stiffeners (minimum of 3)	(a) 5 point pattern over 1 m^2 of plating (b) 5 point pattern over 2 m^2 of plating (c) For web, 5 point pattern over span (2 measurements across web at each end and 1 at centre of span). For flange, single measurements at each end and centre of span
(7) Panel stiffening	Where applicable	Single measurements

Table 3.6.10 Thickness measurement – Double skin bulk carriers – Double side space structure (including wing void spaces of ore carriers), with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
(1) Side shell and inner plating: (i) Upper strake and strakes in way of horizontal girders (ii) All other strakes	(i) Plating between each pair of transverse frames/longitudinals in a minimum of 3 bays along the tank (ii) Plating between every third pair of longitudinals in same 3 bays	(i) Single measurement (ii) Single measurement
(2) Side shell and inner side transverse frames/longitudinals on: (i) Upper strake (ii) All other strakes	(i) Each transverse frame/longitudinal in same 3 bays (ii) Every third transverse frame/ longitudinal in same 3 bays	(i) 3 measurements across web and 1 measurement on flange (ii) 3 measurements across web and 1 measurement on flange
(3) Transverse frames/longitudinals – brackets	Minimum of 3 at top, middle and bottom of tank in same 3 bays	5 point pattern over area of bracket
(4) Vertical web and transverse bulkheads: (i) Strakes in way of horizontal girders (ii) Other strakes	(i) Minimum of 2 webs and both transverse bulkheads (ii) Minimum of 2 webs and both transverse bulkheads	(i) 5 point pattern over approx. 2 m^2 area (ii) 2 measurements between each pair of vertical stiffeners
(5) Horizontal girders	Plating on each girder in a minimum of 3 bays	2 measurements between each pair of longitudinal girder stiffeners
(6) Panel stiffening	Where applicable	Single measurements

■ *Section 7*
Special Survey – Oil tankers (including ore/oil ships and ore/bulk/oil ships) – Hull requirements

7.1 General

7.1.1 The requirements of Sections 2, 4 and 5 are to be complied with as applicable.

7.1.2 In order to maintain and/or assign the **ESP** notation, the following requirements apply to the surveys of the hull structure and piping systems in way of the cargo tanks/cargo holds, pump rooms, cofferdam, pipe tunnels, void spaces, double bottom tanks, etc., in way of the cargo tank area and all salt-water ballast tanks.

7.2 Documentation

7.2.1 The Owner is to obtain, supply and maintain documentation on board as follows:

(a) A survey file comprising reports of structural surveys, thickness measurement and executive hull summary in accordance with the 2011 ESP Code.

(b) Supporting documentation consisting of:
- (i) Main structural plans of cargo tanks/cargo holds and ballast tanks (for ships built in accordance with IACS Common Structural Rules (CSR), these plans are to include for each structural element, both the as-built and the renewal thickness. Any thickness for voluntary addition is also to be clearly indicated on the plans. The midship section plan to be supplied on board the ship is to include the minimum allowable hull girder sectional properties for the tank transverse section in all cargo tanks).
- (ii) Previous repair history.
- (iii) Cargo and ballast history.
- (iv) Records of inspections by ship's personnel with reference to structural deterioration in general, leakages in bulkheads and piping and the condition of the corrosion prevention systems, if any.
- (v) Extent of use of inert gas plant and tank cleaning procedures.
- (vi) Any other information that may help to identify critical structural areas and/or suspect areas requiring inspection.
- (vii) Survey Programme as required by 7.3.

The complete documentation in 7.2.1 is to be readily available for examination by the Surveyor and should be used as a basis for survey.

7.2.2 The documentation is to be kept on board for the lifetime of the ship.

7.3 Planning for survey

7.3.1 A Survey Programme is to be submitted by the Owner and is to include the proposals for survey, including the means of providing access for Close-up Survey, thickness measurement and tank testing and should take account of the information detailed in 7.2.1.

7.3.2 Prior to the development of the Survey Programme a Survey Planning Questionnaire is to be completed and submitted by the Owner, *see* 1.6.12.

7.4 Overall Survey

7.4.1 All cargo tanks/cargo holds, and salt-water ballast tanks including double bottom tanks, pump rooms, pipe tunnels, cofferdams and void spaces bounding cargo tanks/cargo holds, deck and outer hull are to be examined, and this examination is to be supplemented by Close-up Survey, thickness measurement and testing as applicable, to ensure that the structural integrity remains effective.

7.4.2 The examination is to be sufficient to ascertain substantial corrosion, significant deformation, fractures, damages or other structural deterioration and, if deemed necessary by the Surveyor, suitable non-destructive examination may be required.

7.4.3 Where substantial corrosion, as defined in 1.5, is identified and is not rectified, this will be subject to re-examination at Annual and/or Intermediate Surveys. In the case of salt-water ballast tanks and combined tanks for the carriage of salt-water ballast and cargo oil, the examination will be required at Annual Survey and Intermediate Survey. In the case of cargo oil tanks the examination will be required at Intermediate Surveys.

7.4.4 All cargo piping on deck, including Crude Oil Washing (COW) piping, and cargo and ballast piping within those spaces indicated in 7.4.1 are to be examined and tested under working conditions to ensure that tightness and condition remain satisfactory. Special attention is to be given to ballast piping in cargo tanks and any cargo piping in ballast tanks and void spaces.

7.4.5 Where salt-water ballast tanks have been converted to void spaces the survey extent is to be based upon salt-water ballast tank requirements.

7.4.6 Where provided, in association with a corrosion control (**c.c.**) notation as defined in the *Register Book*, the condition of the protective coating or corrosion prevention system of cargo tanks is to be examined.

7.4.7 The attachment to the structure and condition of anodes in tanks are to be examined.

7.4.8 Where fitted, the strums of the cargo suction pipes are to be removed or lifted to facilitate examination of the shell plating and bulkheads in the vicinity, unless other means for visual inspection of these parts are provided.

7.5 Testing

7.5.1 The minimum ballast tank testing requirements are given in Table 3.7.1 and, where required, the Surveyor may extend the tank testing if deemed necessary. The remaining requirements for tank testing, as applicable, are given in 5.3.5.

7.5.2 The minimum cargo tank testing requirements are given in Table 3.7.1; boundaries of cargo tanks are to be tested to the highest point that liquid will rise to under service conditions.
Cargo tank testing carried out by the ship's crew under the direction of the Master may be accepted by the Surveyor provided the following conditions are complied with:
(a) A tank testing procedure has been submitted by the Owner and reviewed by LR prior to the testing being carried out.
(b) There is no record of leakage, distortion or substantial corrosion that would affect the structural integrity of the tank.
(c) The tank testing has been satisfactorily carried out within the special survey window not more than 3 months prior to the date of the survey on which the overall or close-up survey is completed.
(d) The satisfactory results of the testing are recorded in the ship's logbook.
(e) The internal and external condition of the tanks and associated structure is found satisfactory by the Surveyor at the time of the overall and close-up survey.

7.6 Close-up Survey

7.6.1 The minimum requirements for Close-up Survey are given in Table 3.7.2 (Single hull oil tankers), Table 3.7.3 (Double hull oil tankers), Table 3.7.4 (Ore/oil ships) and Table 3.7.5 (Ore/bulk/oil ships).

7.6.2 The Surveyor may extend the Close-up Survey, if deemed necessary, taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system, and the following:
(a) Structural arrangements or details which have suffered defects in similar spaces or on similar ships.
(b) Spaces which have structures approved with reduced scantlings in association with an approved corrosion control system (**c.c.**).

7.6.3 For areas in tanks where coatings are found to be in GOOD condition, as defined in 1.5, the extent of Close-up Surveys may be specially considered.

Table 3.7.1 Tank testing requirements – Single hull and double hull oil tankers, ore/oil ships and ore/bulk/oil ships

Special Survey I (Ships 5 years old)	Special Survey II and subsequent (Ships 10 years old and over)
All ballast tank boundaries Cargo tank boundaries facing ballast tanks, void spaces, pipe tunnels, pump rooms or cofferdams	All ballast tank boundaries All cargo tank bulkheads

Table 3.7.2 Close-up Survey – Single hull oil tankers

Special Survey I (Ships 5 years old)	Special Survey II (Ships 10 years old)	Special Survey III (Ships 15 years old)	Special Survey IV (Ships 20 years old and over)
(1) One web frame ring – in a wing ballast tank, if any, or a cargo wing tank used primarily for water ballast, *see* Note 1 (2) One deck transverse – in a cargo tank, *see* Note 2 (3) One transverse bulkhead, *see* Note 4: (a) in a ballast tank (b) in a cargo wing tank (c) in a cargo centre tank	(1) All web frame rings – in a wing ballast tank, if any, or a cargo wing tank used primarily for water ballast, *see* Note 1 (2) One deck transverse, *see* Notes 2 and 8: (a) in each of the remaining ballast tanks, if any (b) in a cargo wing tank (c) in 2 cargo centre tanks (3) Both transverse bulkheads – in a wing ballast tank, if any, or a cargo wing tank used primarily for water ballast, *see* Note 3 (4) One transverse bulkhead, *see* Note 4: (a) in each remaining ballast tank (b) in a cargo wing tank (c) in 2 cargo centre tanks	(1) All web frame rings, *see* Note 1: (a) in all ballast tanks (b) in a cargo wing tank (2) A minimum of 30% of all web frame rings in each remaining cargo wing tank, *see* Notes 1 and 8 (3) All transverse bulkheads – in all cargo and ballast tanks, *see* Note 3 (4) A minimum of 30% of deck and bottom transverses in each cargo centre tank, *see* Notes 5 and 8. (5) As considered necessary by the Surveyor, *see* Note 6	(1) As Special Survey III (2) Additional transverse areas if deemed necessary by the Surveyor

NOTES
1. Complete transverse web frame ring including adjacent structural members.
2. Deck transverse including adjacent deck structural members.
3. Transverse bulkhead complete, including girder system and adjacent members, and adjacent longitudinal bulkhead structure.
4. Transverse bulkhead lower part including girder system and adjacent structural members.
5. Deck and bottom transverse including adjacent structural members.
6. Additional complete transverse web frame ring.
7. Ballast tank includes peak tanks.
8. Within the mid 0,5 length of the tank. The 30% is to be rounded up to the next whole number of structural items.

7.7 Thickness measurement

7.7.1 The minimum requirements for thickness measurements are given in Table 3.7.6 (Single and double hull oil tankers, including ore/oil ships and ore/bulk/oil ships), *see also* 5.6. For ships built in accordance with the IACS Common Structural Rules (CSR), the number and locations of measurements are detailed in the LR document *Thickness Measurement and Close-Up Survey Guidance*.

7.7.2 In areas where substantial corrosion, as defined in 1.5, has been noted then additional measurements are to be carried out, as applicable, in accordance with Tables 3.7.7, 3.7.8, 3.7.9, 3.7.10, 3.7.11, 3.7.12, 3.7.13, 3.7.14 and 3.7.15 to determine the full extent of the corrosion pattern. The survey will not be considered complete until these additional thickness measurements have been carried out. For double hull oil tankers built in accordance with the IACS Common Structural Rules (CSR), the identified substantial corrosion areas are required to be examined and additional thickness measurements are to be carried out at Annual and Intermediate Surveys.

7.7.3 For **oil tankers** (including ore/oil and ore/bulk/oil ships) of 130 m in length and upwards (as defined by the *International Convention on Load Lines* in force), the ship's longitudinal strength is to be evaluated by using the thickness of structural members measured, renewed and reinforced as appropriate, during the Special Surveys carried out after the ship reaches 10 years of age.

7.7.4 Steel renewal evaluation of hatch covers and hatch coamings of cargo holds on combination carriers with contract for construction on or after 1 January 2004 is to be in accordance with IACS UR S21. These requirements are not applicable to ships built in accordance with the IACS Common Structural Rules (CSR). Further information is provided in the LR document *Thickness Measurement and Close-Up Survey Guidance*.

Table 3.7.3 Close-up Survey – Double hull oil tankers

Special Survey I (Ships 5 years old)	Special Survey II (Ships 10 years old)	Special Survey III (Ships 15 years old)	Special Survey IV (Ships 20 years old and over)
(1) One web frame ring in a complete ballast tank, *see* Notes 1 and 3 (2) One deck transverse in a cargo tank, *see* Notes 4 and 12 (3) One transverse bulkhead in a complete ballast tank, *see* Notes 1 and 6 (4) One transverse bulkhead in a cargo centre tank, *see* Notes 2 and 7 (5) One transverse bulkhead in a cargo wing tank, *see* Note 7	(1) All web frame rings in a complete ballast tank, *see* Notes 1 and 3 (2) The knuckle area and the upper part (approx. 5 m) of one web frame ring in each remaining ballast tank, *see* Note 8 (3) One deck transverse in two cargo tanks, *see* Note 4 (4) One transverse bulkhead in each complete ballast tank, *see* Notes 1 and 6 (5) One transverse bulkhead in two cargo centre tanks, *see* Notes 2 and 7 (6) One transverse bulkhead in a cargo wing tank, *see* Note 7	(1) All web frame rings in all ballast tanks, *see* Note 3 (2) All web frame rings in a cargo tank, *see* Note 9 (3) One web frame ring in each remaining cargo tank, *see* Note 9 (4) All transverse bulkheads – in all cargo and ballast tanks, *see* Notes 5 and 6 (5) As considered necessary by the Surveyor, *see* Note 10	(1) As Special Survey III (2) Additional transverse areas if deemed necessary by the Surveyor, *see* Note 10

NOTES
1. Complete ballast tank means double bottom tank plus the double side tank and the double deck tank, as applicable, even if these are separate.
2. Where there are no centre tanks, the transverse bulkheads in wing tanks are to be subject to Close-up Survey.
3. Web frame ring in a ballast tank includes the vertical web in side tank, hopper web in hopper tank, floor in double bottom tank and deck transverse in a double deck tank and adjacent structural members. In peak tanks a web frame means a complete transverse web frame, including adjacent structural members.
4. Deck transverse including adjacent deck structural members (or external structure on deck in way of the tank, where applicable).
5. Transverse bulkhead complete in cargo tanks, including girder system, adjacent structural members (including longitudinal bulkheads) and internal structure of lower and upper stools, where fitted.
6. Transverse bulkhead complete in ballast tanks, including girder system and adjacent structural members including longitudinal bulkheads, girders in double bottom tanks, inner bottom plating, hopper side, connecting brackets.
7. Transverse bulkhead lower part in cargo tanks, including girder system, adjacent structural members (including longitudinal bulkheads) and internal structure of lower stool, where fitted.
8. The knuckle area and the upper part (approximately 5 m), including adjacent structural members. Knuckle area is the area of the web frame around the connections of the sloping hopper plating to the inner hull bulkhead and the inner bottom plating, up to 2 m from the corners both on the bulkhead and the double bottom.
9. Web frame ring in cargo tank includes deck transverse, longitudinal bulkhead vertical girder and cross ties, where fitted, and adjacent structural members.
10. Additional complete transverse web frame ring.
11. Ballast tanks include peak tanks.
12. Within the mid 0,5 length of the tank.

7.7.5 Steel renewal is required where the gauged thickness is less than t_{net} + 0,5 mm. For definition of t_{net}, *see* Pt 4, Ch 7,12.1.2.

7.7.6 Where the gauged thickness is within the range t_{net} + 0,5 mm and t_{net} + 1,0 mm, a coating (applied in accordance with coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal.

Table 3.7.4 Close-up Survey – Ore/oil ships

Special Survey I (Ships 5 years old)	Special Survey II (Ships 10 years old)	Special Survey III (Ships 15 years old)	Special Survey IV (Ships 20 years old and over)
(1) One web frame ring – in a wing ballast tank, if any, or a cargo wing tank used primarily for water ballast, *see* Note 1 (2) One deck transverse – in a cargo tank, *see* Note 2 (3) One transverse bulkhead, *see* Note 4: (a) in a ballast tank (b) in a cargo wing tank (c) in a cargo centre tank	(1) All web frame rings – in a wing ballast tank, if any, or a cargo wing tank used primarily for water ballast, *see* Note 1 (2) One deck transverse, *see* Notes 2 and 6: (a) in each of the remaining ballast tanks, if any (b) in a cargo wing tank (c) in 2 cargo centre tanks (3) Both transverse bulkheads – in a wing ballast tank, if any, or a cargo wing tank used primarily for water ballast, *see* Note 3 (4) One transverse bulkhead, *see* Note 4: (a) in each remaining ballast tank (b) in a cargo wing tank (c) in 2 cargo centre tanks (5) Selected cargo hold hatch covers and coamings (plating and stiffeners) (6) Selected areas of deck plating inside line of hatch openings between cargo hold hatches	(1) All web frame rings, *see* Note 1: (a) in all ballast tanks (b) in a cargo wing tank (2) One web frame ring – in each remaining cargo wing tank, *see* Notes 1 and 6 (3) One deck transverse – in each cargo centre tank, *see* Notes 2 and 6 (4) All transverse bulkheads– in all cargo and ballast tanks, *see* Note 3 (5) All cargo hold hatch covers and coamings (plating and stiffeners) (6) All deck plating inside line of hatch coamings between cargo hold hatches (7) As considered necessary by the Surveyor, *see* Note 5	(1) As Special Survey III (2) Additional transverse areas if deemed necessary by the Surveyor

NOTES
1. Complete transverse web frame ring including adjacent structural members.
2. Deck transverse including adjacent deck structural members.
3. Transverse bulkhead complete, including girder system and adjacent members, and adjacent longitudinal bulkhead structure.
4. Transverse bulkhead lower part including girder system and adjacent structural members.
5. Additional complete transverse web frame ring.
6. Within the mid 0,5 length of the tank.

Table 3.7.5 Close-up Survey – Ore/bulk/oil ships

Special Survey I (Ships 5 years old)	Special Survey II (Ships 10 years old)	Special Survey III (Ships 15 years old)	Special Survey IV (Ships 20 years old and over)
(1) 25% of shell frames and their end attachments in the forward cargo hold at representative positions (2) Selected frames and their end attachments in remaining cargo holds (3) 1 transverse web with associated plating and longitudinals in 2 representative water ballast tanks of each (i.e., topside, hopper side or side tank) (4) 2 selected cargo hold transverse bulkheads including internal structure of upper and lower stools where fitted. This is to include the aft bulkhead in the forward cargo hold	(1) 25% of shell frames including their end attachments and adjacent shell plating in all cargo holds (2) 1 transverse web with associated plating and longitudinals in each water ballast tank (i.e., topside, hopper side or side tank) (3) Forward and aft transverse bulkhead in 1 side ballast tank, including stiffening system (4) 1 transverse bulkhead in each cargo hold including internal structure of upper and lower stools where fitted. This is to include the aft bulkhead in the forward cargo hold (5) Selected cargo hold hatch covers and coamings (plating and stiffeners) (6) Selected areas of deck plating inside line of hatch openings between cargo hold hatches	(1) All shell frames in the forward cargo hold and 25% of frames in remaining cargo holds, including their end attachments and adjacent shell plating (2) All transverse webs with associated plating and longitudinals in each water ballast tank (i.e., topside, hopper side or side tank) (3) All transverse bulkheads in ballast tanks, including stiffening system (4) All cargo hold transverse bulkheads including internal structure of upper and lower stools, where fitted (5) All cargo hold hatch covers and coamings (plating and stiffeners) (6) All deck plating inside line of hatch openings between cargo hold hatches	(1) All shell frames including their end attachments and adjacent shell plating in all cargo holds (2) All transverse webs with associated plating and longitudinals in each water ballast tank (i.e., topside, hopper side or side tank) (3) All transverse bulkheads in ballast tanks, including stiffening system (4) All cargo hold transverse bulkheads including internal structure of upper and lower stools, where fitted (5) All cargo hold hatch covers and coamings (plating and stiffeners) (6) All deck plating inside line of hatch openings between cargo hold hatches

NOTES
1. Ballast tank includes peak tanks.
2. Close-up Survey of transverse bulkheads to be carried out at four levels:

Level (a)	Immediately above the inner bottom and immediately above the line of gussets (if fitted) and shedders for ships without lower stool.
Level (b)	Immediately above and below the lower stool shelf plate (for those ships fitted with lower stools), and immediately above the line of the shedder plates.
Level (c)	About mid-height of the bulkhead.
Level (d)	Immediately below the upper deck plating and immediately adjacent to the upper wing tank and immediately below the upper stool shelf plate for those ships fitted with upper stools, or immediately below the topside tanks.

Table 3.7.6 Thickness measurement – Single hull and double hull oil tankers, ore/oil ships and ore/bulk/oil ships

Special Survey I (Ships 5 years old)	Special Survey III (Ships 15 years old)	Special Survey IV (Ships 20 years old and over)
(1) 1 section of deck plating for the full beam of the ship within 0,5*L* amidships in way of a ballast tank, if any, or a cargo tank used primarily for water ballast. (2) Measurements for general assessment and recording of corrosion pattern of the structural members subject to Close-up Survey in accordance with Table 3.7.2, Table 3.7.3, Table 3.7.4 or Table 3.7.5. (3) Critical areas, as required by the Surveyor. **Special Survey II (Ships 10 years old)** (1) Within the cargo area: (a) Each deck plate. (b) 1 transverse section, *see* Note 6. (2) Measurements for general assessment and recording of corrosion pattern of the structural members subject to Close-up Survey in accordance with Table 3.7.2, Table 3.7.3, Table 3.7.4 or Table 3.7.5. (3) Selected wind and water strakes outside the cargo area. (4) Critical areas, as required by the Surveyor.	(1) Within the cargo area: (a) Each deck plate. (b) 2 transverse sections, *see* Note 6. (2) Measurements for general assessment and recording of corrosion pattern of the structural members subject to Close-up Survey in accordance with Table 3.7.2, Table 3.7.3, Table 3.7.4 or Table 3.7.5. (3) Selected wind and water strakes outside the cargo area. (4) All wind and water strakes within the cargo area. (5) All cargo hold hatch covers and coamings (plating and stiffeners), *see* Note 5. (6) All transverse webs with associated plating and longitudinals, and the transverse bulkhead complete in the fore peak tank and aft peak tank, *see* Notes 1 and 4. (7) Critical areas, as required by the Surveyor.	(1) Within the cargo area: (a) Each deck plate. (b) 3 transverse sections, *see* Note 6. (c) Each bottom plate. (2) Measurements for general assessment and recording of corrosion pattern of the structural members subject to Close-up Survey in accordance with Table 3.7.2, Table 3.7.3, Table 3.7.4 or Table 3.7.5. (3) All wind and water strakes over the full length of the ship, port and starboard . (4) All cargo hold hatch covers and coamings (plating and stiffeners), *see* Note 5. (5) Remaining exposed main deck plating not considered in item (1) and representative exposed superstructure deck plating (i.e. poop, bridge and forecastle deck). (6) All transverse webs with associated plating and longitudinals, and the trans-verse bulkhead complete in the fore peak tank and aft peak tank, *see* Notes 1 and 4. (7) All keel plates outside the cargo tank length. Also additional bottom plates in way of cofferdams, machinery space and aft end of tanks. (8) Plating of seachests. Also side shell plating in way of overboard discharges, as considered necessary by the Surveyor. (9) Critical areas, as required by the Surveyor.

NOTES
1. For areas in tanks where coatings are found to be in GOOD condition, as defined in 1.5, the extent of thickness measurements may be specially considered, but not dispensed with in its entirety.
2. Transverse sections should be chosen where the largest reductions are likely to occur, or as revealed by deck plating measurements.
3. Where two or three transverse sections are required to be measured, at least one is to include a ballast tank within 0,5*L* amidships.
4. Transverse bulkhead complete including stiffening system.
5. All cargo hold hatch covers and coamings, where fitted, are to be measured on ore/oil and ore/bulk/oil ships.
6. For oil tankers (including ore/oil and ore/bulk/oil ships), with length ≥ 130 m and over 10 years of age, the longitudinal strength is to be evaluated. In such cases, a minimum of three transverse sections are to be measured within 0,5*L* amidships.

Table 3.7.7 Thickness measurement – Single hull oil tankers, ore/oil ships and ore/bulk/oil ships – Bottom structure with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
(1) Bottom plating	Minimum of 3 bays across tank, including aft bay Measurement around and under all suction strums	5 point pattern for each panel between longitudinals and webs
(2) Bottom longitudinals	Minimum of 3 longitudinals in each bay where bottom plating measured	3 measurements in line across flange and 3 measurements on vertical web
(3) Bottom girders and brackets	At fore and aft transverse bulkhead, bracket toes and in centre of tanks	Vertical line of single measurements on web plating with 1 measurement between each panel stiffener, or a minimum of 3 measurements. 2 measurements across face flat. 5 point pattern on girder/bulkhead brackets
(4) Bottom transverse webs	3 webs in bays where bottom plating measured, with measurements at middle and both ends	5 point pattern over 2 m^2 area. Single measurements on face flat
(5) Panel stiffening	Where applicable	Single measurements

Table 3.7.8 Thickness measurement – Single hull oil tankers, ore/oil ships and ore/bulk/oil ships – Deck structure with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
(1) Deck plating	2 bands across tank	Minimum of 3 measurements per plate per band
(2) Deck longitudinals	Minimum of 3 longitudinals in each of 2 bays	3 measurements in line vertically on webs and 2 measurements on flange (if fitted)
(3) Deck girders and brackets	At fore and aft transverse bulkhead, bracket toes and in centre of tanks	Vertical line of single measurements on web plating with 1 measurement between each panel stiffener, or a minimum of 3 measurements. 2 measurements across face flat. 5 point pattern on girder/bulkhead brackets
(4) Deck transverse webs	Minimum of 2 webs with measurement at both ends and middle of span	5 point pattern over 2 m^2 area. Single measurements on face flat
(5) Panel stiffening	Where applicable	Single measurements

Table 3.7.9 Thickness measurement – Single hull oil tankers, ore/oil ships and ore/bulk/oil ships – Shell and longitudinal bulkheads with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
(1) Deckhead and bottom strakes and strakes in way of stringer platforms	Plating between each pair of longitudinals in a minimum of 3 bays	Single measurement
(2) All other strakes	Plating between every 3rd pair of longitudinals in same 3 bays	Single measurement
(3) Longitudinals – deckhead and bottom strakes	Each longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange
(4) Longitudinals – all others	Every third longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange
(5) Longitudinals – bracket	Minimum of 3 at top, middle and bottom of tank in same 3 bays	5 point pattern over area of bracket
(6) Web frames and cross ties	3 webs with minimum of 3 locations on each web, including in way of cross tie connections	5 point pattern over 2 m^2 area, plus single measurements on web frame and cross tie face flats

Table 3.7.10 Thickness measurement – Single hull oil tankers, ore/oil ships and ore/bulk/oil ships – Transverse bulkheads and swash bulkheads with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
(1) Deckhead and bottom strakes in way of stringer platforms	Plating between pair of stiffeners at 3 locations: approx. $^1/_4$, $^1/_2$ and $^3/_4$ width of tank	5 point pattern between stiffeners over 1 m length
(2) All other strakes	Plating between pair of stiffeners at middle location	Single measurement
(3) Strakes in corrugated bulkheads	Plating for each change of scantling at centre of panel and at flange or fabricated connection	5 point pattern over 1 m^2 of plating
(4) Stiffeners	Minimum of 3 typical stiffeners	For web, 5 point pattern over span between bracket connections (2 measurements across web at each bracket connection and one at centre of span). For flange, single measurements at each bracket toe and at centre of span
(5) Brackets	Minimum of 3 at top, middle and bottom of tank	5 point pattern over area of bracket
(6) Deep webs and girders	Measurements at toe of bracket and at centre of span	For web, 5 point pattern over 1 m^2 area. 3 measurements across face flat
(7) Stringer platforms	All stringers with measurements at middle and both ends	5 point pattern over 1 m^2 area plus single measurements near bracket toes and on face flats

Table 3.7.11 Thickness measurement – Double hull oil tankers – Bottom, inner bottom and hopper structure with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
(1) Bottom, inner bottom and hopper plating	Minimum of 3 bays across double bottom tank, including aft bay. Measurement around and under all suction strums	5 point pattern for each panel between longitudinals and floors
(2) Bottom, inner bottom and hopper longitudinals	Minimum of 3 longitudinals in each bay where bottom plating measured	3 measurements in line across flange and 3 measurements on vertical web
(3) Bottom girders, including watertight girders	At the fore and aft watertight floors and in centre of tanks	Vertical line of single measurements on girder plating with 1 measurement between each panel stiffener, or a minimum of 3 measurements
(4) Bottom floors, including watertight floors	3 floors in bays where bottom plating measured, with measurements at both ends and middle	5 point pattern over 2 m^2 area
(5) Hopper web frame ring	3 floors in bays where bottom plating measured	5 point pattern over 1 m^2 of plating. Single measurements on flange
(6) Hopper transverse watertight bulkhead or swash bulkhead	(i) Lower $^1/_3$ of bulkhead (ii) Upper $^2/_3$ of bulkhead (iii) Stiffeners (minimum of 3)	(i) 5 point pattern over 1 m^2 of plating. (ii) 5 point pattern over 2 m^2 of plating. (iii) For web, 5 point pattern over span (2 measurements across web at each end and 1 at centre of span). For flange, single measurement at each end and centre of span.
(7) Panel stiffening	Where applicable	Single measurements

Table 3.7.12 Thickness measurement – Double hull oil tankers – Deck structure with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
(1) Deck plating	2 transverse bands across tank	Minimum of 3 measurements per plate per band
(2) Deck longitudinals	Every 3rd longitudinal in each of 2 bands with a minimum of 1 longitudinal	3 measurements in line vertically on webs and 2 measurements on flange (if fitted)
(3) Deck girders and brackets (usually in cargo tanks only)	At the fore and aft transverse bulkhead, bracket toes and in centre of tanks	Vertical line of single measurements on web plating with 1 measurement between each panel stiffener, or a minimum of 3 measurements. 2 measurements across flange. 5 point pattern on girder / bulkhead brackets
(4) Deck transverse webs	Minimum of 2 webs, with measurements at both ends and middle of span	5 point pattern over 1 m^2 area. Single measurements on the flange
(5) Vertical web and transverse bulkhead in wing ballast tank (two metres from deck)	Minimum of 2 webs, and both transverse bulkheads	5 point pattern over 1 m^2 area
(6) Panel stiffening	Where applicable	Single measurements

Table 3.7.13 Thickness measurement – Double hull oil tankers – Wing ballast tank structure with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
(1) Side shell and longitudinal bulkhead plating: (i) Upper strake and strakes in way of horizontal girders (ii) All other strakes	 (i) Plating between each pair of longitudinals in a minimum of 3 bays (along the tank) (ii) Plating between every 3rd pair of longitudinals on same 3 bays	 (i) Single measurements (ii) Single measurements
(2) Side shell and longitudinal bulkhead longitudinals on: (i) Upper strake (ii) All other strakes	 (i) Each longitudinal in same 3 bays (ii) Every 3rd longitudinal in same 3 bays	 (i) 3 measurements across web and 1 measurement on flange (ii) 3 measurements across web and 1 measurement on flange
(3) Longitudinals – brackets	Minimum of 3 at top, middle and bottom of tank in same 3 bays	5 point pattern over area of bracket
(4) Vertical web and transverse bulkheads (excluding deckhead area): (i) Strakes in way of horizontal girders (ii) Other strakes	 (i) Minimum of 2 webs and both transverse bulkheads (ii) Minimum of 2 webs and both transverse bulkheads	 (i) 5 point pattern over approximately 2 m^2 area (ii) 2 measurements between each pair of vertical stiffeners
(5) Horizontal girders	Plating on each girder in a minimum of 3 bays	2 measurements between each pair of longitudinal girder stiffeners
(6) Panel stiffening	Where applicable	Single measurements

Table 3.7.14 Thickness measurement – Double hull oil tankers – Longitudinal bulkhead structure in cargo tanks with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
(1) Deckhead and bottom strakes, and strakes in way of horizontal stringers on transverse bulkheads	Plating between each pair of longitudinals in a minimum of 3 bays	Single measurement
(2) All other strakes	Plating between every 3rd pair of longitudinals in same 3 bays	Single measurement
(3) Longitudinals on deckhead and bottom strakes	Each longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange
(4) All other longitudinals	Every 3rd longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange
(5) Longitudinals – brackets	Minimum of 3 at top, middle and bottom of tank in same 3 bays	5 point pattern over area of bracket
(6) Web frames and cross ties	3 webs with minimum of 3 locations on each web, including in way of cross tie connections	5 point pattern over approximately 2 m^2 area of webs, plus single measurements on flanges of web frames and cross ties
(7) Lower end brackets (opposite side of web frame)	Minimum of 3 brackets	5 point pattern over approximately 2 m^2 area of brackets, plus single measurements on bracket flanges

Table 3.7.15 Thickness measurement – Double hull oil tankers – Transverse watertight and swash bulkhead structure in cargo tanks with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
(1) Upper and lower stool, where fitted	Transverse band within 25 mm of welded connection to inner bottom/deck plating Transverse band within 25 mm of welded connection to shelf plate	5 point pattern between stiffeners over 1 m length
(2) Deckhead and bottom strakes, and strakes in way of horizontal stringers	Plating between pair of stiffeners at 3 locations; approximately 1/4, 1/2 and 3/4 width of tank	5 point pattern between stiffeners over 1 m length
(3) All other strakes	Plating between pair of stiffeners at middle location	Single measurement
(4) Strakes in corrugated bulkheads	Plating for each change of scantling at centre of panel and at flange of fabricated connection	5 point pattern over approximately 1 m^2 of plating
(5) Stiffeners	Minimum of 3 typical stiffeners	For web, 5 point pattern over span between bracket connections (2 measurements across web at each bracket connection and 1 at centre of span). For flange, single measurement at bracket toe and at centre of span
(6) Brackets	Minimum of 3 at top, middle and bottom of tank	5 point pattern over area of bracket
(7) Horizontal stringers	All stringers with measurements at both ends and middle	5 point pattern over 1 m^2 area, plus single measurements near bracket toes and on flanges

■ *Section 8* Special Survey – Chemical tankers – Hull requirements

8.1 General

8.1.1 The requirements of Sections 2, 4 and 5 are to be complied with as applicable.

8.1.2 In order to maintain and/or assign the **ESP** notation, the following requirements apply to the surveys of the hull structure and piping systems in way of the cargo tanks, pump rooms, cofferdam, pipe tunnels, void spaces, double bottom tanks, etc., in way of the cargo tank area and all salt-water ballast tanks.

8.2 Documentation

8.2.1 The Owner is to obtain, supply and maintain documentation on board as follows:

(a) A survey file comprising reports of structural surveys, thickness measurement and executive hull summary in accordance with the 2011 ESP Code.

(b) Supporting documentation consisting of:

- (i) Main structural plans of cargo tanks and ballast tanks.
- (ii) Previous repair history.
- (iii) Cargo and ballast history
- (iv) Records of inspections by ship's personnel with reference to structural deterioration in general, leakages in bulkheads and piping and the condition of the corrosion prevention systems, if any.
- (v) Extent of use of inert gas plant and tank cleaning procedures.
- (vi) Any other information that may help to identify critical structural areas and/or suspect areas requiring inspection.
- (vii) Survey Programme as required by 8.3.

The complete documentation in 8.2.1 is to be readily available for examination by the Surveyor and should be used as a basis for survey.

8.2.2 The documentation is to be kept on board for the lifetime of the ship.

8.3 Planning for survey

8.3.1 A Survey Programme is to be submitted by the Owner and is to include the proposals for survey, including the means of providing access for Close-up Survey, thickness measurement tank testing and should take account of the information detailed in 8.2.1.

8.3.2 Prior to the development of the Survey Programme a Survey Planning Questionnaire is to be completed and submitted by the Owner, *see* 1.6.12.

8.4 Overall Survey

8.4.1 All cargo tanks and salt-water ballast tanks including double bottom tanks, pump rooms, pipe tunnels, cofferdams and void spaces bounding cargo tanks, deck and outer hull are to be examined, and this examination is to be supplemented by Close-up Survey, thickness measurement and testing as applicable, to ensure that the structural integrity remains effective.

8.4.2 The examination is to be sufficient to ascertain substantial corrosion, significant deformation, fractures, damages or other structural deterioration and, if deemed necessary by the Surveyor, suitable non-destructive examination may be required.

8.4.3 Where substantial corrosion, as defined in 1.5, is identified and is not rectified, this will be subject to re-examination at Annual and/or Intermediate Surveys. In the case of salt-water ballast tanks the examination will be required at Annual Survey and Intermediate Survey. In the case of cargo tanks the examination will be required at Intermediate Surveys.

8.4.4 All cargo piping on deck, and cargo and ballast piping, within those spaces indicated in 8.4.1 are to be examined and tested under working conditions to ensure that tightness and condition remain satisfactory. Special attention is to be given to ballast piping in cargo tanks and any cargo piping in ballast tanks and void spaces.

8.4.5 The survey of stainless steel tanks may be carried out as an Overall Survey supplemented by Close-up Survey as deemed necessary by the Surveyor.

8.4.6 Where salt-water ballast tanks have been converted to void spaces the survey extent is to be based upon salt-water ballast tank requirements.

8.4.7 Where provided, in association with a corrosion control (**c.c.**) notation as defined in the *Register Book*, the condition of the protective coating or corrosion prevention system of cargo tanks is to be examined.

8.4.8 The attachment to the structure and condition of anodes in tanks are to be examined.

8.4.9 Where fitted, the strums of the cargo suction pipes are to be removed or lifted to facilitate examination of the shell plating and bulkheads in the vicinity, unless other means for visual inspection of these parts are provided

8.5 Testing

8.5.1 The minimum ballast tank testing requirements are given in Table 3.8.1 and, where required, the Surveyor may extend the tank testing if deemed necessary. Other arrangements for cargo tank testing will be considered on application. The remaining requirements for tank testing, as applicable, are given in 5.3.5

8.5.2 The minimum cargo tank testing requirements are given in Table 3.8.1, boundaries of cargo tanks are to be tested to the highest point that liquid will rise to under service conditions. Other arrangements for cargo tank testing will be considered on application.
Cargo tank testing carried out by the ship's crew under the direction of the Master may be accepted by the Surveyor provided the following conditions are complied with:

(a) A tank testing procedure has been submitted by the Owner and reviewed by LR prior to the testing being carried out.
(b) There is no record of leakage, distortion or substantial corrosion that would affect the structural integrity of the tank.
(c) The tank testing has been satisfactorily carried out within the special survey window not more than 3 months prior to the date of the survey on which the overall or close-up survey is completed.
(d) The satisfactory results of the testing are recorded in the ship's logbook.
(e) The internal and external condition of the tanks and associated structure is found satisfactory by the Surveyor at the time of the overall and close-up survey.

8.6 Close-up Survey

8.6.1 The minimum requirements for Close-up Survey are given in Table 3.8.2 (Single hull chemical tankers) and Table 3.8.3 (Double hull chemical tankers).

8.6.2 The Surveyor may extend the Close-up Survey, if deemed necessary, taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system, and the following:

(a) Structural arrangements or details which have suffered defects in similar spaces or on similar ships.
(b) Spaces which have structures approved with reduced scantlings in association with an approved corrosion control system (**c.c.**).

8.6.3 For areas in tanks where coatings are found to be in GOOD condition, as defined in 1.5, the extent of Close-up Surveys may be specially considered.

Table 3.8.1 Tank testing requirements – Chemical tankers

Special Survey I (Ships 5 years old)	Special Survey II and subsequent (Ships 10 years old and over)
All ballast tank boundaries Cargo tank boundaries facing ballast tanks, void spaces, pipe tunnels, pump rooms or cofferdams	All ballast tank boundaries All cargo tank bulkheads

Table 3.8.2 Close-up Survey – Single hull chemical tankers

Special Survey I (Ships 5 years old)	Special Survey II (Ships 10 years old)	Special Survey III (Ships 15 years old)	Special Survey IV (Ships 20 years old and over)
(1) One web frame ring in a ballast wing tank, *see* Note 1 (2) One deck transverse in a cargo tank or on deck, *see* Note 2 (3) One transverse bulkhead in a ballast tank, *see* Note 3 (4) One transverse bulkhead in a cargo wing tank, *see* Note 3 (5) One transverse bulkhead in a cargo centre tank, *see* Notes 3 and 5	(1) All web frame rings in a ballast wing tank or double bottom ballast tank, *see* Note 1 (2) One deck transverse in each remaining ballast tank or on deck, *see* Note 2 (3) One deck transverse in a cargo wing tank or on deck, *see* Note 2 (4) One deck transverse in two cargo centre tanks or on deck, *see* Note 2 (5) Both transverse bulkheads in a ballast wing tank, *see* Note 4 (6) One transverse bulkhead in remaining ballast tank, *see* Note 3 (7) One transverse bulkhead in a cargo wing tank, *see* Note 3 (8) One transverse bulkhead in two cargo centre tanks, *see* Notes 3 and 5	(1) All web frame rings in all ballast tanks, *see* Note 1 (2) All web frame rings in a cargo wing tank, *see* Note 1 (3) One web frame ring in each remaining cargo tank, *see* Note 1 (4) All transverse bulkheads – in all cargo and ballast tanks, *see* Notes 4	(1) As Special Survey III (2) Additional transverse areas if deemed necessary by the Surveyor

NOTES
1. Complete transverse web frame ring including adjacent structural members.
2. Deck transverse including adjacent deck structural members (or external structure on deck in way of the tank).
3. Transverse bulkhead lower part including girder system and adjacent structural members.
4. Transverse bulkhead complete, including girder system and adjacent members, and adjacent longitudinal bulkhead structure.
5. Where there are no centre tanks, the transverse bulkheads in wing tanks are to be subject to Close-up Survey.
6. Ballast tank includes peak tanks.

8.7 Thickness measurement

8.7.1 The minimum requirements for thickness measurements are given in Table 3.8.4, *see also* 5.6.

8.7.2 In areas where substantial corrosion, as defined in 1.5, has been noted, then additional measurements are to be carried out, as applicable, in accordance with Tables 3.8.5, 3.8.6, 3.8.7 and 3.8.8 to determine the full extent of the corrosion pattern. The survey will not be considered complete until these additional thickness measurements have been carried out.

8.8 Ships over 10 years old

8.8.1 Selected steel cargo pipes outside cargo tanks and ballast pipes passing through cargo tanks are to be:
(a) Thickness measured at random or selected pipe lengths to be opened for internal inspection.
(b) Pressure tested to the maximum working pressure.

Note

Special attention is to be given to cargo/slop discharge piping through ballast tanks and void spaces.

Table 3.8.3 Close-up Survey – Double hull chemical tankers

Special Survey I (Ships 5 years old)	Special Survey II (Ships 10 years old)	Special Survey III (Ships 15 years old)	Special Survey IV (Ships 20 years old and over)
(1) One web frame ring in a ballast double hull tank, *see* Notes 1 and 9 (2) One deck transverse in a cargo tank or on deck, *see* Note 2 (3) One transverse bulkhead in a ballast tank, *see* Note 5 (4) One transverse bulkhead in a cargo wing tank, *see* Note 3 (5) One transverse bulkhead in a cargo centre tank, *see* Notes 3 and 8	(1) All web frame rings in a ballast wing tank or ballast double hull tank, *see* Notes 1 and 9 (2) The knuckle area and the upper part (approx. 3 m) of one web frame ring in each remaining ballast tank, *see* Note 6 (3) One deck transverse in two cargo tanks, *see* Note 2 (4) One transverse bulkhead in each ballast tank, *see* Note 5 (5) One transverse bulkhead in a cargo wing tank, *see* Note 3 (6) One transverse bulkhead in two cargo centre tanks, *see* Notes 3 and 8	(1) All web frame rings in all ballast tanks, *see* Note 1 (2) All web frame rings in a cargo wing tank, *see* Note 7 (3) One web frame ring in each remaining cargo tank, *see* Note 7 (4) All transverse bulkheads – in all cargo and ballast tanks, *see* 4 and 5	(1) As Special Survey III (2) Additional transverse areas if deemed necessary by the Surveyor

NOTES
1. Web frame ring in a ballast tank includes the vertical web in side tank, hopper web in hopper tank, floor in double bottom tank and deck transverse in a double deck tank (where fitted) and adjacent structural members. In peak tanks, a web frame means a complete transverse web frame ring, including adjacent structural members.
2. Deck transverse including adjacent deck structural members (or external structure on deck in way of the tank), where applicable.
3. Transverse bulkhead lower part in cargo tanks including girder system and adjacent structural members (including longitudinal bulkheads) and internal structure of lower stools, where fitted.
4. Transverse bulkhead complete in cargo tanks, including girder system, adjacent structural members (including longitudinal bulkheads) and internal structure of lower and upper stools, where fitted.
5. Transverse bulkhead complete in ballast tanks, including girder system and adjacent structural members including longitudinal bulkheads, girders in double bottom tanks, inner bottom plating, hopper side, connecting brackets.
6. The knuckle area and the upper part (approximately 3 m), including adjacent structural members. Knuckle area is the area of the web frame around the connections of the sloping hopper plating to the inner hull bulkhead and the inner bottom plating, up to 2 m from the corners both on the bulkhead and the double bottom.
7. Web frame ring in a cargo tank includes deck transverse, longitudinal bulkhead vertical girder and cross ties, where fitted, and adjacent structural members.
8. Where there are no centre tanks, the transverse bulkheads in wing tanks are to be subject to Close-up Survey.
9. Double hull tank includes double bottom and side tank even though these tanks may be separate.
10. Ballast tank includes peak tanks.

Table 3.8.4 Thickness measurement – Single and double hull chemical tankers

<table>
<tr><th>Special Survey I
(Ships 5 years old)</th><th>Special Survey III
(Ships 15 years old)</th><th>Special Survey IV
(Ships 20 years old and over)</th></tr>
<tr><td>(1) 1 section of deck plating for the full beam of the ship within 0,5L amidships (in way of a ballast tank, if any)
(2) Measurements for general assessment and recording of corrosion pattern of the structural members subject to Close-up Survey in accordance with Table 3.8.2 or 3.8.3
(3) Critical areas, as required by the Surveyor</td>
<td rowspan="3">(1) Within the cargo area:
(a) Each deck plate
(b) 2 transverse sections
(2) Measurements for general assessment and recording of corrosion pattern of the structural members subject to Close-up Survey in accordance with Table 3.8.2 or 3.8.3
(3) Selected wind and water strakes outside the cargo area
(4) All wind and water strakes within the cargo area
(5) All transverse webs with associated plating and longitudinals, and the transverse bulkhead complete in the fore peak tank and aft peak tank, see Notes 1 and 4
(6) Critical areas, as required by the Surveyor</td>
<td rowspan="3">(1) Within the cargo area:
(a) Each deck plate
(b) 3 transverse sections
(c) Each bottom plate
(2) Measurements for general assessment and recording of corrosion pattern of the structural members subject to Close-up Survey in accordance with Table 3.8.2 or 3.8.3
(3) All wind and water strakes over the full length of the ship, port and starboard
(4) Remaining exposed main deck plating not considered in item (1) and representative exposed superstructure deck plating (i.e., poop, bridge and forecastle deck)
(5) All transverse webs with associated plating and longitudinals, and the transverse bulkhead complete in the fore peak tank and aft peak tank, see Notes 1 and 4
(6) All keel plates outside the cargo tank length. Also additional bottom plates in way of cofferdams, machinery space and aft end of tanks
(7) Plating of seachests. Also side shell plating in way of overboard discharges, as considered necessary by the Surveyor
(8) Critical areas, as required by the Surveyor</td></tr>
<tr><th>Special Survey II
(Ships 10 years old)</th></tr>
<tr><td>(1) Within the cargo area:
(a) Each deck plate
(b) 1 transverse section
(2) Measurements for general assessment and recording of corrosion pattern of the structural members subject to Close-up Survey in accordance with Table 3.8.2 or 3.8.3
(3) Selected wind and water strakes outside the cargo area
(4) Critical areas, as required by the Surveyor</td></tr>
<tr><td colspan="3">NOTES
1. For areas in tanks where coatings are found to be in GOOD condition, as defined in 1.5, the extent of thickness measurements may be specially considered, but not dispensed with in its entirety.
2. Transverse sections should be chosen where the largest reductions are likely to occur, or as revealed by deck plating measurements.
3. Where two or three transverse sections are required to be measured, at least one is to include a ballast tank within 0,5L amidships.
4. Transverse bulkhead complete including stiffening system.</td></tr>
</table>

Table 3.8.5 Thickness measurement – Single and double hull chemical tankers – Bottom, inner bottom and hopper structure with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
(1) Bottom, inner bottom and hopper plating	Minimum of 3 bays across double bottom tank, including aft bay. Measurement around and under all suction strums	5 point pattern for each panel between longitudinals and floors
(2) Bottom, inner bottom and hopper longitudinals	Minimum of 3 longitudinals in each bay where bottom plating measured	3 measurements in line across flange and 3 measurements on vertical web
(3) Bottom girders, including watertight girders	At the fore and aft watertight floors and in centre of tanks	Vertical line of single measurements on girder plating with 1 measurement between each panel stiffener, or a minimum of 3 measurements. 2 measurements across face flat (if fitted)
(4) Bottom floors, including watertight floors	3 floors in bays where bottom plating measured, with measurements at both ends and middle	5 point pattern over 2 m^2 area
(5) Hopper web frame ring	3 floors in bays where bottom plating measured	5 point pattern over 1 m^2 of plating. Single measurements on flange
(6) Hopper transverse watertight bulkhead or swash bulkhead	(i) Lower $^1/_3$ of bulkhead (ii) Upper $^2/_3$ of bulkhead (iii) Stiffeners (minimum of 3)	(i) 5 point pattern over 1 m^2 of plating (ii) 5 point pattern over 2 m^2 of plating (iii) For web, 5 point pattern over span (2 measurements across web at each end and 1 at centre of span). For flange, single measurement at each end and centre of span
(7) Panel stiffening	Where applicable	Single measurements

Table 3.8.6 Thickness measurement – Single and double hull chemical tankers – Deck structure with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
(1) Deck plating	2 transverse bands across tank	Minimum of 3 measurements per plate per band
(2) Deck longitudinals	Every 3rd longitudinal in each of 2 bands with a minimum of 1 longitudinal	3 measurements in line vertically on webs and 2 measurements on flange (if fitted)
(3) Deck girders and brackets	At the fore and aft transverse bulkhead, bracket toes and in centre of tanks	Vertical line of single measurements on web plating with 1 measurement between each panel stiffener, or a minimum of 3 measurements. 2 measurements across flange. 5 point pattern on girder/bulkhead brackets
(4) Deck transverse webs	Minimum of 2 webs, with measurements at both ends and middle of span	5 point pattern over 1 m^2 area. Single measurements on the flange
(5) Vertical web and transverse bulkhead in wing ballast tank (2 m from deck) – for double hull chemical tankers	Minimum of 2 webs, and both transverse bulkheads	5 point pattern over 1 m^2 area
(6) Panel stiffening	Where applicable	Single measurements

Table 3.8.7 Thickness measurement – Single and double hull chemical tankers – Side shell and longitudinal bulkheads with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
(1) Side shell and longitudinal bulkhead plating:		
(i) Top and bottom strakes, and strakes in way of horizontal girders	(i) Plating between each pair of longitudinals in a minimum of 3 bays (along the tank)	(i) Single measurements
(ii) All other strakes	(ii) Plating between every 3rd pair of longitudinals on same 3 bays	(ii) Single measurements
(2) Side shell and longitudinal bulkhead longitudinals on:		
(i) Top and bottom strakes	(i) Each longitudinal in same 3 bays	(i) 3 measurements across web and 1 measurement on flange
(ii) All other strakes	(ii) Every 3rd longitudinal in same 3 bays	(ii) 3 measurements across web and 1 measurement on flange
(3) Longitudinals – brackets	Minimum of 3 at top, middle and bottom of tank in same 3 bays	5 point pattern over area of bracket
(4) Vertical web and transverse bulkheads of double side tanks (excluding deckhead area):		
(i) Strakes in way of horizontal girders	(i) Minimum of 2 webs and both transverse bulkheads	(i) 5 point pattern over approximately 2 m^2 area
(ii) Other strakes	(ii) Minimum of 2 webs and both transverse bulkheads	(ii) 2 measurements between each pair of vertical stiffeners
(5) Web frames and cross ties for other tanks than double side tanks	3 webs with minimum of 3 locations on each web, including in way of cross tie connections and lower end bracket	5 point pattern over approximately 2 m^2 area of webs, plus single measurements on flanges of web frame and cross ties
(6) Horizontal girders	Plating on each girder in a minimum of 3 bays	2 measurements between each pair of longitudinal girder stiffeners
(7) Panel stiffening	Where applicable	Single measurements

Table 3.8.8 Thickness measurement – Single and double hull chemical tankers – Transverse watertight bulkheads and swash bulkheads with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
(1) Upper and lower stool, where fitted	Transverse band within 25 mm of welded connection to inner bottom/deck plating Transverse band within 25 mm of welded connection to shelf plate	5 point pattern between stiffeners over 1 m length
(2) Top and bottom strakes, and strakes in way of horizontal stringers	Plating between pair of stiffeners at 3 locations; approximately $^1/_4$, $^1/_2$ and $^3/_4$ width of tank	5 point pattern between stiffeners over 1 m length
(3) All other strakes	Plating between pair of stiffeners at middle location	Single measurement
(4) Strakes in corrugated bulkheads	Plating for each change of scantling at centre of panel and at flange of fabricated connection	5 point pattern over approximately 1 m^2 of plating
(5) Stiffeners	Minimum of 3 typical stiffeners	For web, 5 point pattern over span between bracket connections (2 measurements across web at each bracket connection and 1 at centre of span). For flange, single measurement at bracket toe and at centre of span
(6) Brackets	Minimum of 3 at top, middle and bottom of tank	5 point pattern over area of bracket
(7) Horizontal stringers	All stringers with measurements at both ends and middle	5 point pattern over 1 m^2 area, plus single measurements near bracket toes and on flanges
(8) Deep webs and girders	Measurements at toe of bracket and centre of span	For webs, 5 point pattern over 1 m^2 area. 3 measurements across face flat

■ *Section 9*
Ships for liquefied gases

9.1 General

9.1.1 The requirements of Sections 2 to 7 are to be complied with, as applicable.

9.1.2 Prior to the inspection of cargo tanks, surrounding spaces, associated piping, fittings and equipment, etc., the respective items are to be cleaned and thoroughly cleared of gas. Every precaution is to be taken to ensure safety during inspection.

9.1.3 The following documentation, as applicable, is to be available on board the ship:
(a) Relevant instruction and information material such as cargo handling plans, filling limit information, cooling down procedures, etc.
(b) A copy of the IGC Code.
(c) Test records of secondary barrier.
(d) Loading and stability information, including damage stability.

9.1.4 For requirements of Special Survey for electrical equipment, *see* Section 14.

9.2 Annual Surveys – Basic requirements

9.2.1 The Annual Survey is preferably to be carried out during a loading or discharging operation. Access to cargo tanks or inerted hold spaces, necessitating gas freeing/ aerating will normally not be necessary unless required by the Regulations.

9.2.2 The ship's log and operational records for the cargo containment system covering the period from the previous survey are to be examined. Any malfunction of the system entered in the log is to be investigated, the cause ascertained, and that part of the system at fault is to be found or placed in good order.

9.2.3 Instrumentation and safety systems are to be surveyed as follows:
(a) The instrumentation of the cargo installations with regard to pressure, temperature and liquid level is to be verified in good working order by one or more of the following methods:
 (i) Visual external examination.
 (ii) Comparing of read outs from different indicators.
 (iii) Consideration of read outs with regard to the actual cargo and/or actual conditions.
 (iv) Examination of maintenance records with reference to cargo plant instrumentation maintenance manual.
 (v) Verification of calibration status of the measuring instruments.
(b) The low level, high level, and overfill alarms are to be examined and tested to ascertain that they are in working order.
(c) The alarms associated with the following are to be tested as applicable:
 (i) Cargo tank high and low pressure.
 (ii) Cargo tank temperature.
 (iii) Cargo hold pressure.
 (iv) Interbarrier space pressure.
 (v) Inner hull temperature.
 (vi) Secondary barrier temperature.
 (vii) Cargo Hold or Interbarrier bilge level detection.
(d) Control devices for the cargo containment systems and cargo handling equipment, together with any associated shutdown and/or interlock, are to be checked under simulated working conditions and, if necessary, recalibrated. Such safety systems include but are not limited to:
 (i) Cargo tank overfill protection including cargo pump, compressor and other cargo machinery automatic shutdown.
 (ii) Cargo pump, compressor and other cargo machinery shutdown on low cargo tank pressure or cargo tank and interbarrier/hold space differential pressure.
 (iii) Cargo pump automatic shutdown on low level or current;
(e) The emergency shutdown system is to be tested, without flow in the pipe lines, to verify that the system will cause the cargo pumps, compressors and other cargo machinery, as applicable, to stop.
(f) Consideration will be given to the acceptance of simulated tests, provided that they are carried out at the cargo temperature, or comprehensive maintenance records, including details of tests held, in accordance with the cargo plant instrumentation maintenance manual.

9.2.4 Cargo gas leakage detection systems are to be examined and tested to ascertain that they are in working order and calibrated using sample gas.

9.2.5 Inert gas/dry air installations including the means for prevention of backflow of cargo vapour to gas-safe spaces are to be verified as being in satisfactory operating condition.

9.2.6 Ventilation systems and air locks in working spaces are to be checked for satisfactory operation.

9.2.7 Cargo pipeline, valves and fittings are to be generally examined, with special reference to expansion bellows, supports and vapour seals on insulated pipes. It is to be verified that all accessible cargo piping systems are electrically bonded to the hull.

9.2.8 Portable and/or fixed drip trays, or insulation for deck protection in the event of cargo leakage, are to be examined for condition.

9.2.9 The means for accomplishing gas tightness of the wheelhouse doors and windows is to be examined. All windows and side-scuttles within the area required to be of the fixed type (non-opening) are to be examined for gas tightness. The closing devices for all air intakes and openings into accommodation spaces, service spaces, machinery spaces, control stations and approved openings in superstructures and deckhouses facing the cargo area or bow and stern loading/unloading arrangements are to be examined. For ships carrying toxic gases such devices should be capable of being operated from inside the space.

9.2.10 Venting systems, including protection screens if provided, for the cargo tanks, inter-barrier spaces and hold spaces are to be visually examined externally. It is to be verified that the cargo tank relief valves are sealed and that the certificate for the relief valves opening/closing pressures is on board the ship.

9.2.11 Mechanical ventilation fans in gas hazardous zones and spaces are to be visually examined. Adequate spare parts should be carried for each type of fan installed.

9.2.12 Electrical equipment, cables and supports in gas hazardous zones and spaces shall be examined as far as practicable. Alarms and safety systems associated with pressurised lighting systems and any safety device associated with non-safe type electrical equipment that is protected by air-locks are to be verified.

9.2.13 Heating arrangements, if fitted, for cofferdams and other spaces shall be verified in good working order.

9.2.14 All accessible gas-tight bulkhead penetrations including gas-tight shaft sealings are to be visually examined.

9.2.15 The sealing arrangements for tanks or tank domes penetrating decks or tank covers are to be externally examined.

9.2.16 The survey is to consist of an examination for the purpose of ensuring, as far as practicable, that the hull and piping are maintained in a satisfactory condition.

(a) The examination of the hull and piping is to include the following:
  - hull plating and closing appliances as far as can be seen
  - watertight penetrations as far as practicable
  - weather decks
  - flame screens on vents to all bunker tanks
  - bunker and vent piping systems

(b) The examination of the cargo pump rooms and compressor rooms and, as far as practicable, pipe tunnels if fitted is to include the following:
  - all pump room and compressor room bulkheads for signs of leakage or fractures and, in particular, the sealing arrangements of all penetrations of pump room and compressor room bulkheads
  - condition of all piping systems (for cargo piping systems, *see* 9.2.7).

9.2.17 The Surveyor is to carry out an examination and thickness measurement of structure identified at the previous Special Survey or Intermediate Survey as having substantial corrosion, as defined in 1.5. The extent of thickness measurements is to be increased in accordance with Table 3.9.4 to determine the full extent of the corrosion pattern. The survey will not be considered complete until these additional thickness measurements have been carried out.

9.3 Annual Surveys – Reliquefaction/refrigeration equipment

9.3.1 Where reliquefaction or refrigeration equipment for cargo temperature and pressure control is fitted, the following are to be examined, so far as practicable:

(a) The machinery under working conditions.

(b) The shells of all pressure vessels in the system, externally. Insulation need not be removed for this examination, but any deterioration of insulation or evidence of dampness which could lead to external corrosion of the vessels or their connections, is to be investigated.

(c) Primary refrigerant gas and liquid pipes, cargo vapour and liquid condensate pipes and condenser cooling water pipes. Insulation need not be removed, but any deterioration or evidence of dampness is to be investigated.

(d) The reliquefaction/refrigeration plant spare gear.

9.3.2 Reference should be made to the Special Survey requirements for guidance on Continuous Survey arrangements.

9.4 Annual Surveys – Methane burning equipment and other equipment components

9.4.1 The following components are to be generally examined externally. If insulation is fitted, this need not be removed, but any deterioration of insulation, or evidence of dampness which could lead to external corrosion of the vessels or their connections, is to be investigated:

(a) Heat exchangers and pressure vessels for use with methane burning in boilers or machinery.

(b) Cargo heaters, vaporisers, masthead heaters and other miscellaneous pressure vessels.

9.4.2 Controls and interlocks are to be checked.

9.4.3 Alarm systems are to be checked to ascertain that they are in working order.

9.4.4 Exhaust fans and/or pressurising system for gas trunking are to be tested.

9.5 Annual Surveys – Cargo containment systems

9.5.1 Where the insulation arrangement is such that the insulation cannot be examined, the surrounding structures of wing tanks, double bottom tanks and cofferdams are to be examined for cold spots, prior to the survey. This examination is to be held at a convenient cargo discharge operation with the cargo tanks loaded at approximately the minimum notation temperature.

9.5.2 On application by the Owner, consideration will be given to the cold spot examination, where applicable, being carried out by the ship's staff.

9.5.3 When tests are required after repairs, independent cargo tanks, other than independent tanks Type C, are to be tested by hydraulic or hydropneumatic means as appropriate. Test heads and pressures should be as defined in Ch 4,10 of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk*. Cargo tanks of the membrane or semi-membrane type are to be tested by means of a detectable gas in the inter-barrier spaces and discolouring paint on the weld seams of the cargo tanks wall, or other suitable means. Independent cargo tanks of Type C are to be tested hydraulically at 1,25 times the approved maximum vapour pressure.

9.5.4 For membrane containment systems, the Surveyor is to receive confirmation from the Master that the nitrogen control system for insulation and inter-barrier spaces is operating normally.

9.6 Intermediate Surveys

9.6.1 The Intermediate Survey intends to supplement the Annual Survey by testing cargo handling installations with related automatic control, alarm and safety systems for correct functioning. The Intermediate Survey is preferably to be carried out with the ship in a gas-free condition. The extent of the testing required for the Intermediate Survey will normally be such that the survey cannot be carried out during a loading or discharging operation.

9.6.2 In addition to the requirements for Annual Survey and the requirements of 3.2.1 to 3.2.8, the following are to be dealt with as applicable:

(a) Examination of means for draining the vent piping system.
(b) Verification that pipelines and cargo tanks are electrically bonded to the hull.
(c) Verification that the heating arrangements, if any, for steel structures are satisfactory.
(d) Where required by the manufacturer's maintenance instructions, cargo tank and inter-barrier space pressure and vacuum relief valve settings are to be checked and adjusted as required. Cargo tank pressure relief valve harbour settings are also to be checked, if applicable. Cargo tank pressure relief valves are to lift at a pressure not more than the percentage given below, above the maximum vapour pressure for which the tanks have been approved.
   - For 0 to 1,5 bar (0 to 1,5 kgf/cm^2), 10 per cent.
   - For 1,5 to 3,0 bar (1,5 to 3,0 kgf/cm^2), 6 per cent.
   - For pressures exceeding 3,0 bar (3,0 kgf/cm^2), 3 per cent.
   - Valves may be removed from the tanks for the purpose of checking.
(e) A General Examination within the zones and spaces deemed as hazardous such as cargo compressor rooms and spaces adjacent to and zones above cargo areas, for defective and non-certified safe-type electrical equipment, improperly installed, defective and dead wiring. An electrical insulation resistance test of the circuits terminating in, or passing through the hazardous zones and spaces, is to be carried out. If the ship is not in a gas free condition the results of previously recorded test readings may be accepted.

9.6.3 For ships over 5 years of age and up to 10 years of age, an overall survey of representative ballast tanks is to be carried out. Where a hard protective coating is found to be in POOR condition, as defined in 1.5, where a soft or semi-hard coating has been applied or where a protective coating was not applied from the time of construction, the survey is to be extended to other ballast tanks of the same type.

9.6.4 For ships over 10 years of age, an overall survey of all ballast tanks is to be carried out.

(a) If such examinations reveal no visible structural defects, the examination may be limited to verification that the corrosion prevention system remains in GOOD or FAIR condition.
(b) The condition of the corrosion prevention system identified during the Survey may result in the tanks being subject to further examination at Annual Surveys, in accordance with 2.2.28. For independent double bottom ballast tanks, the examination at Annual Surveys will be at the discretion of the Surveyor.

9.6.5 The minimum requirements for Close-up Survey are given in Table 3.9.1.

9.7 Special Survey I (ships five years old) – General requirements

9.7.1 The requirements of 9.1 to 9.6 are to be complied with.

9.7.2 The requirements for Close-up Survey and thickness measurement are given in 9.12 and 9.13.

9.7.3 All cargo tanks are to be examined internally, also externally so far as practicable, particular attention being paid to the plating in way of supports of securing arrangements, tower structures, seatings and pipe connections, also to sealing arrangements in way of the deck penetrations. Provided that the structural examination is satisfactory, that the gas leakage monitoring systems have been found to be operating satisfactorily and that the voyage records have not shown any abnormal operation, cargo tanks do not require to be hydraulically tested. The primary membranes of 'Gas Transport' design should be examined with the primary insulation space under a vacuum of at least -500 mbar gauge. For 'Moss Type' LNG cargo tanks, the Structural Transition Joints (STJ) are to be examined at the port, starboard, forward and aft locations. Insulation is to be removed as required. Non-destructive testing may be required where considered necessary.
For membrane containment systems with corrugated primary barriers, in view of the sloshing loads experienced in service, measurements should be taken inside the cargo tanks of deformations of the primary barrier corrugations in order to assess the condition of the containment system in accordance with the system designer's procedures as approved by LR.

Table 3.9.1 Ships for liquefied gases – Intermediate Surveys

Ships between 10 and 15 years old	Ships greater than 15 years old
(1) Close-up survey of all web frames and both transverse bulkheads in a representative ballast tank, *see* Note 2 and 3. (2) Close-up survey of the upper part of one web frame in one other representative ballast tank. (3) Close-up survey of one transverse bulkhead in one other representative ballast tank, *see* Note 3.	(1) Close-up survey of all web frames and both transverse bulkheads in a two representative ballast tanks, see Notes 2 and 3.

NOTES
1. Ballast tanks include topside, double hull side, double bottom, hopper side, or any combined arrangement of the aforementioned, and peak tanks where fitted.
2. Complete transverse web frame including adjacent structural members.
3. Transverse bulkhead complete, including girder system and adjacent structural members and adjacent longitudinal bulkhead structure.
4. For areas in tanks where coatings are found to be in GOOD condition, as defined in 1.5, the extent of Close-up Survey may be specially considered.
5. The Surveyor may extend the Close-up Survey, if deemed necessary, taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system, the structural arrangements or details which have suffered defects in similar spaces or on similar ships and tanks having structures approved with reduced scantlings.
6. For ships having independent cargo tanks of Type C, with a midship section similar to that of a general cargo ship, the extent of Close-up Survey may be specially considered.

9.7.4 The non-destructive testing of cargo tanks is to be carried out as follows:

(a) Non-destructive testing is to supplement cargo tank inspection with special attention to be given to the integrity of the main structural members, tank shell and highly stressed parts, including welded connections as deemed necessary by the Surveyor. The following items are, inter alia, considered as highly stressed parts:
    (i) Cargo tanks supports and anti-rolling/anti-pitching devices;
    (ii) Web frames or stiffening rings;
    (iii) Swash bulkhead boundaries;
    (iv) Dome and stump connections to tank shell;
    (v) Foundations for pumps, towers, ladders, etc.;
    (vi) Pipe connections.

(b) For independent tanks of Type B, the extent of non-destructive testing shall be as given in the programme specially prepared for the cargo tank design.

(c) Independent cargo tanks of Type C are to be subjected to non-destructive testing of the plating in way of supports and also at selected lengths of welds. Where such testing raises doubt as to the structural integrity, a hydraulic test should be carried out at 1,25 times the approved maximum vapour pressure. Alternatively, consideration will be given to pneumatic testing under special circumstances, provided full details are submitted for approval.

(d) At each alternate Special Survey (i.e., SSII, SSIV and so on), all independent cargo tanks of Type C are to be either:
    (i) Hydraulically or hydro-pneumatically tested to 1,25 times MARVS, followed by non-destructive testing in accordance with paragraph (a) above, or,
    (ii) Subjected to a thorough, planned, non-destructive testing. This testing is to becarried out in accordance with a programme specially prepared for the tank design. If a special programme does not exist, the following applies:
    - cargo tank supports and anti-rolling/anti-pitching devices;
    - stiffening rings;
    - Y-connections between tank shell and a longitudinal bulkhead of bi-lobe tanks;
    - swash bulkhead boundaries;
    - dome and sump connections to the tank shell;
    - foundations for pumps, towers, ladders etc.;
    - pipe connections.

At least 10 per cent of the length of the welded connections in each of the above mentioned areas is to be tested. This testing is to be carried out internally and externally as applicable. Insulation is to be removed as necessary for the required non-destructive testing.

9.7.5 Deck mounted cargo storage tanks are to be examined in the same manner as main cargo tanks.

9.7.6 For membrane containment systems, a tightness test of the primary and secondary barrier shall be carried out in accordance with the system designer's procedures and acceptance criteria as approved by LR. Low differential pressure tests may be used for monitoring the cargo containment system performance, but are not considered an acceptable test for the tightness of the secondary barrier. For membrane containment systems with glued secondary barriers, if the designer's threshold values are exceeded, an investigation is to be undertaken and additional testing such as thermographic or acoustic emissions testing should be carried out.

9.7.7 Where a cargo tank or the hull structure is insulated and the insulation is accessible, the insulation should be examined externally, together with any vapour or protective barrier, and sections removed for examination, if considered necessary by the Surveyor. Special attention should be given to insulation in way of chocks, supports and keys. Portions of the insulation are also to be removed, if required by the Surveyor, to enable the condition of the plating to be ascertained. Where the insulation is not accessible, *see* 9.5.1.

9.7.8 Cargo tank internal pipes and fittings are to be examined, and all valves and cocks in direct communication with the interiors of the tanks are to be opened out for inspection and the connection pipes are to be examined internally, so far as practicable.

9.7.9 Relief valves are to be surveyed as follows:

(a) The pressure relief valves for the cargo tanks are to be opened for examination, adjusted, function tested, and sealed. If the cargo tanks are equipped with relief valves with non-metallic membranes in the main or pilot valves, such non-metallic membranes are to be replaced.

(b) Pressure relief valves are subsequently to be adjusted to lift at a pressure in accordance with 9.6.2(d). Relief valve harbour settings are to be checked, if applicable. Valves may be removed from the shell for the purpose of making this adjustment under pressure of air or other suitable gas.

(c) Where a proper record of continuous overhaul and retesting of individually identifiable relief valves is maintained, consideration will be given to acceptance on the basis of opening, internal examination, and testing of a representative sampling of valves, including each size and type of liquefied gas or vapour relief valve in use, provided there is logbook evidence that the remaining valves have been overhauled and tested since crediting of the previous Special Survey.

(d) Relief valves on cargo gas and liquid pipelines are to have their pressure settings checked. The valves may be removed from the pipelines for this purpose. At the Surveyor's discretion a sample of each size and type of valve may be opened for examination and testing.

9.7.10 All cargo pumps, cargo booster pumps and cargo vapour pumps are to be opened out for examination. If requested by the Owner, these items may be examined on a Continuous Survey basis, provided the interval between examination of each item does not exceed five years. Pumping systems for inter-barrier spaces are to be checked and verified to be in good working order.

9.7.11 Piping for cargo and process systems including valves, actuators and compensators are to be opened for examination. Insulation may need to be removed, as deemed necessary, to ascertain the condition of the piping. If any doubt exists regarding the integrity of the piping based upon visual examination then, where deemed necessary by the Surveyor, a pressure test at 1,25 times MARVS for the pipeline is to be carried out. The complete piping systems are to be tested for leaks after re-assembly.

9.7.12 Equipment for the production of inert gas is to be examined and shown to be operating satisfactorily within the gas specification limits. Pipelines, valves, etc., for the distribution of the inert gas are to be generally examined. Pressure vessels for the storage of inert gas are to be examined internally and externally and the securing arrangements are to be specially examined. Pressure relief valves are to be demonstrated to be in good working order. Liquid nitrogen storage vessels are to be examined, so far as practicable, and all control equipment, alarms and safety devices are to be verified as operational.

9.7.13 Gastight bulkhead shaft seals are to be opened out so that the sealing arrangements may be checked.

9.7.14 Sea connections associated with the cargo handling equipment are to be opened out when the ship is in dry-dock.

9.7.15 The arrangements for discharging the cargo overboard in an emergency are to be checked.

9.8 Special Survey I (ships five years old) – Reliquefaction/refrigeration equipment

9.8.1 Each reciprocating compressor is to be opened out. Cylinder bores, pistons, piston rods, connecting rods, valves and seats, glands, relief devices, suction filters and lubricating arrangements are to be examined. Crankshafts are to be examined, but crankcase glands and the lower half of main bearings need not be exposed if the Surveyor is satisfied with the alignment and wear.

9.8.2 Where other than reciprocating-type compressors are fitted, or where there is a program of replacement instead of surveys on board, alternative survey arrangements will be considered. Each case will be given individual consideration.

9.8.3 The water end covers of condensers are to be removed for examination of the tubes, tubeplates and covers.

9.8.4 Refrigerant condenser cooling water pumps, including standby pump(s) which may be used on other services, are to be opened out for examination.

9.8.5 Where a pressure vessel is insulated, sufficient insulation is to be removed, especially in way of connections and supports, to enable the vessel's condition to be ascertained.

9.8.6 Insulated pipes are to have sufficient insulation removed to enable their condition to be ascertained. Vapour seals are to be specially examined for their condition.

9.8.7 The Surveyor is to satisfy himself that all pressure relief valves and/or safety discs throughout the system are in good order. No attempt, however, is to be made to test primary refrigerant pressure relief valves on board ship.

9.8.8 The items covered by 9.8.1 to 9.8.4 may, at the request of the Owner, be examined on a Continuous Survey basis provided the interval between examination of each item does not exceed five years.

9.9 Special Survey I (ships five years old) – Methane burning equipment

9.9.1 Where methane is used as fuel for main propulsion purposes, the associated compressors and heat exchangers are to be opened out and examined as for reliquefaction/refrigeration equipment. The steam side of steam heaters is to be hydraulically tested to 1,5 times the design pressure.

9.9.2 Methane gas pipe trunks or casings are to be generally examined and the exhaust or inerting arrangements for these trunks are to be verified.

9.9.3 All alarms associated with the methane burning systems are to be verified.

9.10 Special Survey II and Special Surveys thereafter (ships 10 years old and over)

9.10.1 The requirements of 9.1 to 9.9 are to be complied with.

9.10.2 Water cooled condensers in which the primary refrigerant is in contact with the shell are to have the end covers removed and the shell pneumatically tested to a pressure equal to the designed working pressure.

9.10.3 All other pressure vessels in the reliquefaction/ refrigeration system, methane burning system and other handling systems are to be pneumatically tested to a pressure equal to the designed working pressure.

9.10.4 The requirements for Close-up Survey and thickness measurement are given in 9.12 and 9.13.

9.11 Special Survey III and Special Surveys thereafter (ships 15 years old and over)

9.11.1 The requirements of 9.1 to 9.10 are to be complied with.

9.11.2 For independent tanks of Type B, the Owner is to submit proposals for the extent of non-destructive testing of the cargo tanks well in advance of the Special Survey.

9.12 Close-up Survey

9.12.1 The minimum requirements for Close-up Survey are given in Table 3.9.2.

9.12.2 The Surveyor may extend the Close-up Survey, if deemed necessary, taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system and the structural arrangements or details which have suffered defects in similar spaces or on similar ships and tanks having structures approved with reduced scantlings.

9.12.3 For areas in tanks where coatings are found to be in GOOD condition, as defined in 1.5, the extent of Close-up Survey may be specially considered.

9.13 Thickness measurement

9.13.1 The minimum requirements for thickness measurement are given in Table 3.9.3.

9.13.2 In areas where substantial corrosion, as defined in 1.5, has been noted, then additional measurements are to be carried out in accordance with Table 3.9.4 to determine the full extent of the corrosion pattern. The survey will not be considered complete until these additional thickness measurements have been carried out.

Table 3.9.2 Close-up Survey – Ships for liquified gases

Special Survey I (Ships 5 years old)	Special Survey II (Ships 10 years old)	Special Survey III (Ships 15 years old)	Special Survey IV (Ships 20 years old and over)
(1) One web frame in: (a) a topside ballast tank (b) a hopper side ballast tank (c) a double hull side ballast tank *See* Note 2. (2) One transverse bulkhead in a ballast tank, *see* Note 4.	(1) All web frames in either a topside ballast tank or a double hull side ballast tank, *see* Notes 2 and 5. (2) One web frame in each remaining ballast tank, see Note 2. (3) One transverse bulkhead in each ballast tank, *see* Note 3.	(1) All web frames in all ballast tanks, *see* Note 2. (2) All transverse bulkheads in all ballast tanks, *see* Note 3.	(1) All web frames in all ballast tanks, *see* Note 2. (2) All transverse bulkheads in all ballast tanks, *see* Note 3.

NOTES
1. Ballast tanks include topside, double hull side, double bottom, hopper side, or any combined arrangement of the aforementioned, and peak tanks where fitted.
2. Complete transverse web frame ring including adjacent structural members.
3. Transverse bulkhead complete, including girder system and adjacent structural members and adjacent longitudinal bulkhead structure.
4. Transverse bulkhead lower part including girder system and adjacent structural members.
5. If topside tanks and double hull side tanks are not fitted, then another ballast tank is to be selected.
6. For ships having independent cargo tanks of Type C, with a midship section similar to that of a general cargo ship, the extent of Close-up Survey may be specially considered.

Table 3.9.3 Thickness measurement – Ships for liquefied gases

<table>
<tr><th>Special Survey I
(Ships 5 years old)</th><th>Special Survey III
(Ships 15 years old)</th><th>Special Survey IV and subsequent
(Ships 20 years old and over)</th></tr>
<tr><td>(1) 1 section of deck plating for the full beam of the ship within 0,5L amidships in way of a ballast tank, if any
(2) Measurements for general assessment and recording of corrosion pattern of the structural members subject to close-up survey in accordance with Table 3.9.2
(3) Critical areas, as required by the Surveyor</td>
<td rowspan="3">(1) Within the cargo area:
(a) Each deck plate
(b) 2 transverse sections
(2) Measurements for general assessment and recording of corrosion pattern of the structural members subject to Close-up Survey in accordance with Table 3.9.2
(3) Selected wind and water strakes outside the cargo area
(4) All wind and water strakes within the cargo area
(5) All transverse webs with associated plating and longitudinals, and the transverse bulkhead complete in the fore peak tank and aft peak tank, see Notes 1 and 4
(6) Critical areas, as required by the Surveyor</td>
<td rowspan="3">(1) Within the cargo area:
(a) Each deck plate
(b) 3 transverse sections
(c) Each bottom plate
(d) Duct keel plating and internals
(2) Measurements for general assessment and recording of corrosion pattern of the structural members subject to Close-up Survey in accordance with Table 3.9.2
(3) All wind and water strakes over the full length of the ship, port and starboard
(4) Remaining exposed main deck plating not considered in item (1) and representative exposed superstructure deck plating (i.e., poop, bridge and forecastle deck)
(5) All transverse webs with associated plating and longitudinals, and the transverse bulkhead complete in the fore peak tank and aft peak tank, see Notes 1 and 4
(6) All keel plates outside the cargo tank length. Also additional bottom plates in way of cofferdams, machinery space and aft end of tanks
(7) Plating of seachests. Also side shell plating in way of overboard discharges, as considered necessary by the Surveyor
(8) Critical areas, as required by the Surveyor</td></tr>
<tr><th>Special Survey II
(Ships 10 years old)</th></tr>
<tr><td>(1) Within the cargo area:
(a) Each deck plate
(b) 1 transverse section
(2) Measurements for general assessment and recording of corrosion pattern of the structural members subject to Close-up Survey in accordance with Table 3.9.2
(3) Selected wind and water strakes outside the cargo area
(4) Critical areas, as required by the Surveyor</td></tr>
<tr><td colspan="3">NOTES
1. For areas in tanks where coatings are found to be in GOOD condition, as defined in 1.5, the extent of thickness measurements may be specially considered, but not dispensed with in its entirety.
2. Transverse sections should be chosen where the largest reductions are likely to occur, or as revealed by deck plating measurements.
3. Where two or three transverse sections are required to be measured, at least one is to include a ballast tank within 0,5L amidships.
4. Transverse bulkhead complete including stiffening system.
5. Where considered necessary by the Surveyor, the inner bottom plating and adjacent tank supports are to be subject to thickness measurement for general assessment and recording of the corrosion pattern.
6. For those ships designated to carry light oils in the independent cargo tanks, thickness measurement of the independent cargo tank structure is to be carried out as considered necessary by the Surveyor.</td></tr>
</table>

Table 3.9.4 Thickness measurement – Ships for liquefied gases – Structural areas with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
Plating	Suspect area and adjacent plates	5 point pattern over 1 m^2 of plating
Stiffeners	Suspect area	3 measurements each in line across web and flange

Section 10
Dredgers, hopper dredgers, sand carriers, hopper barges and reclamation craft

10.1 General

10.1.1 The requirements of this Section are to be complied with, as applicable, in addition to the survey requirements of Sections 2, 3, 4 and 5. Where surveys are required on dredging or hopper equipment such as gantries, bottom doors and their operating gear, positioning spuds and suction pipe attachments or split hull devices such as actuating and locking devices, these will be limited to the extent considered necessary by the Surveyor to satisfy himself that their condition or malfunction will not adversely affect the ship's structure.

10.1.2 Where applicable, the Docking Survey is to include the examination of hopper doors and their fittings, and of hopper valves.

10.2 Special Surveys

10.2.1 On ships up to 10 years old (Special Survey I and II):
(a) Hoppers are to be cleared and cleaned as necessary and examined.
(b) Where applicable, hopper doors or valves are to be opened and closed, so far as practicable, but keel blocks need not normally be moved specially to permit this to be done.
(c) The integrity of hopper overflows and diluting water inlet and distribution structures is to be confirmed. Weir valves and sluices are to be tested to ensure proper operation, particular attention being paid to the lower weir when weirs are fitted at more than one level.
(d) Attention is to be given to shell plating in way of hopper overflows.
(e) The attachment to the ship's structure of all main items of dredging equipment, including gantries, 'A' frames, spud control gear supports and items provided to facilitate separation of split hulls including hinge pin gudgeons, anchorages for rams and locking devices, is to be carefully examined to ensure that no fracture is present.

10.2.2 On ships 15 years old and over (Special Survey III and subsequent Special Surveys):
(a) Attention is to be given by the Surveyor to the structure in way of dredging pumps.
(b) Hopper doors, valves and items provided to facilitate separation of split hulls are to be checked for proper operation, and their hinges, control gear and other fittings are to be examined for wear or distortion. All seals and weardown strips are to be replaced if necessary, but a watertight seal is not normally required. Attention is to be paid to areas likely to be suffering from excessive erosion.
(c) Those items of dredging gear and equipment whose efficiency is not part of classification but whose failure or malfunctioning is, nevertheless, likely to adversely affect the ship's structure, are to be examined to ensure that the structural integrity of the ship is maintained.

Section 11
Machinery surveys – General requirements

11.1 Annual, Intermediate and Docking Surveys

11.1.1 For Annual, Intermediate and Docking Surveys, *see* Sections 2, 3 and 4.

11.1.2 For ships assigned the notation 'laid-up', a general examination of the machinery is to be carried out in lieu of the normal Annual Survey requirements.

11.2 Complete Surveys

11.2.1 While the ship is in dry-dock, all openings to the sea in the machinery spaces and pump-rooms, together with the valves, cocks and the fastenings with which these are connected to the hull, are to be examined.

11.2.2 All shafts (except screwshafts and tube shafts, for which special arrangements are detailed in Section 17), thrust block and all bearings are to be examined. The lower halves of bearings need not be exposed if alignment and wear are found to be acceptable.

11.2.3 An examination is to be made of all reduction gears complete with all wheels, pinions, shafts, bearings and gear teeth, thrust bearings and incorporated clutch arrangements.

11.2.4 The following auxiliaries and components are also to be examined:
(a) Auxiliary engines, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services.
(b) Steering machinery.
(c) Windlass and associated driving equipment, where fitted.
(d) Evaporators (other than those of vacuum type) and their safety valves, which should be seen in operation under steam.
(e) The holding down bolts and chocks of main and auxiliary engines, gearcases, thrust blocks and intermediate shaft bearings.

11.2.5 All air receivers for essential services, together with their mountings, valves and safety devices, are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to 1,3 times the working pressure.

11.2.6 The valves, cocks and strainers of the bilge system, including bilge injection, are to be opened up as considered necessary by the Surveyor and, together with pipes, are to be examined and tested under working conditions. The oil fuel, feed, lubricating oil and cooling water systems, as well as the ballast connections and blanking arrangements to deep tanks which may carry liquid or dry cargoes, together with all

pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested, as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

11.2.7 Water ingress detection arrangements fitted on single hold cargo ships having length less than 80 m and bulk carriers and flooding detection systems fitted on passenger ships are to be tested to demonstrate that they are in good working order. Alternatively, this testing may be conducted during the required ull Special Survey space examinations, *see also* 5.3.

11.2.8 Fuel tanks which do not form part of the ship's structure are to be examined and, if considered necessary by the Surveyor, they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally at the first survey if they are found satisfactory on external inspection. The mountings, fittings and remote controls of all oil fuel tanks are to be examined, so far as practicable.

11.2.9 Where remote and/or automatic controls are fitted for essential machinery, they are to be tested to demonstrate that they are in good working order.

11.2.10 For ships fitted with a dynamic positioning system, the control system and associated machinery items are to be examined and tested under operating conditions to an approved Test Schedule.

11.2.11 In addition to the above, detailed requirements for steam and gas turbines and steam engines, oil engines, electrical installations and boilers are given in Sections 12, 13, 14 and 15 respectively. In certain instances, upon application by the Owner or where indicated by the maker's servicing recommendations, the Committee will give consideration to the circumstances where deviation from these detailed requirements is warranted, taking account of design, appropriate indicating equipment (e.g., vibration indicators) and operational records.

■ *Section 12*
Turbines and steam engines – Detailed requirements

12.1 Complete Surveys

12.1.1 The requirements of Section 11 are to be complied with.

12.1.2 The working parts of the main engine and attached pumps, and of auxiliary machinery used for essential services, are to be opened out and examined, including:

(a) For reciprocating engines:
- Bulkhead stop valves and manoeuvring valves.
- Cylinders.
- Pistons, piston rods, connecting rods, crossheads and guides.
- Valves and valve gear.
- Crankshaft.

(b) For turbine machinery:
- Blading and rotors.
- Flexible couplings.
- Casings.

12.1.3 In gas turbines and free piston gas generators, the following parts are also to be opened out and examined:
- Impellers or blading.
- Rotors and casings of the air compressors.
- Combustion chambers and burners.
- Intercoolers and heat exchangers.
- Gas and air piping, and fittings.
- Starting and reversing arrangements.

12.1.4 Where gas turbines operate in conjunction with free piston gas generators, the following parts of the latter are to be opened out and examined:
- Gas and air compressor cylinders and pistons.
- Compressor end covers.
- Valves and valve gear.
- Fuel pumps and fittings.
- Synchronising and control gear.
- Cooling system.
- Explosion relief devices.
- Gas and air piping.
- Receivers and valves, including by-pass arrangements.

12.1.5 Condensers, steam reheaters, desuperheaters which are not incorporated in the boilers, and any other appliances used for essential services, are to be examined to the satisfaction of the Surveyor and, if it is considered necessary, they are to be tested.

12.1.6 The manoeuvring of the engines is to be tested under working conditions.

12.1.7 Exhaust steam turbines supplying power for main propulsion purposes in conjunction with reciprocating engines together with their gearing and appliances, steam compressors or electrical machinery, are to be examined, so far as practicable. Where cone connections to internal gear shafts are fitted, the coned ends are to be examined, so far as practicable.

12.1.8 In ships having essential auxiliary machinery driven by oil engines, the prime movers of these auxiliaries are to be examined as detailed in Section 13.

■ *Section 13*
Oil engines – Detailed requirements

13.1 Complete Surveys

13.1.1 The requirements of Section 11 are to be complied with.

13.1.2 The following parts are to be opened out and examined:

- Cylinders and covers.
- Pistons, piston rods, connecting rods, crossheads and guides.
- Valves and valve gear.
- Crankshafts and all bearings.
- Crankcases, bedplates and entablatures.
- Crankcase door fastenings, explosion relief devices and scavenge relief devices.
- Scavenge pumps, scavenge blowers, superchargers and their associated coolers.
- Air compressors and their intercoolers.
- Filters and/or separators and safety devices.
- Fuel pumps and fittings.
- Camshaft drives and balancer units.
- Vibration dampers or detuners.
- Flexible couplings and clutches.
- Reverse gears.
- Attached pumps and cooling arrangements.

13.1.3 Selected pipes in the starting air system are to be removed for internal examination and are to be hammer tested. If any appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming out, or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors.

13.1.4 The electric ignition system, if fitted, is to be examined and tested.

13.1.5 The manoeuvring of engines is to be tested under working conditions. Initial starting arrangements are to be tested.

13.1.6 Where steam is used for essential purposes, the condensing plant, feed pumps and oil fuel burning plant are to be examined and the steam pipes examined and tested as detailed in Section 16.

■ *Section 14* Electrical equipment

14.1 Annual and Intermediate Surveys

14.1.1 The electrical contacts of air circuit-breakers are to be visually inspected and maintained in accordance with the manufacturer's recommendations by suitably qualified and trained personnel. Appropriate maintenance records are to be made available to the attending Surveyor on request.

14.1.2 The requirements of 2.2 and 3.2 are to be complied with as far as applicable.

14.2 Complete Surveys

14.2.1 An electrical insulation resistance test is to be made on the electrical equipment and cables. The installation may be sub-divided, or equipment which may be damaged disconnected, for the purpose of this test.

14.2.2 The fittings on the main and emergency switchboard, section boards and distribution boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

14.2.3 Generator circuit-breakers are to be tested, so far as practicable, to verify that protective devices including preference tripping relays, if fitted, operate satisfactorily.

14.2.4 Air circuit-breakers for essential or emergency services and rated at 800 A and above are to be surveyed to ensure that the manufacturer's recommended number of switching options has not been exceeded. *See* Pt 6, Ch 2,7.3.6. Where a breaker is not fitted with an automatic counter, a written record is to be kept.

14.2.5 The electric cables are to be examined, so far as practicable, without undue disturbance of fixtures or casings, unless opening up is considered necessary as a result of observation or of the tests required by 14.2.1.

14.2.6 The generator prime movers are to be surveyed as required by Sections 12 and 13 and the governing of the engines tested. The motors concerned with essential services together with associated control and switch gear are to be examined and, if considered necessary, are to be operated, so far as practicable, under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.

14.2.7 Where transformers associated with supplies to essential services are liquid-immersed, the Owner is to arrange for samples of the liquid to be taken and tested for dissolved gases, breakdown voltage, acidity and moisture by a competent testing authority, in accordance with the equipment manufacturer's requirements, and a certificate giving the test results is to be made available to the Surveyor on request.

14.2.8 Navigation light indicators are to be tried under working conditions, and correct operation on the failure of supply or failure of navigation lights is to be verified.

14.2.9 The emergency sources of electrical power, their automatic arrangements and associated circuits are to be tested.

14.2.10 Emergency lighting, transitional emergency lighting, supplementary emergency lighting, general emergency alarm and public address systems are to be tested as far as practicable.

14.2.11 Where the ship is electrically propelled, the propulsion motors, generators, propulsion transformers, propulsion conversion equipment, cables, harmonic filters, neutral earthing resistors, dynamic braking resistors and all ancillary electrical equipment that forms part of the propulsion drive and control system, exciters and ventilating plant

(including coolers) associated therewith are to be surveyed, and the insulation resistance to earth is to be tested. Special attention is to be given to windings, commutators and slip-rings. Where practicable, the low voltage and high voltage windings of cast resin propulsion transformers are to be subjected to boroscopic inspection, to assess the physical condition of their insulation and for signs of mechanical and thermal damage. The operation of protective gear and alarm devices is to be checked, so far as practicable. Insulating oil, if used, is to be tested in accordance with 14.2.7. Interlocks intended to prevent unsafe operations or unauthorised access are to be checked to verify that they are functioning correctly. Emergency overspeed governors are to be tested.

14.2.12 A General Examination of the electrical equipment in areas which may contain flammable gas or vapour and/or combustible dust is to be made to ensure that the integrity of the safe-type electrical equipment has not been impaired owing to corrosion, missing bolts, etc., and that there is not an excessive build-up of dust on or in dust protected electrical equipment. Cable runs are to be examined for sheath and armouring defects, where practicable, and to ensure that the means of supporting the cables are in good order. Tests are to be carried out to demonstrate the effectiveness of bonding straps for the control of static electricity. Alarms and interlocks associated with pressurised equipment or spaces are to be tested for correct operation.

14.2.13 For ships having an **OPS** notation assigned, the on-shore power supply arrangements are to be examined and functionally tested whilst connected to an external electrical power supply in accordance with approved test schedules (*see* Pt 7, Ch 13) during the Complete Surveys of machinery or, where it is not practical to provide the facilities and operations for testing during the required Surveys of other machinery items, within 12 months of the due date of the Complete Surveys of machinery.

14.3 Docking Surveys

14.3.1 For tankers five years old and over, 14.2.12 is to be complied with. In addition, an electrical insulation resistance test of the circuits terminating in, or passing through, the hazardous zones and spaces is to be carried out.

■ *Section 15* **Boilers**

15.1 Frequency of surveys

15.1.1 All boilers, economisers, steam receivers, steam heated steam generators, thermal oil and hot water units intended for essential services, together with boilers used exclusively for non-essential services having a working pressure exceeding 3,5 bar and a heating surface exceeding 4,5 m^2 are to be surveyed internally. There is to be a minimum of two internal examinations during each five-year Special Survey cycle. The interval between any two such examinations is not to exceed 36 months. A general external examination is to be carried out at the time of the Annual Survey.

15.1.2 Consideration may be given in exceptional circumstances to an extension of the internal examination of the boiler not exceeding three months beyond the due date. The extension may be granted after the following is satisfactorily carried out:

(a) External examination of the boiler
(b) Examination and operational test of the boiler safety valve relieving gear (easing gear)
(c) Operational tests of the boiler protective devices
(d) Review of the following records since the previous Boiler Survey:
- Operation
- Maintenance
- Repair history
- Feedwater chemistry

In this context 'exceptional circumstances' means unavailability of repair facilities, essential materials, equipment or spare parts, or delays incurred by action taken to avoid severe weather conditions.

15.1.3 An external survey of boilers including tests of safety and protective devices, and tests of safety valves using their relieving gear, is to be carried out annually within the range dates of the Annual Survey of the ship. For exhaust gas heated economisers, the safety valves are to be tested by the Chief Engineer at sea within the range dates of the Annual Survey. This test is to be recorded in the log book and reviewed by the attending Surveyor prior to crediting the Annual Survey.

15.2 Scope of surveys

15.2.1 At the surveys described in 15.1, the boilers, superheaters, economisers and air heaters are to be examined internally on the water-steam side and the fire side. Where considered necessary, the pressure parts are to be tested by hydraulic pressure and the thicknesses of plates and tubes and sises of stays are to be ascertained to determine a safe working pressure. The safety valves and principal mountings on boilers, superheaters and economisers are to be examined and opened up as necessary by the Surveyor. The adjustment of safety valves is to be verified during each boiler internal survey. Boiler safety valves and their relieving gear are to be examined and tested to verify their satisfactory operation. Safety valves are to be set under steam to a pressure not greater than the approved design pressures of the respective parts. As a working tolerance, the setting is acceptable, provided that the valves lift at not more than 103 per cent of the approved design pressure. However, for exhaust gas heated economisers, if steam cannot be raised in port, the safety valves may be set by the Chief Engineer at sea, and the results recorded in the log book and reviewed by the attending Surveyor. The following records since the previous Boiler Survey are to be reviewed as part of the survey:

- Operation
- Maintenance
- Repair history
- Feedwater chemistry.

The remaining mountings are to be examined externally and, if considered necessary by the Surveyor, are to be opened up for internal examination. Collision chocks, rolling stays and boiler stools are to be examined and maintained in an efficient condition.

15.2.2 In addition to the foregoing, in exhaust gas heated economisers of the shell type, all accessible welded joints are to be subjected to a visual examination in order to identify any evidence of cracking. Non-destructive testing may be required for this purpose and may be requested by the Surveyor.

15.2.3 In fired boilers employing forced circulation, the pumps used for this service are to be opened and examined at each Boiler Survey.

15.2.4 The oil fuel burning system is to be examined under working conditions and a General Examination made of fuel tank valves, pipes, deck control gear and oil discharge pipes between pumps and burners.

15.2.5 At each survey of a cylindrical boiler which is fitted with smoke tube superheaters, the saturated steam pipes are to be examined as detailed in Section 16.

15.2.6 At the annual General Examination referred to in 15.1.1 the requirements of 2.2.14 to 2.2.16 are to be complied with.

■ *Section 16*
Steam pipes

16.1 Frequency of surveys

16.1.1 Saturated steam pipes, as well as superheated steam pipes where the temperature of the steam at the superheater outlet is not over 450°C, are to be surveyed 10 years from the date of build (or installation) and thereafter at five-yearly intervals.

16.1.2 Superheated steam pipes where the temperature of the steam at the superheater outlet is over 450°C are to be surveyed five years from the date of build (or installation) and thereafter at five-yearly intervals.

16.1.3 At 10 years from the date of build (or installation) and thereafter at five-yearly intervals, all copper or copper alloy steam pipes over 76 mm external diameter supplying steam for essential services at sea, are to be hydraulically tested to twice the working pressure.

16.2 Scope of surveys

16.2.1 At each survey, a selected number of main steam pipes, also of auxiliary steam pipes, which:
(a) are over 76 mm external diameter,
(b) supply steam for essential services at sea, and
(c) have bolted joints,
are to be removed for internal examination and are to be hydraulically tested to 1,5 times the working pressure. If these selected pipes are found satisfactory in all respects, the remainder need not be tested. So far as practicable, the pipes are to be selected for examination and hydraulic test in rotation, so that in the course of surveys all sections of the pipeline will be tested.

16.2.2 Where main and/or auxiliary steam pipes of the category described in 16.2.1(a) and (b) have welded joints between the lengths of pipe and/or between pipes and valves, the lagging in way of the welds is to be removed, and the welds examined and, if considered necessary by the Surveyor, crack detected. Pipe ranges having welded joints are to be hydraulically tested to 1,5 times the working pressure. Where lengths having ordinary bolted joints are fitted in such pipe ranges and can be readily disconnected, they are to be removed for internal examination and hydraulically tested to 1,5 times the working pressure.

16.2.3 Where, on cylindrical boilers having smoke tube superheaters, the saturated steam pipes adjoining the saturated steam headers are situated partly in the boiler smoke boxes, all such pipes adjoining and cross-connecting these headers in the smoke boxes are, at the surveys required by 16.1, to be included in the pipes selected for examination and testing, as defined in 16.2.1. Where the saturated steam pipes inside the smoke boxes consist of steel castings of substantial construction, these requirements need only be applied to a sample casting. Where steel castings are not fitted, the Surveyor is to satisfy himself of the condition of the ends of the saturated steam pipes in the smoke boxes at each Boiler Survey and, if he considers it necessary, a sample pipe is to be removed for examination.

16.2.4 At the surveys specified in 16.1.3, any of the copper or copper alloy pipes, such as those having expansion or other bends, which may be subject to bending and/or vibration, as well as closing lengths adjacent to steam-driven machinery, are to be annealed before being tested.

16.2.5 Where it is inconvenient for the Owner to fulfil all the requirements of a Steam Pipe Survey at its due date, the Committee will be prepared to consider postponement of the survey, either wholly or in part.

■ *Section 17*
Screwshafts, tube shafts and propellers

17.1 Frequency of surveys

17.1.1 Shafts with keyed propeller attachments and fitted with continuous liners or approved oil glands, or made of approved corrosion resistant materials, are to be surveyed at intervals of five years when the keyway complies fully with the present Rules.

17.1.2 Shafts having keyless-type propeller attachments are to be surveyed at intervals of five years, provided that they are fitted with approved oil glands or are made of approved corrosion resistant materials.

17.1.3 Shafts having solid coupling flanges at the after end are to be surveyed at intervals of five years, provided that they are fitted with approved oil glands or are made of approved corrosion resistant materials.

17.1.4 All other shafts not covered by 17.1.1 to 17.1.3 are to be surveyed at intervals of 2 1/2 years.

17.1.5 Controllable pitch propellers for main propulsion purposes are to be surveyed at the same intervals as the screwshaft.

17.1.6 Directional propeller and podded propulsion units for main propulsion purposes are to be surveyed at intervals not exceeding five years.

17.1.7 Water jet units for main propulsion purposes are to be surveyed at intervals not exceeding five years, provided that the impeller shafts are made of approved corrosion resistant material or have approved equivalent arrangements.

17.1.8 Dynamic positioning and/or thruster-assisted mooring and athwartship thrust propellers and shaftings are to be surveyed at intervals not exceeding five years.

17.2 Normal surveys

17.2.1 All screwshafts are to be withdrawn for examination by LR's Surveyors at the intervals prescribed in 17.1.1 to 17.1.4. The after end of the cylindrical part of the shaft and forward one-third of the shaft cone, or fillet of the flange, are to be examined by a magnetic particle crack detection method. In the case of a keyed propeller attachment, at least the forward one-third of the shaft cone is to be examined with the key removed. Weardown is to be measured and the sterntube bearings, oil glands, propellers and fastenings are to be examined. Controllable pitch propellers, where fitted, are to be opened up and the working parts examined, together with the control gear.

17.2.2 Directional propeller and podded propulsion units, inclusive of the propellers, shafts, gearing, controlgear and the primary electrical components including any control and protection devices, are to be dismantled if considered necessary and generally examined as far as practicable.

17.2.3 Water jet units, including the impeller, casing, shaft, shaft seal, shaft bearing, inlet and outlet channels, steering nozzle, reversing arrangements, and controlgear are to be generally examined so far as practicable.

17.2.4 Dynamic positioning and/or thruster-assisted mooring and athwartship thrust propellers are to be generally examined so far as possible in dry dock and tested under working conditions afloat for satisfactory operation. All accessible parts, including sealing, locking and bearing faces, and any other moving parts are to be examined. Non-destructive examination is to be carried out as considered necessary by the Surveyor on blade/fin roots. Consideration may be given to condition monitoring schemes for determining the condition of the unit.

17.2.5 Podded propulsion unit screwshaft roller bearings are to be renewed when the calculated life at the maximum continuous rating no longer exceeds the survey interval. *See* Pt 5, Ch 9,6.3.7.

17.2.6 Stationary supporting structure and any erosion protection inserts or doublers are to be examined in way of any propulsion devices.

17.3 Screwshaft Condition Monitoring (SCM)

17.3.1 Where oil lubricated shafts with approved oil glands are fitted or where water lubricated sternbush bearings are fitted, and the Owner has complied with the requirements of 17.3.2 or 17.3.3, the ShipRight descriptive note **SCM** (Screwshaft Condition Monitoring) may be entered in column 6 of the *Register Book*.

17.3.2 Oil lubricated bearings:

(a) Lubricating oil analysis is to be carried out regularly at intervals not exceeding six months. The lubricating oil analysis documentation is to be available on board. Each analysis is to include the following minimum parameters:
   - water content,
   - chloride content,
   - bearing material and metal particles content,
   - oil ageing (resistance to oxidation).
(b) Oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube.
(c) Oil consumption is to be recorded.
(d) Bearing temperatures are to be recorded (two temperature sensors or other approved arrangements are to be provided).
(e) Facilities are to be provided for measurement of bearing weardown.
(f) Oil glands are to be capable of being replaced without withdrawal of the screwshaft.

17.3.3 Water lubricated bearings:

(a) A means of monitoring and recording variations in the flow rate of lubricating water using two independent sensors is to be provided.
(b) A means of monitoring and recording variation in the shaft power transmission is to be provided.
(c) A maximum permitted weardown of the sternbush is to be established and approved wear monitoring equipment is to be fitted. The weardown allowance is to include both the absolute maximum allowable weardown and the weardown at which it is recommended to carry out an inspection and maintenance. An alignment analysis considering both the newly installed clearance and the proposed absolute maximum allowable weardown, demonstrating that the system will operate satisfactorily within these two limits, is to be submitted and approved.
(d) For open loop systems the manufacturer is to submit information regarding the required standard of lubricating water filtration and lubricating water filters or separators are to be fitted which are able to achieve this requirement:

- The lubricating water supply is to be fitted with continuous water sediment measuring or turbidity monitoring equipment. The results are to be recorded and retained on board and made available to LR on request, alternatively, there is to be a LR approved extractive sampling and testing procedure with the records held on board and made available to LR on request.

Records of cleaning and replacement of lubrication filters/separators are to be maintained on board. The pumping and water filtration system is to be considered part of the continuous survey cycle and is to be subject to a Periodical Survey.

(e) Where a closed cycle water system is used, the pumping and water filtration systems are to be considered part of the continuous survey cycle and are to be subject to a Periodical Survey. Water analysis is to be carried out regularly at intervals not exceeding six months. Samples are to be taken under service conditions and are to be representative of the water circulating within the stern-tube. Analysis results are to be retained on board and made available to LR on request. The analysis is to include the following parameters:
   (i) Chloride content.
   (ii) Bearing material and metal particles content.

(f) The shaft is to either be constructed of corrosion resistant material or protected with a corrosion resistant protective liner or coating approved by LR. Where a protective liner or coating is used, this is to meet the requirements of Pt 5, Ch 6,3.9 and a means of assessing the condition of this liner is to be submitted and approved.

(g) Glands are to be capable of being replaced without withdrawal of the screwshaft.

(h) There is to be a shaft starting/clutch engagement block to inhibit starting the shaft until lubricating water flow has been established. This is to only act as a starting block; for lubricating water flow alarm *see* Table 3.17.1.

(j) Alternative arrangements are subject to specialconsieation.The means of monitoring and recording lubricating water flow and shaft power variation are to be submitted for approval.

Table 3.17.1 Alarm and safeguard for water lubricated bearings

Item	Alarm	Note
Lubricating water flow	Low	After the shaft start

17.3.4 For maintenance of the descriptive note **SCM**, the records of all data collected in 17.3.2 and 17.3.3 are to be retained on board and audited by LR annually.

17.3.5 Where the requirements for the descriptive note **SCM** have been complied with, the screwshaft need not be withdrawn at surveys as required by 17.2.1, provided all condition monitoring data are found to be within permissible limits and all exposed areas of the shaft are examined by a magnetic particle crack detection method or an alternative approved means for shafts with a protective liner or coating (17.3.3(f)). The remaining requirements of 17.2.1 are to be complied with. Where the Attending Surveyor considers that the data presented is not sufficient to determine the condition of the shaft, the shaft may be required to be withdrawn in accordance with 17.2.1. For water lubricated bearings, the screwshaft is to be withdrawn for examination, as 17.2.1, when the ship reaches 18 years from the date of build or the third Special Survey, whichever comes first.

17.4 Modified Survey

17.4.1 A Modified Survey may be accepted at alternate five-yearly surveys for shafts described in 17.1.1, provided that they are fitted with oil lubricated bearings and approved oil glands, and also for those in 17.1.2 and 17.1.3.

17.4.2 The Modified Survey is to consist of the partial withdrawal of the shaft, sufficient to ascertain the condition of the stern bearing and shaft in way. For keyless propellers or shafts with a solid flange connection to the propeller, a visual examination to confirm the good condition of the sealing arrangements is to be made. The oil glands are to be capable of being replaced without removal of the propeller. The forward bearing and all accessible parts, including the propeller connection to the shaft, are to be examined as far as possible. Wear down is to be measured and found satisfactory. Where a controllable pitch propeller is fitted, at least one of the blades is to be dismantled complete for examination of the working parts and the control gear.

17.4.3 For keyed propellers, the after end of the cylindrical part of the shaft and forward one-third of the shaft cone is to be examined by a magnetic particle crack detection method, for which dismantling of the propeller and removal of the key will be required.

17.4.4 Where the requirements for the descriptive note **SCM** have been complied with as described in 17.3.1 and all data are found to be within permissible limits, partial withdrawal of the shaft will not be required. Where doubt exists regarding any of the above findings, the shaft is to be withdrawn to permit an entire examination.

17.5 Partial Survey

17.5.1 For shafts where the Modified Survey is applicable, upon application by the Owner, the Committee will be prepared to give consideration to postponement of the survey for a maximum period of half the specified cycle provided a Partial Survey is held.

17.5.2 The Partial Survey is to consist of the propeller being backed off in any keyed shaft and the top half of the cone examined by an efficient crack detection method for which removal of the key will be required. On ships less than 15 years old, propellers with keyless connections to the screwshaft are not required to be backed off. Exposed areas of screwshaft, oil gland and seals are to be examined and dealt with as necessary. Weardown is to be measured recorded and reviewed at each screwshaft survey and found satisfactory. Propeller and fastenings are to be examined.

17.5.3 The Committee will be prepared to give consideration to the circumstances of any special case upon application by the Owner.

■ *Section 18* Inert gas systems

18.1 Frequency of surveys

18.1.1 Inert gas systems installed on board ships intended for the carriage of oil or liquid chemicals in bulk are to be surveyed annually in accordance with the requirements of 2.2.32. A Special Survey of the inert gas system, in accordance with the requirements of 18.2, is to be held at intervals not exceeding five years.

18.2 Scope of surveys

18.2.1 At each Special Survey of the inert gas system, the inert gas generator, scrubber and blower are to be opened out as considered necessary and examined. Gas distribution lines and shut-off valves, including soot blower interlocking devices are to be examined as considered necessary. The deck seal and non-return valve are to be examined. Cooling water systems including the effluent piping and overboard discharge from the scrubbers are to be examined. All automatic shut-down devices and alarms are to be tested. The complete installation is to be tested under working conditions on completion of survey.

18.2.2 When, at the request of an Owner, it has been agreed by the Committee that the Complete Survey of the inert gas systems may be carried out on the Continuous Survey basis, the various items of machinery are to be opened for survey in rotation, so far as practicable, to ensure that the interval between consecutive examinations of each item will not exceed five years. In general, approximately one-fifth of the machinery is to be examined each year.

18.2.3 If any examination during Continuous Survey reveals defects, further parts are to be opened up and examined as considered necessary by the Surveyors, and the defects are to be made good to their satisfaction.

18.2.4 *See* 9.7.11 for inert gas systems on ships for liquefied gases.

■ *Section 19* Classification of ships not built under survey

19.1 General

19.1.1 When classification is desired for a ship not built under the supervision of LR's Surveyors, application should be made to the Committee in writing.

19.1.2 Periodical Surveys of such ships, when classed, are subsequently to be held as in the case of ships built under survey.

19.1.3 Where classification is desired for a ship which is classed by another recognised Society, special consideration will be given to the scope of the survey.

19.2 Hull and equipment

19.2.1 Plans showing the main scantlings and arrangements of the actual ship, together with any proposed alterations, are to be submitted for approval. These should comprise plans of the midship section, longitudinal section and decks, and such other plans as may be requested. If plans cannot be obtained or prepared by the Owner, facilities are to be given for LR's Surveyor to obtain the necessary information from the ship.

19.2.2 Particulars of the process of manufacture and the testing of the material of construction are to be supplied.

19.2.3 In all cases, the full requirements of Sections 5, 6, 7, 8, 9 and 10 are to be carried out as applicable. Ships of recent construction will receive special consideration.

19.2.4 During the survey, the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements. For this purpose, and in order to ascertain the amount of any deterioration, parts of the structure will require to be gauged as necessary. Full particulars of the anchors, chain cables and equipment are to be submitted. For ships to which Pt 6, Ch 4 applies, fire protection, detection and extinction are to be in accordance with that Chapter. Loading instruments, where required, are to be in accordance with the Rules, *see* Pt 3, Ch 4,8 as applicable.

19.2.5 When the full survey requirements indicated in 19.2.3 and 19.2.4 cannot be completed at one time, the Committee may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merits of each particular case, which should be submitted for consideration.

19.3 Machinery

19.3.1 To facilitate the survey, plans of the following items (plans of piping are to be diagrammatic), together with the particulars of the materials used in the construction of the boilers, air receivers and important forgings, are to be furnished:

- General pumping arrangements, including air and sounding pipes (Shipbuilder's plan).
- Pumping arrangements at the forward and after ends of oil tankers and drainage of cofferdams and pump rooms.
- General arrangement of cargo piping in tanks and on deck of oil tankers.
- Piping arrangements for cargo oil (F.P. 60°C or above, closed cup test).
- Bilge, ballast and oil fuel pumping arrangements in the machinery space, including the capacities of the pumps on bilge service.
- Arrangement and dimensions of main steam pipes.

- Arrangement of oil fuel pipes and fittings at settling and service tanks.
- Arrangement of oil fuel piping in connection with oil burning installations.
- Oil fuel and cargo oil overflow systems, where these are fitted.
- Arrangement of boiler feed systems.
- Oil fuel settling, service and other oil fuel tanks not forming part of the ship's structure.
- Boilers, superheaters and economisers.
- Air receivers.
- Crank, thrust, intermediate and screw shafting.
- Clutch and reversing gear with methods of control.
- Reduction gearing.
- Propeller (including spare propeller if supplied).
- Electrical circuits.
- Arrangement of compressed air systems for main and auxiliary services.
- Arrangement of lubricating oil systems.
- Arrangement of flammable liquids used for power transmission, control and heating systems.
- Arrangement of cooling water systems for main and auxiliary services.
- General arrangement of cargo tank vents. The plan is to indicate the type and position of the vent outlets from any superstructure, erection, air intake, etc. Ventilation arrangements of cargo and/or ballast pump rooms and other enclosed spaces which contain cargo handling equipment.

19.3.2 Plans additional to those detailed in 19.3.1 are not to be submitted unless the machinery is of a novel or special character affecting classification.

19.3.3 Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted.

19.3.4 For new ships and ships which have been in service less than two years, calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration, as required for ships constructed under Special Survey. For older ships, the circumstances will be specially considered in relation to their service record and type of machinery installed. Where calculations are not submitted, the Committee may require that the machinery certificate be endorsed to this effect. When desired by the Owner, the calculations and investigation of the torsional vibration characteristics of the machinery may be carried out by LR upon special request.

19.3.5 The main and auxiliary machinery, feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys. Working pressures are to be determined from the actual scantlings in accordance with the Rules.

19.3.6 The screwshaft is to be drawn and examined.

19.3.7 The steam pipes are to be examined and tested as required by Section 16.

19.3.8 The bilge, ballast and oil fuel pumping arrangements are to be examined and amended, as necessary, to comply with the Rules.

19.3.9 Oil burning installations are to be examined as required at Complete Surveys and found, or modified, to comply with the requirements of the Rules; they are also to be tested under working conditions.

19.3.10 The electrical equipment is to be examined as required at Complete Surveys.

19.3.11 Where an inert gas system is fitted on ships intended for the carriage of oil in bulk having a flashpoint not exceeding 60°C, the requirements of Pt 5, Ch 15,7, apply.

19.3.12 The whole of the machinery, including essential controls, is to be tried under working conditions to the Surveyor's satisfaction.

19.3.13 First entry reports are to be prepared by the Surveyors.

19.4 Refrigerated cargoes

19.4.1 When classification is desired for an installation not constructed under the supervision of LR's Surveyors, application is to be made to the Committee in writing.

19.4.2 Full particulars and plans are to be forwarded for consideration, together with the particulars of the materials of the crankshafts, pressure vessels and pressure piping. The requirements of Pt 6, Ch 3,1 and Ch 3,4 are to be used for guidance in regard to the information required.

19.4.3 A special examination is to be made at least to the extent required for subsequent Special Surveys, *see* 20.3.

19.4.4 The thickness and material of the insulation, the particulars of the frames, beams, stiffeners and other steelwork within the insulation, the air coolers and/or chamber grid piping, the compressors, evaporators and condensers are to be verified so far as practicable.

19.4.5 The installation is to conform to the requirements of the relevant Sections of Pt 6, Ch 3.

19.4.6 Acceptance tests are to be carried out in accordance with the requirements of Pt 6, Ch 3,5.

■ *Section 20*
Refrigerated cargo installations

20.1 Annual Surveys

20.1.1 The Surveyors are to examine the machinery under working conditions as soon as practicable after a ship's arrival at a port of discharge before the cargo is unloaded. An examination of the refrigerated cargo installation log book (or other records) is to be made and any breakdowns or malfunctions of the plant during the previous twelve months are to be noted and reported to the Committee.

20.1.2 A General Examination of the refrigerating plant is to be carried out, and satisfactory operation of safety devices, controls and thermometry is to be verified. Insulated cargo spaces are to be inspected, and the condition of insulation, lining, scuppers, hatches, coolers, air ducting and air refreshing arrangements are to be checked. The Surveyors may request opening out of suspected items, or recommend repair or renewal of defective items, as a result of inspection.

20.1.3 A General Examination is to be made of electrical motors driving refrigerant compressors, pumps and fans, together with their control gear and cables. Random tests for insulation resistance are to be made on the cables, switchgear, motors, etc., and this resistance is to be not less than 1 MΩ between individual conductors and between those conductors and earth. The installation may be subdivided for the purpose of this test, and the Surveyor may at his discretion accept the results of tests carried out by a competent member of staff or contractor.

20.1.4 A survey book or other permanent record is to be kept on board the ship to show the date of examination of the various parts. This is to be available to the Surveyor at all times, and is to be signed by the Surveyor on the occasion of each survey.

20.2 Special Surveys

20.2.1 At the first Special Survey, the examinations outlined below are to be carried out. Where there is a programme of replacement instead of maintenance on board, alternative survey arrangements will be considered. Each case will be given individual consideration.

20.2.2 Detailed internal examination of each reciprocating compressor, opened up for inspection of cylinders, pistons, connection rods, valves, seats, glands, relief devices, filters, lubrication and crankshaft.

20.2.3 For screw-type compressors, the period before opening up may be extended to six years or 25 000 running hours, whichever is the earlier. Examination should be made of rotors, clearances, gearing, etc.

20.2.4 Refrigerant condenser cooling water pumps, including standby pump(s) which may be used on other services, are to be opened up and their working parts exposed.

20.2.5 Primary and secondary refrigerant pumps are to be opened up and their working parts exposed.

20.2.6 The water end covers of condensers are to be removed for examination of the tubes, tubeplates and covers.

20.2.7 In the case of pressure vessels covered by insulation, any evidence of dampness or deterioration of the insulation which could lead to external corrosion of the vessels or their connections is to be investigated.

20.2.8 Sufficient insulation is to be stripped from insulated pressure vessels to allow the condition of the vessels and their connections to be ascertained. Care is to be taken that in replacement of the insulation, the vapour sealing of the outer covering is made good.

20.2.9 Sufficient insulation is to be stripped from pipes carrying the refrigerant at various points of the system both outside and inside the insulated chambers to permit the condition of the pipes to be ascertained. Sections of piping exposed are to include locations where lengths of piping have been connected by screwed couplings or butt welding. Care is to be taken that when ungalvanised portions of the piping in way of joints have been exposed, they are to be suitably coated and taped, after pressure testing, to prevent corrosion. On replacement of the insulation, the vapour sealing of the outer covering is to be made good.

20.2.10 A General Examination is to be made of all pressure relief valves and/or safety discs throughout the refrigerating plant to ensure that they are in good order and covered by current certification. However, no attempt is to be made to test primary refrigerant pressure relief on board ship.Relief valves are to be removed, overhauled and recalibrated every five years or in accordance with the manufacturer's recommendations, whichever is sooner.

20.2.11 Sea connections to refrigerant condenser cooling water pumps are to be opened up on the occasion of the hull and/or main machinery Special Survey.

20.2.12 The electric motors driving refrigerant compressors, pumps and fans, together with their control gear and cables, are to have their insulation resistance tested and this is to be not less than 1 MΩ between individual conductors and between those conductors and earth. The installation may be subdivided to any desired extent by opening switches, removing fuses or disconnecting appliances for the purpose of this test.

20.2.13 All automatic controls, alarms and safety systems are to be tested and correct operation confirmed.

20.2.14 Sufficient air ducting and insulation lining is to be stripped from the cargo spaces or chamber's overhead and vertical surfaces to allow the condition of the insulation, insulation linings, grounds, supports, hangers and fixtures which support the insulation, grids, meat rails, etc., to be ascertained. Care is to be taken that on replacement, the ducts and linings are sealed against air blowing into the insulation, or against moisture ingress from refrigerated cell or space atmosphere.

20.2.15 Sufficient tank top insulation is to be stripped to allow the condition of the grounds and inner insulation lining to be ascertained.

20.2.16 Due consideration is to be given to the type of insulation used in the cargo spaces and chambers when determining the amount of insulation lining to be removed. Where organic foam insulants have been used, including panel systems or foamed *in situ*, or other insulants in slab form, the removal of panels or linings is to be at the Surveyor's discretion.

20.2.17 Under normal circumstances, the condition of the cargo space and chamber insulation, grounds, etc., can be ascertained when the Special Survey of the ship's steel structure is being held.

20.2.18 Arrangements made for defrosting air coolers, and for draining condensate from trays below coolers, are to be examined to ascertain that they are in working order. Trace heating elements around drain pipes should be specially examined.

20.2.19 Any air refreshing arrangements are to be examined.

20.3 Subsequent Special Survey

20.3.1 A subsequent Special Survey is to be held approximately five years from the date of the previous Special Survey. Where a Continuous Survey procedure has been agreed, the interval between consecutive examinations of each item should not exceed five years.

20.3.2 In addition to the requirements for the first Special Survey as detailed in 20.2 and 20.3.3 to 20.3.5 are to be complied with.

20.3.3 'Shell-and-tube' condensers and evaporators (secondary refrigerant coolers) in which the primary refrigerant is in the shell, are to have the shell pneumatically tested with the refrigerant, or air, or a mixture of inert gas and refrigerant (with the end covers removed) at pressures as stated in Pt 6, Ch 3,2.5.5.

20.3.4 Shell-and-tube evaporators (secondary refrigerant coolers) in which the secondary refrigerant is in the shell are to have the shell hydraulically tested (with the end covers removed) to 1,5 times the design pressure, but in no case less than 2,9 bar g. After refitting the end covers, the primary refrigerant side is to be pneumatically tested as stated in 20.3.3, and an examination made as far as practicable for gas leakage in the shell with the secondary refrigerant connection removed.

20.3.5 Heat exchangers used for cooling refrigerant liquid by the suction return gas to a compressor are not subject to internal corrosion, and would normally require to be specially examined internally only if leakage is suspected between high and low pressure sides. This type of heat exchanger, together with others using brine or water, are to be examined and tested at the discretion of the Surveyor according to the design of such equipment.

20.4 Loading Port Survey

20.4.1 When a Loading Port Certificate is required by the Owner or his representative, a survey as detailed in 20.4.2 to 20.4.7 is to be carried out at the loading port. The certificate is not in respect of the cargo to be loaded or the manner in which it is to be stowed.

20.4.2 The refrigerating installation is to be examined under working conditions, and the temperatures in the cargo chambers are to be noted.

20.4.3 A General Examination of the generating plant supplying electric power to the refrigerated cargo installation is to be carried out to confirm that it complies with Pt 6, Ch 3,6.1.

20.4.4 The refrigerated cargo spaces and chambers are to be examined in an empty state to ascertain that they are clean and free from odour which may adversely affect the cargo to be loaded, that the air cooler coils and cooling grids and their connections are free from leakage, that cargo battens, where fixed to the vertical surfaces, are in good order, that cargo gratings or dunnage battens (*see* Pt 6, Ch 3) are available as necessary for the floors or decks, and that no damage has been sustained to the insulation or its lining prior to the loading of the refrigerated cargo. Any indications of defective insulation not considered to warrant immediate attention are to be noted and specially reported.

20.4.5 All scuppers and bilge suctions draining insulated spaces are to be examined to ensure that they are in good working order, and that any liquid seals are primed.

20.4.6 If the ship loads at more than one port, one survey only at the first loading port will be required, provided that it includes the examination of all spaces or chambers which are to be used for refrigerated cargo during the voyage, and that general cargo is not subsequently carried in any of the spaces or chambers prior to loading the refrigerated cargo.

20.4.7 In the case of ships engaged on voyages of less than two months' duration, a Loading Port Certificate will be considered as valid for two months, provided that the cargoes carried are of such a nature as not to damage the insulation or appliances in the insulated chambers, nor to affect, by taint or mould, the refrigerated cargoes loaded during that period. For longer voyages, the certificate is valid for only one cargo from the loading port(s) to the discharge port(s).

20.4.8 If there is no LR Surveyor available at the loading port(s), or if none is obtainable from a port within a reasonable distance, the Committee will accept the report of a survey held at the loading port by two competent engineers of the ship.

20.5 Refrigerating plant on ships not classed with LR

20.5.1 In the case of refrigerating installations being constructed under Special Survey on ships not intended to be classed with LR, the installation is to comply with the applicable requirements of Pt 6, Ch 3.

20.5.2 The generator engines and electrical equipment, which supply power to the refrigerating installations are to be constructed in accordance with the requirements of the Classification Society concerned and the installation is also to comply with the requirements of Pt 6, Ch 3,6.1.2. Such a plant is to be examined generally and under working conditions by the Surveyors.

■ *Section 21* Controlled atmosphere systems

21.1 Retention of class

21.1.1 It is a prerequisite of the **CA** notation that the refrigeration installation on board already conforms to a ✠**Lloyd's RMC** notation, *see* Ch 2,2.6.1.

21.1.2 For the retention of Class, the CA systems are to be submitted for Periodical Surveys by LR's Surveyors as specified in 21.2 and 21.3.

21.2 Annual Surveys

21.2.1 Annual Surveys are to be carried out from the date of the Initial Classification Survey to verify that the CA system remains satisfactory.

21.2.2 The complete CA installation is to be visually examined and tested for the following main aspects:
(a) CA zone sealing arrangements including cleats and hinges, pressure/vacuum (P/V) valves, door locks, ventilation of adjacent spaces, warning notices.
(b) CA zones to be individually tested for airtightness to the design pressure. Testing by ship's staff, within one month prior to the survey may be accepted, based on a written report by the Master subject to visual inspection confirming the airtightness.
(c) Operation and performance testing of the gas supply equipment, including controls, alarms, interlocks, safety devices.
(d) Ventilation arrangements including fans.
(e) Electrical supply arrangements.
(f) Gas analysers and analysing equipment and calibration.
(g) RH sensors and calibrations.
(h) Permanent and portable gas monitoring, calibration and personnel safety equipment.
(j) Witnessing of the air leakage.
(k) Voyage logs, records of CA zone airtightness and calibration of instruments.
(l) Verification that an Operating and Safety Manual is on board, is complete and that the responsible officers have countersigned to confirm that they are familiar with its contents.

21.2.3 On satisfactory completion of this survey, a new Annual Survey 'AS', with date, will be assigned.

21.3 Special Surveys

21.3.1 Special Surveys are to be carried out at intervals of five years from the date of the Initial Classification Survey to verify that all machinery, CA zones and safety arrangements remain satisfactory. On request from Owners, all surveyable items may be examined on a continuous basis. With this option, 20 per cent of all items are to be presented for survey annually.

21.3.2 Each CA zone is to be subjected to an airtightness test.

21.3.3 The extent of dismantling is to be at the LR Surveyor's discretion, but is to be sufficient for the Surveyor to be satisfied as to the condition of the installation.

21.3.4 On satisfactory completion of this survey, a new Special Survey 'SS', or 'RMC CS' with date, will be assigned.

■ *Section 22* Bow, inner, side shell and stern doors on Ro-Ro ships

22.1 General

22.1.1 The requirements of Sections 2 to 5 are to be complied with, as applicable.

22.1.2 The requirements in this Section are applicable to the survey of bow, inner, side shell and stern doors on roll on-roll off passenger (Ro-Pax) ships and roll on-roll off (Ro-Ro) cargo ships.

22.1.3 Annual Survey and Special Survey of bow, inner, side shell and stern doors are to include examinations, tests and checks to a sufficient extent in order to verify that they are in satisfactory condition, remain in compliance with applicable requirements, and are subject to proper maintenance and operation in accordance with the Operation and Maintenance Manual (OMM) or manufacturer's recommendations.

22.2 Definitions

22.2.1 For the application of the requirements in this Section, a **Ro-Ro ship** is a ship that utilises a loading ramp to enable wheeled vehicles to be rolled on and rolled off the ship.

22.2.2 A **Ro-Pax ship** is a passenger ship with Ro-Ro spaces or special category spaces.

22.2.3 **Ro-Ro spaces** are those that extend over a substantial length or the entire length of the ship, and are not normally sub-divided. These spaces can be loaded and unloaded (normally in a horizontal direction) with motor vehicles with fuel in their tanks for their own propulsion and/or goods (either packaged or in bulk, in rail or road cars (including tankers), trailers, containers, pallets, demountable tanks or in other stowage units or receptacles).

22.2.4 **Special category spaces** are enclosed vehicle spaces (above or below the bulkhead deck) that vehicles can be driven on to and from, and that can be accessed by passengers. Special category spaces may be accommodated on more than one deck, provided that the total overall clear height for vehicles does not exceed 10 m.

22.2.5 **Securing devices** are used to keep the door closed by preventing it from rotating about its hinges.

22.2.6 **Supporting devices** are used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the ship's structure.

22.2.7 A **locking device** is used to lock a securing device in the closed position.

22.2.8 A **Close-up Survey** is defined in 1.5.

22.3 Annual Surveys

22.3.1 The survey is to consist of an examination to verify, as far as is practicable, that the bow, inner, side shell and stern doors are maintained in a satisfactory condition.

22.3.2 The Surveyor is to obtain confirmation that no unapproved changes have been made to the bow, inner, side shell and stern doors since the last survey.

22.3.3 Where applicable, Surveyors are to verify that the Operation and Maintenance Manual (OMM), including any revisions, is available on board. It is to be verified that documented operating procedures for closing and securing the doors are kept on board and posted at the appropriate place(s). The Surveyor is to apply particular attention to the register of inspections and its contents (contained within the OMM) as a basis for the survey.

22.3.4 An examination of the bow, inner, side shell and stern doors is to be carried out, with particular attention to be applied to the following:

(a) The structural arrangement of doors, including plating, secondary stiffeners, primary structure, hinging arms and weld connections;
(b) Shell structure surrounding the opening of the doors and the securing, supporting and locking devices, including shell plating, secondary stiffeners, primary structure and associated weld connections;
(c) Hinges and bearings, thrust bearings;
(d) Hull and door side supports for securing, supporting and locking devices.

NOTE
If a crack is identified, an examination by non-destructive testing is to be carried out in the surrounding area and for similar items, as considered necessary by the Surveyor.

22.3.5 A Close-up Survey of the securing, supporting and locking devices is to be carried out. As a minimum, the Close-up Survey is to include the following:

(a) Cylinder securing pins, supporting brackets, back-up brackets (where fitted) and their weld connections;
(b) Hinge pins, supporting brackets, back-up brackets (where fitted) and their weld connections;
(c) Locking hooks, securing pins, supporting brackets, back-up brackets (where fitted) and their weld connections;
(d) Locking pins, supporting brackets, back-up brackets (where fitted) and their weld connections;
(e) Locating and stopper devices and their weld connections.

22.3.6 The clearances of hinges, bearings and thrust bearings are to be measured where no dismantling is required. If the function test is not satisfactory, dismantling may be required to measure the clearances. If dismantling is carried out, a visual examination of hinge pins and bearings, together with non-destructive testing of the hinge pin, is to be carried out. The clearances of the securing, supporting and locking devices are to be measured, where indicated in the Operation and Maintenance Manual (OMM).

22.3.7 An examination of the sealing arrangements, including packing material/rubber gaskets, retaining bars or channels and associated weld connections, is to be carried out.

22.3.8 An examination of the drainage arrangements, including bilge wells and drain pipes, where fitted, is to be carried out. A test of the bilge system between the inner and outer doors is to be carried out.

22.3.9 A function test of doors is to be carried out. The Surveyor is to check the satisfactory operation of the bow, inner, side shell and stern doors during a complete opening and closing operation including, as applicable:

(a) Proper working of the hinging arms and hinges;
(b) Proper engagement of the thrust bearings;
(c) Device for locking the door in the open position;
(d) Securing, supporting and locking devices;
(e) Proper sequence of the interlock system for the opening/closing system and the securing and locking devices;
(f) Mechanical lock of the securing devices;
(g) Proper locking of hydraulic securing devices in the event of a loss of the hydraulic fluid, according to the procedure contained in the Operation and Maintenance Manual (OMM);
(h) Correct indication of open/closed position of doors and securing/locking devices at navigation bridge and other control stations;
(j) Isolation of the hydraulic securing/locking devices from other hydraulic systems;
(k) Confirmation that the operating panels are inaccessible to unauthorised persons;
(l) Verification that a notice plate giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour is placed at each operating panel and supplemented by warning indicator lights;
(m) Examination of electrical equipment for opening, closing and securing the doors.

22.3.10 A function test of the indicator system is to be carried out. The Surveyor is to check the satisfactory operation of the indicator system, where fitted, including the following, as applicable:

(a) Proper visible indication and audible alarm on the navigation bridge panel, according to the selected function 'harbour/sea voyage' and on the operating panel;
(b) Lamp test function on both panels;
(c) Verification that it is not possible to turn off the indicator light on both panels;
(d) Verification of fail safe performance, according to the procedure contained in the Operation and Maintenance Manual (OMM);
(e) Confirmation that power supply for the indicator system is supplied by the emergency source or other secure power supply and is independent of the power supply for operating the doors;
(f) Proper condition of sensors and protection from water, ice formation and mechanical damage.

22.3.11 A test of the water leakage detection system, where fitted, is to be carried out. The test is to include verification of a proper audible alarm on the navigation bridge panel and on the engine control room panel, according to the procedure contained in the Operation and Maintenance Manual (OMM).

22.3.12 A test of the television surveillance system, where fitted, is to be carried out. The test is to include verification of a proper indication on the navigation bridge monitor and on the engine control room monitor.

22.3.13 A hose test, or equivalent, is to be carried out. If the results of the visual examination and function test are satisfactory, the tightness test need not be carried out unless considered necessary by the Surveyor.

22.3.14 Following the visual examinations and function tests, non-destructive testing and thickness measurements may be required as considered necessary by the Surveyor.

22.4 Special Surveys

22.4.1 The requirements of 22.3 are to be complied with as applicable.

22.4.2 The securing, supporting and locking devices, including their weld connections, are to be subjected to non-destructive testing and thickness measurement to the extent considered necessary by the Surveyor. The maximum allowable diminution is 15 per cent of the as-built thickness.

22.4.3 The effectiveness of the sealing arrangements is to be verified by carrying out a hose test, or equivalent.

22.4.4 The clearances of hinges, bearings and thrust bearings are to be measured. Unless otherwise specified in the Operation and Maintenance Manual (OMM), or by the manufacturer's recommendation, the measurement of clearances may be limited to representative bearings where dismantling is needed in order to measure the clearances. If dismantling is carried out, a visual examination of hinge pins and bearings, together with non-destructive testing of the hinge pin, is to be carried out.

22.4.5 The non-return valves of the drainage system are to be dismantled and examined.

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Rules for the Manufacture, Testing and Certification of Materials

July 2014

Lloyd's Register

A guide to the Rules

and published requirements

Rules for the Manufacture, Testing and Certification of Materials

Introduction

The Rules are published as a complete set; individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Numbering and Cross-References

A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e., Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right hand digits may be added or omitted depending on the degree of precision required:

(a) In same Chapter, e.g., *see* 2.1.3 (i.e., down to paragraph).

(b) In another set of Lloyd's Register Rules, e.g., *see* Pt 5, Ch 3,2.1 of the Rules and Regulations for the Classification of Ships.

The cross-referencing for Figures and Tables is as follows:

(a) In same Chapter, e.g., as shown in Fig. 2.3.5 (i.e., Chapter, Section and Figure Number).

(b) In another set of Lloyd's Register Rules, e.g., *see* Table 2.7.1 in Pt 3, Ch 2 of the Rules and Regulations for the Classification of Special Service Craft.

Rules updating

The Rules are generally published annually and changed through a system of Notices. Subscribers are forwarded copies of such Notices when the Rules change.

Current changes to Rules that appeared in Notices are shown with a black rule alongside the amended paragraph on the left hand side. A solid black rule indicates amendments and a dotted black rule indicates corrigenda.

July 2014

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■ *Section 1* Scope

1.1 General

1.1.1 Materials used for the construction, conversion, modification or repair of ships, other marine structures and associated machinery which are classed or are intended for classification by Lloyd's Register (hereinafter refered to as LR), are to be manufactured, tested and inspected in accordance with these Rules.

1.1.2 Wrought, cast and extruded materials are to comply with the requirements of Chapters 1 and 2, and the appropriate specific requirements of Chapters 3 to 9 of these Rules. Mooring and anchoring equipment is to comply with the requirements of Chapters 1 and 2, and the appropriate specific requirements of Chapter 10. Manufacturers of these materials must be approved by LR according to the requirements in Sections 2 or 3. Only those materials within a manufacturer's scope of approval may be used.

1.1.3 Welding consumables are to comply with the requirements of Chapter 11 of these Rules.

1.1.4 Where welding is used for the construction, conversion, modification or repair of ships, other marine structures and associated machinery which are classed or are intended for classification by LR, welding qualifications and tests shall be performed according to Chapter 12 of these Rules. All welding shall be performed according to Chapter 13 of these Rules.

1.1.5 Plastics materials are to comply with the requirements of Chapter 14 of these Rules.

1.1.6 The materials and components which are to comply with these requirements for the purposes of classification are defined in the relevant Rules dealing with design and construction.

■ *Section 2* Approval and survey requirements

2.1 Approval and survey requirements – General

2.1.1 Marine materials manufactured in accordance with Chapters 3 to 10 of these Rules are to be made at works which have been approved by LR for the type and grade of product being supplied.

2.1.2 Materials manufactured in accordance with Chapters 3 to 10 of these Rules are to be manufactured, tested and inspected under Survey according to the requirements of one of the following two schemes:
(a) The Materials Survey Scheme, *see* 2.3.
(b) The Materials Quality Scheme, *see* 2.4.

2.1.3 For the purposes of survey, LR Surveyors are to be allowed access to all relevant parts of the works, and are to be provided with the necessary facilities and information to enable them to verify that the manufacture is being carried out in accordance with the approved procedures. Facilities are also to be provided for the selection of test material, the witnessing of mechanical tests and the examination of materials, as required by these Rules.

2.1.4 Where a production process, testing or examination of materials is sub-contracted, this must be with the approval of LR. Surveyors are to be allowed access to the sub-contractor's premises in order to conduct Surveys according to the requirements of these Rules.

2.1.5 Products manufactured in accordance with Chapters 11 and 14 are to be approved in accordance with the requirements therein. For these materials, approval is given for a specific product on a type approval basis, rather than the approved manufacturer/survey arrangements applied to materials covered by Chapters 3 to 10.

2.2 LR Approval – General

2.2.1 Unless specifically stated in other Chapters of these Rules, all LR approvals apply to materials used in applications intended for marine service, as described in 1.1.

2.2.2 The procedures for application for approval of manufacturers and products, the details of the information to be supplied by the manufacturer, and the test programme to be conducted on the products are given in the appropriate book of LR's *Materials and Qualification Procedures for Ships* (MQPS). This is published in the CD Live section of LR's web site at http://www.lr.org.

2.2.3 LR publishes lists of approved manufacturers and approved products. The lists are published in the CD Live section of LR's website, http://www.lr.org.
The lists are as follows:

- *List of Approved Manufacturers of Materials*.
- *Approved Welding Consumables for Use in Ship Construction*.
- *Lists of Paints, Resins, Reinforcements and Associated Materials*.
- *Lists of Approved Anchors*.

2.2.4 For initial LR approval as an Approved Manufacturer for a particular material, the manufacturer is required to demonstrate to the satisfaction of LR, that the necessary manufacturing and testing facilities are available, and are supervised by suitably qualified personnel. A specified programme of tests is to be carried out under the supervision of LR Surveyors, and the results are to be to the satisfaction of LR.

2.2.5 If the results of the initial assessment of the manufacturer, and the test programme are considered satisfactory, the manufacturer will be added to the list of approved manufacturers of materials, and a certificate of approval will be issued to the manufacturer by LR, showing the scope of materials and grades covered by the approval. Initial approval will generally be under the Materials Survey Scheme, *see* 2.3.

2.2.6 Approved manufacturers who meet the entry requirements, may apply for approval under the Materials Quality Scheme, *see* 2.4.

2.2.7 When a manufacturer has more than one works, the manufacturer's approval shall only be valid for the works where the test programme was conducted.

2.2.8 It is the manufacturer's responsibility to advise LR of all changes to the manufacturing process parameters that may affect the application of the material, prior to the adoption of the changes in production. Additional approval tests may be required to maintain the approval.

2.2.9 Maintenance of approval is dependent on the manufacturer continuing to meet the requirements of the applicable sections of these Rules.

2.2.10 Where it is considered that an approved manufacturer is not maintaining its responsibilities to comply with these Rules, the approval may be suspended by LR until such time that agreed corrective and preventive actions are considered to have been satisfactorily carried out. If considered necessary, LR may require that the normal level of testing and inspection is increased.

2.2.11 In all instances, LR will reduce the scope of, or withdraw approval from, a manufacturer where it becomes apparent that the manufacturer is unable to maintain compliance with these Rules, or the scope of approval.

2.2.12 Where a manufacturer disagrees with any decisions made with regard to LR approval, they may appeal in writing to LR.

2.2.13 Any documents, data or other information received as part of the approval process, will be treated as strictly confidential, and will not be disclosed to any third party, without the manufacturer's prior written consent.

2.2.14 The approved works will be subject to a periodic inspection of all relevant parts of the works, at intervals not exceeding three years. The procedure for this periodic inspection is given in Book B of LR's *Materials and Qualification Procedures for Ships* (MQPS). This periodic inspection is in addition to the regular visits made according to 2.3.7.

2.3 Materials Survey Scheme

2.3.1 Materials according to Chapters 3 to 10 of these Rules and produced under the Materials Survey Scheme will be subject to Direct Survey by an LR Surveyor. The scheme requires the Surveyor to survey and certify all materials according to the requirements of these Rules.

2.3.2 Approved manufacturers are to request a survey of the material by an LR Surveyor, when required. Manufacturers must provide the Surveyor with details of the order, specification and any special conditions additional to the requirements of these Rules.

2.3.3 All mechanical tests required by these Rules are to be witnessed. The Surveyor may allow part of this task to be carried out by a member of the works staff by prior written agreement.

2.3.4 Before final acceptance, all materials are to be submitted to the specified tests and examinations under conditions acceptable to the Surveyor. The results are to comply with the Rules, and all materials are to be to the satisfaction of the Surveyor.

2.3.5 The specified tests and examinations are to be carried out prior to the despatch of finished materials from the manufacturer's works. Where materials are supplied in the rough or unfinished condition, as many as possible of the specified tests are to be carried out by the manufacturer, and any tests or examinations that are not completed are to be carried out under survey at a subsequent stage of manufacture.

2.3.6 In the event of any material proving unsatisfactory during subsequent working, machining or fabrication, such material is to be rejected, notwithstanding any previous certification.

2.3.7 In addition to witnessing test results, the Surveyor is responsible for ensuring that the manufacturing process, inspection, testing, identification and certification are properly conducted. As part of the Materials Survey Scheme, regular visits will be made to all relevant parts of the works to check for compliance against the requirements of these Rules, and to ensure that the manufacturer is maintaining the capability to consistently produce approved materials.

2.3.8 The Surveyor, when satisfied that the material fully meets the requirements of these Rules, will certify the material in accordance with Section 3 and the appropriate Chapter of these Rules.

2.4 Materials Quality Scheme

2.4.1 The manufacturer may apply to be approved under the Materials Quality Scheme, where the following requirements are met:

(a) The manufacturer has been approved by LR for a minimum of three years and continues to maintain their LR works approval according to 2.2.14; and
(b) The manufacturer has a quality management system, which has been certified as meeting the requirements of ISO 9001 by a certification body recognised by LR, which is one accredited by a member of the International Accreditation Forum; and
(c) The manufacturer has a satisfactory history of quality performance in the manufacture and supply of LR approved materials.

2.4.2 Special consideration may be given to manufacturers who have not been approved under the Materials Survey Scheme, and may be considered onto the Materials Quality Scheme providing:

(a) They have a quality management system, which has been certified as meeting the requirements of ISO 9001 by a certification body recognised by LR, which is one accredited by a member of the International Accreditation Forum.
(b) They can demonstrate a history of satisfactory supply of materials, which LR deems to be equivalent to those for which approval under the Materials Quality Scheme is requested.

In this case, the initial assessment of the manufacturer will include the product testing regime, as required for initial approval under the Materials Survey Scheme, *see* 2.2.4.

2.4.3 The Scheme is based on a Scheme Certification Schedule, made between LR and each individual manufacturer. The schedule will stipulate:

(a) The scope of approved products covered by the approval.
(b) The process route applied by the manufacturer for each approved product.
(c) The arrangements for LR scheme, audits, including scope, frequency, schedule, etc.
(d) Agreed procedures for certification of approved materials.
(e) Information to be supplied periodically to LR by the manufacturer.
(f) Procedures for the use of the scheme mark.

2.4.4 The contents of the Scheme Certification Schedule are to remain confidential between LR and the manufacturer.

2.4.5 The Materials Quality Scheme is based on a technical audit approach, and is designed to complement the quality management systems audits performed to ISO 9001. The role of the Surveyor in scheme audits is to:

(a) Verify that the quality management system is being maintained and audited to the requirements of ISO 9001.
(b) Verify that the requirements of these Rules are being implemented.
(c) Verify that the requirements of this Scheme are being implemented.
(d) Perform Scheme audits, which focus on the technical aspects of the product realisation process, particularly with regard to Rule requirements.
(e) Perform witness testing as required.
(f) Verify the data supplied to LR periodically by the manufacturer, as part of the Scheme requirements.

2.4.6 The Materials Quality Scheme may be applied to any approved manufacturer who meets the eligibility requirements, and who applies to be approved under the scheme. If approved under the scheme, the manufacturer's name will appear on the List of Approved Manufacturers published by LR, with an indication that they are approved under this scheme.

2.4.7 The scheme is available to manufacturers producing approved materials according to Chapters 3 to 10 of these Rules.

2.4.8 The procedures for application for approval for the Materials Quality Scheme are given in Book M of LR's *Materials and Qualification Procedures for Ships* (MQPS).

2.4.9 Where LR is satisfied that the manufacturer meets all of the requirements of the Scheme, and that it is appropriate for the products being manufactured, a Scheme Certification Schedule will be issued, which must be signed by an authorised representative of the manufacturer.

2.4.10 Once the Scheme Certification Schedule has been signed by both parties, LR will issue the manufacturer with a certificate of approval according to the Materials Quality Scheme.

2.4.11 Maintenance of approval will be according to the Scheme Certification Schedule, agreed between LR and the manufacturer, and these Rules.

2.4.12 It is the responsibility of the attending Surveyor, to perform regular Scheme audits at the manufacturer's works in accordance with the Scheme Certification Schedule, and the requirements of these Rules.

2.4.13 It is not the intention to repeat the audit according to ISO 9001, conducted by the recognised certification body. The Surveyor is, however, to be satisfied that these audits are being conducted effectively. Where appropriate, the Surveyor may conduct a partial audit to ISO 9001 to verify this.

2.4.14 Witness tests may be conducted as part of the Scheme audit. This will involve the selection of material, and the witness of sampling and testing according to the requirements of the appropriate chapter of these Rules. Such witness testing may be on LR grades, or materials which the Surveyor deems to be equivalent (for the purposes of audit testing only).

2.4.15 Once every three years, a full assessment of scheme compliance will be conducted by a Surveyor who is not the regular attending Surveyor. This assessment is in addition to the periodic inspection requirement made according to 2.2.14.

2.4.16 In the event of any change, which means that the manufacturer no longer meets the requirements for the Materials Quality Scheme (for example the loss of ISO 9001 approval), the Scheme certificate of approval will be revoked. The manufacturer will revert to the Materials Survey Scheme, and will be subject to survey according to that scheme.

■ *Section 3*
Certification of materials

3.1 General

3.1.1 All materials subject to these Rules are to be supplied with appropriate certification, as required by the relevant requirements of these Rules. This will normally be a LR certificate or a manufacturer's certificate validated by LR, although a manufacturer's certificate may be accepted where allowed by the relevant requirements of these Rules.

3.1.2 Manufacturers approved under the Materials Quality Scheme are licensed to apply the scheme mark to manufacturer's certificates according to the requirements of the scheme, *see* 2.4.

3.1.3 The following certificate types are to be used, (a) and (b) for the Materials Survey Scheme, and (d) for the Materials Quality Scheme:

(a) **LR Certificate**
This type of certificate is issued by LR based on the results of testing and inspection being satisfactorily carried out in accordance with the requirements of these Rules.

(b) **Manufacturer's certificate validated by LR**
A manufacturer's certificate, validated by LR on the basis of inspection and testing carried out by the manufacturer and which is in accordance with the requirements of these Rules, may be accepted. In this case, the certificate will include the following statement:
"We hereby certify, that the material has been made by an approved process and satisfactorily tested in accordance with the Rules of Lloyd's Register."

(c) **Manufacturer's certificate**
This type of certificate is issued by the manufacturer, based on the results of testing and inspection being satisfactorily carried out in accordance with the requirements of these Rules, or the applicable National or International standard. The certificate is to be validated by the manufacturer's authorised representative, independent of the manufacturing department. The certificate will contain a declaration that the products are in compliance with the requirements of these Rules or the applicable National or International standard.

(d) **Manufacturer's certificate issued under the Materials Quality Scheme**
Where a manufacturer is approved according to the Materials Quality Scheme, they will issue manufacturer's certificates bearing the scheme mark. The certificates must also bear the following statement:
"This certificate is issued under the arrangements authorised by Lloyd's Register (operating group) in accordance with the requirements of the Materials Quality Scheme and scheme number MQS ……."

3.1.4 Where these Rules allow for the issue of a manufacturer's certificate for materials, either validated by an LR Surveyor, or bearing the Materials Quality Scheme mark, the manufacturer is to ensure that a copy of the certificate is supplied to LR.

3.2 Materials Survey Scheme

3.2.1 The requirements for certification of materials according to the Materials Survey Scheme, are established by the relevant requirements of these Rules.

3.2.2 The manufacturer is to supply the surveyor with any additional customer order requirements that are in addition to the requirements of these Rules, when the request for the issue or validation of the certificate is made.

3.3 Materials Quality Scheme

3.3.1 Part of the certification schedule, will include an agreement for the manufacturer, to apply the scheme mark to manufacturer's certificates, relating to approved products within the scope of approval of the manufacturer.

3.3.2 The use of the scheme mark is governed by the following:

(a) The use of the scheme mark is not transferable. It is only to be used in conjunction with the manufacturer and works name and location shown on the certificate of approval.
(b) The scheme mark must be applied to all manufacturers' certificates relating to approved materials produced under the Scheme.
(c) In no circumstances is the scheme mark to be applied to test certificates relating to non-approved products.
(d) The scheme mark is not to be used in any way which may imply approval for products which are not covered within the manufacturer's scope of approval.
(e) Where a manufacturer is removed or suspended from the scheme, use of the scheme mark must cease immediately.

3.3.3 The certificate as given in 3.1.3(d) is to be validated by an authorised representative of the manufacturer. The size and position of the scheme mark and statement on the manufacturer's certificate must be agreed by LR.

3.3.4 Where manufacturers are approved under this scheme, the manufacturer's certificate, issued according to these requirements, fully meets the materials certification requirements of these Rules.

3.4 Electronic certification

3.4.1 Where these Rules allow the issue of manufacturers' test certificates, under either the Materials Survey Scheme or the Materials Quality Scheme, these may be issued in electronic format provided that:

(a) All tests and inspections have been satisfactorily completed, according to the requirements of these Rules.

(b) Procedures are in place to ensure that electronic certificates are only issued, according to the requirements of these Rules.
(c) The certification system is subject to regular inspection by the attending Surveyor.
(d) A copy of the electronic certificate is supplied to LR. This copy will be deemed to be the original of the test certificate.

3.4.2 In addition to the requirements of 3.4.1, for items certified under the Materials Survey Scheme, the LR office stamp and Surveyor's name may be applied electronically. This is only allowed where the Surveyor has access to the results of the relevant tests and inspections, and is able to authorise by access to the electronic system, the application of the LR office stamp and Surveyor's name on the test certificate. The name of the authorising Surveyor is to be the name included on the certificate. The authorisation may be conducted electronically either at the manufacturers' works, or remotely by the Surveyor.

3.4.3 If the LR office stamp and name are being applied electronically according to 3.4.2, then the manufacturer is to ensure that the Surveyor is provided with all relevant information regarding the customer order, when the request for authorisation is made.

■ *Section 4* General requirements for manufacture

4.1 General

4.1.1 The following definitions are applicable to these Rules:

Item: A single forging, casting, plate, tube or other rolled product as delivered.
Piece: The rolled product from a single slab or billet or from a single ingot if this is rolled directly into plates, strip, sections or bars.
Batch: A number of similar items or pieces presented as a group for acceptance testing.
Wide flat: Flat product of a width over 150 mm, up to and including 1250 mm and thickness generally over 4 mm. Edges are square cut, i.e., hot rolled on the four sides. Supplied in lengths, not coils.
Plate/sheet: Flat rolled product whereby the edges are allowed to deform freely. Supplied flat and generally in square or rectangular shapes with a width of 600 mm or over, but other shapes may also apply.

4.1.2 Where a manufacturer purchases semi-finished products (e.g., slabs) for the purpose of re-processing (e.g., rolling), the manufacturer is to ensure that the materials are from an LR approved manufacturer, and manufactured within the scope of approval of that manufacturer. The aim of chemical analysis, dimensions, surface and internal quality checks are to be agreed between the manufacturer and purchaser. The semi-finished materials must be supplied with appropriate certification, according to these Rules.

4.1.3 It is the responsibility of the manufacturer, to ensure compliance with all relevant aspects of these Rules. All deviations are to be recorded as non-compliances, and brought to the attention of the Surveyor, along with corrective actions taken. Failure to do this is considered to render the material as not complying with these Rules.

4.1.4 The manufacturer is to maintain all test and inspection records required by these Rules for at least seven years. Records are to be made available to LR on request.

4.1.5 Where material is produced which does not meet all aspects of these Rules, the manufacturer may apply to LR for a concession to certify the material as approved. LR will consider each application on a case-by-case basis, although concession will only normally be granted in exceptional circumstances. If the concession is granted, a formal written numbered concession will be issued to the manufacturer. The concession number must be applied to the approval certificate, whether it is an LR certificate or a validated manufacturer's certificate.

4.2 Chemical composition

4.2.1 The ladle analysis used for certification purposes is to be determined after all alloying elements have been added and sufficient time allowed for such additions to equalise throughout the ladle.

4.2.2 The method of taking samples is to ensure that the reported analysis is representative of the cast. In addition, the manufacturer must determine and certify the chemical composition of every heat of material.

4.2.3 Where more than one sample is taken, the method of averaging for the final certificate result and the determination of acceptable variations in composition are to be agreed with the Surveyor.

4.2.4 The chemical composition of ladle samples is to be determined by the manufacturer in an adequately equipped and competently staffed laboratory. The manufacturer's analysis will be accepted, but may be subject to occasional independent checks if required by the Surveyor.

4.2.5 The analysis is to include the content of all the elements detailed in the relevant Sections of the Rules and, where appropriate, the National or International Standard applied.

4.2.6 At the discretion of the Surveyors, a check chemical analysis of suitable samples from products may also be required. These samples are to be taken from the material used for mechanical tests but, where this is not practicable, an alternative procedure for obtaining a representative sample is to be agreed with the manufacturer. For product samples, the permissible limits of deviation from the specified ladle analysis are to be in accordance with an appropriate International or National Standard specification.

4.3 Heat treatment

4.3.1 Materials are to be supplied in the condition specified in, or permitted by, the relevant Chapters of these Rules.

4.3.2 Heat treatment is to be carried out in properly constructed furnaces, which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole item to be uniformly heated to the necessary temperature. In the case of very large components, which require heat treatment, alternative methods will be specially considered.

4.3.3 The manufacturer is to maintain the records, including the temperature charts of all heat treatments, for at least seven years.

4.4 Test material

4.4.1 Sufficient test material is to be provided for the preparation of the test specimen detailed in the specific requirements. It is, however, in the interests of manufacturers to provide additional material for any re-tests which may be necessary, as insufficient or unacceptable test material may be a cause for rejection.

4.4.2 The test material is to be representative of the item or batch and is not to be separated until all the specified heat treatment has been completed, except where provision for an alternative procedure is made in subsequent Chapters of these Rules.

4.4.3 All test material is to be selected by the Surveyor or an authorised deputy and identified by suitable markings which are to be maintained during the preparation of the test specimens.

4.5 Mechanical tests

4.5.1 The dimensions, number and direction of test specimens are to be in accordance with the requirements of Chapter 2 and the specific requirements for the product.

4.5.2 Where Charpy impact tests are required, a set of three test specimens is to be prepared and the average energy value is to comply with the requirements of subsequent Chapters. One individual value may be less than the required average value, provided that it is not less than 70 per cent of that value.

4.5.3 In the Rules, mechanical properties are specified in SI units, but alternative units may be used for acceptance testing. In such cases, the specified values are to be converted in accordance with the appropriate conversions given in Table 1.4.1. It is preferred that test results be reported in SI units, but alternative units may be used provided that the test certificate gives, in the same units, the equivalent specification values.

Table 1.4.1 Conversions from SI units to metric and Imperial units

1 N/mm^2 or MPa	=	0,102 kgf/mm^2
1 N/mm^2 or MPa	=	0,0647 $tonf/in^2$
1 N/mm^2 or MPa	=	0,145 x 10^3 lbf/in^2
1J	=	0,102 kgf m
1J	=	0,738 ft lbs
1 kgf/mm^2	=	9,81 N/mm^2 or MPa
1 $tonf/in^2$	=	15,4 N/mm^2 or MPa
1 lbf/in^2	=	6,89 x 10^{-3} N/mm^2 or MPa
1 kgf m	=	9,81 J
1 ft lbf	=	1,36 J

4.6 Re-test procedures

4.6.1 Re-test procedures are to be in accordance with the requirements of Ch 2,1.4.

4.7 Rectification of defective material

4.7.1 Small surface imperfections may be removed by mechanical means provided that, after such treatment, the dimensions are acceptable, the area is proved free from defects and the rectification has been completed in accordance with any applicable requirements of subsequent Chapters of these Rules and to the satisfaction of the Surveyor.

4.7.2 The repair of defects by welding, can be accepted only when permitted by the appropriate specific requirements and provided that the agreement of the Surveyor is obtained before the work is commenced. When a repair has been agreed, it is necessary in all cases to prove by suitable methods of non-destructive examination that the defects have been completely removed before welding is commenced. Welding procedures and inspection on completion of the repair, are to be in accordance with the appropriate specific require-ments and are to be to the satisfaction of the Surveyor.

4.7.3 Manufacturers wishing to carry out welding work must have at their disposal the necessary workshops, lifting gear, welding equipment, pre-heating, and where necessary annealing facilities and testing devices, as well as certified welders and supervisors to enable them to perform the work properly. Proof shall be furnished to the Surveyor that these conditions are satisfied before welding work begins.

4.8 Identification of materials

4.8.1 The manufacturer is to adopt a system of identification, which will enable all finished materials to be traced to the original cast, and the Surveyors are to be given full facilities for tracing the material when required. When any item has been identified by the personal mark of a Surveyor, or his deputy, this is not to be removed until an acceptable new identification mark has been made by a Surveyor. Failure to comply with this condition will render the item liable to rejection.

4.8.2 Before any item is finally accepted, it is to be clearly marked by the manufacturer in at least one place with the particulars detailed in the appropriate specific requirements.

4.8.3 Where hard stamps such as the LR brand stamp are issued to manufacturers to carry out the stamping on behalf of LR, the procedure for issue, maintenance and use of stamps is to be agreed in writing.

4.8.4 Hard stamping is to be used except where this may be detrimental to the material, in which case stencilling, painting or electric etching is to be used. Paints used to identify alloy steels are to be free from lead, copper, zinc or tin, i.e., the dried film is not to contain any of these elements in quantities of more than 250 ppm.

4.8.5 Where a number of identical items are securely fastened together in bundles, the manufacturer need only brand the top item of each bundle. Alternatively, a durable label giving the required particulars may be attached to each bundle.

■ *Section 5* Non-destructive examination

5.1 General NDE requirements

5.1.1 Prior to the final acceptance of materials, surface inspection and verification of dimensions, non-destructive examination is to be carried out in accordance with the requirements detailed in this Section and subsequent Chapters of these Rules.

5.1.2 It is the manufacturer's responsibility for maintaining the required tolerances and making the necessary measurements. Periodic surveys by the Surveyor do not absolve the manufacturer from this responsibility.

5.1.3 When there is visible evidence to doubt the soundness of any material or component, such as flaws in test specimens or suspicious surface marks, the manufacturer is expected to prove the quality of the material by a suitable method.

5.1.4 Acceptance criteria are detailed in subsequent Chapters of these Rules. Alternative specifications may be submitted for consideration, provided they demonstrate equivalence to these Rules.

5.2 Personnel qualifications

5.2.1 The shipyard, fabricator or manufacturer is to ensure that personnel carrying out non-destructive examination or interpreting the results of non-destructive examination are qualified to the appropriate level of a nationally recognised scheme such as ISO 9712, PCN, ACCP or SNT-TC-1A. Level 1 personnel are not permitted to interpret results to Codes or Standards.

5.2.2 When certification of personnel is made on an in-house basis under a scheme such as SNT-TC-1A, practical examinations are to be relevant to material, product type, joint configuration, material thickness and acceptance criteria of items inspected for Classification purposes.

5.2.3 Personnel qualifications of NDE operators are to be randomly checked by the Surveyor.

5.3 Non-destructive examination methods

5.3.1 Non-destructive examination methods are to comply with the relevant requirements of these Rules.

5.4 Non-destructive examination procedures

5.4.1 All non-destructive examinations are to be carried out to a procedure that is representative of the item under inspection. As a minimum the procedures are to be in accordance with the following:

(a) Procedures are to identify the component to be examined, the NDE method, equipment to be used and the full extent of the examinations including any test restrictions.
(b) Procedures are to specify the qualification and certification requirements of the inspection personnel to be employed.
(c) Procedures are to state the degree of surface preparation required and the methods of preparation to be used before the examinations are made.
(d) Procedures are to state the reference standards for testing and the acceptance criteria to be applied to the results of the inspections.
(e) Procedures are to include the requirement for components to be positively identified and for a datum system or marking system to be applied to ensure repeatability of inspections.
(f) Procedures are to identify any requirements for increasing the extent of applied NDE where defects have been found during spot examination.
(g) Procedures are to identify reporting requirements.
(h) Procedures are to be reviewed by the Surveyor to ensure they are appropriate for the product type.
(j) Procedures for radiography are to specify the acceptable optical density within the area of interest on the radiograph.
(k) The minimum optical density within the area of interest on a radiograph is to be equal to or greater than 2,0 for gamma ray and 1,8 for X-ray. A maximum density of 4,0 is acceptable.
(l) Procedures are to include the method and requirements for equipment calibrations and functional checks.
(m) Procedures are to be approved by an operator qualified to a minimum of Level III in accordance with a recognised standard.
(n) The Surveyor will review procedures for compliance with this Section.

5.4.2 The shipyard, fabricator or manufacturer may submit other Codes or Standards for consideration by LR, providing they are equivalent to these Rules. Where no agreed acceptance standard is in place, the acceptance levels contained in the subsequent Chapters of these Rules are to apply.

5.4.3 In the event that proposed acceptance criteria are not considered to be equivalent to these Rules, the criteria may be submitted for special consideration.

5.5 Non-destructive examination reports

5.5.1 NDE reports are to include all information required to identify how the examination was executed and are to include the following information where appropriate:

(a) Date of test.
(b) Name and qualification of operator with signatures of the operator.
(c) Details of the component identification, description of test location and volume examined.
(d) Heat treatment status.
(e) Weld type, procedure and configuration.
(f) Surface condition.
(g) Test procedure.
(h) Equipment used.
(j) Test results with a map or record of reportable and/or reject indications, giving location, dimensions and nature of indications.
(k) Reference to acceptance criteria and evaluation in accordance to these criteria.
(l) Material type and thickness.
(m) Calibration.

■ *Section 6* References

6.1 General

6.1.1 The locations of National and International Standards referenced in these Rules are shown in Table 1.6.1.

Table 1.6.1 List of National and International Standards (*see continuation*)

Rule reference	Standard
Chapter 1 – General Requirements	ISO 9001: 2008 SNT-TC-1A:2012 ISO 9712:2012
Chapter 2 – Testing Procedures for Metallic Materials	ISO 6892-1: 2009 ISO 185: 2005 ISO 2566-1: 1999 ISO 148-1: 2009 ISO 7500-1: 2004 ISO 6506-1: 2006 ISO 6506-2: 2006 ISO 6506-3: 2006 ISO 6507-1: 2006 ISO 6507-2: 2006 ISO 6507-3: 2006 ISO 6508-1: 2006 ASTM E23-Rev C (2012)
Chapter 3 – Rolled Steel Plates, Strip, Sections and Bars	EN 10160: 1999 ASTM A578-07 ASTM E112-Rev C (2012) ISO 7452:2002 ASTM E208-06 ASTM E381-01 (2006) ASTM A255-2010
Chapter 4 – Steel Castings	ASTM G48-11 ISO 1161: 1984/Amendment 1: 2007
Chapter 5 – Steel Forgings	ASTM E112-12 ASTM G48-11
Chapter 8 – Aluminium Alloys	ASTM G66-99 (2005)e1 ASTM G67-04
Chapter 9 – Copper Alloys	ASTM E272-2010 EN 1057: 2006 +A1: 2010
Chapter 10 – Equipment for Mooring and Anchoring	ISO 1704: 2008 ISO 1834: 1999 ISO 4565: 1986 ASTM E112-2010 ASTM E381-01 (2006) ASTM A255-2010
Chapter 11 – Approval of Welding Consumables	ISO 3690: 2000 ISO 10042: 2005 ASTM G48-11
Chapter 12 – Welding Qualifications	ISO 6947: 2011 ISO 5817: 2007 ISO 6520-1: 2007 ISO 6507-1: 2005 ISO 10042: 2005 ASTM G48-11 ISO 25239-3: 2011 ISO 25239-4: 2011
Chapter 13 – Requirements for Welded Construction	ISO 9712/Cor1: 2006 ISO 6520-1: 2007 SNT TC-1A-2011 AWS D3.6M:2010 ISO 10042: 2005 ISO 25239-5: 2011

Table 1.6.1 List of National and International Standards (*conclusion*)

Rule reference	Standard
Chapter 14 – Plastics Materials	ISO 527-2: 2012 ISO 178: 2010 ISO 62: 2008 ISO 75-2: 2004 ISO 604: 2002 ISO 527-4: 1997 ISO 14125: 1998/ amd1:2011 ISO 14130: 1997/ corr1:2003 ISO 1172: 1996 ISO 1922- 2012 ASTM C273/C273M-11 ASTM C393/C393M-11 ISO 845- 2006 ASTM C297/C297M-04 ISO 844-2007 ISO 1922-2001 ISO 180-2000 ASTM D2583-07 BS 2782-10 Method 1001: 1977 ISO 175: 2010 BS 1088-1: 2003 BS 1088-2: 2003

■ *Section 1* General requirements for testing

1.1 Preparation of test specimens

1.1.1 The requirements specified below detail all the tests that may be applied to metallic materials. The specific tests and the test specimen types required for each material type, grade and product type are detailed in the subsequent Chapter of these Rules.

1.1.2 Where test material is cut from products by shearing or flame cutting, a reasonable margin is required to allow sufficient material to be removed from the cut edges during machining of the test specimens.

1.1.3 Test specimens are to be prepared in such a manner that they are not subjected to any significant work hardening, cold straining or heating during straightening or machining.

1.1.4 Test samples are not to be removed from the material they represent until heat treatment is complete. For castings in cases where test samples are separately cast, the castings and samples are to be heat treated together.

1.1.5 Dimensional tolerances are to comply with a relevant ISO specification.

1.2 Testing machines

1.2.1 All tests are to be carried out by competent personnel. Testing machines are to be maintained in a satisfactory and accurate condition and are to be recalibrated at approximately annual intervals. This calibration is to be carried out by organisations of standing that have been approved or recognised by a National Authority and are to be to the satisfaction of the Surveyor. A record of all calibrations is to be kept available in the test house.

1.2.2 Tensile testing machine load cells are to be calibrated with an accuracy of ± one per cent in accordance with ISO 7500-1 or another recognised National Standard.

1.2.3 Impact tests are to be carried out on Charpy V-notch machines calibrated to ISO 148 or ASTM E23 dependent on the testing machine type. The testing machines are to be calibrated using either a direct or indirect method. Other National Standards equivalent to ISO 148 may be considered.

1.2.4 Hardness testing machines, together with their associated measuring microscopes, are to be directly and indirectly calibrated to ISO 6506-2, 6507-2 or equivalent standards applicable to the type of hardness test. Other National Standards equivalent to ISO 6507-2 and 6506-2 standards may be considered. Routine hardness checks with standard hardness blocks calibrated to ISO 6506-3 or ISO 6507-3 or equivalent are to be carried out at a frequency which demonstrates calibration consistency.

1.3 Discarding of test specimens

1.3.1 If a test specimen fails because of faulty preparation or incorrect operation of the testing machine it may be discarded and replaced by a new test specimen prepared from material adjacent to the original test.

1.3.2 In addition to the discarding of test specimens as indicated in 1.3.1, a tensile test specimen may also be discarded when the specified minimum elongation is not obtained and the distance between the fracture and the nearest gauge mark is less than one-quarter of the gauge length.

1.4 Re-testing procedures

1.4.1 Where the result of any test, other than an impact test, does not comply with the requirements, two additional tests of the same type are to be made from the same test sample, or if sufficient material is not available, a further representative sample taken from the item under test. For acceptance of the material, satisfactory results are to be obtained from both of these additional tests.

1.4.2 Where the result of any test taken from a weld procedure approval test, other than an impact test, does not comply with the requirements, two additional tests of the same type are to be made from the same weld test assembly. Where insufficient original welded assembly is available, a new assembly is to be prepared using the same conditions as the original test weld. For acceptance, satisfactory results are to be obtained from both of these additional tests.

1.4.3 Where the result of any test taken from a welding consumable approval test, other than an impact test, does not comply with the requirements, two additional tests of the same type are to be made from the same weld test assembly. Where insufficient original welded assembly is available, a new assembly is to be prepared using welding consumables from the same batch. If the new assembly is made with the same procedure (particularly the same number of runs) as the original assembly, only the duplicate re-test specimens need be prepared and tested. For acceptance of a weld consumable batch, satisfactory results are to be obtained from both of these additional tests.

1.4.4 Where the results from a set of three impact test specimens do not comply with the requirements, an additional set of three impact test specimens may be tested provided that, of the original set tested, not more than two individual values are less than the required average value and, of these, not more than one is less than 70 per cent of this average value. The results obtained are to be combined with the original results to form a new average which, for acceptance, is to be not less than the required average value. Additionally, for these combined results, not more than two individual values are to be less than the required average value and, of these, not more than one is to be less than 70 per cent of this average value.

1.4.5 The additional tests detailed in 1.4.1 and 1.4.2 are, where possible, to be made on material adjacent to the original samples. For castings, where insufficient material remains in the original test samples, the additional test may be made on other test samples representative of the castings. *See also* 1.3 for discarding of test specimens.

1.4.6 When unsatisfactory results are obtained from tests representative of a batch of material, the item or piece from which the tests were taken is to be rejected. The remainder of the material in the batch may be accepted provided that two further items or pieces are selected and tested with satisfactory results. If the tests from one or both or these additional items or pieces give unsatisfactory results, the batch is to be rejected.

1.4.7 When a batch of material is rejected, the remaining items or pieces in the batch may be resubmitted individually for test, and those which give satisfactory results may be accepted.

1.4.8 At the option of the manufacturer, rejected material may be resubmitted as another grade and may then be accepted, provided that the test results comply with the appropriate requirements.

1.4.9 When material which is intended to be supplied in the ‘as-rolled’ or ‘hot-finished’ condition fails test, it may be suitably heat treated and resubmitted for test. Similarly, materials supplied in the heat treated condition may be reheat treated and resubmitted for test. Unless otherwise agreed by the Surveyor, such reheat treatment is to be limited to one repeat of the final heat treatment cycle.

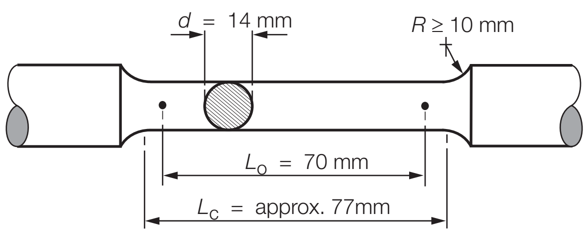
■ *Section 2* Tensile tests

2.1 Dimensions of test specimens

2.1.1 Proportional test specimens with a gauge length L_o of $5{,}65\sqrt{S_o}$ or $5d$, where S_o is the cross-sectional area, d the diameter and L_c the parallel test length, have been adopted as the standard form of test specimen, and in subsequent Chapters in these Rules the minimum percentage elongation values are given for test specimens of these proportions.

2.1.2 The gauge length is to be greater than 20 mm and may be rounded off to the nearest 5 mm provided that the difference between the adjusted gauge length and the calculated one is less than 10 per cent of the calculated gauge length.

2.1.3 For forgings and castings (excluding those in grey cast iron) proportional test specimens of circular cross-section are to be machined to the dimensions shown in Fig. 2.2.1.

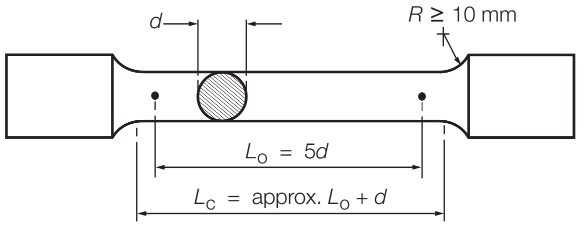


NOTE: For nodular cast iron and materials with a specified elongation less than 10%, $R \geq 20$ mm

Fig. 2.2.1
Test specimen dimensions for forgings and castings – I

2.1.4 For hot rolled bars and similar products, the test specimens are to be as in Fig. 2.2.1, except that for small sizes they may consist of a suitable length of bar or other product tested in the full cross-section.

2.1.5 As an alternative to 2.1.3 and 2.1.4, proportional or non-proportional test specimens of other dimensions may be used, subject to any requirements for minimum cross-sectional area given in subsequent Chapters of these Rules. Where the size of proportional test specimens is other than as shown in Fig. 2.2.1, the general dimensions are to conform with Fig. 2.2.2.



NOTE: For nodular cast iron and materials with a specified elongation less than 10%, $R \geq 1,5d$

Fig. 2.2.2
Test specimen dimensions for forgings and castings – II and aluminium alloys

2.1.6 For plates, strip and sections, the test specimens are to be machined to the dimensions shown in Fig. 2.2.3 or Fig. 2.2.4. Where the capacity of the available testing machine is insufficient to allow the use of a test specimen of full thickness, this may be reduced by machining one of the rolled surfaces. Alternatively, for materials over 40 mm thick, test specimens of circular cross-section machined to the dimensions shown in Fig. 2.2.1 may be used. The axes of these test specimens are to be located at approximately one quarter of the thickness from one of the rolled surfaces.

2.1.7 As an alternative to 2.1.6, test specimens with a width of other than 25 mm may be used subject to any requirements for minimum cross-sectional area given in subsequent Chapters of these Rules. A ratio of width/thickness of 8:1 should not be exceeded.

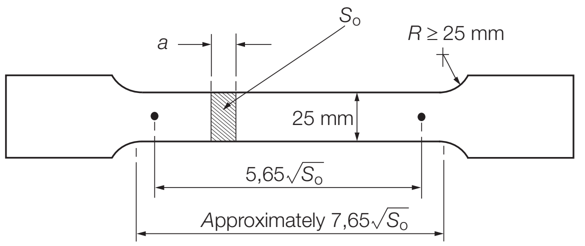
2.1.8 For pipes and tubes, the test specimens may consist of a suitable length tested in full cross-section with the ends plugged. The gauge length is to be $5,65\sqrt{S_o}$ or 50 mm, and the length of the test specimen between the grips or plugs, whichever is the smaller, is to be not less than the gauge length plus D, where D is the external diameter. Alternatively, test specimens may be prepared from strips cut longitudinally and machined to the dimensions shown in Fig. 2.2.5 or Fig. 2.2.6. The parallel test length is not to be flattened, but the enlarged ends may be flattened for gripping in the testing machine.
The cross-sectional area of this type of test specimen is to be calculated from:

$S_o = ab$

where

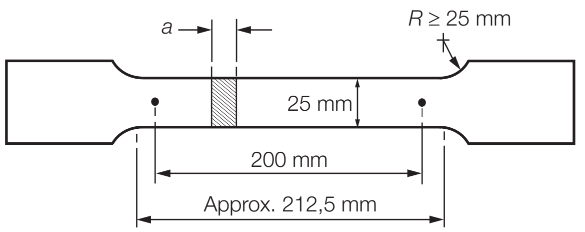
S_o = cross-sectional area
a = average radial thickness
b = average width

Test specimens of circular cross-section may also be used provided that the wall thickness is sufficient to allow the machining of such specimens to the dimensions shown in Fig. 2.2.1, with their axes located at the mid-wall thickness.



a = thickness of material

Fig. 2.2.3
Test specimen dimensions for plates, strip and sections – I and aluminium alloys



a = thickness of material

Fig. 2.2.4
Test specimen dimensions for plates, strip and sections – II

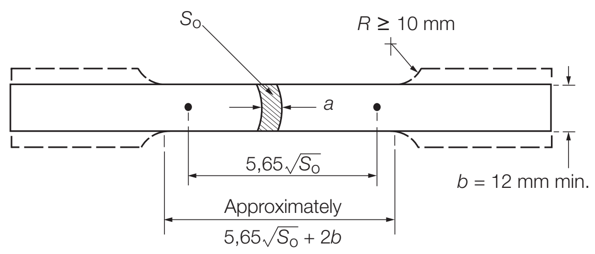


Fig. 2.2.5
Test specimen dimensions for pipes and tubes – I

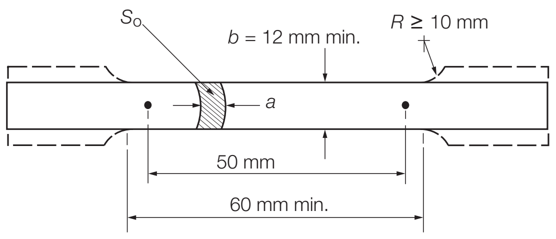


Fig. 2.2.6
Test specimen dimensions for pipes and tubes – II

2.1.9 For wire, the test specimen may consist of a suitable length tested in full cross-section. The gauge length is to be 200 mm and the parallel test length 250 mm.

2.1.10 For grey iron castings, the test specimens are to be machined to the dimensions shown in Fig. 2.2.7 or Fig. 2.2.8.

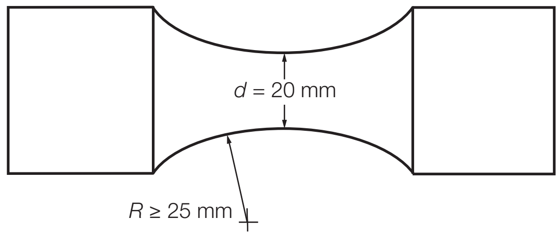


Fig. 2.2.7
Test specimen dimensions for grey iron castings – I

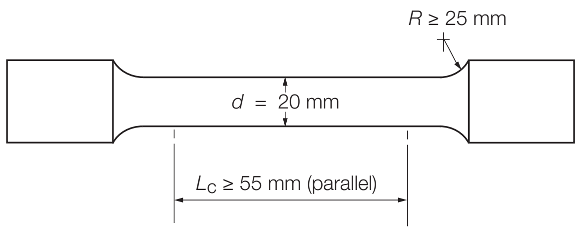


Fig. 2.2.8
Test specimen dimensions for grey iron castings – II

2.1.11 For aluminium alloy plates and sections of thickness, *a*, less than or equal to 12,5 mm; the dimensions of rectangular cross-sectioned test specimens are to be as shown in Fig. 2.2.3. The rectangular cross-sectioned test specimen surfaces should remain as rolled/extruded. Where the thickness, *a*, is greater than 12,5 mm the test specimens are to be of round type as shown in Fig. 2.2.2.

2.1.12 Deposited weld metal tensile test specimens are to be machined to the dimensions shown in Fig. 2.2.9, and may be heated to a temperature not exceeding 250°C for a period not exceeding 16 hours for hydrogen removal, prior to testing.

2.1.13 Butt weld tensile test specimens are to be machined to the dimensions shown in Fig. 2.2.10. For thicknesses of more than 2 mm, the test width is to be 25 mm. For thicknesses less than 2 mm, the test width is to be reduced to 12 mm. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

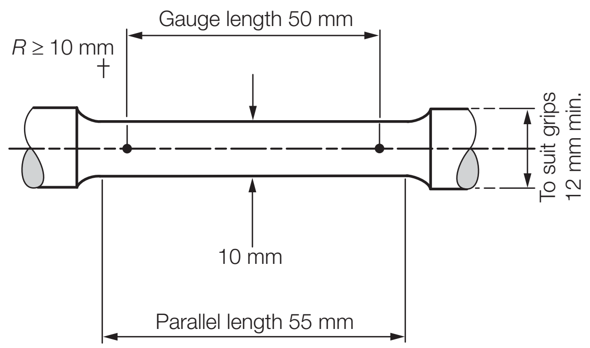


Fig. 2.2.9
Test specimen for deposited weld metal tensile

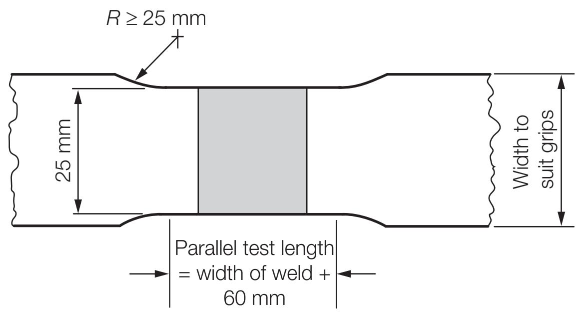


Fig. 2.2.10 Test specimen for butt weld

2.1.14 Through-thickness tensile test specimens may be, at the option of the steelmaker, either plain test specimens or test specimens with welded extensions in accordance with a Recognised Standard. The extension pieces are to be of steel with a tensile strength exceeding that of the plate to be tested and may be attached to the plate surfaces by manual, resistance or friction welding carried out in such a way as to ensure a minimal heat affected zone.

2.1.15 Tolerances on tensile specimen dimensions are to be in accordance with ISO 6892-1 or another Recognised Standard as appropriate.

2.2 Definition of yield stress for steel

2.2.1 The yield phenomenon is not exhibited by all the steels detailed in these Rules but, except for austenitic and duplex stainless steels, the term 'yield stress' is used throughout when requirements are specified for acceptance testing at ambient temperature. For the purposes of the Rules, the terms 'yield stress' and 'yield strength' are to be regarded as synonymous.

2.2.2 Where reference is made to 'yield stress' in the requirements for carbon, carbon-manganese and alloy steel products and in the requirements for the approval of welding consumables, either the upper yield stress or, where this is not clearly exhibited, the 0,2 per cent proof stress or the 0,5 per cent proof stress under load is to be determined. In cases of dispute, the 0,2 per cent proof stress is to be determined.

2.2.3 For austenitic and duplex stainless steel products and welding consumables, both the 0,2 and the 1,0 per cent proof stresses are to be determined.

2.3 Procedure for testing at ambient temperature

2.3.1 Except as provided in 2.3.5, the elastic stress rate for the determination of the upper yield for steels and copper alloys is to be between 6 and 60 N/mm^2 per second and between 2 and 20 N/mm^2 per second for aluminium. After reaching the yield or proof load, the straining rate may be increased to a maximum of 0,008s^{-1} for the determination of the tensile strength.

2.3.2 For steel, the upper yield stress is to be calculated from:

(a) the value of stress measured at the commencement of plastic deformation, or
(b) on a load/extension diagram using the value of stress measured at the first peak obtained during yielding even when the peak is equal to or less than any subsequent peaks observed during plastic deformation at yield.

2.3.3 When a well defined yield point cannot be obtained, the 0,2 or 1,0 per cent proof stress (non-proportional elongation) is to be determined from an accurate load/extension diagram by drawing a line parallel to the straight elastic portion and a distance from it where the amount represents 0,2 or 1,0 per cent of the extensometer gauge length. The point of intersection of this line with the plastic portion of the diagram represents the proof load, from which the 0,2 or 1,0 per cent proof stress can be calculated.

2.3.4 For stainless steels, the 1,0 per cent proof stress and/or 0,2 per cent proof stress is specified as required by the relevant Chapters in these Rules.

2.3.5 For the determination of the tensile strength of flake graphite cast iron, the stress rate is not to exceed 10 N/mm^2 per second.

2.3.6 A measured elongation value is to be regarded as valid only if the fracture occurs within the gauge length and at least the following distances from the gauge marks:

Round test specimen: 1,25*d*
Flat test specimen: *a* plus width of specimen

The measurement is valid irrespective of the position of the fracture, if the percentage elongation after fracture reaches at least the specified value, and this is to be stated in the test report.

2.4 Equivalent elongations

2.4.1 When a gauge length other than $5{,}65\sqrt{S_o}$ is used, the equivalent percentage elongation value is to be calculated using the following formula:

$$A = \frac{A_R}{2}\left(\frac{L_o}{\sqrt{S_o}}\right)^{0{,}40}$$

where
A_R = actual measured percentage elongation of test specimen
S_o = actual cross-sectional area of test specimen
L_o = actual gauge length of test piece
A = equivalent percentage elongation for a test specimen with a gauge length of $5{,}65\sqrt{S_o}$.

2.4.2 Alternatively, where a number of test specimens of similar material and dimensions are involved, the actual percentage elongation values may be recorded, provided that the equivalent specified minimum elongation value appropriate for the test specimen dimensions is calculated from the formula in 2.4.1 and is recorded on the test certificate.

2.4.3 For proportional test specimens having a gauge length other than $5{,}65\sqrt{S_o}$, the equivalent elongation may be calculated using the following factors (*d* is the diameter of the test specimen):

Actual gauge length	Factor for equivalent elongation on $5{,}65\sqrt{S_o}$
$4\sqrt{S_o}$	x 0,870
$8{,}16\sqrt{S_o}$	x 1,158
$11{,}3\sqrt{S_o}$	x 1,317
4*d*	x 0,916
8*d*	x 1,207

2.4.4 For non-proportional test specimens with gauge lengths of 50 mm and 200 mm, the equivalent elongation values tabulated in ISO 2566 are to apply.

2.4.5 The above conversions are reliable only for carbon, carbon-manganese and low alloy steels with a tensile strength not exceeding 700 N/mm^2 in the hot rolled, annealed, normalised, or normalised and tempered condition.

2.4.6 For alloy steels in the quenched and tempered condition, the following conversions may be used for proportional test specimens with a gauge length of $4\sqrt{S_o}$:

Actual percentage elongation on $4\sqrt{S_o}$	Equivalent elongation on $5{,}65\sqrt{S_o}$
22	17
20	15
18	13
17	12
16	12
15	11
14	10
12	8
10	7
8	5

2.4.7 Any proposals to use conversion factors for equivalent elongation values for the following materials are to be agreed with the Surveyors:

(a) Carbon, carbon-manganese and alloy steels in the normalised or normalised and tempered condition with a tensile strength exceeding 700 N/mm^2.
(b) Cold-worked steels.
(c) Austenitic stainless steels.
(d) Non-ferrous alloys.

2.5 Procedure for testing at elevated temperatures

2.5.1 The test specimens used for the determination of lower yield or 0,2 per cent proof stress at elevated temperatures are to have an extensometer gauge length of not less than 50 mm and a cross-sectional area of not less than 65 mm^2. Where, however, this is precluded by the dimensions of the product or by the test equipment available, the test specimen is to be of the largest practicable dimensions.

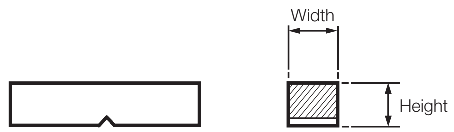
2.5.2 The heating apparatus is to be such that the temperature of the specimen during testing does not deviate from that specified by more than ±5°C.

2.5.3 The straining rate when approaching the lower yield or proof load is to be controlled within the range 0,1 to 0,3 per cent of the extensometer gauge length per minute.

2.5.4 The time intervals used for estimation of strain rate from measurements of strain are not to exceed 6 seconds.

Table 2.3.1 Dimensions and tolerances for Charpy V-notch impact test specimens

Dimension	Nominal	Tolerance
Length, in mm	55	±0,60
Height, in mm, *see* Note 1	10	±0,075
Width, in mm, *see* Note 1		
– standard specimen	10	±0,11
– standard subsidiary specimen	7,5	±0,11
– standard subsidiary specimen	5	±0,06
Angle of notch	45°	±2°
Height below notch, in mm	8	±0,075
Root radius, in mm	0,25	±0,025
Distance of plane of symmetry of notch from ends of test piece, in mm, *see* Note 1	27,5	±0,42, *see* Note 2
Angle between plane of symmetry of notch and longitudinal axis of test piece	90°	±2°
Angle between adjacent longitudinal faces of test piece	90°	±2°



NOTES
1. The test piece is to have a surface roughness better than R*a* 5 µm except for the ends.
2. For machines with automatic positioning of the test piece the tolerance is to be taken as ±0,165 mm.

■ *Section 3* **Impact tests**

3.1 Dimensions of test specimens

3.1.1 Impact tests are to be of the Charpy V-notch type. The test specimens are to be machined to the dimensions and tolerances given in Table 2.3.1 and are to be carefully checked for dimensional accuracy.

3.1.2 For material under 10 mm in thickness, the largest possible size of standard subsidiary Charpy V-notch test specimen is to be prepared with the notch cut on the narrow face. Generally, impact tests are not required when the thickness of the material is less than 6 mm.

3.2 Testing procedures

3.2.1 All impact tests are to be carried out on Charpy machines approved by Lloyd's Register (hereinafter referred as LR) and having a striking energy of not less than 150 J.

3.2.2 Charpy V-notch impact tests may be carried out at ambient or lower temperatures in accordance with the specific requirements given in subsequent Chapters of these Rules. Where the test temperature is other than ambient, the temperature of the test specimen is to be controlled to within ±2°C for sufficient time to ensure uniformity throughout the cross-section of the test specimen, and suitable precautions are to be taken to prevent any significant change in temperature during the actual test. In cases of dispute, ambient temperature is to be considered as 18°C to 25°C.

3.2.3 For acceptance, the average energy value for a set of three impact tests must be equal to or greater than the appropriate specified minimum average value. Additionally, only one individual value may be less than the required average value but not less than 70 per cent of this average value.

3.2.4 Where standard subsidiary Charpy V-notch test specimens are necessary, the minimum energy values required are to be reduced as follows:

Specimen 10 x 7,5 mm: 5/6 of tabulated energy.
Specimen 10 x 5 mm: 2/3 of tabulated energy.

3.2.5 When reporting results, the specimen dimensions and the units used for expressing the energy absorbed (Joules) and the testing temperature are to be clearly stated.

■ *Section 4*
Ductility tests for pipes and tubes

4.1 Bend tests

4.1.1 The test specimens are to be cut as circumferential strips of full wall thickness and with a width of not less than 40 mm. For thick walled pipes, the thickness of the test specimens may be reduced to 20 mm by machining. The edges of the specimens may be rounded to a radius of 1,6 mm.

4.1.2 Testing is to be carried out at ambient temperature, and the specimens are to be doubled over a former whose diameter is to be in accordance with the specific requirements for the material. For submerged arc welded tube the test piece is to be bent with the root of the weld in tension. For other tubes, the test piece is to be bent in the original direction of curvature. In all cases, the welds are to be in the middle of the test specimen. The test is considered to be satisfactory if, after bending, the specimens are free from cracks and laminations. Small cracks at the edges of the test specimens are to be disregarded.

4.2 Flattening tests

4.2.1 Ring test specimens are to be cut with the ends perpendicular to the axis of the pipe or tube. The length of the specimen is to be equal to 1,5 times the external diameter of the pipe or tube, but is to be not less than 10 mm or greater than 100 mm. Alternatively, the length of the test specimen may be 40 mm irrespective of the external diameter.

4.2.2 Testing is to be carried out at ambient temperature and is to consist of flattening the specimens in a direction perpendicular to the longitudinal axis of the pipe. Flattening is to be carried out between two plain parallel and rigid platens which extend over both the full length and the width after flattening of the test specimen. Flattening is to be continued until the distance between the platens, measured under load, is not greater than the value given by the formula:

$$H = \frac{t\,(1 + C)}{C + \frac{t}{D}}$$

where
- H = distance between plates, in mm
- t = specified thickness of the pipe, in mm
- D = specified outside diameter, in mm
- C = a constant dependent on the steel type and detailed in the specific requirements

After flattening, the specimens are to be free from cracks or other flaws. Small cracks at the ends of the test specimens may be disregarded.

4.2.3 For welded pipes or tubes, the weld is to be placed at 90° to the direction of flattening.

4.3 Drift expanding tests

4.3.1 The test specimens are to be cut with the ends perpendicular to the axis of the tube. The edges of the end to be tested may be rounded by filing.

4.3.2 For metallic tubes, the length of the specimen is to be at least 1,5 times the external diameter of the tube except when a mandrel with an included angle of 30° is used, in which case the length of the specimen is to be twice the external diameter of the tube. In all cases the length of section remaining cylindrical after test is not be less than 0,5 times the external diameter.

4.3.3 Testing is to be carried out at ambient temperature and is to consist of expanding the end of the tube symmetrically by means of a hardened conical steel mandrel having a total included angle of 30°, 45° or 60°, *see* Fig. 2.4.1. The mandrel is to be forced into the test specimen at a rate not exceeding 50 mm/min until the percentage increase in the outside diameter of the end of the test specimen is not less than the value given in the specific requirements for boiler and superheater tubes, *see* Chapter 6. The mandrel is to be lubricated, but there is to be no rotation of the tube or mandrel during the test. The expanded portion of the tube is to be free from cracks or other flaws.

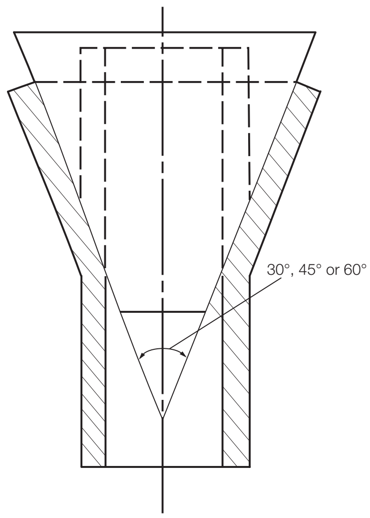


Fig. 2.4.1 Drift expanding test

4.4 Flanging tests

4.4.1 The test specimens are to be cut with the ends perpendicular to the axis of the tube. The length of the specimens is to be at least equal to the external diameter of the tube and such that after testing the portion that remains cylindrical is not less than half the external diameter. The edges of the end to be tested may be rounded by filing.

4.4.2 Testing is to be carried out at ambient temperature and is to consist of flanging the end of the tube symmetrically by means of hardened conical steel mandrels. The rate of flanging is not to exceed 50 mm/min.

4.4.3 The first stage of flanging is to be carried out with a conical angled mandrel having an included angle of approximately 90°, *see* Fig. 2.4.2(a). The completion of the test is achieved with a second forming tool as shown in Fig. 2.4.2(b). The mandrels are to be lubricated and there is to be no rotation of the tube or mandrels during the test. The test is to continue until the drifted portion has formed a flange perpendicular to the axis of the test specimens. The percentage increase in the external diameter of the end of the specimens is to be not less than the value given in the specific requirements for boiler and superheater tubes, *see* Chapter 6. The cylindrical and flanged portion of the tube is to be free from cracks or other flaws.

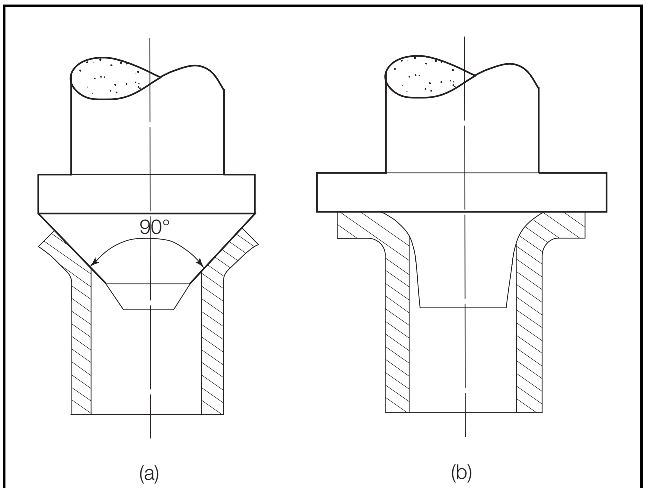


Fig. 2.4.2 Flanging test

Section 5
Embrittlement tests

5.1 Temper embrittlement tests

5.1.1 The test material is to be heat treated in accordance with the specification except that after tempering:
(a) half the material is to be water quenched;
(b) the other half is to be cooled from the tempering temperature to 300°C at a rate not exceeding 10°C per minute.

5.1.2 Impact tests in accordance with Section 3 are to be made on the material in each condition at temperatures over a range wide enough to establish the upper and lower shelf energies and temperatures, tests being made at no less than three intermediate temperatures.

5.1.3 A set of three specimens is to be tested at each temperature. The results are to be plotted separately for each condition, in the form illustrated in Fig. 2.5.1. In addition, the test temperatures, proportions of crystallinity and absorbed energies for all the specimens tested are to be reported.

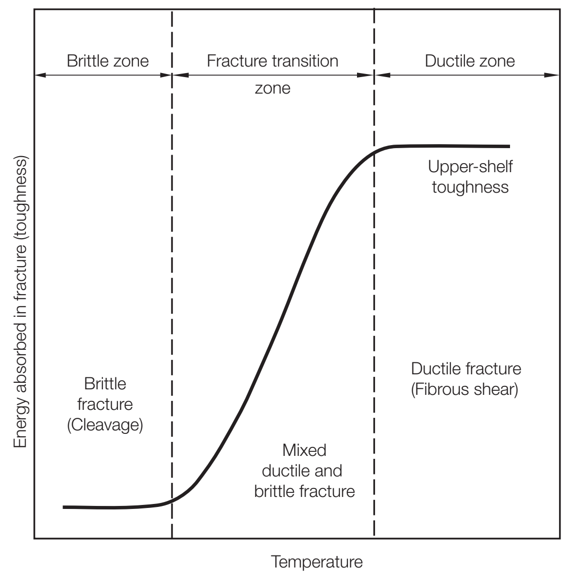


Fig. 2.5.1 Idealised transition curve

5.1.4 The transition temperature for each condition is to be taken as the mid-temperature of the fracture transition zone. The difference between the two transition temperatures is to be reported.

5.2 Strain age embrittlement tests

5.2.1 The test material is to be heat treated in accordance with the specification and then subjected to five per cent strain. Half of the test material is then to be heated to 250°C and held for one hour.

5.2.2 Impact tests in accordance with 5.1.2 are to be made in both the strained and unstrained conditions.

5.2.3 The tests are to comply with 5.1.3.

5.2.4 The test results are treated in accordance with 5.1.4.

5.3 Hydrogen embrittlement tests

5.3.1 Two specimens are to be tested. The specimens are to be of a diameter of 20 mm. Where this is not practicable a diameter of 14 mm may be accepted.

5.3.2 One specimen is to be tested within a maximum of 3 hours after machining. Where the specimen diameter is 14 mm, the time limit is 1,5 hours. Alternatively, the specimen may be cooled to –60°C immediately after machining and kept at that temperature for a maximum period of 5 days before being tested.

5.3.3 The other specimen is to be tested after baking at 250°C for 4 hours. Where the specimen diameter is 14 mm the baking time is to be 2 hours.

5.3.4 A strain rate not exceeding $0{,}0003s^{-1}$ is to be used during the entire test, until fracture occurs.

5.3.5 Tensile strength, elongation and reduction of area are to be reported.

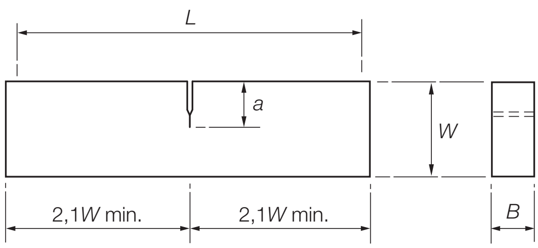
5.3.6 The ratio Z_1/Z_2 is to be reported, where Z_1 is the reduction in area without baking and Z_2 the reduction in area after baking.

■ *Section 6* Crack tip opening displacement tests

6.1 Dimensions of test specimens

6.1.1 Unless agreed otherwise, tests are to be made on specimens of the full section thickness and which conform to a nationally agreed standard.

6.1.2 Normally the specimens are to be rectangular with the main dimensions as indicated in Fig. 2.6.1 and are to be tested in three point bending.

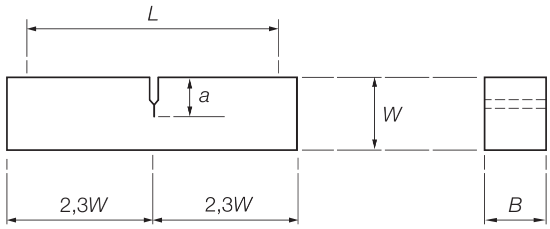


B = thickness
W = width = $2B$
a = effective crack length = $0{,}45W$ to $0{,}55W$
L = loading span = $4W$

Fig. 2.6.1
Outline dimensions of the preferred specimen

6.1.3 A subsidiary specimen as in Fig. 2.6.2 may be used by agreement.

6.1.4 In each case the notch is to be positioned at the centre of the loading span; its root radius is not to exceed 0,10 mm. The notch is to be extended by the generation of a fatigue crack to give an effective crack length of the dimension *a*. For this purpose, the fatigue stress ratio, R_1, is to be within the range 0 to 0,1 and the fatigue intensity is not to exceed $0{,}63\sigma_\gamma B^{1/2}$ where σ_γ is the 0,2 per cent proof stress at the test temperature.



B = thickness
W = width = B
a = effective crack length (to be agreed between the purchaser and manufacturer)
L = loading span = $4W$

Fig. 2.6.2
Outline dimensions of the subsidiary specimen

6.2 Test equipment

6.2.1 Whenever possible, tests are to be made using machines operating under displacement control. The type of control is to be recorded.

6.2.2 The test equipment is to be calibrated annually.

6.2.3 The crack opening displacement gauge is to have an accuracy of at least one per cent. It is to be calibrated at least once every day of testing and at intervals of no more than 10 tests. It should be demonstrated that the calibration is satisfactory for the test conditions.

6.3 Testing procedures

6.3.1 Tests are to be made in a recognised test house in accordance with a nationally accepted standard.

6.3.2 Unless otherwise agreed, all tests on unwelded wrought material are to be made on specimens taken transverse to the principal working direction and are to be through-thickness notched.

6.3.3 Where tests are made on weld material, the fatigue crack should be arranged to sample the maximum amount of unrefined weld metal.

6.3.4 Where tests are made on the Heat Affected Zone (H.A.Z.) of a weld, a K or single bevel weld preparation is recommended. The region of lowest fracture toughness in the Heat Affected Zone should be identified for the particular steel and weld procedure by means of preliminary tests. The fatigue crack is to be accurately positioned to sample as high a proportion of this critical region as possible and after testing has been completed, the specimen is to be sectioned to check that this has been achieved. Sufficient tests should be made to ensure that the critical region has been sampled in at least three specimens.

6.3.5 At least three valid tests are to be made for each material condition. Invalid tests are to be disregarded and the tests repeated.

6.3.6 Local pre-compression of the test specimen ahead of the notch is acceptable in order to provide an acceptably even fatigue crack front.

6.3.7 The temperature of the test piece is to be measured to within ±2°C over the range minus 196°C to +200°C and to within ±5°C outside this range. The temperature should be measured at a point on the specimen not farther than 2 mm away from the crack tip.

6.4 Validity requirements

6.4.1 The test is to be regarded as invalid if:

(a) the fatigue crack front is not in a single plane;
(b) any part of the fatigue crack surface lies in a plane whose angle with the plane of the notch exceeds 10°;
(c) the length of any part of the fatigue crack is less than 0,025W or 1,25 mm, whichever is the greater;
(d) the difference between the maximum and minimum lengths of the fatigue crack exceeds 0,1W;
(e) the difference between any two of the lengths of the fatigue crack at 0,25B, 0,5B and 0,75B exceeds 0,05W.

6.4.2 In addition, for tests on welds and Heat Affected Zones (H.A.Z.), the following criteria are to be complied with:

(a) Weld metal. The fatigue crack front shall not extend outside the weld metal deposit and 80 per cent should be within 2 mm of the fusion line.
(b) Grain coarsened H.A.Z.. The fatigue crack should be within 0,5 mm of the fusion line and should sample all of the grain coarsened H.A.Z. present. However, if fusion line irregularities prevent this, a sample including as much grain coarsened H.A.Z. as possible may be accepted.
(c) Subcritical/intercritical H.A.Z. boundary. The fatigue crack is to sample the boundary between the subcritical and intercritical regions of the H.A.Z. However, if fusion line irregularities prevent this, a sample including as much relevant microstructure as possible may be accepted.

6.5 Test reports

6.5.1 The test report is to include:

(a) details of the material, its condition and size;
(b) the thickness and width of the test specimen;
(c) the fatigue pre-cracking conditions;
(d) the test temperature and environment;
(e) the test machine control system and rate of change of displacement or load;
(f) crack length measurements;
(g) force/displacement records, preferably in the form of an autographic record;
(h) the critical crack opening displacement;
(j) a photograph of the fracture;
(k) any observation on the fracture surface.

■ *Section 7* Bend tests

7.1 Dimensions of test specimens

7.1.1 Flat bend test specimens are to be of rectangular cross-section with dimensions as defined in Fig. 2.7.1.

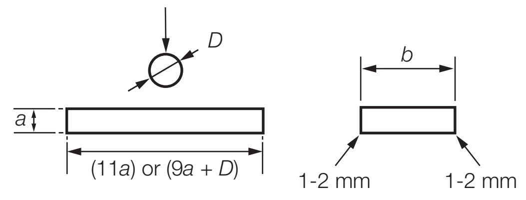


Fig. 2.7.1 Bend test specimen

7.1.2 For plates, sections and strip the dimensions shall be full thickness and width 30 mm. Where the rolled thickness exceeds 25 mm the compression face may be reduced to 25 mm.

7.1.3 For forgings, castings and semi-finished products the thickness shall be 20 mm and width 25 mm.

7.1.4 Butt weld face and root bend test specimens are to be 30 mm in width and of the full plate thickness. Where the thickness exceeds 25 mm, two side bend test specimens may be tested in place of the face and root specimens specified. The side bend specimens should be 10 mm minimum thickness. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

7.1.5 The edges on the tension side of bend samples are to be rounded to a radius of 1 to 2 mm.

7.2 Testing procedures

7.2.1 The bend sample is plastically deformed by plunging a mandrel between two fixed points as shown in Fig. 2.7.2.

7.2.2 For aluminium welds a guided bend is required to ensure even deformation as shown in Fig. 2.7.3.

7.2.3 Bend tests are to be conducted at ambient temperature at the highest convenient rate of bending (but not impact).

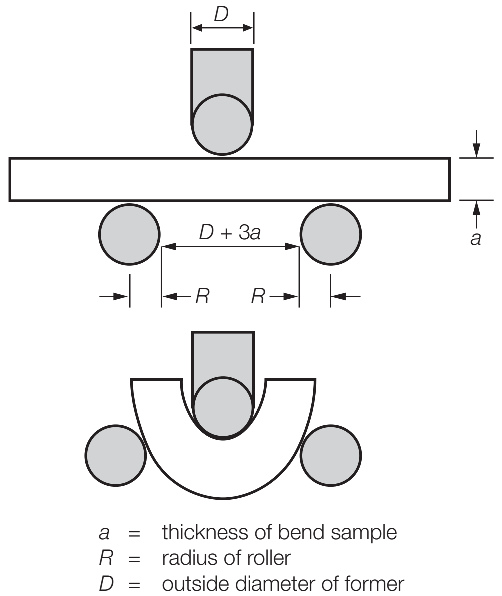


Fig. 2.7.2 Bend test

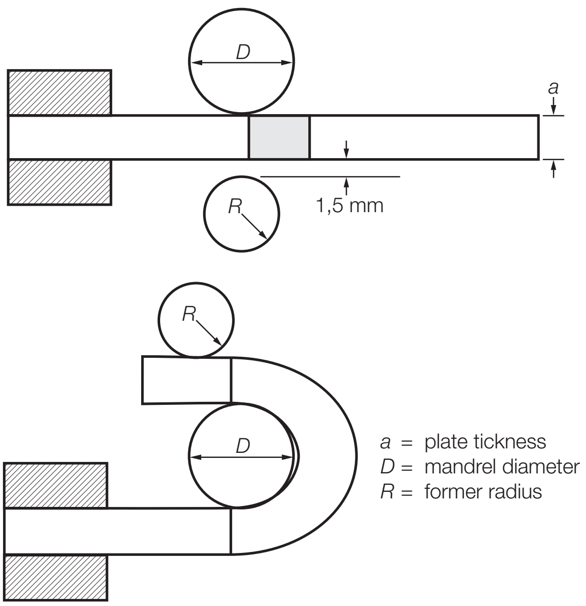


Fig. 2.7.3 Guide bend test for aluminium

■ *Section 8*
Hardness testing

8.1 Dimensions of test specimens

8.1.1 Test pieces must be held rigidly in relation to the indenter and located such that the surface to be tested is at right angles to the axis of the indenter.

8.1.2 The surface finish of the test piece is to be such as to be able to measure the indent accurately.

8.2 Testing procedure

8.2.1 Hardness testing is to be carried out according to ISO 6506-1, ISO 6507-1 or equivalent for the type of hardness test.

■ *Section 9*
Corrosion tests

9.1 Intergranular corrosion test

9.1.1 For all products other than pipes, the material for the test specimens is to be taken adjacent to that for the tensile test and is to be machined to suitable dimensions for either a round or rectangular section bend test. The diameter or thickness is to be not more than 12 mm, and the total surface area is to be between 1500 mm^2 and 3500 mm^2.

9.1.2 For pipes with an outside diameter not exceeding 40 mm, the test specimens are to consist of a full cross-section. For larger pipes, the test specimens are to be cut as circumferential strips of full wall thickness and having a width of not less than 12,5 mm. In both cases the total surface area is to be between 1500 mm^2 and 3500 mm^2.

9.1.3 Specimens are to be heated to a temperature of 700 ± 10ºC for 30 minutes, followed by rapid cooling in water. They are then to be placed on a bed of copper turnings (50 g per litre of test solution) and immersed for 15 to 24 hours in a boiling solution of the following composition:

- 100 g of hydrated copper sulphate granules ($CuSO_4$. $5H_2O$)
- 184 g (100 ml) sulphuric acid (density 1,84 g/ml) added dropwise to distilled water to make 1 litre of solution.

Precautions are to be taken during boiling to prevent concentration of the solution by evaporation.

9.1.4 After immersion, the full cross-section test specimens from pipes are to be subjected to a flattening test in accordance with Ch 2,4.2. All other test specimens are to be bent, at ambient temperature, through 90º over a former with a diameter equal to twice the diameter or thickness of the test specimen.

9.1.5 After flattening or bending, the test specimens are to be free from cracks on the outer, convex surface.

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for hot rolled plates and sections intended for use in the construction of ships, other marine structures, machinery, boilers and pressure vessels.

1.1.2 This Chapter is not applicable to hot rolled bars intended for the manufacture of bolts, plain shafts, etc., by machining operations only. Where used for this purpose, hot rolled bars are to comply with the requirements of Chapter 5.

1.1.3 Plate and strip which is hot coiled after rolling and subsequently uncoiled, cold flattened and cut to the required dimensions are also subject to the appropriate requirements of this Chapter.

1.1.4 Plates, strip, sections and bars are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2, the general requirements of this Section and the appropriate specific requirements given in Sections 2 to 10.

1.1.5 As an alternative to 1.1.4, materials which comply with National or proprietary specifications may be accepted, provided that these specifications give equivalence to the requirements of this Chapter or are approved for a specific application. Particular attention is to be taken of the minimum required under thickness tolerance, *see* 1.6. Generally, survey and certification of such materials are to be carried out in accordance with the requirements of Chapter 1.

1.1.6 Steels intended for high heat input welding above 50 kJ/cm are to be specially approved. Approval will be indicated on the manufacturer's approval certificate by adding a high heat input welding notation to the grade approved, e.g., EH36-W300, indicating approval up to 300 kJ/cm.

1.2 Steel with guaranteed through thickness properties – 'Z' grade steel

1.2.1 When plate material, intended for welded construction, will be subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, 'Z' grade steel. These strains are usually associated with thermal contraction and restraint during welding, particularly for full penetration 'T'-butt welds, but may also be associated with loads applied in service or during construction. Where these strains are of sufficient magnitude, lamellar tearing may occur. Requirements for 'Z' grade plate material are detailed in Section 8. It is the responsibility of the fabricator to make provision for the use of this material.

1.2.2 Steels intended to have guaranteed through thickness properties will include the supplementary suffix Z25 or Z35 in the designation, for example: LR DH36 Z35.

1.3 Corrosion resistant steels for cargo oil tanks of crude oil tankers

1.3.1 This sub-Section refers to normal and higher strength steels that have approved enhanced corrosion resistance properties intended for application in the internal cargo oil tanks of crude oil tankers.

1.3.2 The additional approval procedures for these steels include specific corrosion tests, *see* Ch 1,2.2.

1.3.3 Normal and higher strength corrosion resistant steels are to be manufactured, tested and certified in accordance with the applicable requirements of Section 2 or Section 3 and the requirements detailed in this sub-Section.

1.3.4 Corrosion resistant steels for cargo oil tanks are primarily intended to apply to steel plates, wide flats and sections up to 50 mm thick and to bars up to 50 mm in diameter.

1.3.5 Corrosion resistant steels for cargo oil tanks are to be identified with one of the following supplementary suffixes, RCU, RCB or RCW in the designation, for example, LR DH36 RCB. These suffixes relate to the area of the tank for which approval testing has been obtained:

RCU, for lower surface of strength deck and surrounding structures;
RCB, for upper surface of inner bottom plating and surrounding structures;
RCW, for both strength deck and inner bottom plating.

1.3.6 Corrosion resistant steels are not to be used in applications other than those specified in 1.3.1.

1.3.7 The weldability of corrosion resistant steels is similar to conventional normal and higher strength steels. Therefore the welding requirements specified in Chapters 11 to 13 are to be adhered with the exception that each corrosion resistant steel is approved with a specified brand of welding consumable and associated welding process.

1.3.8 Each manufacturer's approval certificate for corrosion resistant steels will state the steel grade and area of application designation, specified chemical composition range including additive and/or controlling element percentages to improve corrosion resistance, and brand of welding consumables and welding process used for approval.

1.4 Manufacture

1.4.1 All materials are to be manufactured at works which have been approved by Lloyd's Register (hereinafter referred to as 'LR') for the type and grade of steel which is being supplied and for the relevant steel-making and processing route.

1.4.2 Steel is to be cast in metal ingot moulds or by the continuous casting process. The size of the ingot, billet or slab is to be proportional to the dimensions of the final product such that the reduction ratio is normally to be at least 3 to 1. Sufficient discard is to be taken to ensure soundness in the portion used for further processing.

1.4.3 The cast analysis to be used for certification purposes is to be determined after all alloying additions have been carried out and sufficient time allowed for such an addition to homogenise.

1.4.4 Material may be supplied either as-rolled, normalised, normalising rolled, or thermomechanically controlled rolled. The following definitions apply:

(a) As-rolled (AR) refers to rolling of steel at high temperature followed by air cooling. The rolling and finishing temperatures are typically in the austenite recrystallisation region and above the normalising temperature. The strength and toughness properties of steel produced by this process are generally less than those of steel heat treated, after rolling, or steel produced by advanced processes.

(b) Normalising (N) refers to an additional heating cycle of rolled steel above the critical temperature, A_{c3}, and in the lower end of the austenite recrystallisation region followed by air cooling. The process improves the mechanical properties of as-rolled steel by refining the grain size.

(c) Normalising rolling (NR), also known as controlled rolling, is a rolling procedure in which the final deformation is carried out in the normalising temperature range, resulting in a material condition generally equivalent to that obtained by normalising.

(d) Thermomechanically controlled rolling (TM) is a procedure which involves the strict control of both the steel temperature and the rolling reduction. Generally a high proportion of the rolling reduction is carried out close to the A_{r3} temperature and may involve the rolling in the dual phase temperature region. Unlike normalising rolling the properties conferred by TM (TMCP) cannot be reproduced by subsequent normalising or other heat treatment. The use of accelerated cooling on completion of TM may also be accepted subject to the special approval by LR.

(e) Accelerated Cooling, (AcC) is a process which aims to improve mechanical properties by controlled cooling with rates higher than air cooling immediately after the final TM operation. Direct quenching is excluded from accelerated cooling. The material properties conferred by TM and AcC cannot be reproduced by subsequent normalising or other austenitising heat treatment.

(f) Quenching and Tempering (QT),is a heat treatment process in which steel is heated to an appropriate temperature above the A_{c3} and then cooled with an appropriate coolant for the purpose of hardening the microstructure, followed by tempering, a process in which the steel is re-heated to an appropriate temperature, not higher than the A_{c1} to restore the toughness properties by improving the microstructure.

1.4.5 Where material is being produced by a normalising rolling or a thermomechanically controlled process (T.M.) an additional program of tests for approval is to be carried out under the supervision of the Surveyors and the results are to be to the satisfaction of LR.

1.4.6 Weldable high strength steels may be supplied in the quenched and tempered condition for other marine structures, *see* Section 10.

1.5 Quality of materials

1.5.1 Surface and internal imperfections not prejudicial to the proper application of the steel are not, except by special agreement, to be grounds for rejection. Where necessary, suitable methods of non-destructive examination may be used for the detection of harmful surface and internal defects. The extent of this examination, together with an appropriate acceptance standard, is to be agreed between the purchaser, steelmaker and Surveyor and is to be included in the manufacturing specification.

1.6 Dimensional tolerances

1.6.1 The tolerances on thickness of a given product are defined as:

(a) Minus tolerance is the lower limit of the acceptable range below the nominal thickness.

(b) Plus tolerance is the upper limit of the acceptable range above the nominal thickness.

Nominal thickness is defined by the purchaser at the time of enquiry and order.

1.6.2 The average thickness of a product or products is defined as the arithmetic mean of the measurements made in accordance with the requirements in 1.6.11.

1.6.3 For materials of nominal thickness 5 mm and more intended for hull structural purposes as detailed in Sections 2, 3 and 10, the minus tolerance on thickness of plates, strip and wide flats is 0,3 mm, irrespective of nominal thickness. For wide flats, this applies only where the width is greater than or equal to 600 mm. The average thickness of a product or products is not to be less than the nominal thickness. For thicknesses below 5 mm, the thickness tolerances are to be specially agreed. Plus tolerance is to be in accordance with a National or International Standard.

1.6.4 Class C of ISO 7452 may be applied in lieu of 1.6.3. Where this standard is applied, both the requirements in 1.6.11 and the portion of the footnote of Table B.2 in ISO 7542, that reads; 'Also a minus side of thickness of 0,3 mm is permitted,' are not applicable. Additionally, if ISO 7452 is applied, the steel mill is to ensure that the number of measurements and measurement distribution is appropriate to establish that the plates produced are greater than or equal to the specified nominal thickness.

1.6.5 The minus tolerance on bars and sections (except for wide flats with a width ≥ 600 mm) is to be in accordance with the requirements of a recognised National or International Standard.

1.6.6 The Shipbuilder and Owner may agree in individual cases whether they wish to specify a more stringent minus tolerance than that given in this Chapter.

1.6.7 The minus tolerances for plates and wide flats intended for machinery structures are given in Section 5.

1.6.8 For materials intended for applications as detailed in Sections 4 and 6, no minus tolerance is permitted in the thickness of plates and strip. The minus tolerances on sections are to comply with the requirements of a recognised National or International Standard.

1.6.9 For the materials detailed in Section 7, the minus tolerance of material intended for use in the construction of cargo tanks is not to exceed 0,3 mm. For other applications, no minus tolerance is permitted in the thickness of plates and strip.

1.6.10 Dimensional tolerances for material detailed in Section 9 are given in Table 3.9.3.

1.6.11 The average thickness and thickness tolerance is to be measured at locations of a product or products as defined below:

(a) An automated method or manual method may be applied to the thickness measurements. The procedure and the records of measurements are to be made available to the Surveyor and copies provided on request.
(b) At least two lines among Line 1, Line 2 or Line 3, as shown in Fig. 3.1.1, are to be selected for the thickness measurements and at least three points on each selected line as shown in Fig. 3.1.1 are to be selected for thickness measurement on each piece rolled from a single slab or ingot. If more than three points are taken on each line, then the number of points shall be equal on each line.

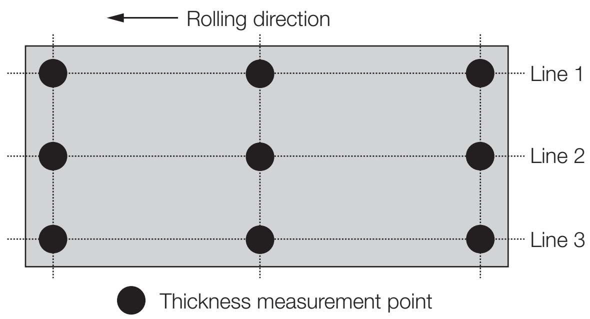


Fig. 3.1.1 Location of thickness measuring points

(c) For automated methods, the measuring points at sides are to be located not less than 10 mm but not greater than 300 mm from the transverse or longitudinal edges of the product.
(d) For manual methods, the measuring points at sides are to be located not less than 10 mm but not greater than 100 mm from the transverse or longitudinal edges of the product.
(e) Additional measurements may be requested by the Surveyor.

1.6.12 Local surface depressions resulting from imperfections and ground areas resulting from the elimination of defects may be disregarded provided that they are in accordance with the requirements of a recognised National or International Standard.

1.6.13 Tolerances relating to length, width, flatness and plus thickness are to comply with a National or International Standard.

1.6.14 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer. Occasional checking by the Surveyor does not absolve the manufacturer from this responsibility.

1.6.15 The Shipbuilder is responsible for the storage and maintenance of product(s) delivered with acceptable surface conditions.

1.7 Heat treatment

1.7.1 Acceptable conditions of supply are specified in subsequent Sections of this Chapter.

1.7.2 The manufacturer is to carry out any heat treatment which may be necessary to prevent hydrogen cracking or to make the material in a safe condition for transit. The Surveyor is to be advised of any heat treatment proposed.

1.7.3 Where material is manufactured using a thermo-mechanically controlled process consideration must be given to the possibility of consequent reduction in mechanical properties if it is subjected to heating for forming or stress relieving or is welded using a high heat input.

1.8 Test material and mechanical tests

1.8.1 Depending on the type of product, provision is made in subsequent Sections of this Chapter for the testing of individual items or for batch testing. Where the latter is permitted, all materials in a batch presented for acceptance tests are to be of the same product form, (e.g., plates, flats, sections, etc.), from the same cast and in the same condition of supply.

1.8.2 The test samples are to be fully representative of the material and, where appropriate, are not to be cut from the material until heat treatment has been completed. The test specimens are not to be separately heat treated in any way.

1.8.3 The test material is to be taken from the thickest piece in each batch, *see* Ch 1,4.1.

1.8.4 Test material is to be taken from the following positions:

(a) At the square cut end of plates and flats greater than 600 mm wide, approximately one-quarter width from an edge, *see* Fig. 3.1.2(a).
(b) For flats 600 mm or less in width, bulb flats and other solid sections, at approximately one-third of the width from an edge, *see* Fig. 3.1.2(b), (c) and (d). Alternatively, in the case of channels, beams or bulb angles, at approximately one-quarter of the width from the centreline of the web, *see* Fig. 3.1.2(c).
(c) For rectangular hollow sections, at approximately the centre of any side, *see* Fig. 3.1.2(e). For circular hollow sections, at any position on the periphery.
(d) For bars intended for purposes as detailed in Sections 2, 3, 5 and 9, at approximately one-third of the radius or half-diagonal from the outer surface, *see* Fig. 3.1.2(f). For smaller bars, the position of the test material is to be as close as is possible to the above.
(e) For bars intended for the applications detailed in Sections 4, 6 and 7 at approximately 12,5 mm below the surface. For bars up to 25 mm diameter, the test specimens may be machined coaxially.
(f) For plates and flats with thicknesses in excess of 40 mm, full thickness specimens may be prepared, but when instead a machined round specimen is used then the axis is to be located at a position lying one-quarter of the product thickness from the surface as shown in Fig. 3.1.2(g).

1.8.5 Tensile test specimens and impact test specimens, where required for the type and grade of product being supplied, are to be prepared from each item or batch of material submitted for acceptance.

1.8.6 Where the finished width of plates and flats is greater than 600 mm, the tensile test specimens are to be cut with their principal axes perpendicular to the final direction of rolling. For all other rolled products, the principal axes are to be parallel to the final direction of rolling.

1.8.7 The tensile test specimens are to be machined to the dimensions detailed in Ch 2,2.1.6 and 2.1.7.

1.8.8 Impact test specimens are to be cut with their principal axes either parallel (longitudinal test) or perpendicular (transverse test) to the final direction of rolling, as required by subsequent Sections of this Chapter. Where both longitudinal and transverse impact properties are shown for a particular grade, only the longitudinal test is required to be carried out, unless otherwise specified by the purchase order or subsequent Sections of this Chapter. However, for plates and wide flats, by certifying that the product meets the requirements of the Rules, the manufacturer guarantees that the acceptance values will be met if tested in the transverse direction. The Surveyor may request testing in this direction to confirm conformity.

1.8.9 Impact test specimens are to be of the Charpy V-notch type, machined to the dimensions detailed in Chapter 2. They are to be taken from a position within 2 mm of one of the rolled surfaces, except that for plates and sections over 40 mm thick, the axes of the test specimens are to be at one-quarter of the thickness from one of the rolled surfaces. For bars and other similar products the axes of the test specimens are to be as specified in 1.8.4(d).

1.8.10 Standard test specimens 10 mm square are to be used, except where the thickness of the material does not allow this size of test specimen to be prepared. In such cases the largest possible size of subsidiary test specimen, in accordance with Table 2.3.1 is to be prepared, with the notch cut on the narrow face. Alternatively, for material of suitable thickness, the rolled surfaces may be retained so that the test specimen width will be the full thickness of the material. In such cases the tolerances for width given in Table 2.3.1 in Chapter 2 are not applicable. The notch is to be cut in a face of the test specimen which was originally perpendicular to the rolled surface. The position of the notch is to be not nearer than 25 mm to a flame-cut or sheared edge.

1.8.11 Impact tests are not required when the nominal material thickness is less than 6 mm.

1.8.12 The test procedures used for all tensile and impact tests are to be in accordance with the requirements of Chapter 2.

1.9 Visual and non-destructive examination

1.9.1 Surface inspection and verification of dimensions are the responsibility of the steelmaker and are to be carried out on all material prior to despatch. Acceptance by the Surveyors of material later found to be defective shall not absolve the steelmaker from this responsibility.

1.9.2 With the exception of 'Z' grade plate material (*see* Section 8) and bars for offshore mooring cable (*see* Section 9), the non-destructive examination of materials is not required for acceptance purposes, *see also* 1.5.1. However, manufacturers are expected to employ suitable methods of non-destructive examination for the general maintenance of quality standards.

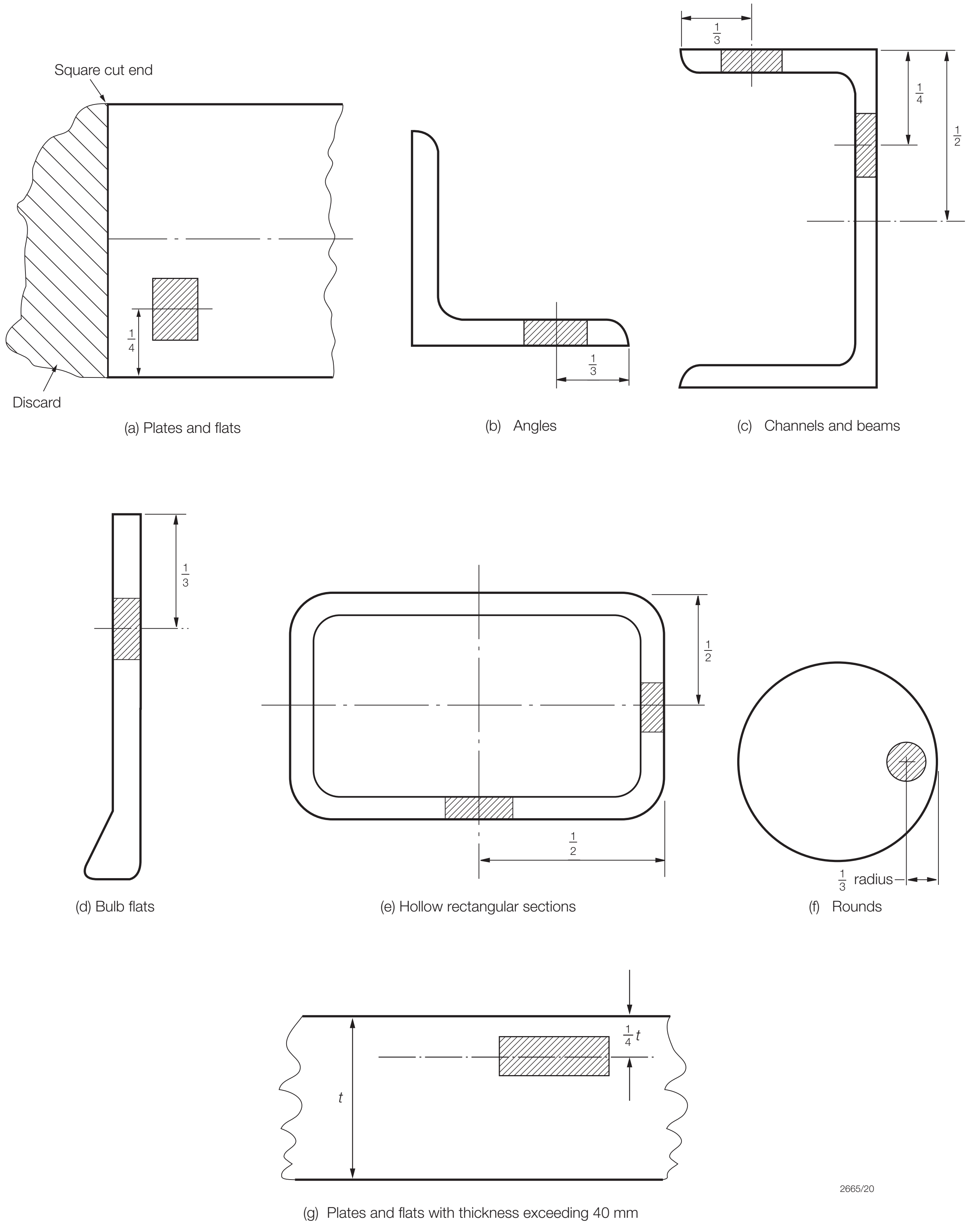


Fig. 3.1.2 Position of test material

1.10 Rectification of defects

1.10.1 For materials intended for structural purposes as detailed in Sections 2, 3 and 5, surface defects may be removed by local grinding provided that:

(a) the thickness is in no place reduced to less than 93 per cent of the nominal thickness, but in no case by more than 3 mm,

(b) each single ground area does not exceed 0,25 m^2,

(c) the total area of local grinding does not exceed two per cent of the total surface,

(d) the ground areas have smooth transitions to the surrounding surface.

Where necessary, the entire surface may be ground to a maximum depth as given by the underthickness tolerances of the product. The extent of such rectification is to be agreed in each case with the Surveyors and is to be carried out under their supervision, unless otherwise agreed. They may request that complete removal of the defect is proven by suitable non-destructive examination of the affected area.

1.10.2 Surface defects which cannot be dealt with as in 1.10.1 may be repaired by chipping or grinding followed by welding, subject to the Surveyor's consent and under his supervision, provided that:

(a) after removal of the defect and before welding, the thickness of the item is in no place reduced by more than 20 per cent,

(b) each single weld does not exceed 0,125 m^2,

(c) the total area of welding does not exceed two per cent of the surface of the side involved,

(d) the distance between any two welds is not less than their average width,

(e) the welds are of reasonable size and made with an excess layer of beads which is then ground smooth to the surface level,

(f) elimination of the defect is proven by suitable non-destructive examination of the affected area,

(g) welding is carried out by an approved procedure and by competent operators using approved electrodes and the repaired area is ground smooth to the correct nominal thickness,

(h) when requested by the Surveyor, the item is normalised or otherwise suitably heat treated after welding and grinding, and

(j) at the discretion of the Surveyor, the repaired area is proven free from defects by suitable non-destructive examination.

1.10.3 For materials intended for applications as detailed in Sections 4, 6 and 7, surface defects may be removed by grinding in accordance with 1.10.1, except that when the thickness is reduced below that given in the approved plans, acceptance will be subject to special consideration. Weld repairs may also be carried out generally in accordance with 1.10.2, except that in all cases suitable heat treatment after welding and non-destructive testing of the repaired areas is required. The fabricator is to be advised regarding the position and extent of all repairs.

1.10.4 For plates which have been produced by a T.M. process or by normalising rolling, repair by welding will be approved by the Surveyor only after procedure tests have shown that the mechanical properties have not been impaired.

1.10.5 Cracks, shells, sand patches and sharp edged seams are always considered defects which would impair the end use of the product and which require rejection or repair irrespective of their size and number. The same applies to other imperfections exceeding the acceptable limits.

1.11 Identification of materials

1.11.1 Every finished item is to be clearly marked by the manufacturer in at least one place with LR's brand Ʀ and the following particulars:

(a) The manufacturer's name or trade mark.

(b) The grade of steel. The designations given in subsequent Sections of this Chapter may be preceded by the letters 'LR' in order to fully describe the grade, e.g. LR A, LR 490FG. LR LT-FH40, LR 316L, etc.

(c) When the material complies with the requirements of Section 8, the grade is to include the suffix Z25 or Z35, e.g., LR AH36 Z35.

(d) Identification number and/or initials which will enable the full history of the item to be traced.

(e) If required by the purchaser, his order number or other identification mark.

The above particulars, but excluding the manufacturer's name or trade mark where this is embossed on finished products, are to be encircled with paint or otherwise marked so as to be easily recognisable.

1.11.2 Where a number of light materials are securely fastened together in bundles, the manufacturer may brand only the top piece of each bundle or, alternatively, a firmly fastened durable label containing the identification may be attached to each bundle.

1.11.3 In the event of any material bearing LR's brand failing to comply with the test requirements, the brand is to be unmistakably defaced, *see also* Ch 1,4.8.

1.12 Certification of materials

1.12.1 Unless a LR certificate is specified in other parts of the Rules, a manufacturer's certificate validated by LR is to be issued (*see* Ch 1,3.1) and is to include the following particulars:

(a) Purchaser's name and order number.

(b) If known, the contract number for which the material is intended.

(c) Address to which material is dispatched.

(d) Name of steelworks.

(e) Description and dimensions of the material.

(f) Specification or grade of the steel.

(g) Identification number of piece, including test specimen number where appropriate.

(h) Cast number and chemical composition of ladle samples.

(j) Mechanical test results (not required on shipping statements).

(k) Condition of supply.

1.12.2 Before the test certificates are signed by the Surveyor, the steelmaker is required to provide a written declaration stating that the material has been made by an approved process, and that it has been subjected to and has withstood satisfactorily the required tests in the presence of the Surveyor, or an authorised deputy. The following form of declaration will be accepted if stamped or printed on each test certificate with the name of the steelworks and signed by an authorised representative of the manufacturer:

> 'We hereby certify that the material has been made by an approved process and satisfactorily tested in accordance with the Rules of Lloyd's Register'.

1.12.3 When steel is not produced at the works at which it is rolled, a certificate is to be supplied by the steelmaker stating the process of manufacture, the cast number and the chemical composition of ladle samples. The works at which the steel was produced must be approved by LR.

1.12.4 The manufacturer of coiled plate is required to issue a certificate which clearly identifies the material as coil. The certificate issued should include the words; 'Coils covered by this certificate require further processing at a works approved by Lloyd's Register before being certified as plate in accordance with the Rules of Lloyd's Register' in addition to the requirements of 1.12.2.

1.12.5 The supplier of plate cut from coil is required to issue a certificate which clearly identifies the product as finished plate meeting the requirements of the Rules in accordance with 1.12.2.

1.12.6 The form of certificates produced by computer systems is to be agreed with the Surveyor.

■ *Section 2*
Normal strength steels for ship and other structural applications

2.1 Scope

2.1.1 The requirements of this Section are primarily intended to apply to steel plates and wide flats not exceeding 100 mm in thickness and sections and bars not exceeding 50 mm in thickness in Grades A, B, D and E. For greater thicknesses, variations in the requirements may be permitted or required for particular applications.

2.1.2 Additional approval tests may be required to verify the suitability for forming and welding of Grade E plate exceeding 50 mm in thickness.

2.2 Manufacture and chemical composition

2.2.1 The method of deoxidation and the chemical composition of ladle samples are to comply with the requirements given in Table 3.2.1.

2.2.2 Small variations from the chemical compositions given in Table 3.2.1 may be allowed for Grade E steel in thicknesses exceeding 50 mm or when any Grade of steel is supplied in a thermo-mechanically controlled processed condition, provided that these variations are documented and approved in advance.

2.2.3 The manufacturer's declared analysis will be accepted subject to occasional checks if required by the Surveyors.

2.2.4 For plate supplied from coil, the chemical analysis can be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

2.3 Condition of supply

2.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.2.2. Where alternative conditions are permitted these are at the option of the steelmaker, unless otherwise expressly stated in the order for the material, but a steelmaker is to supply materials only in those conditions for which he has been approved by LR.

2.3.2 Where normalising rolling and thermomechanically controlled rolling (T.M.) processes are used, it is the manufacturer's responsibility to ensure that the programmed rolling schedules are adhered to. Where deviation from the programmed rolling schedule occurs, the manufacturer must ensure that each affected piece is tested and that the local Surveyor is informed.

2.3.3 If a steel product supplied in the T.M. condition is to be subjected to heating for forming or stress relieving or is to be welded by a high energy input process, consideration must be given to the possibility of a consequent reduction in mechanical properties.

2.4 Mechanical tests

2.4.1 The results of all tensile tests and the average energy value from each set of three impact tests are to comply with the appropriate requirements given in Table 3.2.3 except where enhanced by the requirements of this Section.

Table 3.2.1 Chemical composition and deoxidation practice

Grade	A	B	D	E
Deoxidation	For $t \leq 50$ mm: Any method (for rimmed steel, *see* Note 1)	For $t \leq 50$ mm: Any method except rimmed steel	For $t \leq 25$ mm: Killed	Killed and fine grain treated with aluminium
	For $t > 50$ mm: Killed	For $t > 50$ mm: Killed	For $t > 25$ mm: Killed and fine grain treated with aluminium	
Chemical composition % (*see* Note 5)				
Carbon	0,21 max. (*see* Note 2)	0,21 max.	0,21 max.	0,18 max.
Manganese	2,5 x C% min.	0,80 min. (*see* Note 3)	0,60 min.	0,70 min.
Silicon	0,50 max.	0,35 max.	0,10 – 0,35	0,10 – 0,35
Sulphur	0,035 max.	0,035 max.	0,035 max.	0,035 max.
Phosphorus	0,035 max.	0,035 max.	0,035 max.	0,035 max.
Aluminium (acid soluble)	—	—	0,015 min. (*see* Note 4)	0,015 min. (*see* Note 4)
	Carbon + $^{1}/_{6}$ of the manganese content is not to exceed 0,40%			

NOTES
1. For Grade A, rimmed steel may only be accepted for sections up to a maximum thickness of 12,5 mm, provided that it is stated on the test certificates or shipping statements to be rimmed steel.
2. The maximum carbon content for Grade A steel may be increased to 0,23% for sections.
3. Where Grade B is impact tested the minimum manganese content may be reduced to 0,60%.
4. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0,020%.
5. Where additions of any other elements are made as part of the steel-making practice, the content is to be recorded.

Table 3.2.2 Condition of supply

Grade	Thickness, mm	Conditions of supply			
A and B	≤50	Any			(*see* Note 1)
	>50 ≤100	N	NR	TM	(*see* Note 2)
D	≤35	Any			(*see* Note 1)
	>35 ≤100	N	NR	TM	(*see* Note 3)
E	≤100	N		TM	(*see* Note 4)

N = normalised
NR = normalising rolled
TM = thermomechanically controlled-rolled

NOTES
1. 'Any' includes as-rolled, normalised, normalising rolled and thermomechanically controlled-rolled.
2. Plates, wide flats, sections and bars may be supplied in the as-rolled condition, subject to special approval from LR.
3. Sections in Grade D steel may be supplied in thicknesses greater than 35 mm in the as-rolled condition provided that satisfactory results are consistently obtained from Charpy V-notch impact tests.
4. Sections in Grade E steel may be supplied in the as-rolled and normalising rolled conditions provided that satisfactory results are consistently obtained from Charpy V-notch impact tests.

2.4.2 With the exception given in 2.4.4, one tensile test is to be made for each batch presented unless the mass of finished material is greater than 50 tonnes, in which case one test is to be made from a different piece from each 50 tonnes or fraction thereof. Additional tests are to be made for every variation of 10 mm in the thickness or diameter of products from the same cast. For sections, the thickness to be considered is the thickness of the product at the point at which samples are taken for mechanical tests. A piece is to be regarded as the rolled product from a single slab or billet, or from a single ingot if this is rolled directly into plates, strip, sections or bars.

2.4.3 For Grades A and B where plate is supplied from coil, results of the tensile test can be transposed from the certificate of the coil manufacture onto the certificate issued by the re-processor. If the coil mass exceeds 50 tonnes, testing will additionally be required from two locations representing the start and end of the coil. For Grades D and E, the mechanical properties must be sampled from the de-coiled plate in accordance with the frequency specified in the Rules.

2.4.4 For plates of thickness exceeding 50 mm in Grade E steel, one tensile test is to be made on each piece.

Table 3.2.3 Mechanical properties for acceptance purposes

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Charpy V-notch impact test (*see* Notes 3, 4, 5, 6 and 7)		
				Thickness mm	Average energy J minimum	
					Longitudinal	Transverse (*see* Note 3)
A B D E	235	400 – 520 (*see* Note 1)	22 (*see* Note 2)	≤50 >50 ≤70 >70 ≤100	27 34 41	20 24 27

Impact tests are to be made on the various grades at the following temperatures:

A grade	not required
B grade	0°C
D grade	–20°C
E grade	–40°C

NOTES

1. For sections in Grade A, the upper limit of the tensile strength range may be exceeded at the discretion of the Surveyor.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm (*see* Fig. 2.2.4 in Chapter 2), the minimum elongation is to be:

Thickness mm	≤5	>5 ≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤30	>30 ≤35	>35 ≤50
Elongation %	14	16	17	18	19	20	21	22

3. Tests are to be taken in the longitudinal direction. Normally, transverse test specimens are not required. Transverse test results for plates and wide flats are to be garenteed by the supplier.
4. *See* 2.4.5 and 2.4.6.
5. *See* 2.4.7.
6. *See* 1.8.11.
7. *See* 2.4.14.

2.4.5 For Grade A steel, Charpy V-notch impact tests are not required when the thickness does not exceed 50 mm, or up to 100 mm thick if the material is supplied in either the normalised or thermo-mechanically controlled-rolled condition and has been fine grain treated. However, the manufacturer should confirm, by way of regular in-house checks, that the material will meet a requirement of 27 J at +20°C. The results of these checks shall be reported to the Surveyor. The frequency of these checks should as a minimum be every 250 tonnes.

2.4.6 When Grade A steel is supplied in a thickness greater than 50 mm and either, in the normalising rolled condition, or when special approval has been given to supply in the as-rolled condition, a set of three impact test specimens is to be tested from each batch of 50 tonnes or fraction thereof.

2.4.7 Impact tests are not required for Grade B steel of 25 mm or less in thickness. However, the manufacturer is to confirm, by way of regular in-house tests, and on occasional material selected by the Surveyor, that the material meets the requirement in Table 3.2.3. The results of the tests are to be reported to the Surveyor. The frequency of the in-house checks are to be, as a minimum, one set of three impact test specimens for every 250 tonnes.

2.4.8 For Grade B steels of thicknesses above 25 mm, supplied in the as-rolled or normalising rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 25 tonnes, one extra set of tests is to be made from a different piece from each 25 tonnes or fraction thereof.

2.4.9 For Grade B steels of thicknesses above 25 mm, supplied in the furnace normalised or thermomechanically controlled-rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 50 tonnes, one extra set of tests is to be made from a different piece from each 50 tonnes or fraction thereof.

2.4.10 For Grade D steels supplied in the as-rolled or normalising rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 25 tonnes, one extra set of tests is to be made from a different piece from each 25 tonnes or fraction thereof.

2.4.11 For Grade D steels, supplied in the furnace normalised or thermomechanically controlled-rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 50 tonnes, one extra set of tests is to be made from a different piece from each 50 tonnes or fraction thereof.

2.4.12 For plates in Grade E steel, one set of three impact test specimens is to be made from each piece. For bars and sections in Grade E steel, one set of three test specimens is to be made from each 25 tonnes or fraction thereof. When, subject to the special approval of LR, sections are supplied in the as-rolled or normalising rolled conditions, one set of impact tests is to be taken from each batch of 15 tonnes or fraction thereof.

2.4.13 The results of all tensile tests and the average energy values from each set of three impact tests are to comply with the appropriate requirements given in Table 3.2.3. For impact tests, one individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 1,4.6 for re-test procedures.

2.4.14 For batch tested Grade B and D steel plates supplied in a condition other than furnace normalised, with a thickness equal to, or greater than 25 mm and 12 mm respectively, and where the average value of one set of tests is less than 40 J, two further items from the same batch are to be selected and tested. If these fail to achieve an average of 40 J on either set, each individual piece of the heat is to be tested. The plates are acceptable provided they meet the requirements of Table 3.2.3. Additional testing is not required where the manufacturer can demonstrate to the satisfaction of the Surveyor that the plate was rolled outside the limits of the programmed rolling schedule. In this instance the plate should be rejected, *see also* 2.3.2.

2.4.15 Where standard subsidiary Charpy V-notch test specimens are necessary, *see* Ch 2,3.2.4.

2.5 Identification of materials

2.5.1 The particulars detailed in 1.11 are to be marked on all materials which have been accepted. Where a number of light materials are bundled, the bundle is to be identified in accordance with 1.11.2.

2.6 Certification of materials

2.6.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.12 and, additionally, are to indicate if sections in Grade A steel of rimming quality have been supplied. As a minimum, the chemical composition is to include the contents of any grain refining elements used and the residual elements, as detailed in Table 3.2.1.

■ *Section 3*
Higher strength steels for ship and other structural applications

3.1 Scope

3.1.1 Provision is made for material to be supplied in four strength levels, 27S, 32, 36 and 40.

3.1.2 Provisions for material supplied in H47 strength grades are specifically intended for hatch comings and deck structure of container ships.

3.1.3 The required notch toughness is designated by subdividing the strength levels into Grades AH, DH, EH and FH.

3.1.4 For the designation to fully identify a steel and its properties the appropriate grade letters should precede the strength level number, e.g. AH32 or FH40.

3.1.5 The requirements of this Section are primarily intended to apply to plates, wide flats, sections and bars not exceeding the thickness limits given in Table 3.3.1. For greater thicknesses, variations in the requirements may be permitted or required for particular applications but a reduction of the required impact energy is not allowed.

Table 3.3.1 Maximum thickness limits

Steel designation				Maximum thickness mm	
				Plates and wide flats	Sections and bars
AH 27S	DH 27S	EH 27S	FH27S	100 (see Note 1)	50
AH 32	DH 32	EH 32	FH32		
AH 36	DH 36	EH 36	FH36		
AH 40	DH 40	EH40	FH40		
(*see* Note 2)		EH 47			Not applicable

NOTES
1. Where the thickness exceeds 50 mm, the steel must initially be approved by way of a Nil Ductility Test, in accordance with ASTM E208, to show adequate crack arrest properties. The Nil Ductility Test Temperature is to be agreed for the thickness approved to ensure the crack arrest temperature is below the minimum design temperature. Where the thickness exceeds 70 mm and the material is used specifically as a crack arrest plate, the material must be specially approved with a crack arrest fracture toughness Kca ≥ 6000 N/mm^{1,5}.
2. Minimum thickness for H47 strength level is 50 mm, *see* 3.1.2.

3.1.6 It should be noted that the fatigue strength of weldments in steels of high strength levels may not be greater than those of steels of lower strength levels.

3.2 Alternative specifications

3.2.1 Steels differing from the requirements of this Section in respect of chemical composition, deoxidation practice, condition of supply or mechanical properties may be accepted subject to special approval by LR. Such steels are to be given a special designation, *see* 3.7.2.

3.3 Manufacture

3.3.1 All the grades of steel are to be in the killed and fine grain treated condition.

3.4 Chemical composition

3.4.1 The chemical compositions of ladle samples for all grades of steel are to comply with the requirements given in Table 3.3.2. The requirements for H47 strength grade steels are given in Table 3.3.3.

3.4.2 The carbon equivalent is to be calculated from the ladle analysis using the formula given below and is not to exceed the maximum value agreed between the fabricator and the steelmaker when the steel is ordered.

$$\text{Carbon equivalent} = \text{C} + \frac{\text{Mn}}{6} + \frac{\text{Cr} + \text{Mo} + \text{V}}{5} + \frac{\text{Ni} + \text{Cu}}{15}$$

For TM steels, the agreed carbon equivalent is not to exceed the values given in Table 3.3.4.

3.4.3 The cold cracking susceptibility, P_{cm}, may be used instead of the carbon equivalent for evaluating weldability, in which case the following formula is to be used for calculating the P_{cm} from the ladle analysis:

$$P_{cm} = \text{C} + \frac{\text{Si}}{30} + \frac{\text{Mn} + \text{Cr} + \text{Cu}}{20} + \frac{\text{Ni}}{60} + \frac{\text{Mo}}{15} + \frac{\text{V}}{10} + 5\text{B}$$

The maximum allowable P_{cm} is to be agreed with LR and is to be included in the manufacturing specification and reported on the certificate.

3.4.4 The cold cracking susceptibility, P_{cm}, is to have a maximum value of 0,22 per cent for steels of H47 strength grade.

3.4.5 Small deviations in chemical composition from that given in Table 3.3.2 for plates exceeding 50 mm in thickness in Grades EH36, EH40, FH36 and FH40 may be approved provided that these deviations are documented and approved in advance.

3.4.6 Where the grain refining elements Niobium, Titanium and Vanadium are used either singly or in combination, the chemical composition is to be specifically approved for each Grade in combination with the rolling procedure to be used.

Table 3.3.2 Chemical composition

Grades	AH, DH, EH	FH
Carbon % max.	0,18	0,16
Manganese %	0,9 – 1,60 (*see* Note 1)	0,9 – 1,60
Silicon % max.	0,50	0,50
Phosphorus % max.	0,035	0,025
Sulphur % max.	0,035	0,025
Grain refining elements (*see* Note 2)		
Aluminium (acid soluble) %	0,015 min. (*see* Note 3)	
Niobium %	0,02 – 0,05	
Vanadium %	0,05 – 0,10	
Titanium %	0,02 max.	
Total (Nb + V + Ti) % (*see* Note 5)	0,12 max.	
Residual elements		
Nickel % max.	0,40	0,80
Copper % max.	0,35	0,35
Chromium % max.	0,20	0,20
Molybdenum % max.	0,08	0,08
Nitrogen % max.		0,009 (0,012 max. if Al is present)

NOTES
1. For AH grade steels in all strength levels and thicknesses up to 12,5 mm, the specified minimum manganese content is 0,70%.
2. The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of each element is not applicable.
3. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0,020%.
4. Alloying elements other than those listed above are to be included in the approved manufacturing specification.
5. The grain refining elements are to be in accordance with the approved specification.

Table 3.3.3 Chemical composition for Grade EH 47

Chemical element	max. (%)
Carbon	0,20
Manganese	2,00
Silicon	0,55
Phosphorus	0,030
Sulphur	0,030
Nickel	2,00
Chromium	0,25
Molybdenum	0,080
Grain refining elements (*see* Note 1) Aluminium (acid soluble)	0,015 min (*see* Note 2)
Residual elements Copper 0,35	

NOTES
1. The grain refining elements niobium, vanadium and titanium are to be in accordance with the approved specification.
2. The total aluminium content may be determined instead of the acid soluble content. In these cases the total aluminium content is to be not less than 0,020%.

3.4.7 When any grade is supplied in an approved thermomechanically controlled processed condition, variations in the specified chemical composition may be considered, provided that these variations are documented and approved in advance.

3.4.8 For plate supplied from coil, the chemical analysis can be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

3.5 Condition of supply

3.5.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.3.5 or Table 3.3.6. Where alternative conditions are permitted, these are at the option of the steelmaker, unless otherwise expressly stated in the order for the material.

3.5.2 Where normalising rolling and thermomechanically controlled rolling (T.M.) processes are used, it is the manufacturer's responsibility to ensure that the programmed rolling schedules are adhered to. Where deviation from the programmed rolling schedule occurs, the manufacturer must ensure that each affected piece is tested and that the local Surveyor is informed.

3.5.3 The use of precipitation hardening steels is not acceptable, except where such hardening is incidental to the use of grain refining elements.

3.6 Mechanical tests

3.6.1 The results of all tensile tests and the average energy value from each set of three Charpy V-notch impact tests are to comply with the appropriate requirements given in Table 3.3.7 except where enhanced by the requirements of this Section.

3.6.2 For steels in the as-rolled, normalised, normalising rolled or T.M. conditions, one tensile test is to be made for each batch of 50 tonnes or fraction thereof. Additional tests are to be made for every variation of 10 mm in the thickness or diameter of products from the same cast.

3.6.3 Where plate is supplied from coil, both the tensile tests and the Charpy V-notch tests are to be taken from the de-coiled plate in accordance with the frequency specified for the Grade as required by this Section.

3.6.4 For steels in the quenched and tempered condition a tensile test is to be made on each plate as heat treated. For continuously heat treated plates, one tensile test is to be made for each 50 tonnes or fraction thereof from a single cast. Additional tests are to be made for every variation of 10 mm in the thickness of the products from a single cast. The tensile test specimens are to be taken with their axes transverse to the main direction of rolling.

Table 3.3.4 Carbon equivalent requirements for higher tensile strength steels up to 100 mm in thickness when supplied in the TM condition

Grade				Carbon Equivalent, max. (%)	
				$t \leq 50$	$50 < t \leq 100$
AH 27S	DH 27S	EH 27S	FH 27S	0,36	0,38
AH 32	DH 32	EH 32	FH 32	0,36	0,38
AH 36	DH 36	EH 36	FH 36	0,38	0,40
AH 40	DH 40	EH 40	FH 40	0,40	0,42
		EH 47		Not applicable (*see* Table 3.3.1)	0,49

NOTE
t = thickness, in mm.

Table 3.3.5 Conditions of supply for plates and wide flats

Grade	Grain refining practice (*see* Note 1)	Thickness range mm	Conditions of supply (*see* Note 2)				
AH 27S AH 32 AH 36	Al or Al + Ti	≤ 20	AR	N	NR	TM	
		>20 ≤ 100	—	N	NR	TM	(*see* Note 3)
	Nb or V or Al + (Nb or V) or Al + (Ti) + (Nb or V)	≤ 12,5	AR	N	NR	TM	
		>12,5 ≤ 100	—	N	NR	TM	
AH 40	Any practice	≤ 12,5	AR	N	NR	TM	
		>12,5 ≤ 50	—	N	NR	TM	
		>50 ≤ 100	—	N	—	TM	QT
DH 27S DH 32 DH 36	Al or Al + Ti	≤ 20	AR	N	NR	TM	
		>20 ≤ 100	—	N	NR	TM	(*see* Note 4)
	Nb or V or Al + (Nb or V) or Al + (Ti) + (Nb or V)	≤ 12,5	AR	N	NR	TM	
		>12,5 ≤ 100	—	N	NR	TM	
DH 40	Any practice	≤ 50	—	N	NR	TM	
		>50 ≤ 100	—	N	—	TM	QT
EH 27S EH 32 EH 36	Any practice	≤ 100	—	N	—	TM	
EH 40	Any practice	≤ 100	—	N	—	TM	QT
FH 27S FH 32 FH 36 FH 40	Any practice	≤ 100	—	N	—	TM	QT
EH 47	Any practice	≤ 50	Not applicable				
		>50 ≤100	—	—	—	TM	QT

NOTES
1. Grain refining elements used singly or in any combination, require specific approval from Materials and NDE Department, London office.
2. AR = as-rolled   N = furnace normalised   NR = normalising rolled
   TM = thermomechanically controlled-rolled   QT = quenched and tempered
3. Material up to 35 mm thick may be supplied in the as-rolled condition provided that prior approval has been obtained from LR.
4. Material up to 25 mm thick may be supplied in the as-rolled condition provided that prior approval has been obtained from LR.

3.6.5 For products in the AH and DH grades, at least one set of three impact tests is to be made on the thickest piece in each batch of 50 tonnes when supplied in either the normalised or thermomechanically controlled condition. When the products are supplied in the as-rolled or normalising rolled conditions a set of impact test specimens is to be taken from a different piece from each 25 tonnes or fraction thereof. When supplied in the quenched and tempered condition, a set of impact tests is to be made on each length as heat treated. Test specimens from the quenched and tempered plates are to have their axes transverse to the main rolling direction.

3.6.6 For plates and wide flats in the EH and FH grades supplied in the normalised or thermomechanically controlled conditions, one set of impact tests is to be made on each piece. For plates supplied in the quenched and tempered condition a set of impact tests is to be made on each length as heat treated. Test specimens from the quenched and tempered plates are to have their axes transverse to the main rolling direction.

3.6.7 For plates and wide flats in H47 strength grade, one set of impact tests is to be made on each piece.

3.6.8 For sections and bars in the EH and FH grades supplied in the normalised or thermomechanically controlled conditions, one set of impact tests is to be made on the thickest piece in a batch not exceeding 25 tonnes. For sections supplied in the as-rolled or normalising rolled conditions the batch size is not to exceed 15 tonnes.

Table 3.3.6 Conditions of supply for sections and bars

Grade	Grain refining practice (*see* Note 1)	Thickness range mm	Conditions of supply (*see* Note 2)			
AH 27S AH 32 AH 36	Al or Al + Ti	≤20	Any			
		>20 ≤50	N	NR	TM	(*see* Note 3)
	Nb or V or Al + Nb or Al + V or Al + (Ti) + (Nb or V)	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	(*see* Note 3)
AH 40	Any practice	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	
DH 27S DH 32 DH 36	Al or Al + Ti	≤20	Any			
		>20 ≤50	N	NR	TM	(*see* Note 3)
	Nb or V or Al + Nb or Al + V or Al + (Ti) + (Nb or V)	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	(*see* Note 3)
DH 40	Any practice	≤50	N	NR	TM	
EH 27S EH 32 EH 36	Any practice	≤50	N	TM		(*see* Notes 3 and 4)
EH 40	Any practice	≤50	N	TM	QT	
FH 27S FH 32 FH 36 FH 40	Any practice	≤50	N	TM	QT	(*see* Note 4)

NOTES
1. Grain refining elements used singly or in any combination require specific approval from Materials and NDE Department, London Office.
2. N = furnace normalised; NR = normalising rolled
   TM = thermomechanically controlled-rolled; QT = quenched and tempered
3. Subject to the special approval of LR, sections may be supplied in the as-rolled condition provided satisfactory results are consistently obtained from Charpy V-notch impact tests.
4. Subject to the special approval of LR, sections may be supplied in the NR condition.

3.6.9 For batch tested plates in a condition other than furnace normalised, with a thickness equal to 12 mm or greater, and where the average value of one set of tests is less than 50 J, two further items from the same batch are to be selected and tested. If these fail to achieve an average of 50 J on either set, each individual piece of the heat is to be tested. The plates are acceptable provided they meet the requirements of Table 3.3.7. Additional testing is not required where the manufacturer can demonstrate to the satisfaction of the Surveyor that the plate was rolled outside the limits of the programmed rolling schedule. In this instance the plate should be rejected, *see also* 3.5.2.

3.6.10 Where standard subsidiary impact specimens are necessary, *see* Ch 2,3.2.4.

3.7 Identification of materials

3.7.1 The particulars detailed in 1.11 are to be marked on all materials which have been accepted and, for ease of recognition, are to be encircled or otherwise marked with paint. Where a number of light products are bundled, the bundle is to be identified in accordance with 1.11.2.

3.7.2 Steels which have been specially approved and which differ from the requirements of this Section are to have the letter ‘S’ after the agreed identification mark.

3.8 Certification of materials

3.8.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.12 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, the chemical composition is to include the contents of any grain refining elements used and of the residual elements.

3.8.2 For steels which have been specially approved, the agreed identification mark, the specified minimum yield stress and, if applicable, the contents of alloying elements are additionally to be stated on the test certificate or shipping statement.

3.8.3 The steelmaker is to provide the Surveyor with a written declaration as detailed in 1.12.2.

Table 3.3.7 Mechanical properties for acceptance purposes (*see* Note 1) (*continued*)

Grades (*see* Note 3)	Yield Stress N/mm^2 min.	Tensile Strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % min. (*see* Note 2)	Charpy V-notch impact tests (*see* Notes 3, 4 and 5) Average energy J minimum					
				$t \leq 50$ mm		$50 < t \leq 70$ mm		$70 < t \leq 100$ mm	
				Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
AH 27S DH 27S EH 27S FH 27S	265	400 – 530	22	27	20	34	24	41	27
AH 32 DH 32 EH 32 FH 32	315	440 – 570	22	31	22	38	26	46	31
AH 36 DH 36 EH 36 FH 36	355	490 – 630	21	34	24	41	27	50	34
AH 40 DH 40 EH 40 FH 40	390	510 – 650	20	39	26	46	31	55 (*see* Note 8)	37 (*see* Note 8)
EH 47	460	570 – 720	17	—	—	53	35	64 (*see* Note 8)	42 (*see* Note 8)

Impact tests are to be made on the various grades at the following temperatures:

AH grades 0°C
DH grades –20°C
EH grades –40°C
FH grades –60°C

Table 3.3.7 Mechanical properties for acceptance purposes (*conclusion*)

NOTES
1. The requirements for products thicker than those detailed in the table are subject to agreement, *see* 3.1.4.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm, *see* Fig. 2.2.4 in Chapter 2, the minimum elongation is to be:

Thickness mm		≤5	>5 ≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤30	>30 ≤40	>40 ≤50	>50
Elongation %	Strength levels 27S, 32	14	16	17	18	19	20	21	22	To be specially agreed
	Strength level 36	13	15	16	17	18	19	20	21	
	Strength level 40	12	14	15	16	17	18	19	20	

3. Subject to special approval by LR, the minimum tensile strength may be reduced to 470 N/mm^2, for grades AH36, DH36, EH36 and FH36, in the TM condition when micro-alloying elements Nb, Ti or V are used singly and not in combination and provided the yield to tensile strength ratio does not exceed 0,89. For plates with a thickness ≤12 mm, the yield to tensile strength ratio is to be specially considered.
4. Tests are to be taken in the longitudinal direction. Normally, transverse test specimens are not required. Transverse test results for plates and wide flats are to be guaranteed by the supplier.
5. *See* 1.8.11
6. *See* 3.6.9.
7. For steel of H47 strength grade, the yield to tensile strength ratio is not to exceed 0,94.
8. The Charpy V-notch impact energy for crack arrest steels of grade EH40, FH40 and EH47 intended for longitudinal strength members in container ships in thickness between 85 mm and 100 mm are to be:

Grade	$85 < t \leq 100$ mm	
	Longitudinal	Transverse
AH40 DH40 EH40 FH40 EH47	75 J	50 J

■ Section 4
Steels for boilers and pressure vessels

4.1 Scope

4.1.1 Provision is made in this Section for carbon, carbon-manganese and alloy steels intended for use in the construction of boilers and pressure vessels. In addition to specifying mechanical properties at ambient temperature for the purposes of acceptance testing, these requirements also give details of appropriate mechanical properties at elevated temperatures which may be used for design purposes.

4.1.2 Where it is proposed to use a carbon or carbon-manganese steel with a specified minimum tensile strength intermediate to those given in this Section, corresponding minimum values for the yield stress, elongation and mechanical properties at elevated temperatures may be obtained by interpolation.

4.1.3 Carbon and carbon-manganese steels with a specified minimum tensile strength of greater than 490 N/mm^2 but not exceeding 520 N/mm^2 may be accepted, provided that details of the proposed specification are submitted for approval.

4.1.4 Where it is proposed to use alloy steels other than as given in this Section, details of the specification are to be submitted for approval. In such cases the specified minimum tensile strength is not to exceed 600 N/mm^2.

4.1.5 Materials intended for use in the construction of the cargo tanks and process pressure vessels storage tanks for liquefied gases and for other low temperature applications are to comply with the requirements of Section 6 or 7, as appropriate.

4.2 Manufacture and chemical composition

4.2.1 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements of Table 3.4.1.

Table 3.4.1 Chemical composition and deoxidation practice

Grade of steel	Deoxidation	Chemical composition %						
Carbon and carbon-manganese steels		C max.	Si	Mn	P	S	Al	Residual elements
360 AR	Any method except rimmed steel	0,18	0,50 max.	0,40 – 1,20	0,040 max.		–	Cr 0,25 max. Cu 0,30 max. Mo 0,10 max. Ni 0,30 max. Total 0,70 max.
410 AR		0,21		0,40 – 1,30			–	
460 AR		0,23		0,80 – 1,50			–	
360	Any method except rimmed steel	0,17	0,35 max.	0,40 – 1,20	0,035 max.		–	
410		0,20		0,50 – 1,30			–	
460		0,20 (*see* Note 1)	0,40 max.	0,80 – 1,40			–	
490	Killed		0,10 – 0,50	0,90 – 1,60			–	
360 FG	Killed fine grained	0,17	0,35 max.	0,40 – 1,20	0,035 max.		(*see* Note 2)	
410 FG		0,20		0,50 – 1,30				
460 FG		0,20 (*see* Note 1)	0,40 max.	0,80 – 1,50				
490 FG			0,10 – 0,50	0,90 – 1,60				
510 FG		0,22						

Alloy steel		C	Si	Mn	P S	Al	Cr	Mo	Residual elements
13Cr Mo 45	Killed	0,10–0,18	0,15–0,35	0,4–0,8	0,035 max.	(*see* Note 3)	0,70–1,30	0,40–0,60	Cu 0,30 max.
11Cr Mo 910		0,08–0,18	0,15–0,50				2,00–2,50	0,90–1,10	Ni 0,30 max.

NOTES
1. For thicknesses greater than 30 mm, carbon 0,22% max.
2. Aluminium (acid soluble) 0,015% min. or
   Aluminium (total) 0,018% min.
   Niobium, vanadium or other suitable grain refining elements may be used either in place of or in addition to aluminium.
3. Aluminium (acid soluble or total) 0,020% max.

4.2.2 For plate supplied from coil, the chemical analysis may be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

4.3 Heat treatment

4.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.4.2 except that, when agreed, material intended for hot forming may be supplied in the as-rolled condition.

Table 3.4.2 Condition of supply

Grade of steel	Condition of supply
Carbon and carbon-manganese 360 AR to 460 AR	As-rolled Maximum thickness or diameter is 40 mm
Carbon and carbon-manganese 360 to 490	Normalised or normalised rolled
Carbon and carbon-manganese 360 FG to 510 FG	Normalised or normalised rolled
13Cr Mo 45	Normalised and tempered
11Cr Mo 910	Normalised and tempered

4.4 Mechanical tests

4.4.1 For plates, a tensile test specimen is to be taken from one end of each piece when the mass does not exceed 5 tonnes and the length does not exceed 15 m. When either of these limits is exceeded, tensile test specimens are to be taken from both ends of each piece. A piece is to be regarded as the rolled product from a single slab or from a single ingot if this is rolled directly into plates.

4.4.2 For strip, tensile test specimens are to be taken from both ends of each coil.

4.4.3 Sections and bars are to be presented for acceptance test in batches containing not more than 50 lengths, as supplied. The material in each batch is to be of the same section size, from the same cast and in the same condition of supply. One tensile test specimen is to be taken from material representative of each batch, except that additional tests are to be taken when the mass of a batch exceeds 10 tonnes.

4.4.4 Where plates are required for hot forming and it has been agreed that the heat treatment will be carried out by the fabricator, the tests at the steelworks are to be made on material which has been cut from the plates and given a normalising and tempering heat treatment in a manner simulating the treatment which will be applied to the plates.

4.4.5 If required by the Surveyors or by the fabricator, test material may be given a simulated stress relieving heat treatment prior to the preparation of the test specimens. This has to be stated on the order together with agreed details of the simulated heat treatment and the mechanical properties which can be accepted.

4.4.6 The results of all tensile tests are to comply with the appropriate requirements given in Tables 3.4.3 to 3.4.5.

Table 3.4.3 Mechanical properties for acceptance purposes: carbon and carbon-manganese steels – As-rolled

Grade of steel	Thickness mm	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum
360 AR	≤ 40	190	360–480	24
410 AR	≤ 40	215	410–530	22
460 AR	≤ 40	240	460–580	21

4.4.7 Where plate is supplied from coil, the tensile tests are to be taken from the de-coiled plate in accordance with the frequency specified for the Grade as required by this Section.

4.4.8 All test specimens are to be taken in the transverse direction unless otherwise agreed.

4.4.9 When material will be subject to strains in a through thickness direction, it is recommended that it should have specified through thickness properties in accordance with the requirements of Section 8.

4.5 Identification of materials

4.5.1 The particulars detailed in 1.11 are to be marked on all materials which have been accepted.

4.6 Certification of materials

4.6.1 At least two copies of each test certificate are to be provided. They are to be of the type and to give the information detailed in 1.12 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the content of any grain refining elements used and of the residual elements, as detailed in Table 3.4.1.

4.7 Mechanical properties for design purposes

4.7.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Tables 3.4.6 to 3.4.8.

4.7.2 These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than given in Tables 3.4.6 to 3.4.8.

4.7.3 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on material from each cast. Where materials of more than one thickness are supplied from one cast, the thickest material is to be tested. The test specimens are to be prepared from material adjacent to that used for tests at ambient temperature. The axis of the test specimens, is to be between mid and quarter thickness of the material and the test specimens are to be machined to dimensions in accordance with the requirements of Chapter 2. The test procedure is also to be as detailed in Chapter 2, and the results are to comply with the requirements of the National or proprietary specifications.

4.7.4 As an alternative to 4.7.3, a manufacturer may carry out an agreed comprehensive test program for a stated grade of steel to demonstrate that the specified minimum mechanical properties at elevated temperatures can be consistently obtained. This test program is to be carried out under supervision of the Surveyors, and the results submitted for assessment and approval. When a manufacturer is approved on this basis, tensile tests at elevated temperatures are not required for acceptance purposes but, at the discretion of the Surveyors, occasional check tests of this type may be requested.

4.7.5 Values for the estimated average stress to rupture in 100 000 hours are given in Table 3.4.9 and may be used for design purposes.

Table 3.4.4 Mechanical properties for acceptance purposes: carbon and carbon-manganese steels – Normalised or normalised rolled

Grade of steel	Thickness mm (*see* Note)	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_0}$ % minimum
360	>3 ≤16 >16 ≤40 >40 ≤63	205 195 185	360 – 480	26 26 25
410	>3 ≤16 >16 ≤40 >40 ≤63	235 225 215	410 – 530	24 24 23
460	>3 ≤16 >16 ≤40 >40 ≤63	285 255 245	460 – 580	22 22 21
490	>3 ≤16 >16 ≤40 >40 ≤63	305 275 265	490 – 610	21 21 20
360 FG	>3 ≤16 >16 ≤40 >40 ≤63	235 215 195	360 – 480	26 26 25
410 FG	>3 ≤16 >16 ≤40 >40 ≤63	265 245 235	410 – 530	24 24 23
460 FG	>3 ≤16 >16 ≤40 >40 ≤63	295 285 275	460 – 580	22 22 21
490 FG	>3 ≤16 >16 ≤40 >40 ≤63	315 315 305	490 – 610	21 21 21
510 FG	>3 ≤16 >16 ≤40 >40 ≤63	355 345 335	510 – 650	21

NOTE
For thicknesses greater than 63 mm, the minimum values for yield stress may be reduced by 1% for each 5 mm increment in thickness over 63 mm. The minimum elongation values may also be reduced one unit, for all thicknesses over 63 mm. For thicknesses over 100 mm, the above values are to be agreed.

Table 3.4.5 Mechanical properties for acceptance purposes: alloy steels – Normalised and tempered

Grade of steel	Thickness mm (see Note)	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_0}$ % minimum
13Cr Mo45	≤63	305	470–620	20
11Cr Mo910	≤16 >16 ≤63	275 265	480–630	18

NOTE
For thicknesses greater than 63 mm, the minimum values for yield stress may be reduced by 1% for each 5 mm increment in thickness over 63 mm. The minimum elongation values may also be reduced one unit, e.g., for all thicknesses over 63 mm. For thicknesses over 100 mm, the above values are to be agreed.

Table 3.4.6 Mechanical properties for design purposes (*see* 4.7.1) **: carbon and carbon-manganese steels – As-rolled**

Grade of steel	Thickness mm	Design temperature °C (*see* Note)						
		50	100	150	200	250	300	350
		Nominal minimum lower yield or 0,2% proof stress N/mm^2						
360 AR	≤ 40	154	153	152	145	128	108	102
410 AR	≤ 40	186	183	181	174	155	134	127
460 AR	≤ 40	218	213	210	203	182	161	153

NOTE
Maximum permissible design temperature is 350°C.

Table 3.4.7 **Mechanical properties for design purposes** (*see* 4.7.1)**: carbon and carbon-manganese steels – Normalised or controlled-rolled**

Grade of steel	Thickness mm (*see* Note)	Design temperature °C								
		50	100	150	200	250	300	350	400	450
		Nominal minimum lower yield or 0,2% proof stress N/mm^2								
360	>3 ≤16	183	175	172	168	150	124	117	115	113
	>16 ≤40	173	171	169	162	144	124	117	115	113
	>40 ≤63	166	162	158	152	141	124	117	115	113
410	>3 ≤16	220	211	208	201	180	150	142	138	136
	>16 ≤40	204	201	198	191	171	150	142	138	136
	>40 ≤63	196	192	188	181	168	150	142	138	136
460	>3 ≤16	260	248	243	235	210	176	168	162	158
	>16 ≤40	235	230	227	220	198	176	168	162	158
	>40 ≤63	227	222	218	210	194	176	168	162	158
490	>3 ≤16	280	270	264	255	228	192	183	177	172
	>16 ≤40	255	248	245	237	214	192	183	177	172
	>40 ≤63	245	240	236	227	210	192	183	177	172
360 FG	>3 ≤16	214	204	185	165	145	127	116	110	106
	>16 ≤40	200	196	183	164	145	127	116	110	106
	>40 ≤63	183	179	172	159	145	127	116	110	106
410 FG	>3 ≤16	248	235	216	194	171	152	141	134	130
	>16 ≤40	235	228	213	192	171	152	141	134	130
	>40 ≤63	222	215	204	188	171	152	141	134	130
460 FG	>3 ≤16	276	262	247	223	198	177	167	158	153
	>16 ≤40	271	260	242	220	198	177	167	158	153
	>40 ≤63	262	251	235	217	198	177	167	158	153
490 FG	>3 ≤16	297	284	265	240	213	192	182	173	168
	>16 ≤40	293	279	260	237	213	192	182	173	168
	>40 ≤63	286	272	256	234	213	192	182	173	168
510 FG	>3 ≤63	313	290	270	255	235	215	200	180	—

NOTE
For thicknesses greater than 63 mm, the values for lower yield or 0,2% proof stress are to be reduced by 1% for each 5 mm increment in thickness up to 100 mm. For thicknesses over 100 mm, the values are to be agreed and verified by test.

Table 3.4.8 **Mechanical properties for design purposes** (*see* 4.7.1)**: alloy steels – Normalised and tempered**

Grade of steel	Thickness mm (see Note)	Design temperature °C									
		50	100	200	300	350	400	450	500	550	600
		Nominal minimum lower yield or 0,2% proof stress N/mm^2									
13CrMo 45	>3 ≤63	284	270	248	216	203	199	194	188	181	174
11CrMo 910	>3 ≤63	255	249	233	219	212	207	194	180	160	137

NOTE
For thicknesses greater than 63 mm, the values for lower yield or 0,2% proof stress are to be reduced by 1% for each 5 mm increment in thickness up to 100 mm. For thicknesses over 100 mm, the values are to be agreed and verified by test.

Table 3.4.9 Mechanical properties for design purposes (*see* 4.7.5)**: estimated average values for stress to rupture in 100 000 hours (units N/mm^2)**

Temperature °C	Grades of steel				
	Carbon and carbon-manganese			Low alloy	
	360FG 410FG 460FG	360 410 460	490 490FG 510FG	13CrMo 45	11CrMo 910
380	171	219	227	—	—
390	155	196	203	—	—
400	141	173	179	—	—
410	127	151	157	—	—
420	114	129	136	—	—
430	102	109	117	—	—
440	90	92	100	—	—
450	78	78	85	290	—
460	67	67	73	262	—
470	57	57	63	235	210
480	47	48	55	208	186
490	36	—	47	181	165
500	—	—	—	155	145
510	—	—	—	129	128
520	—	—	—	103	112
530	—	—	—	80	98
540	—	—	—	62	84
550	—	—	—	49	72
560	—	—	—	42	61
570	—	—	—	36	51
580	—	—	—	—	44

■ *Section 5*
Steels for machinery fabrications

5.1 General

5.1.1 Steel plates, sections or bars intended for use in the construction of major components of welded machinery structures, such as bedplates, crankcases, frames and entablatures, are to comply with one of the following alternatives:

(a) Any grade of normal strength structural steel as detailed in Section 2.
(b) Any grade of higher tensile structural steel as detailed in Section 3.
(c) Any grade of carbon-manganese boiler or pressure vessel steel as detailed in Section 4, except that for this application batch testing is acceptable. The size of a batch and the number of tensile tests are to be as detailed in Section 2.

5.1.2 The minus tolerances for products for machinery structures are to be in accordance with Table 3.5.1.

Table 3.5.1 Under thickness tolerances

Nominal thickness, *t* (mm)	Minus tolerance (mm)
$5 \le t < 8$	–0,4
$8 \le t < 15$	–0,5
$15 \le t < 25$	–0,6
$25 \le t < 40$	–0,8
$t \ge 40$	–1,0

5.2 Certification of materials

5.2.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.12 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements.

■ *Section 6*
Ferritic steels for low temperature service

6.1 Scope

6.1.1 This Section gives specific requirements for carbon-manganese and nickel alloy steels intended for use in the construction of cargo tanks, storage tanks and process pressure vessels for liquefied gases.

6.1.2 The requirements of this Section are also applicable for other types of pressure vessels where the use of steels with guaranteed impact properties at low temperatures is required.

6.1.3 Provision is made for plates and sections up to 40 mm thick.

6.1.4 Steels with alternative chemical compositions or mechanical properties or in a different supply condition may be given special consideration.

6.2 Manufacture and chemical composition

6.2.1 All steels are to be in the killed and fine grain treated condition.

6.2.2 The chemical compositions of carbon-manganese steels are to comply with the appropriate requirements for Grades AH, DH, EH and FH strength levels 27S, 32, 36 and 40, *see* Table 3.3.2. For the uses defined in 6.1.1 and 6.1.2, however, these grades are to be designated LT–AH, LT–DH, LT–EH and LT–FH respectively.

6.2.3 The chemical compositions of nickel alloy steels are to comply with the appropriate requirements of Table 3.6.1.

Table 3.6.1 Chemical compositions of nickel alloy steels

<table>
<tr><th>Grade of steel</th><th>C</th><th>Si</th><th>Mn</th><th>Ni</th><th>P</th><th>S</th><th>Residual elements</th><th>Aluminium</th></tr>
<tr><td>1½ Ni</td><td>0,18 max.</td><td rowspan="4">0,10 – 0,35</td><td>0,30 – 1,50</td><td>1,30 – 1,70</td><td rowspan="4">0,025 max.</td><td rowspan="4">0,020 max.</td><td rowspan="4">Cr 0,25 max.
Cu 0,35 max.
Mo 0,08 max.
Total 0,60 max.</td><td rowspan="4">Total 0,020% min.

Acid soluble 0,015% min.</td></tr>
<tr><td>3½ Ni</td><td>0,15 max.</td><td rowspan="3">0,30 – 0,90</td><td>3,20 – 3,80</td></tr>
<tr><td>5Ni</td><td>0,12 max.</td><td>4,70 – 5,30</td></tr>
<tr><td>9Ni</td><td>0,10 max.</td><td>8,50 – 10,0</td></tr>
</table>

6.2.4 For plate supplied from coil, the chemical analysis may be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

6.3 Heat treatment

6.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.6.2.

Table 3.6.2 Supply conditions

<table>
<tr><th>Grade</th><th>Plates</th><th>Sections and bars</th></tr>
<tr><td>LT – AH</td><td rowspan="2">N TM</td><td rowspan="3">Any</td></tr>
<tr><td>LT – DH</td></tr>
<tr><td>LT – EH</td><td rowspan="2">Normalised (see Note)
T.M.C.P.
Quenched and tempered</td></tr>
<tr><td>LT – FH</td><td>N TM</td></tr>
<tr><td>1½ Ni
3½ Ni
5Ni</td><td colspan="2">Normalised (see Note)
Normalised and tempered
Quenched and tempered</td></tr>
<tr><td>9Ni</td><td colspan="2">Double normalised and tempered
Quenched and tempered</td></tr>
<tr><td colspan="3">NOTE
Where the term 'Normalised' is used it does not include normalising rolling.</td></tr>
</table>

6.4 Mechanical tests

6.4.1 For plates, tensile test specimens are to be taken from both ends of each piece. A piece is to be regarded as the rolled product from a single slab or from a single ingot if this is rolled directly into plates.

6.4.2 For strips, tensile test specimens are to be taken from both ends of each coil.

6.4.3 Sections and bars are to be presented for acceptance test in batches containing not more than 50 lengths, as supplied. The material in each batch is to be of the same section size, from the same cast and in the same condition of supply. One tensile test specimen is to be taken from material representative of each batch, except that additional tests are to be taken when the mass of a batch exceeds 10 tonnes.

6.4.4 One set of three Charpy V-notch impact test specimens is to be taken for each tensile test specimen required.

6.4.5 For plates, these impact test specimens are to be cut with the principal axis perpendicular to the final direction of rolling. For sections, the impact test specimens are to be taken longitudinally.

6.4.6 The results of all tensile tests are to comply with the appropriate requirements given in Table 3.6.3. The ratio between the yield stress and the tensile strength is not to exceed 0,9 for normalised and TM steels and 0,94 for QT steels.

6.4.7 The average value for the three impact tests is to comply with the appropriate requirements given in Table 3.6.3. One individual value may be less than the required value provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedures.

6.4.8 Where standard subsidiary impact specimens are necessary, *see* Ch 2,3.2.4.

6.4.9 Where plate is supplied from coil, both the tensile tests and the Charpy V-notch tests are to be taken from the de-coiled plate in accordance with the frequency specified for the Grade as required by this Section.

6.5 Identification of materials

6.5.1 The particulars detailed in 1.11 are to be marked on all materials which have been accepted.

Table 3.6.3 Mechanical properties for acceptance purposes (*see* Note 1)

Grade of steel		Yield stress N/mm2 min.	Tensile strength N/mm2	Elongation on 5,65 $\sqrt{S_o}$ % min.	Charpy V-notch impact tests (*see* Note 3)	
					Test temp. °C	Impact energy
LT – AH	27S 32 36 40	265 315 355 390	400 – 530 440 – 590 490 – 620 510 – 650	22 22 21 20	0	Plates – transverse tests Average energy 27 J min Sections and bars – longitudinal tests Average energy 41 J min
LT – DH	27S 32 36 40	265 315 355 390	400 – 530 440 – 590 490 – 620 510 – 650	22 22 21 20	–20	
LT – EH	27S 32 36 40	265 315 355 390	400 – 530 440 – 590 490 – 620 510 – 650	22 22 21 20	–40	
LT – FH	27S 32 36 40	265 315 355 390	400 – 530 440 – 590 490 – 620 510 – 650	22 22 21 20	–60	
1 1/2 Ni		275	490 – 640	22	–65	
3 1/2 Ni		285	450 – 610	21	–95	
5Ni		390	540 – 740	21	–110	
9Ni		490	640 – 790	18	–196	

NOTES
1. These requirements are applicable to products not exceeding 40 mm in thickness. The requirements for thicker products are subject to agreement.
2. The minimum design temperatures at which plates of different thicknesses in the above grades may be used are given in Fig. 3.6.1 and Fig. 3.6.2. Consideration will be given to the use of thicknesses greater than those in the Tables or to the use of design temperatures below –165°C.
3. Impact tests are not required on thicknesses less than 6 mm.

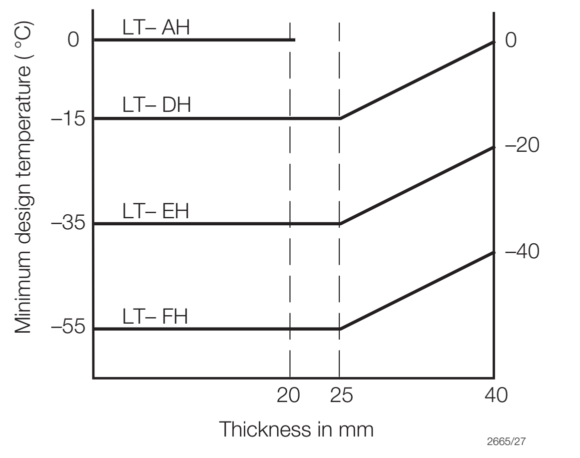


Fig. 3.6.1
Minimum design temperatures for carbon-manganese grades

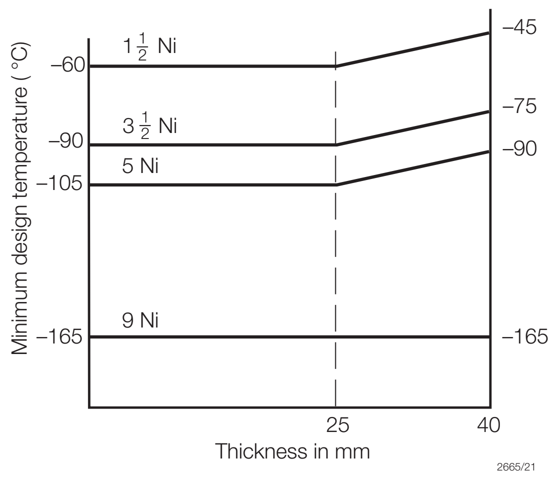


Fig. 3.6.2
Minimum design temperatures for nickel grades

6.6 Certification of materials

6.6.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.12 together with general details of the heat treatment. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements as detailed in Tables 3.3.2 or 3.6.1.

■ *Section 7* Austenitic and duplex stainless steels

7.1 Scope

7.1.1 Provision is made in this Section for rolled products in austenitic and duplex (austenite plus ferrite) stainless steels intended for use in the construction of cargo tanks, storage tanks and process pressure vessels for chemicals and liquefied gases.

7.1.2 Austenitic stainless steels are suitable for applications where the lowest design temperature is not lower than –165°C.

7.1.3 Austenitic stainless steels are also suitable for service at elevated temperatures, and for such applications the proposed specification should contain, in addition to the requirements of 7.1.6, minimum values for 0,2 and 1,0 per cent proof stresses at the design temperature.

7.1.4 Duplex stainless steels are suitable for applications where the lowest design temperature is above 0°C. Any requirement to use duplex stainless steels below 0°C will be subject to special consideration.

7.1.5 Duplex stainless steels are also suitable for service at temperatures up to 300°C, and for such applications the proposed specification should include, in addition to the requirements of 7.1.6, a minimum value for 0,2 per cent proof stress at the design temperature.

7.1.6 A specification giving details of the chemical composition, heat treatment and mechanical properties, including, for the austenitic grades, both the 0,2 and 1,0 per cent proof stresses, is to be submitted for consideration and approval.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the requirements given in Table 3.7.1.

7.2.2 Consideration will be given to the use of steels whose compositions are outside the scope of Table 3.7.1.

7.3 Heat treatment

7.3.1 All materials are to be supplied in the solution treated condition.

Table 3.7.1 Chemical composition

Type and grade of steel	Chemical composition % (*see* Note)									
	C	Si	Mn	P	S	Cr	Ni	Mo	N	Other
Austenitic										
304 L	0,03	1,0	2,0	0,045	0,03	17,0—20,0	8,0—13,0	—	0,10	—
304 LN						17,0—20,0	8,0—12,0	—	0,10—0,22	—
316 L						16,0—18,5	10,0—15,0	2,0—3,0	0,10	—
316 LN						16,0—18,5	10,0—14,5	2,0—3,0	0,10—0,22	—
317 L						18,0—20,0	11,0—15,0	3,0—4,0	0,10	—
317 LN						18,0—20,0	12,5—15,0	3,0—4,0	0,10—0,22	—
321	0,08					17,0—19,0	9,0—12,0	—	0,10	5 x C ≤ Ti ≤ 0,7
347	0,08					17,0—19,0	9,0—13,0	—	0,10	10 x C ≤ Nb ≤ 1,0
Duplex										
UNS S 31803	0,03	1,0	2,0	0,03	0,02	21,0—23,0	4,5—6,5	2,5—3,5	0,08—0,20	—
UNS S 32750	0,03	0,80	1,2	0,035	0,02	24,0—26,0	6,0—8,0	3,0—5,0	0,24—0,32	Cu 0,50 max.

NOTE
All figures are a maximum value except where a range is shown.

Table 3.7.2 Mechanical properties for acceptance purposes

Type and grade of steel	0,2% Proof stress (N/mm^2) minimum	1% Proof stress (N/mm^2) minimum	Tensile strength (N/mm^2) minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum
Austenitic				
304L	170	210	485	40
304LN	205	245	515	40
316L	170	210	485	40
316LN	205	245	515	40
317L	205	245	515	40
317LN	240	280	550	40
321	205	245	515	40
347	205	245	515	40
Duplex				
UNS S 31803	450	—	620	25
UNS S 32750	550	—	795	15

7.4 Mechanical tests

7.4.1 Tensile test specimens are to be taken in accordance with the appropriate requirements of 4.4 and 6.4.1.

7.4.2 For the duplex grades, one set of three Charpy V-notch impact test specimens machined from the longitudinal direction for each tensile test is to be tested at –20°C. The average energy value of the three specimens is to be not less than 41 Joules.

7.4.3 Unless otherwise agreed, impact tests are not required from the austenitic grades of steel given in this Section.

7.4.4 Where standard subsidiary Charpy V-notch test specimens are necessary, *see* Ch 2,3.2.4.

7.4.5 The results of all tensile tests are to comply with the requirements of Table 3.7.2 or the approved specification.

7.5 Metallographic examination for sigma phase

7.5.1 The microstructure of all grades listed in Table 3.7.1 are to be examined metallographically at x400 magnification to demonstrate that sigma phase remains below 0,1 per cent of the observable area at a frequency of one per heat.

7.6 Intergranular corrosion tests

7.6.1 For certain specific applications such as storage tanks for chemicals, it may be necessary to demonstrate that the material used is not susceptible to intergranular corrosion resulting from grain boundary precipitation of chromium-rich carbides.

7.6.2 When required, one test of this type is to be carried out for each tensile test. The material for the test is to be taken adjacent to that for the tensile test.

7.6.3 Unless otherwise agreed or required for a particular chemical cargo, the testing procedure is to be as given in 7.6.4, *see* Ch 2,9.

7.6.4 Wherever practical, exposed cut edges should be avoided. However, where any such edges are to remain after fabrication is completed, it is to be shown by an appropriate test, that the corrosion resistance is adequate for the cargoes expected to be encountered.

7.7 Clad plates

7.7.1 Carbon or carbon-manganese steel plates, clad on one or both surfaces with a suitable grade of austenitic or duplex stainless steel, may be used for the construction of cargo or storage tanks for chemicals.

7.7.2 The carbon or carbon-manganese steel base plates are to comply with the requirements of Section 4, and the austenitic cladding material generally with the requirements of this Section.

7.7.3 The process of manufacture is to be specially approved and may be either by roll cladding, or by explosive bonding.

7.7.4 Where the use of clad materials is proposed, the material specification is to be submitted for consideration, together with details of the extent, and the acceptance standards for non-destructive examination.

7.8 Identification of materials

7.8.1 The particulars detailed in 1.11 are to be marked on all materials which have been accepted.

7.9 Certification of materials

7.9.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.12 and, where applicable, the results obtained from intercrystalline corrosion tests, and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements, as detailed in Table 3.7.1.

Section 8
Plates with specified through thickness properties

8.1 Scope

8.1.1 Provision is made in this Section for 'Z' grade plate and wide flat material with improved ductility in the through thickness or 'Z' direction, *see* Fig. 3.8.1. The use of this material is recommended for certain types of welded structures (*see* 1.2) in order to minimise the possibility of lamellar tearing either during fabrication or erection.

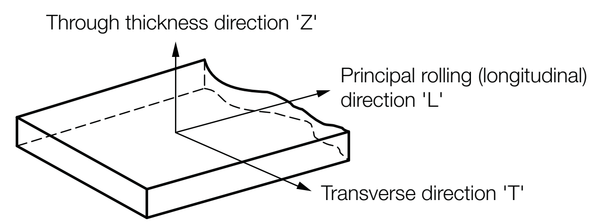


Fig. 3.8.1 Schematic of testing directions

8.1.2 Through thickness properties are characterised by specified values for reduction of area in a through thickness tensile test.

8.1.3 Provision is made for two grades Z25 and Z35. For normal ship applications the Z25 grade is applicable, whilst the Z35 grade is for more severe applications.

8.1.4 This 'Z' grade material is to comply with the requirements of Sections 2, 3, 4, 5 and 6 as appropriate, and the additional requirements of this Section.

8.1.5 The test procedure detailed in this Section may also be used to demonstrate that no unacceptable amount of banding of any detrimental phase, such as sigma is present, *see* 7.5.

8.2 Manufacture

8.2.1 All plates and wide flats are to be manufactured at works, which have been approved by LR for this quality of material.

8.2.2 It is recommended that the steel should be efficiently vacuum de-gassed. The sulphur content is not to exceed 0,008 per cent.

8.2.3 Consideration will be given to proposals for alternative methods of improving through thickness properties.

8.3 Test material

8.3.1 Unless otherwise agreed, through thickness tensile tests are only required for plate materials where the thickness exceeds 15 mm for carbon and alloy steels, or 10 mm in the case of austenitic and duplex stainless steels.

8.3.2 For plates and wide flats, one test sample is to be taken close to the longitudinal centreline from one end of each rolled piece representing the batch, *see* Table 3.8.1 and Fig. 3.8.2. The test sample must be large enough to accommodate the preparation of 6 specimens. 3 test specimens are to be prepared while the rest of the sample remains for possible retest.

Table 3.8.1 Batch size dependent on product and sulphur content

Product	S > 0,005%	$S \leq$ 0,005%
Plates	Each piece (parent plate)	Maximum 50 t of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness ≤ 25 mm	Maximum 10 t of products of the same cast, thickness and heat treatment	Maximum 50 t of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness > 25 mm	Maximum 20 t of products of the same cast, thickness and heat treatment	Maximum 50 t of products of the same cast, thickness and heat treatment

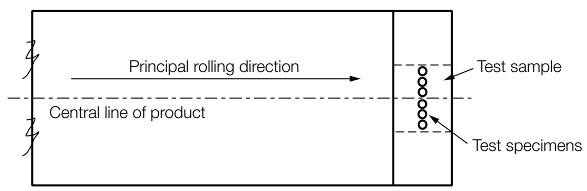


Fig. 3.8.2
Plate and wide flat sampling position

8.3.3 The dimensions of the test specimens are to be in accordance with Ch 2,2.1.12.

8.3.4 Alternatively, test sampling may be carried out in accordance with an accepted National or International Standard.

8.4 Mechanical tests

8.4.1 The three through thickness tensile test specimens are to be tested at ambient temperature, and for acceptance are to give a minimum average reduction of area value of not less than that shown in Table 3.8.2. Only one individual value may be below the minimum average, but should not be less than the minimum individual value shown for the appropriate grade.

Table 3.8.2 Reduction of area acceptance values

Grade	Z25	Z35
Minimum average	25%	35%
Minimum individual	15%	25%

8.4.2 If the average value fails to comply with 8.4.1, three additional tests may be made on specimens from the same test sample. The results of these tests are to be added to those previously obtained to form a new average, which for acceptance is to be not less than 25 per cent for grade Z25 or 35 per cent for grade Z35. No individual results in the re-test shall be below 25 per cent for grade Z25 or 35 per cent for grade Z35, *see* Fig. 3.8.3.

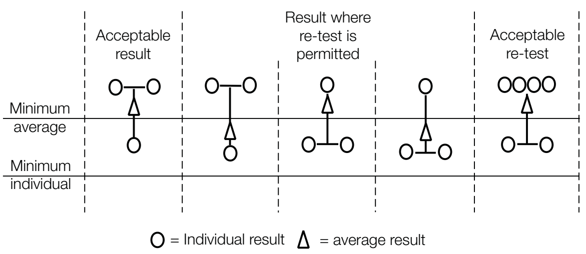


Fig. 3.8.3
Diagram showing acceptance/rejection and re-test criteria

8.4.3 Where batch testing is permitted, and failure after re-test occurs, the tested piece is to be rejected. Each remaining piece in the batch may be individually tested and accepted, based on satisfactory results.

8.4.4 If the fracture of a test specimen occurs in the weld or in the heat affected zone the test is to be regarded as invalid and is to be repeated on a new test specimen.

8.5 Non-destructive examination

8.5.1 All 'Z' grade plates are to be ultrasonically tested in the final supply condition with a probe frequency of 3-5 MHz. The testing is to be performed in accordance with and in compliance with either EN 10160 Level S1/E1 or ASTM A 578 Level C.

8.6 Identification of materials

8.6.1 Products which comply with the requirements of this Section are to have the notation Z25 or Z35 added to the steel grade designation.

8.7 Certification of materials

8.7.1 The following information is required to be included on the certificate in addition to the appropriate steel grade requirements:
(a) Through thickness reduction in area (%), individual results and average.
(b) Steel grade with Z25 or Z35 notation.

8.7.2 Steel grade requirements are to comply with Sections 1 to 7.

■ *Section 9*
Bars for welded chain cables

9.1 Scope

9.1.1 Provision is made in this Section for rolled steel bars intended for the manufacture of three Grades (U1, U2 and U3) of stud link chain cable for the anchoring and mooring of ships and five Grades (R3, R3S, R4, R4S and R5) of offshore mooring cable.

9.1.2 For the ship grades, U1, U2 and U3, approval will permit the supply of bars of the appropriate grades and size to any chain cable manufacturer.

9.1.3 For the offshore grades, R3, R3S, R4, R4S and R5, approval is confined to bar to be supplied to a nominated chain manufacturer and will be given only after successful testing of a completed chain. Separate approvals are required if bar is to be supplied to more than one cable manufacturer. Approval of a higher grade does not cover approval of a lower grade, as all grades must be individually approved.

9.1.4 For all grades, approval is normally given for diameters of bars no greater than those of the bars used in procedure tests.

9.2 Manufacture

9.2.1 All grades of bar material are to be made from killed steel, and all grades of bar material except for Grade U1 chain cables are to be fine grained. For Grades R4S and R5 the austenite grain size is to be 6 or finer, in accordance with ASTM E112.

9.2.2 The bars are to be made to a specification approved by LR which should include the manufacturing procedure, deoxidation practice, heat treatment and mechanical properties.

9.2.3 The rolling reduction ratio of bars for Grades R3, R3S, R4, R4S and R5 must be at least 5:1.

9.3 Chemical composition

9.3.1 For Grades U1, U2 and U3 the chemical composition should be generally within the limits given in Table 3.9.1.

9.3.2 For Grades R3, R3S, R4, R4S and R5 the chemical composition is to comply with an approved specification, *see* 9.2.2.

9.3.3 For Grades R4, R4S and R5 chain cable the steel should contain a minimum of 0,2 per cent molybdenum. The reported composition is to include the contents of antimony, arsenic, tin, copper, nitrogen, aluminium and titanium.

9.3.4 For Grades R4S and R5 the steel used must be vacuum degassed.

9.4 Heat treatment

9.4.1 Unless stipulated otherwise, the bars are to be supplied in the as-rolled condition, but the supplier is to be advised by the chain manufacturer of the heat treatment to be used for the completed chain in order that the mechanical test specimens may be tested in the condition of heat treatment used for the chain.

9.4.2 For Grades U1 and U2, the samples selected from each batch may be tested either in the as-rolled condition, or after heat treatment where the chain is to be used in the heat treated condition, in full cross-section and in a manner simulating the heat treatment applied to the finished cable.

9.4.3 For Grades U3, R3, R3S, R4, R4S and R5 the sample is to be tested after heat treatment as detailed in 9.4.2.

9.5 Embrittlement tests

9.5.1 For Grades R3, R3S, R4, R4S and R5 the bar manufacturer is to provide evidence that the material is not susceptible to strain ageing, or to temper brittleness under the conditions of manufacture of the chain. The results of the relevant tests are to be reported to LR at the approval stage. Approval will be restricted to the specified steel composition and if later this is altered then re-approval will be required. Temper brittleness testing may be waived, if the chain is to be quenched after tempering.

9.5.2 Each heat of steel bars of grades R3S, R4, R4S and R5 is to be tested for hydrogen embrittlement (*see* Ch 2,5.3). In the case of continuous casting, test samples representing both the beginning and the end of the heat are to be taken. In the case of ingot casting, test samples representing two different ingots are to be taken.

9.5.3 Each sample is to be heat treated in a manner simulating the heat treatment of the finished chain. From each sample, two specimens are to be prepared from the mid-diameter of the bar and tested in accordance with Ch 2,5.3.

9.5.4 The ratio Z_1/Z_2 is to be greater than or equal to 0,85, where Z_1 is the reduction in area without baking and Z_2 the reduction in area after baking.

9.5.5 If the requirement is not met, the material is to be subjected to a hydrogen degassing treatment which is subject to approval by LR. Further tests are to be performed after degassing.

9.6 Mechanical tests

9.6.1 Bars of the same nominal diameter are to be presented for test in batches of 50 tonnes or fraction thereof from the same cast. A suitable length from one bar in each batch is to be selected for test purposes. Test pieces are to be taken from the positions as shown in Fig. 3.9.1.

9.6.2 For all grades, one tensile test is to be taken from each sample length selected. Additionally, for Grades U3, R3, R3S, R4, R4S and R5 material, one set of three Charpy V-notch impact test specimens is to be prepared. Impact tests are also required for Grade U2 when the chain is to be supplied in as-welded condition.

Table 3.9.1 Chemical composition of killed steel bars

Grade	Chemical composition %												
	C max.	Si	Mn	P max.	S max.	Al	Nb max.	V max.	N max.	Cr max.	Cu max.	Ni max.	Mo max.
U1	0,20	0,15–0,35	0,40 min.	0,04	0,04	–	–	–	–	–	–	–	–
U2	0,24	0,15–0,55	1,60 max.	0,035	0,035	0,02 min. *see* Note 1	–	–	–	–	–	–	–
U3	0,33	0,15–0,35	1,90 max.	0,04	0,04	0,065 max. *see* Note 2	0,05 *see* Note 2	0,10 *see* Note 2	0,015	0,25	0,35	0,40	0,08

NOTES
1. Aluminium may be partly replaced by other grain refining elements.
2. To obtain fine grain steel, at least one of these grain refining elements must be present in sufficient amount.

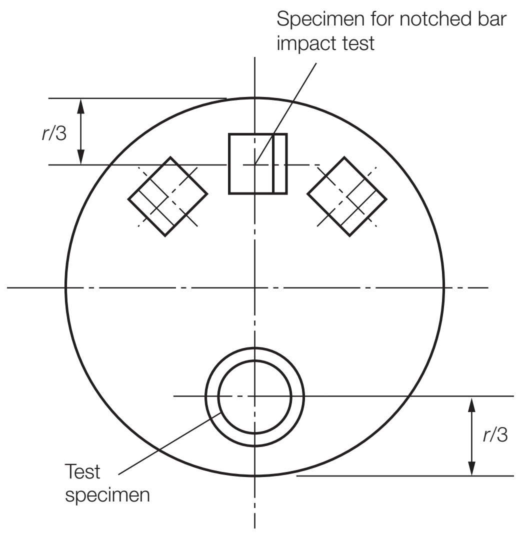


Fig. 3.9.1 Sampling of steel bars

9.6.3 The results of all tensile and, where applicable, impact tests are to be in accordance with the appropriate requirements of Table 3.9.2.

9.6.4 Failure to meet the requirements will result in the rejection of a batch of material, unless it is clearly attributed to improper simulated heat treatment. This is to be confirmed to be to the satisfaction of LR, and further heat treatment and testing will be required prior to acceptance.

9.7 Structure and hardenability tests

9.7.1 For Grades R4S and R5, the following tests are to be carried out on each heat:

(a) Assessment and quantification of the level of non-metallic micro inclusion. These must be acceptable for the final product.
(b) Macro etching on a representative sample, in accordance with ASTM E381 or equivalent. This must be free from any injurious segregation or porosity.
(c) Jominy hardenability tests in accordance with ASTM A255 or equivalent.

9.8 Dimensional tolerances

9.8.1 The tolerances on diameter and ovality of the bar are to be in accordance with Table 3.9.3.

Table 3.9.2 Mechanical properties

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests		
					Test temperature °C	Average energy J minimum	Average energy flash weld J minimum
U1	–	370–490	25	—	—	—	—
U2	295	490–690	22	—	0 (*see* Note 1)	27	—
U3	410	690 minimum	17	40	0 –20 (*see* Note 2)	60 35	— —
R3	410 (*see* Note 3)	690 minimum (*see* Note 3)	17	50	0 –20 (*see* Note 2)	60 40	50 30
R3S	490 (*see* Note 3)	770 minimum (*see* Note 3)	15	50	0 –20 (*see* Note 2)	65 45	53 33
R4	580 (*see* Note 3)	860 minimum (*see* Note 3)	12	50	–20	50	36
Grade R4S (*see* Note 4)	700 (*see* Note 3)	960 minimum (*see* Note 3)	12	50	–20	56	40
Grade R5 (*see* Note 4)	760 (*see* Note 3)	1000 minimum (*see* Note 3)	12	50	–20	58	42

NOTES
1. Impact tests may be waived when the chain cable is to be supplied in one of the heat treated conditions given in Table 10.2.3.
2. Testing may be carried out at either 0°C or –20°C, at the option of LR.
3. The ratio of yield strength to tensile strength should not exceed 0,92.
4. The maximum hardness for R4S is to be HB330, and for R5 is to be HB340.

Table 3.9.3 Dimensional tolerance of bar stock

Nominal diameter mm	Tolerance on diameter mm	Tolerance on roundness ($d_{max} - d_{min}$) mm
≤20	–0/+1,0	0,60
>20 ≤25	–0/+1,0	0,60
>26 ≤35	–0/+1,2	0,80
>36 ≤50	–0/+1,6	1,10
>51 ≤80	–0/+2,0	1,50
>81 ≤100	–0/+2,6	1,95
>101 ≤120	–0/+3,0	2,25
>121 ≤160	–0/+4,0	3,00
>161 ≤210	–0/+5,0	4,00

9.9 Non-destructive examination

9.9.1 For the grades U1, U2 and U3 all bars are to be free from internal and surface defects that might impair proper workability, use and strength. Subject to agreement by the Surveyor, surface defects may be removed by grinding provided the acceptable tolerances are not exceeded.

9.9.2 For the R3, R3S, R4, R4S and R5 grades all bars are to be inspected by a magnetic particle or eddy current method, and are also to be subjected to ultrasonic examination.

9.9.3 All non-destructive examination is to be carried out in accordance with approved procedures, in accordance with Ch 1,5.

9.9.4 All non-destructive examination operators are to be qualified in the method of non-destructive examination, to a minimum of Level II in accordance with a recognised standard.

9.9.5 The bars are to be free from pipes, cracks, flakes, and injurious surface defects such as seams, laps, and rolled-in mill scale. Longitudinal discontinuities may be removed by blending to a smooth contour provided that their depth is not greater than 1 per cent of the bar diameter, and that the required diameter tolerances are not compromised. The contour radiuses are to be a minimum of four times the excavation depth.

9.9.6 The frequency of non-destructive testing may be reduced at the discretion of LR, provided statistical evidence is available that the required quality is achieved consistently.

9.10 Identification

9.10.1 Each bar is to be identified in accordance with 1.10 and, in addition, is to be marked with the appropriate grade of chain cable.

9.11 Certification of materials

9.11.1 Each consignment of bars is to be accompanied by a certificate of a type and in accordance with 1.12, but with the addition of the grade of chain cable, the rolling reduction ratio, the results of the hydrogen embrittlement,micro inclusion, macro etch and hardenability tests, where required by each grade.

■ *Section 10* High strength quenched and tempered steels for welded structures

10.1 Scope

10.1.1 Provision is made in this Section for weldable high strength quenched and tempered steel plates and wide flats up to 70 mm thick. However, special consideration will be given to thicknesses up to 50 mm supplied in the TM rolled condition.

10.1.2 Plates and wide flats exceeding 70 mm in thickness as well as other product forms may also be supplied in accordance with the requirements of this Section, provided that the prior agreement of LR is obtained.

10.1.3 The steels may be supplied in six strength levels with minimum yield stresses of 420, 460, 500, 550, 620 and 690 N/mm^2 respectively.

10.1.4 Each strength level is sub-divided into four grades AH, DH, EH and FH, differing essentially in the required levels of notch toughness.

10.1.5 For the designation to fully identify a steel and its properties, the appropriate grade letter should precede the strength level number, e.g., EH 42.

10.1.6 Steels differing in strength level, mechanical properties and chemical composition from those detailed in this Section may be supplied, subject to special approval from LR. Such steels are to have the letter 'S' after the agreed identification mark.

10.2 Manufacture and chemical composition

10.2.1 The steels are to be fully killed and fine grain treated.

10.2.2 The chemical composition is to comply with the requirements of the approved manufacturing specification and the limits set in Table 3.10.1.

Table 3.10.1 Chemical composition

Grade	AH	DH EH	FH
Carbon % max	0,21	0,20	0,18
Manganese % max	1,70	1,70	1,60
Silicon % max	0,55	0,55	0,55
Phosphorus % max	0,035	0,030	0,025
Sulphur % max	0,035	0,030	0,025
Nitrogen % max	0,020	0,020	0,020
Grain refining elements (*see* Note 1)			
Aluminium (acid soluble) % min (*see* Note 2)		0,015	
Niobium %		0,02—0,05	
Vanadium %		0,03—0,10	
Titanium % max		0,02	
Total (Nb + V + Ti) % max		0,12	

NOTES
1. The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the content is to be within the limits given in the Table. When used in combination, these limits are not applicable but the proportions of the grain refining elements are to be in accordance with the approved manufacturing specification.
2. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is not to be less than 0,020%.
3. Alloying elements and residual elements other than those listed in the Table (e.g., Ni, Cr, Cu, Mo and B) are to be included in the approved manufacturing specification.

10.2.3 The cold cracking susceptibility, P_{cm}, may be used as an alternative to the carbon equivalent for evaluating weldability. It is to be calculated from the ladle analysis using the following formula:

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn + Cr + Cu}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B$$

The maximum allowable P_{cm} is to be agreed with LR and is to be included in the approved manufacturing specification.

10.3 Mechanical properties

10.3.1 At least one tensile test piece and one set of three Charpy V-notch impact tests specimens are to be taken from each piece as heat treated.

10.3.2 For continuously heat treated products, one tensile test piece and a set of three impact test specimens are to be taken from each plate as heat treated.

10.3.3 For plates and wide flats with widths exceeding 600 mm, the tensile and impact test specimens are to be taken with their axes transverse to the final direction of rolling. For other products, the impact test specimens are to be taken in the longitudinal direction but the tensile test specimens may be taken in either the longitudinal or transverse direction as agreed with LR.

10.3.4 The results of all tests are to comply with the appropriate requirements of Table 3.10.2.

10.3.5 Where standard subsidiary impact test specimens are necessary, *see* Ch 2,3.2.4.

10.4 Identification of materials

10.4.1 The particulars detailed in 1.11 are to be marked on each piece which has been accepted and, for ease of recognition, are to be encircled or otherwise marked with paint.

10.5 Certification of materials

10.5.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.12 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements as detailed in Table 3.10.1.

Table 3.10.2 Mechanical properties for acceptance purposes

Grade	Yield stress N/mm^2 min. (*see* Note 1)	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum (*see* Note 2)		Charpy V-notch impact tests (*see* Note 4)		
					Test temperature	Average energy J minimum	
			Transverse	Longitudinal	°C	Transverse	Longitudinal
AH 42 DH 42 EH 42 FH 42	420	530 – 680	18	20	0 –20 –40 –60	28	42
AH 46 DH 46 EH 46 FH 46	460	570 – 720	17	19	0 –20 –40 –60	31	46
AH 50 DH 50 EH 50 FH 50	500	610 – 770	16	18	0 –20 –40 –60	33	50
AH 55 DH 55 EH 55 FH 55	550	670 – 830	16	18	0 –20 –40 –60	37	55
AH 62 DH 62 EH 62 FH 62	620	720 – 890	15	17	0 –20 –40 –60	41	62
AH 69 DH 69 EH 69 FH 69	690	770 – 940	14	16	0 –20 –40 –60	46	69

NOTES
1. Where a distinct yield stress indication is not obtainable during tensile testing the 0,2% proof stress is applicable.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm (*see* Fig. 2.2.4 in Chapter 2) the minimum elongation is to be:

Thickness mm		≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤40	>40 ≤50	>50 ≤70
Strength levels								
Elongation %	42	11	13	14	15	16	17	18
	46	11	12	13	14	15	16	17
	50 and 55	10	11	12	13	14	16	16
	62	9	11	12	12	13	14	15
	69	9	10	11	11	12	13	14

These values apply to transverse specimens. Where the use of longitudinal specimens has been agreed, the values are to be increased by 2%.
3. The ratio of yield strength to tensile strength should not exceed 0,94.
4. Impact tests are not required on thicknesses less than 6 mm.

Section

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for steel castings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems.

1.1.2 Where required by the relevant Rules dealing with design and construction, castings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the general requirements given in this Section and the appropriate specific requirements given in Sections 2 to 9.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Where small castings are produced in large quantities, or where castings of the same type are produced in regular quantities, alternative survey procedures, in accordance with Ch 1,2.4 may be adopted.

1.2 Manufacture

1.2.1 Castings are to be made at foundries approved by LR. The steel used is to be manufactured by a process approved by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 All flame cutting, scarfing or arc-air gouging to remove surplus metal is to be undertaken in accordance with recognised good practice and is to be carried out before the final heat treatment. Preheating is to be employed where necessitated by the chemical composition and/or thickness of the casting. The affected areas are to be either machined or ground smooth for a depth of about 2 mm unless it has been shown that the material has not been damaged by the cutting process. Special examination will be required to find any cracking in way of the cut surfaces.

1.2.3 Where two or more castings are joined by welding to form a composite item, details of the proposed welding procedure are to be submitted for approval. Welding approval procedure tests will be required*, see also* the requirements of 1.9.

1.3 Quality of castings

1.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved specification.

1.3.2 The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.3.3 The locations of all chaplets are to be noted and to be subject to close visual inspection (and when necessary ultrasonic examination) to ensure complete fusion.

1.4 Chemical composition

1.4.1 All castings are to be made from killed steel. The chemical composition of the ladle sample is to be within the limits given in the relevant Section of this Chapter. Where general overall limits are specified, the chemical composition is to be appropriate for the type of steel, dimensions and required mechanical properties of the castings.

1.4.2 Except where otherwise specified, suitable grain refining elements may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

1.5 Heat treatment

1.5.1 All castings are to be heat treated in accordance with the requirements given in the relevant Section of this Chapter.

1.5.2 Heat treatment is to be carried out in a properly constructed furnace which is efficiently maintained and has adequate means of temperature control. The furnace dimensions are to be such as to allow the steel castings to be uniformly heated to the necessary temperature. Sufficient thermocouples are to be connected to the steel castings to show that their temperature is adequately uniform and the temperatures are to be recorded throughout the heat treatment. Alternative procedures are to be approved by LR, Materials and NDE department. Copies of these records are to be presented to the Surveyor together with a sketch showing the positions at which the temperature measurements were carried out. The records are to identify the furnace that was used and give details of the individual steel castings, the heat treatment temperature and time at temperature and the date. The Surveyor is to examine the charts and confirm the details on the certificate. In the case of very large components which require heat treatment, alternative methods will be specially considered.

1.5.3 If a casting is locally reheated, or any straightening operation is performed after the final heat treatment, a subsequent stress relieving heat treatment may be required in order to avoid the possibility of harmful residual stresses.

1.6 Test material and test specimens

1.6.1 Test material sufficient for the tests specified in Sections 2 to 9 and for possible re-test purposes is to be provided for each casting. The test samples are to be either integrally cast or gated to the casting and are to have a thickness of not less than 30 mm.

1.6.2 The test samples are not to be detached from the casting until the heat treatment specified in 1.5.1 has been completed and they have been properly identified.

1.6.3 As an alternative to 1.6.1 and 1.6.2, where a number of small castings of about the same size, each of which is under 1000 kg in mass, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted, using separately cast test samples of suitable dimensions. The test samples are to be properly identified and heat treated together with the castings which they represent. At least one test sample is to be provided for each batch of castings.

1.6.4 The test specimens are to be prepared in accordance with the requirements of Chapter 2. Tensile test specimens are to have a cross-sectional area of not less than 150 mm^2.

1.6.5 Re-test procedures are to be in accordance with Ch 2,1.4.

1.7 Visual and non-destructive examination

1.7.1 This Section gives the general requirements for non-destructive examination of steel castings. As an alternative, castings may be examined in accordance with a National Specification, provided it gives reasonable equivalence to these Rules.

1.7.2 All castings are to be cleaned and adequately prepared for inspection. Suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting.

1.7.3 The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.7.4 Unless otherwise agreed, the accuracy and verification of dimensions are the responsibility of the manufacturer.

1.7.5 All castings are to be presented to the Surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces. Castings are to be subject to magnetic particle examination or dye penetrant inspection (for austenitic stainless steel castings, *see* Section 8) in accordance with 1.7.9, unless more specific requirements for non-destructive examination are included in subsequent Sections of this Chapter, other parts of the Rules or the agreed specification.

1.7.6 Where specified or required by the Rules non-destructive examination is to be carried out before acceptance. All tests are to be in accordance with the requirements of Ch 1,5.

1.7.7 The manufacturer is to provide the Surveyor with a signed report confirming that non-destructive examination has been carried out and that such inspection has not revealed any significant defects.

1.7.8 Where magnetic particle examination is specified or required, this is to be carried out using a suspension of magnetic particles in a suitable fluid. The dry powder method is not acceptable for the final inspection. Prods are not permitted on finished machined surfaces.

1.7.9 Where required, magnetic particle or dye penetrant testing is to be carried out by the manufacturer whenever appropriate and also when the castings are in the finished condition. The tests are to be made in the presence of the Surveyor unless otherwise specially agreed. The castings are to be examined in the following areas:
(a) At all accessible fillets and changes of section.
(b) At positions where surplus metal has been removed by flame cutting, scarfing or arc-air gouging.
(c) In way of fabrication weld preparations, for a distance not less than 50 mm form the edge.
(d) In way of welds.
(e) In way of chaplets.
(f) At other positions agreed with the Surveyor to include areas which may be subjected to high stress in service.

1.7.10 Where required by subsequent Sections or by the agreed specification, ultrasonic examination is to be carried out by the manufacturer, but Surveyors may request to be present in order to verify that the examination is carried out in accordance with the agreed procedure. This examination is to be carried out in the following areas:
(a) At positions which may be subjected to high stresses in service, as agreed with the Surveyor.
(b) In way of fabrication weld preparations, for a distance not less than 50 mm form the edge.

(c) At positions where subsequent machining may expose filamentary shrinkage or other defects (e.g., bolt holes, bearing bores).
(d) In way of welding.
(e) In way of riser positions.
(f) At positions where experience shows that significant internal defects may occur: these are to be agreed between the manufacturer and the Surveyor.

1.7.11 Radiographic examination, where required, is to be carried out by the manufacturer in areas generally as indicated for ultrasonic examination in 1.7.10. All radiographs are to be submitted to the Surveyor for examination and acceptance. The radiographic technique and acceptance standards are to be to the satisfaction of the Surveyor and in accordance with any requirements of the approved specification.

1.7.12 In the event of any casting proving to be defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

1.7.13 The general acceptance criteria given in 2.5.2 are to be applied where no specific acceptance criteria are stated in the subsequent Sections of this Chapter.

1.8 Pressure testing

1.8.1 Where required by the relevant Rules, castings are to be pressure tested in the final machined condition before final acceptance. These tests are to be carried out in the presence of the Surveyors and are to be to their satisfaction.

1.9 Rectification and dressing of castings

1.9.1 When unacceptable defects are found in a casting, these are to be removed by machining or chipping. Flame-scarfing or arc-air gouging may also be used provided that preheating is employed when necessary and that the surfaces of the resulting excavation are subsequently ground smooth. Complete elimination of the defective material is to be proven by adequate non-destructive examination. Shallow grooves or excavations resulting from the removal of defects may, at the discretion of the Surveyor, be accepted provided that they will cause no appreciable reduction in the strength of the castings and that they are suitably blended by grinding. Complete elimination of the defective material is to be verified by magnetic particle or dye penetrant testing.

1.9.2 Where flame scarfing or arc-air gouging is used, the requirements detailed in 1.2.2 are to apply.

1.9.3 Grinding wheels for use on austenitic stainless steels are to be of an iron-free type and shall have been used only on stainless steels.

1.9.4 All proposals to repair a defective casting by welding are to be submitted to the Surveyor before this work is commenced. The Surveyor is to satisfy himself that the number, position and size of the defects are such that the casting can be effectively repaired.

1.9.5 A statement and/or sketch detailing the extent and position of all welds is to be prepared by the manufacturer. Copies of these sketches are to be submitted to LR, and copies are to be attached to the certificates for the castings.

1.9.6 All welding is to be carried out by an approved welder and in accordance with an approved welding procedure which includes the features referred to in 1.9.6 to 1.9.13.

1.9.7 Where welding is required, a grain refining heat treatment is to be given to the whole casting prior to carrying out welding unless agreed otherwise with the Surveyor. Grain refining heat treatment requires heating above the upper critical temperature.

1.9.8 Any excavations are to be of suitable shape to allow good access for welding and, after final preparation for welding, are to be re-examined by suitable non-destructive testing methods to ensure that all defective material has been eliminated.

1.9.9 All castings in alloy steels other than austenitic and duplex stainless steels are to be suitably preheated prior to welding. Castings in carbon-manganese steels may also be required to be preheated, depending on their chemical composition, the dimensions, configuration and positions of the welds.

1.9.10 Welding is to be carried out under cover, in positions free from draughts and adverse weather conditions. As far as possible, all welding is to be carried out in the downhand (flat) position.

1.9.11 The welding consumables used are to be of an appropriate composition, giving a weld deposit with mechanical properties similar and in no way inferior to those of the parent castings. The use of low hydrogen type welding consumables is preferred. Welding procedure tests are to be carried out by the manufacturer to demonstrate that satisfactory mechanical properties can be obtained after heat treatment as detailed in 1.9.12, and the results of these tests are to be presented to the Surveyor.

1.9.12 After welding is completed, the castings are to be given the heat treatment specified in Sections 2 to 9, or a stress relieving heat treatment at a temperature of not less than 550°C. The type of heat treatment required will be dependent on the chemical composition of the casting and the dimensions, positions and nature of the repairs.

1.9.13 Special consideration may be given to a local stress relieving heat treatment. where both the welded area is small and machining of the casting has reached an advanced stage, prior agreement is to be obtained from LR in writing. The welding procedure is to be such that residual stresses are minimised.

1.9.14 On completion of heat treatment, all welds and adjacent material are to be ground smooth and examined by magnetic particle, or liquid penetrant testing, ultrasonic or radiographic examination. The Surveyor is to attend at these inspections, to witness the results of magnetic particle or liquid penetrant examination and to examine any radiographs. Satisfactory results are to be obtained from all forms of non-destructive examination used.The acceptance criteria for the NDE of welds are to be in accordance with subsequent Sections of this Chapter or where these do not exist, Tables 13.2.4 to 13.2.6 in Chapter 13, as appropriate.

1.9.15 Where no welding has been made on a casting, the manufacturer is to provide the Surveyor with a written statement that this is the case.

1.9.16 The foundry is to maintain full records detailing the weld procedure, heat treatment and the extent and location of all welds made to each casting. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

1.9.17 For rectification of defective steel castings for crankshafts, *see* 4.7.

1.10 Identification of castings

1.10.1 The manufacturer is to adopt a system of identification, which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities to trace the castings when required.

1.10.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following particulars:

(a) Identification number, cast number or other marking which will enable the full history of the casting to be traced.
(b) Manufacturer's name or trade mark.
(c) LR or Lloyd's Register and the abbreviated name of LR's local office.
(d) Personal stamp of Surveyor responsible for inspection.
(e) Test pressure, where applicable.
(f) Date of final inspection.

1.10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

1.11 Certification of materials

1.11.1 A LR certificate is to be issued, *see* Ch 1,3.1.

1.11.2 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting or batch of castings which has been accepted:

(a) Purchaser's name and order number.
(b) Description of castings and steel grade.
(c) Identification number.
(d) Steel-making process, cast number, chemical analysis of ladle samples and, in the case of the Special grade (*see* Section 2), the chemical analysis of the product or test bar.
(e) General details of heat treatment including the temperature and time at temperature.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

1.11.3 Where applicable, the manufacturer is to provide a signed report regarding non-destructive examination as required by 1.7.7 together with a statement and/or sketch detailing the extent and position of all weld repairs made to each casting as required by 1.9.5 or the statement detailed in 1.9.15.

■ *Section 2*
Castings for ship and other structural applications

2.1 Scope

2.1.1 The requirements for carbon-manganese steel castings, intended for ship and other structural applications where the design and acceptance tests are related to mechanical properties at ambient temperature, are given in this Section.

2.1.2 Provision is made for two quality grades, Normal and Special.

2.1.3 Where it is proposed to use carbon-manganese steels of higher specified minimum tensile strength than required by 2.4.3, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval.

2.2 Chemical composition

2.2.1 The chemical composition of ladle samples is to comply with Table 4.2.1.

2.2.2 For the Special grade, the product of the aluminium and nitrogen contents is to comply with the following formula:

$$(\%\ Al_{acid\ sol} \times \%\ N)\ 10^5 \leq 60$$

2.2.3 For the Special grade, a check chemical analysis on the product or a test bar is mandatory. The check analysis on the product or test bar is to comply with the requirements of Table 4.2.1.

Table 4.2.1 Chemical composition

Quality grade	Normal	Special (*see* Note 3)
Carbon	0,23% max.	0,23% max.
Silicon	0,60% max.	0,60% max.
Manganese	0,70–1,60%	0,70–1,60%
Sulphur	0,040% max.	0,035% max.
Phosphorus	0,040% max.	0,035% max.
Aluminium – (acid soluble)	—	0,015–0,080% (*see* Notes 1 and 2)
Residual elements:		
Copper	0,30% max.	0,30% max.
Chromium	0,30% max.	0,30% max.
Nickel	0,40% max.	0,40% max.
Molybdenum	0,15% max.	0,15% max.
Total	0,80% max.	0,80% max.

NOTES
1. The total aluminium content may be determined instead of the acid soluble content, in which case the total aluminium content is to be 0,020–0,10%.
2. Grain refining elements other than aluminium may be used subject to special agreement with LR.
3. For the Special grade, the nitrogen content is to be determined.

2.3 Heat treatment

2.3.1 Castings are to be supplied:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered at a temperature of not less than 550°C; or
(d) quenched and tempered at a temperature of not less than 550°C.

2.3.2 For larger castings where a coarse of microstructure may be present in heavier thickness, a double austenising heat treatment may be required to ensure adequate grain refinement. A coarse microstructure will be indicated by an increased attenuation of approxiamtely 30 dB/m at 2 MHz during ultrasonic examination.

2.3.3 Following weld repair and or the attachment of handling brackets, all castings are to be subject to post weld heat treatment at a temperature of not less than 550°C before delivery.

2.4 Mechanical tests

2.4.1 At least one tensile test is to be made on material representing each casting or batch of castings.

2.4.2 Where the casting is of complex design, or where the finished mass exceeds 10 tonnes, two test samples are to be provided. Where large castings are made from two or more casts which are not mixed in a ladle prior to pouring, two or more test samples are required corresponding to the number of casts involved. These are to be integrally cast at locations as widely separated as possible.

2.4.3 The results of these tests are to comply with the following requirements:

Yield stress	200 N/mm^2 min.
Tensile strength	400 N/mm^2 min.
Elongation on $5{,}65\sqrt{S_o}$	25% min.
Reduction of area	40% min.

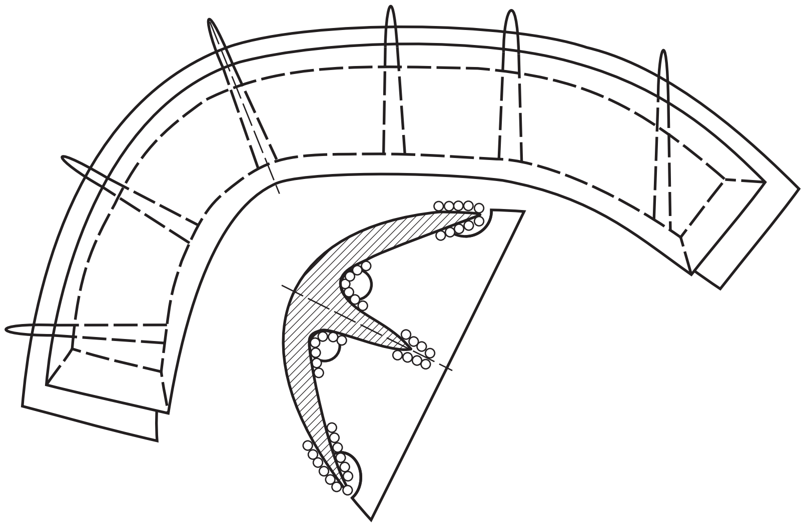
2.4.4 A set of three Charpy V-notch impact test specimens is to be provided with each casting in the Special grade. These may be taken from a small extension of the thickest part of the casting or from a block cast integrally with the casting and having dimensions representative of the largest section thickness of the casting. These are to be tested in accordance with Chapter 2 and are to have an average energy of not less than 27J at 0°C.

2.5 Non-destructive examination

2.5.1 Castings used in ship construction for the sternframe, rudder and propeller shaft supports are to be examined by ultrasonic and magnetic particle methods in accordance with 1.7. The type and extent of non-destructive examination of castings for other structural applications are to be specially agreed by the Surveyor.

2.5.2 The extent and methods of non-destructive examination to be applied to typical hull steel castings are shown in Figs. 4.2.1 to 4.2.6 in addition to the areas specified in 1.7.9 and 1.7.10.

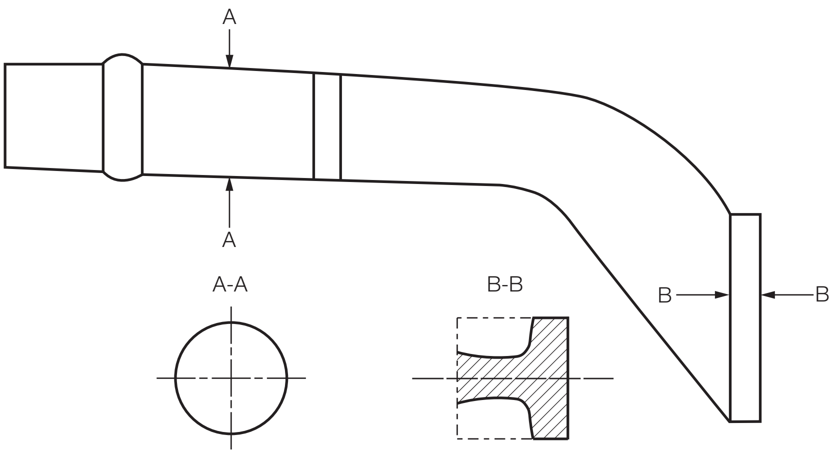
2.5.3 Acceptance levels for Visual Inspection are to be taken as follows:
(a) No cracks or hot tears are permitted.
(b) Castings are to be free of other injurious indications to the satisfaction of the Surveyor.
(c) Additional magnetic particle, dye penetrant or ultrasonic testing may be required for a more detailed evaluation of surface irregularities at the request of the Surveyor. These examinations are in addition to those required by 2.6.



Location of non-destructive examination

1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and Ultrasonic testing

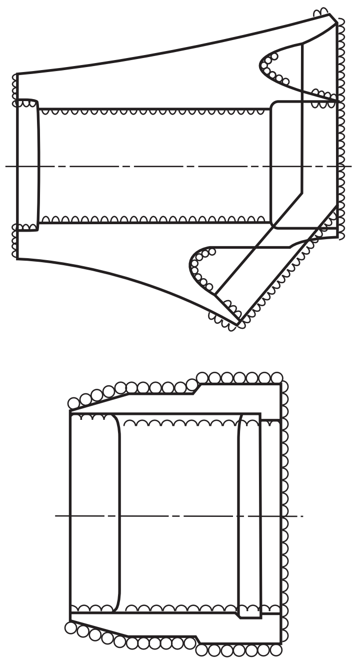
Fig. 4.2.1 Extent of non-destructive evaluation for stern frame castings



Location of non-destructive examination

All surfaces: Visual examination
Magnetic particle and ultrasonic testing

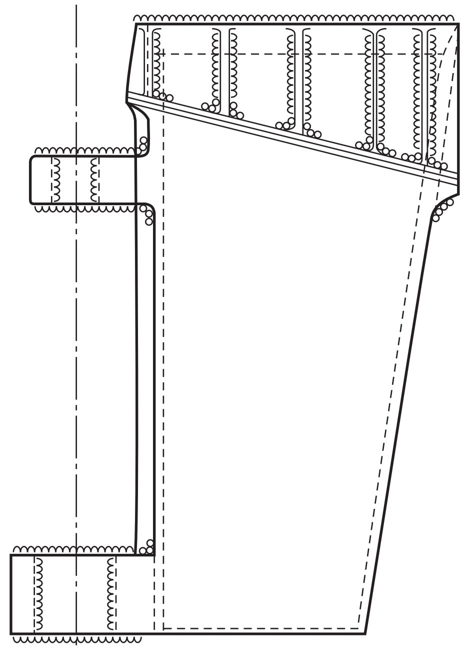
Fig. 4.2.2 Extent of non-destructive evaluation for rudder stock castings



Location of non-destructive examination

1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and ultrasonic testing
3. Location indicated with (⌒⌒⌒): Ultrasonic testing

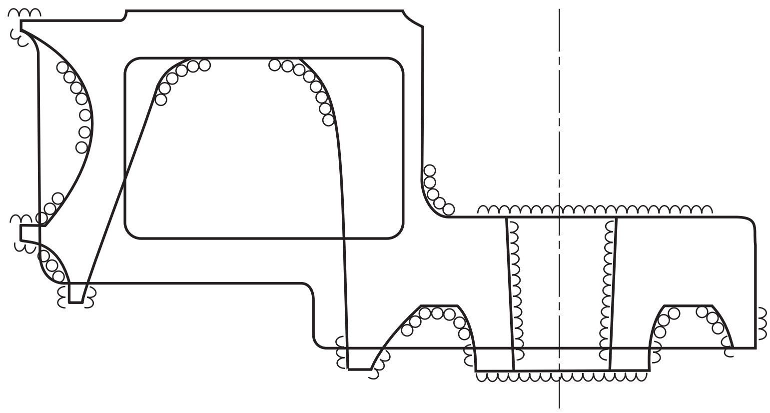
Fig. 4.2.3
Extent of non-destructive evaluation for stern boss castings



Location of non-destructive examination

1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and Ultrasonic testing
3. Location indicated with (⌒⌒⌒): Ultrasonic testing

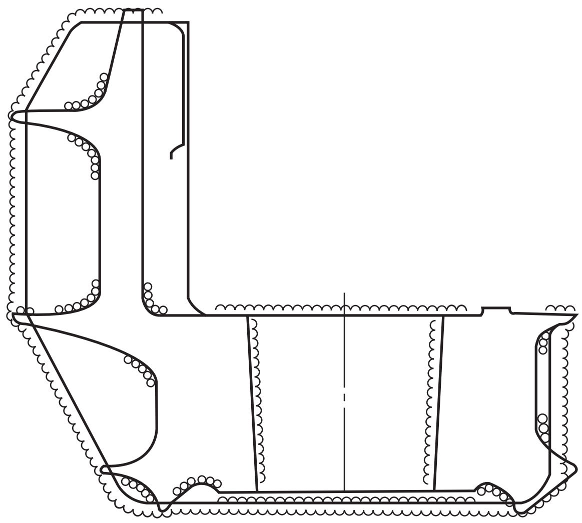
Fig. 4.2.4
Extent of non-destructive evaluation for rudder hanging castings



Location of non-destructive examination

1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and Ultrasonic testing
3. Location indicated with (⌒⌒⌒): Ultrasonic testing

Fig. 4.2.5 Extent of non-destructive evaluation for rudder (upper part) castings



Location of non-destructive examination
1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and Ultrasonic testing
3. Location indicated with (⏝⏝⏝): Ultrasonic testing

Fig. 4.2.6
Extent of non-destructive evaluation for rudder (lower part) castings

2.6 Acceptance levels for surface crack detection

2.6.1 The following definitions apply to indications associated with magnetic particle and dye penetrant inspection:

(a) **Linear indication**. An indication in which the length is at least three times the width.
(b) **Non-linear indication**. An indication of circular or elliptical shape with a length less than three times the width.
(c) **Aligned indication**. Three or more indications in a line, separated by 2 mm or less, edge-to-edge.
(d) **Open indication**. An indication visible after removal of the magnetic particles, or that can be detected by the use of contrast dye penetrant.
(e) **Non-open indication**. An indication that is not visually detectable after removal of the magnetic particles, or that cannot be detected by the use of contrast dye penetrant.
(f) **Relevant indication**. An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1,5 mm are to be considered relevant.

2.6.2 For the purpose of evaluating indications, the surface is to be divided into reference band length of 150 mm for level MT1/PT1 and into reference areas of 225 cm^2 for level MT2/PT2. The band length and/or area is to be taken in the most unfavourable location, relative to the indications being evaluated.

2.6.3 The following quality levels recommended for magnetic particle testing (MT) and/or dye penetrant testing (PT) are;
(a) Level MT1/PT1 – fabrication weld preparation areas.
(b) Level MT2/PT2 – other locations indicated on Figs. 4.2.1 to 4.2.6.

The acceptance criteria are shown in Table 4.2.2. Cracks and hot tears are not acceptable.

2.6.4 Acceptance criteria for ultrasonic testing are shown in Table 4.2.3 as UT1 and UT2. Discontinuities within the examined zones interpreted to be cracks or hot tears, are not acceptable.

2.6.5 Level UT1 is applicable to the following:
(a) Fabrication weld preparations for a distance of 50 mm.
(b) 50 mm depth from the final machined surface including boltholes.
(c) Fillet radii to a depth of 50 mm and within a distance of 50 mm from the radius end.
(d) Castings subject to cyclic bending stresses, e.g., rudder horn, rudder castings and rudder stocks, the outer one third of thickness in the zones shown in Figs. 4.2.1 to 4.2.6.

2.6.6 Level UT2 is applicable to the following:
(a) For locations which are not specified in 2.6.5, nominated for ultrasonic testing in Figs. 4.2.1 to 4.2.6 or on the inspection plan.
(b) Positions outside locations nominated for level UT1 examination where feeders and gates have been removed.
(c) Castings subject to cyclic bending stresses, at the central one third of thickness in the zones shown in Figs. 4.2.1 to 4.2.6.

Table 4.2.2 Acceptance criteria for surface inspection evaluation

Quality level	Maximum number of indication	Type of indication	Maximum number each type	Maximum dimension of single indication, mm (*see* Note 2)
MT1/PT1	4 in 150 mm length	Non-linear Linear Aligned	4, *see* Note 1 4, *see* Note 1 4, *see* Note 1	5 3 3
MT2/PT2	20 in 22500 mm^2 area	Non-Linear Linear Aligned	10 6 6	7 5 5

NOTES
1. Minimum of 30 mm between relevant indications.
2. In weld repairs, the maximum dimension is 2 mm.

Table 4.2.3 Ultrasonic acceptance criteria for marine steel castings

Quality level	Allowable disc shape according to the Distance-Gain Size (DGS), mm	Maximum number of indications to be registered, *see* Note 1	Allowable length of linear indications, mm, *see* Note 2
UT1	>6	0	0
UT2	12–15 >15	5 0	50 0

NOTES
1. Grouped in an area measuring 300 x 300 mm.
2. Measured on the scanning surface.

2.6.7 Ultrasonic acceptance criteria for casting areas not nominated in Figs. 4.2.1 to 4.2.6 will be subject to special consideration, based on the anticipated stress levels and the type, size and position of the discontinuity.

2.6.8 Parts which are welded are to be examined by the same method as at the initial inspection as well as by additional methods as required by the Surveyor.

■ *Section 3* Castings for machinery construction

3.1 Scope

3.1.1 This Section gives the material requirements for carbon-manganese steel castings intended for use in machinery construction and which are not within the scope of Sections 4 to 7.

3.1.2 Where it is proposed to use steels of higher carbon content than is indicated in 3.2.1, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval.

3.1.3 The manufacture or repair of cast steel connecting rods is not permitted, except where the manufacturing and quality control procedures have been approved by LR. For approval purposes, tests are to be carried out at the place of manufacture using the proposed process to demonstrate that the castings are sound. Tests are to be carried out to confirm that the appropriate mechanical properties are attained within the casting, including areas where weld repairs have been performed. Any changes to manufacturing, repair and quality control procedures are to be submitted to LR for approval, *see also* Ch 1,2.2.

3.2 Chemical composition

3.2.1 The chemical composition of ladle samples is to comply with the following limits, except as specified in 3.2.2:

Carbon	0,40% max.
Silicon	0,60% max.
Manganese	0,50–1,60%
Sulphur	0,040% max.
Phosphorus	0,040% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Nickel	0,40% max.
Molybdenum	0,15% max.
	Total 0,80% max.

3.2.2 Castings which are intended for parts of a welded fabrication are to be of weldable quality with a carbon content generally not exceeding 0,23 per cent.

3.2.3 Proposals to use steels with higher carbon content, or alloy steels, for welded construction will be subject to special consideration.

3.3 Heat treatment

3.3.1 Castings are to be supplied:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered at a temperature of not less than 550°C; or
(d) quenched and tempered at a temperature of not less than 550°C.

3.3.2 Engine bedplate castings, turbine castings and any other castings where dimensional stability and freedom from internal stresses are important, are to be given a stress relief heat treatment. This is to be at a temperature not lower than 550°C, followed by furnace cooling to 300°C or lower. Alternatively, full annealing may be used provided that the castings are furnace cooled to 300°C or lower.

3.4 Mechanical tests

3.4.1 At least one tensile test is to be made on material representing each casting or batch of castings.

3.4.2 Where the casting is of complex design, or where the finished mass exceeds 10 tonnes, two test samples are to be provided. Where large castings are made from two or more casts which are not mixed in a ladle prior to pouring, two or more test samples are required corresponding to the number of casts involved. The test samples are to be integrally cast at locations as widely separated as possible.

3.4.3 Table 4.3.1 gives the minimum requirements for yield stress, elongation and reduction of area corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. Intermediate levels of minimum tensile strength may be specified, in which case minimum values for yield stress, elongation and reduction of area may be obtained by interpolation.

Table 4.3.1 Mechanical properties for acceptance purposes: carbon and carbon-manganese steel castings for machinery construction

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum	Reduction of area % minimum
400–550	200	25	40
440–590	220	22	30
480–630	240	20	27
520–670	260	18	25
560–710	300	15	20
600–750	320	13	20

3.4.4 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 4.3.1.

3.4.5 The results of all tensile tests are to comply with the requirements of Table 4.3.1 appropriate to the specified minimum tensile strength.

3.4.6 For alloy steel castings and carbon-manganese steel castings containing more than 0,40 per cent carbon, the results of all mechanical tests are to comply with an approved specification.

3.4.7 When a casting, or a batch of castings, has failed to meet the mechanical test requirements, it may be re-heat treated and re-submitted for acceptance tests but this may not be carried out more than twice, *see* Ch 1,4.6.

3.5 Non-destructive examination

3.5.1 All piston crowns and cylinder covers are to be examined by ultrasonic testing. In addition, where these castings are intended for engines having a bore size larger than 400 mm, they are to be examined by magnetic particle or dye penetrant testing in accordance with 1.7.

3.5.2 Engine bedplate castings are to be examined by ultrasonic and magnetic particle or dye penetrant testing in accordance with 1.7.

3.5.3 Turbine castings are to be examined by magnetic particle or dye penetrant testing in accordance with 1.7. In addition, an ultrasonic or radiographic examination is to be made in way of fabrication weld preparations.

3.5.4 Other castings are to be examined by non-destructive methods where specified.

■ *Section 4* Castings for crankshafts

4.1 Scope

4.1.1 This Section gives the requirements for carbon and carbon-manganese steel castings for semi-built crankshafts.

4.1.2 Where it is proposed to use steels of higher carbon content than is indicated in 4.3.1, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. For alloy steels, the specified minimum tensile strength is not to exceed 700 N/mm^2.

4.2 Manufacture

4.2.1 The method of producing combined web and pin castings is to be approved. For this purpose, tests to demonstrate the soundness of the casting and the properties at important locations may be required.

4.3 Chemical composition

4.3.1 The chemical composition of ladle samples is to comply with the following limits:

Carbon	0,40% max. (*but see* 4.7.4(c))
Silicon	0,60% max.
Manganese	0,50–1,60%
Sulphur	0,040% max.
Phosphorus	0,040% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Nickel	0,40% max.
Molybdenum	0,15% max.
	Total 0,80% max.

4.4 Heat treatment

4.4.1 Castings are to be supplied either:

(a) fully annealed and cooled in the furnace to a temperature of 300°C or lower; or

(b) normalised and tempered at a temperature of not less than 550°C, and cooled in the furnace to a temperature of 300°C or lower.

4.5 Mechanical tests

4.5.1 Proposals for the number of tests and the location of test material on the casting are to be submitted by the manufacturer.

4.5.2 Not less than one tensile test and three impact tests are to be made on material representing each casting. The impact tests are to be carried out at ambient temperature.

4.5.3 Table 4.4.1 gives the minimum requirements for yield stress and elongation corresponding to different strength levels, and it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2 to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 4.4.1 Mechanical properties for acceptance purposes: carbon-manganese steel castings for crankshafts

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests average energy J minimum (*see* Note)
400–550	200	28	45	32
440–590	220	26	45	28
480–630	240	24	40	25
520–670	260	22	40	20
550–700	275	20	35	18

NOTE
Impact tests are to be made at ambient temperature.

4.5.4 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 4.4.1.

4.5.5 The results of all tests are to comply with the requirements of Table 4.4.1 appropriate to the specified minimum tensile strength. For the impact tests, one individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 1,4.6 for re-test procedures.

4.6 Non-destructive examination

4.6.1 Magnetic particle examination is to be carried out over all surfaces in accordance with Fig. 4.4.1.

4.6.2 Each casting is to be examined by ultrasonic testing, and the extent of examination and defect acceptance criteria, using the DGS (Distance Gain Size) technique, are to be as shown in Fig. 4.4.2. Alternative ultrasonic procedures may be submitted for approval.

4.7 Rectification of defective castings

4.7.1 The requirements of 1.9 apply, except where amended by this Section.

4.7.2 Where castings have shallow surface defects, consideration is first to be given to removing such defects by grinding and blending or by machining the surface where there is excess metal on the Rule dimension.

4.7.3 Subject to prior agreement and submission of the detailed welding procedure for approval by LR, welding may be carried out prior to the final austenitising heat treatment.

4.7.4 Approval for welding will not be given in the following circumstances:
(a) For the rectification of repetitive defects caused by improper foundry technique or practice.
(b) For the building up by welding of surfaces or large shallow depressions.
(c) Where the carbon content of the steel exceeds 0,30 per cent.
(d) Where the carbon equivalent of the steel, given by $C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$ exceeds 0,65 per cent.

4.7.5 Provided that the Surveyors are satisfied that welding is justified, they may also authorise welding to the surfaces of crankwebs, following the final austenitising heat treatment, within the following limits:
(a) In general, the volume of the largest groove which is to be welded is not to exceed 3,2t cm^3, where t is the web axial thickness, in cm. The total volume of all grooves which are to be welded is not to exceed 9,6t cm^3 per crankweb.
(b) The welds do not extend within the cross-hatched zones marked on Fig. 4.4.3 for semi-built crank throws.
(c) Larger welds on balance weights may be permitted at the discretion of the Surveyor, provided that such repairs are wholly contained within the balance weight and do not affect the strength of the crankweb.

4.7.6 Subsequent to the final austenitising heat treatment, welding may be authorised in the surface of the bore for the journal (or pin) within the following limits:
(a) In general, the welds are to be not less than 125 mm apart.
(b) The welds are not to be located within circumferential bands of $\frac{t}{5}$ from the edges of the bores, nor at any position within the inner 120° arc of the bores, as cross-hatched on Fig. 4.4.3.
(c) The volume of the largest weld is to be not more than 1,1t cm^3, where t is the web axial thickness at the bore, in cm, and not more than three welds are to be made in any one bore surface.

4.7.7 After all defective material has been removed from a region, and this has been proven in the presence of the Surveyor by magnetic particle inspection or other suitable method, the excavation is to be suitably shaped to allow good access for welding.

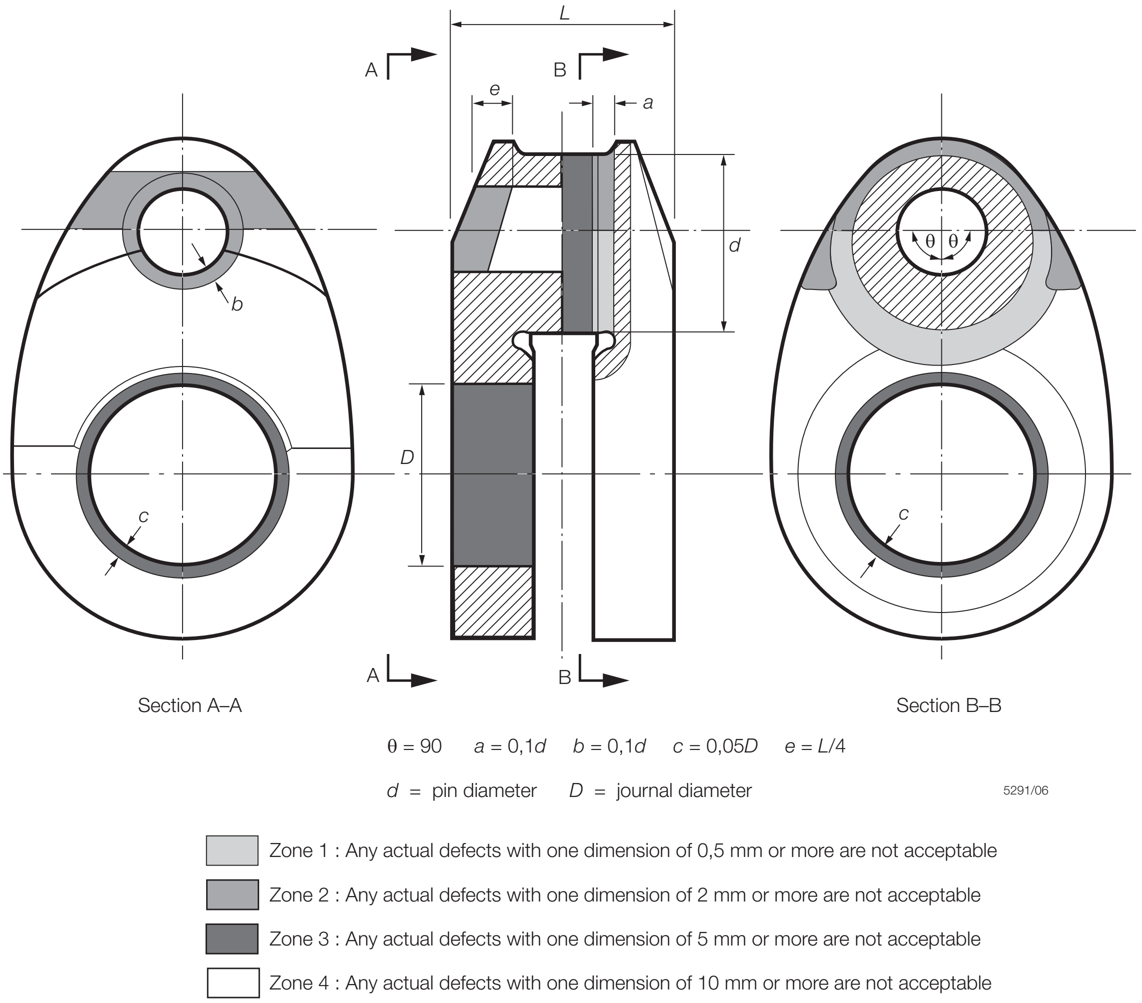


Fig. 4.4.1 Magnetic particle inspection acceptance levels

4.7.8 At the discretion of the Surveyor, the size of a groove may be increased beyond the limiting sizes given in 4.7.5 or 4.7.6, if the removal of further metal will facilitate welding.

4.7.9 Welding is to be carried out by approved welders using approved procedures. The welds are to be made by an electric arc process using low hydrogen type consumables which will produce a deposited metal that is not inferior in properties to the parent metal.

4.7.10 All castings are to be given a preliminary refining heat treatment prior to the commencement of welding. Before welding, the material is to be preheated in accordance with the qualified procedure. Where possible, preheating is to be carried out in a furnace. The preheat temperature is to be maintained until welding is completed, and preferably until the casting is placed in the furnace for post-weld heat treatment.

4.7.11 Where welding is carried out after the final austenitising heat treatments, a post-weld stress relieving heat treatment is to be applied at a temperature of not less than 600ºC, *see also* 1.5.2.

4.7.12 Welds are to be dressed smooth by grinding. The surfaces of the welds and adjacent parent steel are to be proven by magnetic particle and, where appropriate, ultrasonic inspection, *see* 1.9.15 and 1.9.14.

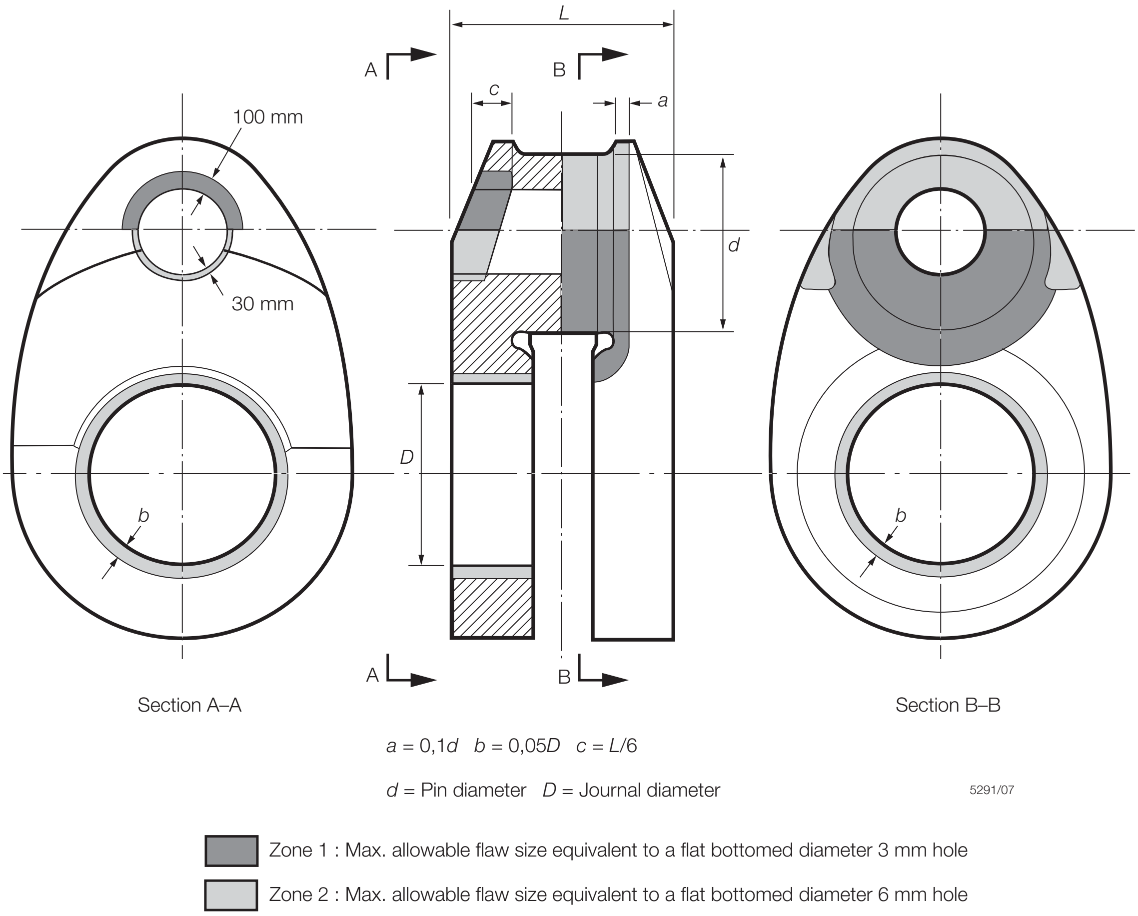


Fig. 4.4.2 Ultrasonic examination acceptance levels

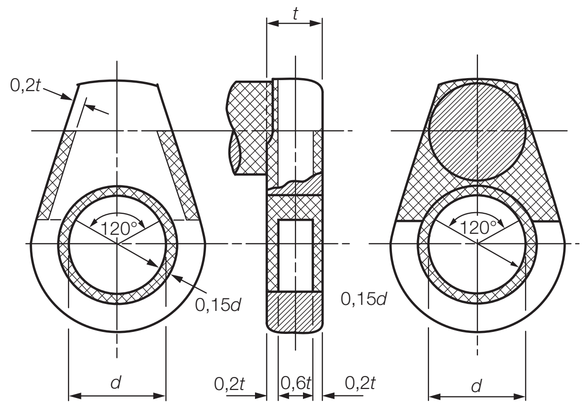


Fig. 4.4.3
Areas of semi-built crank throws to which weld repairs are not permitted

■ *Section 5* Castings for propellers

5.1 Scope

5.1.1 This Section gives the requirements for steel castings for one-piece propellers and separately cast blades and hubs for fixed pitch and controllable pitch propellers (CPP). These include contra-rotating propellers, azipods and azimuth thrusters. The requirements for copper alloy propellers, blades and hubs are given in Ch 9,1.

5.1.2 These castings are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and Ch 4,1 as well as the requirements of this Section.

5.1.3 Full details of the manufacturer's specification are to be submitted for approval. These should include the chemical composition, heat treatment, mechanical properties, micro-structure and repair procedures.

5.1.4 Special requirements are given for castings which are intended for ice service in Table 4.5.2.

5.2 Chemical composition

5.2.1 The chemical composition of ladle samples is to comply with the approved specification, *see* 5.1.3.

5.2.2 Typical cast steel propeller alloys are given in Table 4.5.1.

5.3 Heat treatment

5.3.1 Martensitic stainless steel castings are to be austenitised, quenched and tempered in accordance with the approved specification, *see* 5.1.3.

5.3.2 Austenitic stainless steel castings are to be solution treated in accordance with the approved specification, *see* 5.1.3.

5.4 Mechanical tests

5.4.1 The test material is to be cast integral with the boss of propeller castings, or with the flange of separately cast propeller blades. Alternatively, the test material may be attached on blades in an area between 0,5 and 0,6*R*, where *R* is the radius of the propeller.

5.4.2 The test material is not to be removed from the casting until final heat treatment has been carried out. Removal is to be by non-thermal procedures.

5.4.3 At least one tensile test and for the martensitic stainless steel grades one set of three Charpy V-notch impact tests are to be made on material representing each casting. The results are to comply with the requirements of Table 4.5.2 or the approved specification.

5.4.4 As an alternative to 5.4.3, where a number of small propeller castings of about the same size, and less than 1 m in diameter, are made from one cast and heat treated together in the same furnace, a batch testing procedure may be adopted using separately cast test samples of suitable dimensions. At least one set of mechanical tests is to be provided for each multiple of five castings in the batch.

5.4.5 Separately cast test bars may be used subject to prior approval of the Surveyor. Test bars must be cast from the same heat, or heats, and must also be heat treated with castings they represent.

5.5 Non-destructive examination

5.5.1 On completion of machining and grinding, the whole surface of each casting is to be examined in accordance with Ch 9,1.8.

5.5.2 When appropriate, magnetic particle inspection may be used in lieu of liquid penetrant testing.

5.5.3 Castings are to be free from cracks and hot tears.

Table 4.5.1 Typical chemical composition for steel propeller castings

Alloy type	C Max. (%)	Mn Max. (%)	Cr (%)	Mo Max. (%) (*see* Note)	Ni (%)
Martensitic (12Cr 1Ni)	0,15	2,0	11,5–17,0	0,5	Max. 2,0
Martensitic (13Cr 4Ni)	0,06	2,0	11,5–17,0	1,0	3,5–5,0
Martensitic (16Cr 5Ni)	0,06	2,0	15,0–17,5	1,5	3,5–6,0
Austenitic (19Cr 11Ni)	0,12	1,6	16,0–21,0	4,0	8,0–13,0

NOTE
Minimum values are to be in accordance with the agreed specification or recognised National or International Standards.

Table 4.5.2 Typical mechanical properties for steel propeller castings

Alloy type	Yield stress or, 0,2% proof stress minimum, N/mm^2	Tensile strength minimum N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests J minimum (*see* Notes 1 and 2)
Martensitic (12Cr 1Ni)	440	590	15	30	20
Martensitic (13Cr 4Ni)	550	750	15	35	30
Martensitic (16Cr 5Ni)	540	760	15	35	30
Austenitic (19Cr 11Ni)	180 (*see* Note 3)	440	30	40	—

NOTES
1. When a general service notation **Ice Class 1AS, 1A, 1B or 1C** is required, the tests are to be made at –10°C.
2. For general service or where the notation **Ice Class 1D** is required, the tests are to be made at 0°C.
3. $R_{p1,0}$ value is 205 N/mm^2.

5.6 Rectification of defective castings

5.6.1 The rectification of defective castings is to be undertaken in accordance with 1.9 and the following paragraphs.

5.6.2 Removal of defective material is to be by mechanical means, e.g., by grinding, chipping or milling. The resultant grooves are to be blended into the surrounding surface so as to avoid any sharp contours.

5.6.3 Grinding in severity zone A may be carried out to an extent that maintains the blade thickness. Repair by welding is generally not permitted in zone A and will only be allowed after special consideration.

5.6.4 Defects in severity zone B that are not deeper than $t/40$ mm (t is the minimum local thickness according to the Rules) or 2 mm, whichever is the greater, are to be removed by grinding. Those defects that are deeper may be repaired by welding subject to prior approval of the Surveyor.

5.6.5 Repair welding is generally permitted in severity zone C.

5.6.6 Welds having an area of less than 5 cm^2 are to be avoided. The maximum surface area of repairs is to be in accordance with Table 9.1.4 in Chapter 9.

5.6.7 Welding is to be in accordance with the approved specification, *see* 5.1.3.

5.6.8 After weld repair, the propeller or blade is to be heat treated in such fashion as will minimise the residual stresses. For martensitic stainless steels, this will involve full heat treatment as specified in the approved specification.

5.6.9 LR reserves the right to restrict the amount of repair work accepted from a manufacturer when it appears that repetitive defects are the result of improper foundry techniques or practices.

5.6.10 All welds are to be inspected by the appropriate NDE method, *see* 1.7.

5.7 Identification

5.7.1 Castings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all castings which have been accepted:

(a) Identification mark which will enable the full history of the item to be traced.
(b) Type of steel, this should include or allow identification of the chromium and nickel contents.
(c) LR or Lloyd's Register and the abbreviated name of Lloyd's Register's local office.
(d) Personal stamp of Surveyor responsible for the final inspection.
(e) LR certificate number.
(f) Skew angle, if in excess of 25°.
(g) Ice class symbol, where applicable.
(h) Date of final inspection.

5.8 Certification of materials

5.8.1 In addition to the requirements in Ch 4,1.11, the manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting:

(a) Description of casting with drawing number.
(b) Diameter, number of blades, pitch, direction of turning.
(c) Skew angle, if in excess of 25°.
(d) Final mass.
(e) Vessel identification, where known.

■ *Section 6*
Castings for boilers, pressure vessels and piping systems

6.1 Scope

6.1.1 This Section gives the requirements for carbon-manganese and alloy steel castings for boilers, pressure vessels and piping systems for use at temperatures not lower than 0°C.

6.1.2 Where it is proposed to use alloy steels other than as given in this Section, details of the specification are to be submitted for approval. In such cases, the specified minimum tensile strength is not to exceed 600 N/mm^2.

6.1.3 Castings which comply with these requirements are acceptable for liquefied gas piping systems where the design temperature is not lower than 0°C. Where the design temperature is lower than 0°C, and for other applications where guaranteed impact properties at low temperatures are required, the castings are to comply with the requirements of Section 7 or 8.

6.2 Chemical composition

6.2.1 The chemical composition of ladle samples is to comply with the limits specified in Table 4.6.1.

6.3 Heat treatment

6.3.1 Castings are to be supplied:

(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered; or
(d) quenched and tempered.

6.4 Mechanical tests

6.4.1 A tensile test is to be made on material representing each casting, unless a batch testing procedure has been agreed, *see* 1.6.

6.4.2 The tensile test is to be carried out at ambient temperature, and unless agreed otherwise with the Surveyor, the results are to comply with the requirements of Table 4.6.2.

Table 4.6.1 Chemical composition of steel castings for boilers, pressure vessels and piping systems

Type of steel	Chemical composition %										
	C max.	Si max.	Mn	S max.	P max.	Residual elements					
Carbon-manganese	0,25	0,60	0,50-1,20	0,040	0,040	Cr 0,30 max. Mo 0,15 max. Cu 0,30 max. Ni 0,40 max. Total 0,80 max.					
						Cr	Mo	V	Residual elements Cr	Residual elements Cu	Residual elements Ni
1/2 Mo	0,20	0,60	0,50–1,00	0,040	0,040	—	0,45-0,65	—	0,30 max.	0,30 max.	0,40 max.
1 Cr 1/2 Mo	0,20	0,60	0,50-0,80	0,040	0,040	1,00-1,50	0,45-0,65	—	—	0,30 max.	0,40 max.
2 1/4 Cr1 Mo	0,18	0,60	0,40-0,70	0,040	0,040	2,00-2,75	0,90-1,20	—	—	0,30 max.	0,40 max.
1/2 Cr 1/2 Mo 1/4 V	0,10–0,15	0,45	0,40-0,70	0,030	0,030	0,30-0,50	0,40-0,60	0,22-0,30	—	0,30 max.	0,30 max.

Table 4.6.2 Mechanical properties for acceptance purposes: steel castings for boilers, pressure vessels and piping systems

Type of steel	Yield stress minimum N/mm^2	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Reduction of area % minimum
Carbon-manganese	275	485-655	22	25
1/2Mo	260	460-590	18	30
1Cr1/2Mo	280	480-630	17	20
21/4 Cr1 Mo	325	540-630	17	20
1/2Cr1/2Mo1/4V	295	510-660	17	20

6.4.3 Where it is proposed to use a carbon-manganese steel with a specified minimum tensile strength intermediate to those given in this Section, corresponding minimum values for the yield stress, elongation and reduction of area may be obtained by interpolation.

6.4.4 Carbon-manganese steels with a specified minimum tensile strength of greater than 490 N/mm^2, but not exceeding 520 N/mm^2, may be accepted provided that details of the proposed specification are submitted for approval.

6.5 Non-destructive examination

6.5.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.7 to 1.7.11 and additionally as agreed between the manufacturer, purchaser and Surveyor.

6.6 Mechanical properties for design purposes

6.6.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 100°C and higher are given in Table 4.6.3. These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than those given in Table 4.6.3.

6.6.2 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on each casting or each batch of castings. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature, and the test procedure is to be in accordance with the requirements of Chapter 2. The results of all tests are to comply with the requirements of the National or proprietary specification.

6.6.3 Values for the estimated average stress to rupture in 100 000 hours are given in Table 4.6.4 and may be used for design purposes.

Table 4.6.3 Mechanical properties for design purposes (*see* 6.6.1)

Type of steel	Nominal minimum lower yield or 0,2% proof stress N/mm²										
	Temperature °C										
	100	150	200	250	300	350	400	450	500	550	600
Carbon-manganese	225	214	201	186	163	156	152	—	—	—	—
1/2Mo	242	236	226	207	186	175	169	158	145	136	126
1Cr1/2Mo	240	—	212	—	196	—	184	—	160	—	117
21/4Cr1 Mo	323	312	305	296	290	280	273	258	240	211	180
1/2Cr1/2Mo1/4V	264	—	244	—	230	—	214	—	194	—	144

Table 4.6.4 Mechanical properties for design purposes (*see* 6.6.3)**: estimated average stresses to rupture in 100,000 hours (N/mm²)**

Temperature °C	Type of steel			
	1/2Mo	1Cr1/2Mo	21/4Cr1Mo	1/2Cr1/2Mo1/4V
430	308	—	—	—
440	276	—	—	—
450	245	—	222	277
460	212	—	199	237
470	174	236	177	206
480	133	186	156	181
490	103	148	139	159
500	84	120	124	140
510	71	100	111	124
520	60	84	99	109
530	—	70	—	96
540	—	58	—	85
550	—	—	—	75
560	—	—	—	66

■ *Section 7*
Ferritic steel castings for low temperature service

7.1 Scope

7.1.1 This Section gives the requirements for castings in carbon-manganese and nickel alloy steels, intended for use in liquefied gas piping systems where the design temperature is lower than 0°C, and for other applications where guaranteed impact properties at low temperatures are required.

7.1.2 Where it is proposed to use alternative steels, particulars of the specified chemical composition, mechanical properties and heat treatment are to be submitted for approval.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the limits specified in Table 4.7.1. Carbon-manganese steels are to be made by fine grain practice.

7.3 Heat treatment

7.3.1 Castings are to be supplied:
(a) normalised; or
(b) normalised and tempered; or
(c) quenched and tempered.

7.4 Mechanical tests

7.4.1 One tensile test and one set of three Charpy V-notch impact test specimens are to be prepared from material representing each casting or batch of castings.

7.4.2 The tensile test is to be carried out at ambient temperature, and the results are to comply with the appropriate requirements given in Table 4.7.2.

7.4.3 The average value for impact test specimens is to comply with the appropriate requirements given in Table 4.7.2. One individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedure.

7.5 Non-destructive examination

7.5.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.7 to 1.7.11 and additionally agreed between the manufacturer, purchaser and Surveyor.

Table 4.7.1 Chemical composition of ferritic steel castings for low temperature service

Type of steel	Chemical composition %						
	C max.	Si max.	Mn	S max.	P max.	Ni	Residual elements max.
Carbon-manganese	0,25	0,60	0,70-1,60	0,030	0,030	0,80 max.	Cr 0,25 Cu 0,30 Mo 0,15 V 0,03 Total 0,60
$2^1/_4$Ni	0,25	0,60	0,50-0,80	0,025	0,030	2,00-3,00	
$3^1/_2$Ni	0,15	0,60	0,50-0,80	0,020	0,025	3,00-4,00	

Table 4.7.2 Mechanical properties for acceptance purposes: ferritic steel castings for low temperature service

Type of steel	Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Reduction or area % minimum	Charpy V-notch impact test	
						Test temperature °C	Average energy J minimum
Carbon-manganese	400 430 460	200 215 230	400-550 430-580 460-610	25 23 22	40 35 30	–60 (*see* Note)	27
$2^1/_4$Ni	490	275	490-640	20	35	–70	34
$3^1/_2$Ni	490	275	490-640	20	35	–95	34

NOTE
The test temperature for carbon-manganese steels may be 5°C below the design temperature if the latter is above –55°C, with a maximum test temperature of –20°C.

■ *Section 8*
Stainless steel castings

8.1 Scope

8.1.1 This Section gives the requirements for castings in austenitic and duplex stainless steels for machinery, marine structures, piping systems in ships for liquefied gases, and in bulk chemical tankers.

8.1.2 Austenitic stainless steels castings are suitable for applications where the lowest design temperature is not lower than –165°C.

8.1.3 Duplex stainless steels castings are suitable for applications where the lowest design temperature is above 0°C. Any requirement to use duplex stainless steels castings below 0°C will be subject to special consideration.

8.1.4 Where it is proposed to use alternative steels, particulars of the specified chemical composition, mechanical properties and heat treatment are to be submitted for approval.

8.2 Chemical composition

8.2.1 The chemical composition of ladle samples is to comply with the requirements given in Table 4.8.1.

8.3 Heat treatment

8.3.1 Austenitic stainless steel castings are to be solution treated, at a temperature of not less than 1000°C and cooled rapidly in water.

8.3.2 Duplex stainless steels castings are to be solution treated at a temperature of not less that 1100°C and cooled rapidly in water.

8.4 Mechanical tests

8.4.1 One tensile test specimen is to be prepared from material representing each casting or batch of castings. In addition, where the castings are intended for liquefied gas applications, where the design temperature is lower than –55°C, one set of three Charpy V-notch impact test specimens is to be prepared.

8.4.2 The tensile test is to be carried out at ambient temperature, and the results are to comply with the requirements given in Table 4.8.2.

Table 4.8.1 Chemical composition of stainless steel castings

Type of steel	Chemical composition %								
	C	Si	Mn	S	P	Cr	Mo	Ni	Others
Austenitic									
304L	0,03	0,20-1,5	0,50-2,0	0,040		17,0-21,0	—	8,0–12,0	—
304	0,08						—	8,0–12,0	—
316L	0,03						2,0–3,0	9,0–13,0	—
316	0,08						2,0–3,0	9,0–13,0	—
317	0,08						3,0–4,0	9,0–12,0	—
347 (*see* Note 1)	0,06						—	9,0–12,0	Nb ≥ 8 x C ≤ 0,90
Duplex									
UNS J 92205 (*see* Note 3)	0,03	1,00	1,50	0,020	0,035	21,0–23,0	2,5–3,5	4,5–6,5	N 0,15–0,20 Cu 1,00

NOTES
1. When guaranteed impact values at low temperature are not required, the maximum carbon content may be 0,08% and the maximum niobium may be 1,00%.
2. Where a single value is shown (and not a range of values), the value is to be taken as maximum.
3. The grade UNS J 92205 is the cast equivalent of UNS S 31803.

Table 4.8.2 Mechanical properties for acceptance purposes: stainless steel castings

Type of steel	Tensile strength N/mm^2 minimum	1,0% proof stress N/mm^2 minimum	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests	
					Test temperature °C	Average energy J minimum
Austenitic						
304L	430	215	26	40	–196	41
304	480	220				
316L	430	215	26	40	–196	41
316	480	220				
317	480	240				
347	480	215	22	35	–196	41
Duplex						
UNS J 92205 (*see* Note)	600	420	20	35	0	41

NOTE
The grade UNS J 92205 is the cast equivalent of UNS S 31803.

8.4.3 The average value for impact test specimens is to comply with the appropriate requirements given in Table 4.8.2. One individual value may be less than the required average value, provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedures.

8.5 Corrosion tests

8.5.1 Where corrosive conditions are anticipated in service, for grades 304, 316 and 317, intergranular corrosion tests are required in accordance with Ch 2,8.1. Such tests may also be required for grades 304L, 316L and 347.

8.5.2 Where corrosive conditions are anticipated in service, for duplex stainless grades pitting corrosion tests are required in accordance with ASTM G48 Method C. For duplex stainless steel grade UNS J 92205 the test temperature is to be 20°C. Following the test, no pitting corrosion is to be observed at 20x magnification. The use of a weight loss method may be accepted subject to special consideration.

8.6 Non-destructive examination

8.6.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.7 to 1.7.11 and additionally agreed between the manufacturer, purchaser and Surveyor.

■ *Section 9* Steel castings for container corner fittings

9.1 General

9.1.1 This Section gives the requirements for cast steel corner fittings used in the fabrication of freight and tank containers. The fittings are also to comply with the requirements of the latest edition of International Standard ISO 1161.

9.1.2 The castings are to be made in foundries approved by LR. These foundries are also to be specially approved for the manufacture of container corner castings. In order to comply with these requirements, the manufacturer is required to verify that the casting soundness, mechanical properties, weldability and dimensional tolerances required by this Section and the manufacturing specification are met.

9.1.3 Castings may be released on the basis of an LR survey or, alternatively, the manufacturer may be approved by means of a Quality Assurance Scheme as detailed in Ch 1,2.

9.2 Chemical composition

9.2.1 Chemical analysis is to be carried out on each cast.

9.2.2 The chemical composition of the ladle samples is to comply with the limits given in Table 4.9.1.

9.2.3 The carbon equivalent:

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \ (\%)$$

must not exceed 0,45 per cent.

9.3 Heat treatment

9.3.1 Castings are to be supplied either:

(a) normalised; or

(b) water or oil quenched and tempered at a temperature of not less than 550°C.

9.4 Mechanical tests

9.4.1 At least one tensile test is to be made on each batch of castings, using separately cast test bars which are to be from the same cast and heat treatment lot as the castings they represent.

9.4.2 The results of the tensile tests are to comply with the following:

Yield stress	220 N/mm^2 min.
Tensile strength	430–600 N/mm^2
Elongation on $\sqrt{S_o}$	25% min.
Reduction of area	40% min.

9.4.3 Impact tests are not required on all casts, but may be required on a random basis at the discretion of the Surveyor.

9.4.4 When required, the impact test specimens are to be tested in accordance with Ch 1,4.5 and Ch 2,3.2. In general, tests are to be made at a temperature of –20°C and the minimum average energy obtained is to be 27J.

9.5 Non-destructive examination

9.5.1 Ultrasonic or radiographic testing is to be carried out, in accordance with 1.7.10 or 1.7.11 respectively, on at least one casting from each cast or from every 400 castings, whichever is the lesser.

Table 4.9.1 Chemical composition of steel castings for container corner fittings

Chemical composition %										
C max.	Mn	Si max.	P max.	S max.	Cr max.	Ni max.	Cu max.	Mo max.	Al acid soluble min. (*See* Notes)	Cr + Ni + Cu + Mo max.
0,20	0,90 to 1,50	0,50	0,035	0,035	0,25	0,30	0,20	0,08	0,015	0,70

NOTES
1. The total aluminium content may be determined instead of the acid soluble content. In such cases, the total aluminium content is to be not less than 0,02%.
2. Aluminium may be replaced partly or totally by other grain refining elements as stated in the approved specification.

9.6 Repair of defects

9.6.1 Minor defects may be removed by grinding provided that the allowable minus tolerance is not exceeded.

9.6.2 Defects which exceed the allowable minus tolerance may be removed by grinding or chipping followed by welding, provided the weld depth does not exceed 40 per cent of the wall thickness and that the following requirements are met:
(a) welding is not to be carried out in the as-cast condition; the grain structure has to be refined by heat treatment,
(b) the casting is to be preheated to 80–100°C,
(c) welding is to be performed only by qualified welders in accordance with a qualified welding procedure,
(d) all welded castings are to be post-weld heat treated at a temperature not less than 550°C,
(e) the welded areas are to be ground or machined flush with the adjacent surface and inspected by magnetic particle or dye penetrant examination as appropriate.

9.7 Identification

9.7.1 Each casting is to be clearly marked by the manufacturer with at least the following:
(a) manufacturer's name or trade mark,
(b) cast number or identification number which will enable the full history of the casting to be traced.

9.7.2 Where the casting has been inspected and found acceptable it is to be marked with the Surveyor's personal stamp.

9.7.3 The markings may be stamped or cast on the inner surface of the casting.

9.8 Certification of materials

9.8.1 For each consignment an LR certificate, *see* Ch 1,3.1, is to be issued for castings made under LR survey or alternatively a manufacturer's certificate is to be issued containing at least the following:
(a) Purchaser's name and order number.
(b) Grade of steel.
(c) Drawing and/or specification number.
(d) Cast number and chemical composition.
(e) Details of the heat treatment.
(f) Number and weight of the castings.
(g) Results of inspections and mechanical tests.
See Ch 1,3.1, for manufacturers approved under a Quality Assurance Scheme.

Section

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for steel forgings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems. These requirements are also applicable to rolled slabs and billets used as a substitute for forgings and to rolled bars used for the manufacture (by machining operations only) of shafts, bolts, studs and other components of similar shape.

1.1.2 When required by the relevant Rules dealing with design and construction, forgings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the general requirements given in this Section and the appropriate specific requirements given in Sections 2 to 9.

1.1.3 As an alternative to 1.1.2, steel forgings which comply with National or proprietary specifications, may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter, or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Normalised forgings with mass up to 1000 kg each may be batch tested. A batch is to consist of forgings of similar shape and dimensions, made from the same steel-making heat, heat treated together and with a total mass not exceeding 6 tonnes.

1.1.5 Quenched and tempered forgings with mass up to 500 kg each may be batch tested. A batch is to consist of forgings of similar shape and dimensions, made from the same steel-making heat, heat treated together in the same furnace and with a total mass not exceeding 3 tonnes.

1.1.6 A batch testing procedure may also be used for hot rolled bars, *see* 3.4.3.

1.1.7 Where small forgings are produced in large quantities, or where forgings of the same type are produced in regular quantities, alternative survey procedures in accordance with Ch 1,2.4 may be adopted.

1.2 Manufacture

1.2.1 Forgings are to be made at works which have been approved by Lloyd's Register (hereinafter referred to as LR). The steel used, is to be manufactured in accordance with the requirements of Ch 3,1.4.

1.2.2 When forgings are made directly from ingots, or from blooms or billets forged from ingots, the ingots are to be cast in chill moulds with the larger cross-section uppermost and with efficient feeder heads.

1.2.3 Adequate top and bottom discards are to be made to ensure freedom from piping and harmful segregations in the finished forgings.

1.2.4 The forgings are to be gradually and uniformly hot worked and are to be formed as closely as possible to the finished shape and size. The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment.

1.2.5 For certain components, such as crankshafts, where grain flow is required in the most favourable direction, having regard to the mode of stressing in service, the proposed method of manufacture may require special approval by LR. In such cases, tests may be required to demonstrate that a satisfactory structure and grain flow are obtained.

1.2.6 The reduction ratio (reduction of area expressed as a ratio) is to be calculated with reference to the average cross-sectional area of the ingot or continuously cast material, where appropriate. Where an ingot is initially upset, this reference area may be taken as the average cross-sectional area after this operation.

1.2.7 For components forged directly from ingots or from forged blooms or billets, and in which the fibre deformation is mainly longitudinal, the reduction ratio is not to be less than 3:1.

1.2.8 For forgings made from rolled billets, or where fibre deformation has taken place in more than one direction, the reduction ratio is not to be less than 4:1.

1.2.9 Where rolled bars are used as a substitute for forgings and the requirements of 1.2.2 are not complied with, the reduction ratio is to be not less than 6:1.

1.2.10 Where the length of any section of a shaft forging is less than its diameter (e.g., a collar), the reduction ratio is to be not less than half that given in 1.2.7, 1.2.8 or 1.2.9 respectively.

1.2.11 Disc type forgings, such as gear wheels, are to be made by upsetting, and the thickness of any part of the disc is to be not more than one-half of the length of the billet from which it was formed, provided that this billet has received an initial forging reduction of not less than 1,5:1. Where the piece used has been cut directly from an ingot, or where the billet has received an initial reduction of less than 1,5:1, the thickness of any part of the disc is to be not more than one-third of the length of the original piece.

1.2.12 Rings and other types of hollow forgings are to be made from pieces cut from ingots or billets and which have been suitably punched, bored or trepanned prior to expanding or hollow forging. Alternatively, pieces from hollow cast ingots may be used. The wall thickness of the forging is to be not more than one-half of the thickness of the prepared hollow piece from which it was formed. Where this is not practicable, the forging procedure is to be such as to ensure that adequate work is given to the piece prior to punching, etc. This may be either longitudinal or upset working of not less than 2:1.

1.2.13 The shaping of forgings or rolled slabs and billets by flame cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognised good practice and, unless otherwise approved, is to be carried out before the final heat treatment. Preheating is to be employed where necessitated by the composition and/or thickness of the steel. For certain components, subsequent machining of all flame cut surfaces may be required, *see* 4.2.4.

1.2.14 Where two or more forgings are joined by welding to form a composite component, details of the proposed welding procedure are to be submitted for approval. Welding approval procedure tests may be required.

1.3 Quality

1.3.1 All forgings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

1.4 Chemical composition

1.4.1 All forgings are to be made from killed steels, and the chemical composition of ladle samples is to comply with the requirements detailed in subsequent Sections in this Chapter. Where general overall limits are specified, the chemical composition selected is to be appropriate for the type of steel, dimensions and required mechanical properties of the forgings being manufactured.

1.4.2 Except where otherwise specified, suitable grain refining elements such as aluminium, niobium or vanadium may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

1.4.3 For alloy steel forgings, the chemical composition of ladle samples is to generally comply with the following overall limits and the requirements of the approved specifications:

Carbon	0,45% max.
Silicon	0,45% max.
Manganese	0,30% min.
Sulphur	0,035% max.
Phosphorus	0,035% max.
Copper	0,30% max.

And at least one of the following elements is to comply with the minimum content:

Chromium	0,40% min.
Molybdenum	0,15% min.
Nickel	0,40% min.

The contents of all alloying elements and significant impurities detailed in the specification are to be reported.

1.5 Heat treatment

1.5.1 At an appropriate stage of manufacture, after completion of all hot working operations, forgings are to be suitably heat treated to refine the grain structure and to obtain the required mechanical properties. Acceptable heat treatment procedures are to be such as to avoid the formation of hair-line cracks and are detailed in Sections 2 to 9.

1.5.2 Heat treatment is to be carried out in a properly constructed furnace which is efficiently maintained and has adequate means of temperature control. The furnace dimensions are to be such as to allow all the steel forgings to be uniformly heated to the necessary temperature. In the case of very large forgings, alternative methods of heat treatment will be specially considered. Sufficient thermocouples are to be connected to the steel forging(s) in the furnace to show that the temperature is adequately uniform and the temperatures are to be recorded throughout the heat treatment. Copies of these records are to be presented to the Surveyor together with a sketch showing the positions at which the temperature measurements were carried out. The records are to identify the furnace that was used and give details of the steel-making heat, the heat treatment temperature, time at temperature and the date. The Surveyor is to examine the charts and confirm the details on the certificate. Alternative procedures are to be approved by LR's Materials and NDE Department.

1.5.3 Where forgings are to be quenched and tempered and cannot be hot worked close to size and shape, they are to be suitably rough machined or flame cut prior to being subjected to this treatment.

1.5.4 If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat treated.

1.5.5 If any straightening operation is performed after the final heat treatment, consideration should be given to a subsequent stress relieving heat treatment in order to avoid the possibility of harmful residual stresses.

1.5.6 Where it is intended to surface harden forgings, full details of the proposed procedure and specification are to be submitted for approval. For the purposes of this approval, the manufacturer will be required to demonstrate by tests that the proposed procedure gives a uniform surface layer of the required hardness and depth and that it does not impair the soundness and properties of the steel.

1.5.7 Where induction hardening or nitriding is to be carried out after machining, forgings are to be heat treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

1.5.8 Where carburising is to be carried out after machining, forgings are to be heat treated at an appropriate stage (generally either by full annealing or by normalising and tempering) to a condition suitable for subsequent machining and carburising.

1.5.9 The forge is to maintain records of heat treatment identifying the furnace used, furnace charge, thermocouple location, date, temperature and time at temperature. The records are to be presented to the Surveyor on request.

1.6 Test material

1.6.1 Test material, sufficient for the required tests and for possible re-test purposes, is to be provided with a cross-sectional area of not less than that part of the forging which it represents. This test material is to be integral with each forging, except in the case of small forgings which are batch tested, *see* 1.6.4.

1.6.2 Where a forging is subsequently divided into a number of components, all of which are heat treated together in the same furnace, for test purposes this may be regarded as one forging and the number of tests required is to be related to the total length and mass of the original multiple forging, *see* 2.4.2.

1.6.3 Except for components which are to be carburised, test material is not to be cut from a forging until the heat treatment detailed in Sections 2 to 9 has been completed. The testing procedure for components which are to be carburised is to be in accordance with the details given in Section 5.

1.6.4 Where a number of small forgings of about the same size are made from one cast and heat treated together in the same furnace, batch testing procedures (*see* 1.1.4) may be adopted using one of the forgings for test purposes, or alternatively using separately forged test samples. These test samples are to have a forging reduction similar to that used for the forgings which they represent. They are to be properly identified and heat treated together with the forgings.

1.7 Mechanical tests

1.7.1 Specimens for mechanical tests are to be prepared as required by Sections 2 to 9.

1.7.2 Test specimens are normally to be cut with their axes mainly parallel (longitudinal test) or mainly tangential (tangential test) to the principal axial direction of each product.

1.7.3 Unless otherwise agreed, the longitudinal axis of the test specimens is to be positioned as follows:

(a) for thickness or diameter ≤ 50 mm, the axis is to be at the mid-thickness or the centre of the cross-section;

(b) for thickness or diameter > 50 mm, the axis is to be at one quarter thickness (mid-radius) or 80 mm, whichever is less, below any heat treated surface;

Test pieces shall be taken in such a way that no part of the gauge length is machined from material closer than 12,5 mm to any heat treated surface. For impact testing, this requirement is to apply to the complete test piece.

1.7.4 Tensile test specimens are to be machined to the dimensions detailed in Chapter 2. Where this is precluded by the dimensions of the forging, the test specimen is to be of the largest practicable cross-sectional area.

1.7.5 Impact test specimens are to be prepared in accordance with the requirements of Chapter 2.

1.7.6 The procedures used for the tensile and impact tests are to be in accordance with the requirements of Chapter 2.

1.7.7 Hardness tests, preferably of the Brinell type, are to be carried out when specified in subsequent Sections in this Chapter.

1.8 Visual and non-destructive examination

1.8.1 Before acceptance, all forgings are to be presented to the Surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces and bores.

1.8.2 Forgings are to be examined in the condition for final delivery. Surfaces are to be clean and free from dirt, grease, paint, etc. Black forgings are to be suitably descaled by either shotblasting or flame descaling methods.

1.8.3 All forgings are to be free of cracks, crack-like indications, laps, seams, folds, or other injurious indications. At the request of the Surveyor, additional magnetic particle, dye penetrant and ultrasonic testing may be required for a more detailed evaluation of surface irregularities.

1.8.4 When specified in subsequent Sections in this Chapter, or by an approved procedure for welding composite components, *see* 1.2.14, appropriate non-destructive examination is also to be carried out before acceptance. All tests are to be carried out in accordance with the requirements of Ch 1,5.

1.8.5 Magnetic particle and dye penetrant testing is to be carried out when the forgings are in the finished machined condition, *see also* Ch 1,2.3.5. For magnetic particle testing, attention is to be paid to the contact between the forging and the clamping devices of stationary magnetisation benches in order to avoid local overheating or burning damage on its surface. Prods are not permitted on finished machined items. Unless otherwise agreed, these tests are to be carried out in the presence of the Surveyor.

1.8.6 The following definitions apply to indications associated with magnetic particle and dye penetrant inspection:

(a) **Linear indication**. An indication in which the length is at least three times the width.
(b) **Nonlinear indication**. An indication of circular or elliptical shape with a length less than three times the width.
(c) **Aligned indication**. Three or more indications in a line, separated by 2 mm or less edge-to-edge.
(d) **Open indication**. An indication visible after removal of the magnetic particles or that can be detected by the use of contrast dye penetrant.
(e) **Non-open indication**. An indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of contrast dye penetrant.
(f) **Relevant indication**. An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1,5 mm are to be considered relevant.

1.8.7 Acceptance standards for defects found by visual or non destructive examinations are to be in accordance with any specific requirements of the approved plan, and with equivalence to any additional requirements of this Chapter. In all cases they are to be to the satisfaction of the Surveyor.

1.8.8 Where required, ultrasonic examination is to be carried out after the forgings have been machined to a condition suitable for this type of examination and after the final heat treatment. Both radial and axial scanning are to be carried out where appropriate for the shape and the dimensions of the forgings being examined. Scanning is to take into account near surface examination. Unless otherwise agreed, examinations are to be carried out by the manufacturer, although Surveyors may request to be present in order to verify that the examination is being carried out in accordance with the agreed procedure.

1.8.9 If the forging is supplied in the black condition for machining at a separate works, the manufacturer is to ensure that a suitable ultrasonic examination is carried out to verify the internal quality of the forging.

1.8.10 In the circumstance detailed in either 1.8.8 or 1.8.9, the manufacturer is to provide the Surveyor with a signed report confirming that ultrasonic examination has been carried out and that such inspection has not revealed any significant internal defects.

1.8.11 Unless otherwise agreed, the accuracy and verification of dimensions are the responsibility of the manufacturer.

1.8.12 In the event of any forging proving defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

1.8.13 When required by the conditions of approval for surface hardened forgings (*see* 1.5.6) additional test samples are to be processed at the same time as the forgings which they represent. These test samples are subsequently to be sectioned in order to determine the hardness, shape and depth of the locally hardened zone and which are to comply with the requirements of the approved specification.

1.9 Rectification of defects

1.9.1 Small surface imperfections may be removed by grinding or by chipping and grinding. Complete elimination of these imperfections is to be proved by magnetic particle or dye penetrant examination (as appropriate to the material). At the discretion of the Surveyor, the resulting shallow grooves or depressions can be accepted, provided that they are blended by grinding.

1.9.2 Repairs by welding are not generally permitted, but special consideration will be given to such repairs where they are of a minor nature and in areas of low working stresses. In such cases, full details of the proposed repair and subsequent inspection procedures are to be submitted for review by the Surveyors prior to the commencement of the proposed rectification. A report and/or sketch detailing the extent and location of all repairs, together with details of the post-weld heat treatment and non-destructive examination are to be provided for record purposes and are to be attached to the certificate.

1.9.3 Repair welding is not permitted for crankshafts or similar rotating components.

1.9.4 Where fabrication welding is involved, *see* 1.2.14, any repair of defects is to be carried out in accordance with the approved welding procedure.

1.9.5 The forging manufacturer is to maintain records of repairs and subsequent inspections traceable to each forging. The records are to be presented to the Surveyor on request.

1.9.6 Non-open indications evaluated as segregation are acceptable.

1.10 Identification

1.10.1 The manufacturer is to adopt a system of identification, which will enable all finished forgings to be traced to the original cast, forging process and heat treatment batch, and the Surveyor is to be given full facilities for so tracing the castings when required.

1.10.2 Forgings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all forgings which have been accepted:

(a) Identification number, cast number or other marking which will enable the full history of the forging to be traced.
(b) LR or Lloyd's Register and the abbreviated name of LR's local office.
(c) Personal stamp of Surveyor responsible for inspection.
(d) Test pressure, where applicable.
(e) Date of final inspection.

1.10.3 Modified arrangements for the identification of small forgings manufactured in large numbers, as with closed-die forgings may be agreed with the Surveyor.

1.11 Certification of materials

1.11.1 A LR certificate is to be issued, *see* Ch 1,3.1.

1.11.2 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each forging or batch of forgings which has been accepted:

(a) Purchaser's name and order number.
(b) Description of forgings and steel quality.
(c) Identification number.
(d) Steel-making process, cast number and chemical analysis of ladle samples.
(e) General details of heat treatment.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

1.11.3 As a minimum, the chemical composition of ladle samples is to include the content of all the elements detailed in the specific requirements.

1.11.4 Where applicable, the manufacturer is also to provide a signed report regarding ultrasonic examination as required by 1.8.8, a report of magnetic particle inspection and a statement and/or sketch detailing all repairs by welding as required by 1.9.2.

1.11.5 When steel is not produced at the works at which it is forged, a certificate is to be supplied by the steelmaker stating the process of manufacture, cast number and the chemical composition of ladle samples. The works at which the steel was produced is to have been approved by LR, *see* 1.4.3.

■ *Section 2*
Forgings for ship and other structural applications

2.1 Scope

2.1.1 This Section gives the specific requirements for carbon-manganese steel forgings intended for ship and other structural applications such as rudder stocks, pintles, etc.

2.1.2 Where it is proposed to use an alloy steel, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval, *see* 1.4.3.

2.2 Chemical composition

2.2.1 For forgings to which structural items are to be attached by welding or which are intended for parts of a fabricated component, or are to be weld cladded or may be subject to weld repair in service, the chemical composition of ladle samples is to comply with the following:

Carbon	0,23% max.
Silicon	0,45% max.
Manganese 0,30–1,50% but not less than 3 times the actual carbon content for components which are not given a post-weld heat treatment	
Sulphur	0,035% max.
Phosphorus	0,035% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Molybdenum	0,15% max.
Nickel	0,40% max.
Total	0,85% max.

For samples from forgings, the carbon content is not to exceed 0,26 per cent.

2.2.2 It is recommended that forgings for rudder stocks, pintles and rudder coupling bolts comply with 2.2.1 in order to obtain satisfactory weldability for any future repairs by welding in service.

2.2.3 For forgings not intended for welding the carbon content may be 0,65 per cent max., *see* 3.2.1.

2.3 Heat treatment

2.3.1 Carbon-manganese steel forgings are to be:

(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered at a temperature of not less than 550°C.
(d) quenched and tempered.

2.3.2 Alloy steel forgings are to be quenched and then tempered at a temperature of not less than 550°C. Alternatively, they may be supplied in the normalised and tempered condition, in which case the specified mechanical properties are to be agreed by LR.

2.4 Mechanical tests

2.4.1 At least one tensile specimen is to be taken from each forging or batch of forgings.

2.4.2 Where a forging exceeds both 4 tonnes in mass and 3 m in length, tensile test specimens are to be taken from each end. These limits refer to the 'as forged' mass and length but exclude the test material.

2.4.3 Unless otherwise agreed between the manufacturer and the Surveyor, the test specimens are to be cut in a longitudinal direction.

2.4.4 The results of all tensile tests are to comply with the requirements given in Table 5.2.1 appropriate to the specified minimum tensile strength. Forgings may be supplied to any specified minimum tensile strength within the general limits given in Table 5.2.1, and intermediate values may be obtained by interpolation. *See* 2.4.6 for rudder stocks, pintles, and rudder coupling keys and bolts.

2.4.5 For large forgings, where tensile tests are taken from each end, the variation in tensile strength is not to exceed 70 N/mm^2.

2.4.6 For rudder stocks, pintles, and rudder coupling keys and bolts, the minimum specified yield strength is not to be less than 200 N/mm^2, *see* Table 13.2.4 in Pt 3, Ch 13.

2.4.7 Impact tests are required for rudder stocks to be fitted to vessels which have an ice class notation. The tests are to be carried out at minus 10°C and the average energy value is to be not less than 27J.

2.5 Non-destructive examination

2.5.1 Surface inspections are to be carried out by visual examination and magnetic particle testing (or dye penetrant testing where appropriate).

2.5.2 Surface inspections are to be carried out in the zones I and II as indicated in Fig. 5.2.1.

2.5.3 For the purpose of evaluating indications, the surface is to be divided into reference areas of 225 cm^2. The area is to be taken in the most unfavourable location relative to the indication being evaluated.

2.5.4 The allowable number and size of indications in the reference area is given in Table 5.2.2.

2.5.5 Volumetric inspection is to be carried out by ultrasonic testing using the contact method.

2.5.6 Ultrasonic testing is to be carried out on rudder stocks having a finished diameter of 200 mm or greater.

2.5.7 Ultrasonic testing is to be carried out in the zones I to III as indicated in Fig. 5.2.2. Areas may be upgraded to a higher zone at the discretion of the Surveyor.

Table 5.2.1 Mechanical properties for ship and other structural applications

Steel type	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ min.%		Reduction of area min. %	
			Long.	Tang.	Long.	Tang.
C and C-Mn	180	360-480	28	20	50	35
	200	400-520	26	19	50	35
	220	440-560	24	18	50	35
	235	470-590	23	17	45	35
	240	480-600	22	16	45	30
	260	520-640	21	15	45	30
	280	560-680	20	14	40	27
	300	600-750	18	13	40	27
	320	640-790	17	12	40	27
	340	680-830	16	12	35	24
	360	720-870	15	11	35	24
	380	760-910	14	10	35	24
Alloy	350	550-570	20	14	50	35
	400	600-750	18	13	50	35
	450	650-800	17	12	50	35

Table 5.2.2 Steel forgings surface inspection

Inspection zone	Maximum number of indications	Type of indication	Maximum number each type	Maximum dimension, mm
I	3	Linear Non-linear Aligned	0, *see* Note 3 0, *see* Note	— 3,0 —
II	10	Linear Non-linear Aligned	3, *see* Note 7 3, *see* Note	3,0 5,0 3,0

NOTE
Linear or aligned indications are not permitted on bolts, which receive a direct fluctuating load, e.g., main bearing bolts, connecting rod bolts, crosshead bearing bolts and cylinder cover bolts.

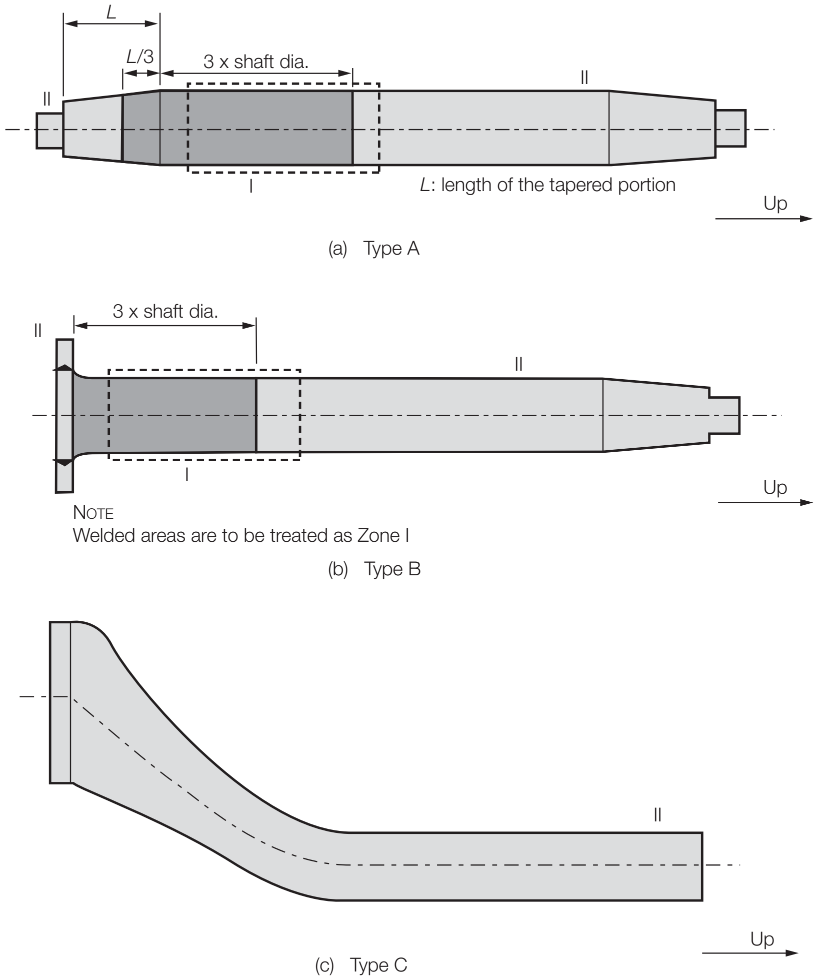
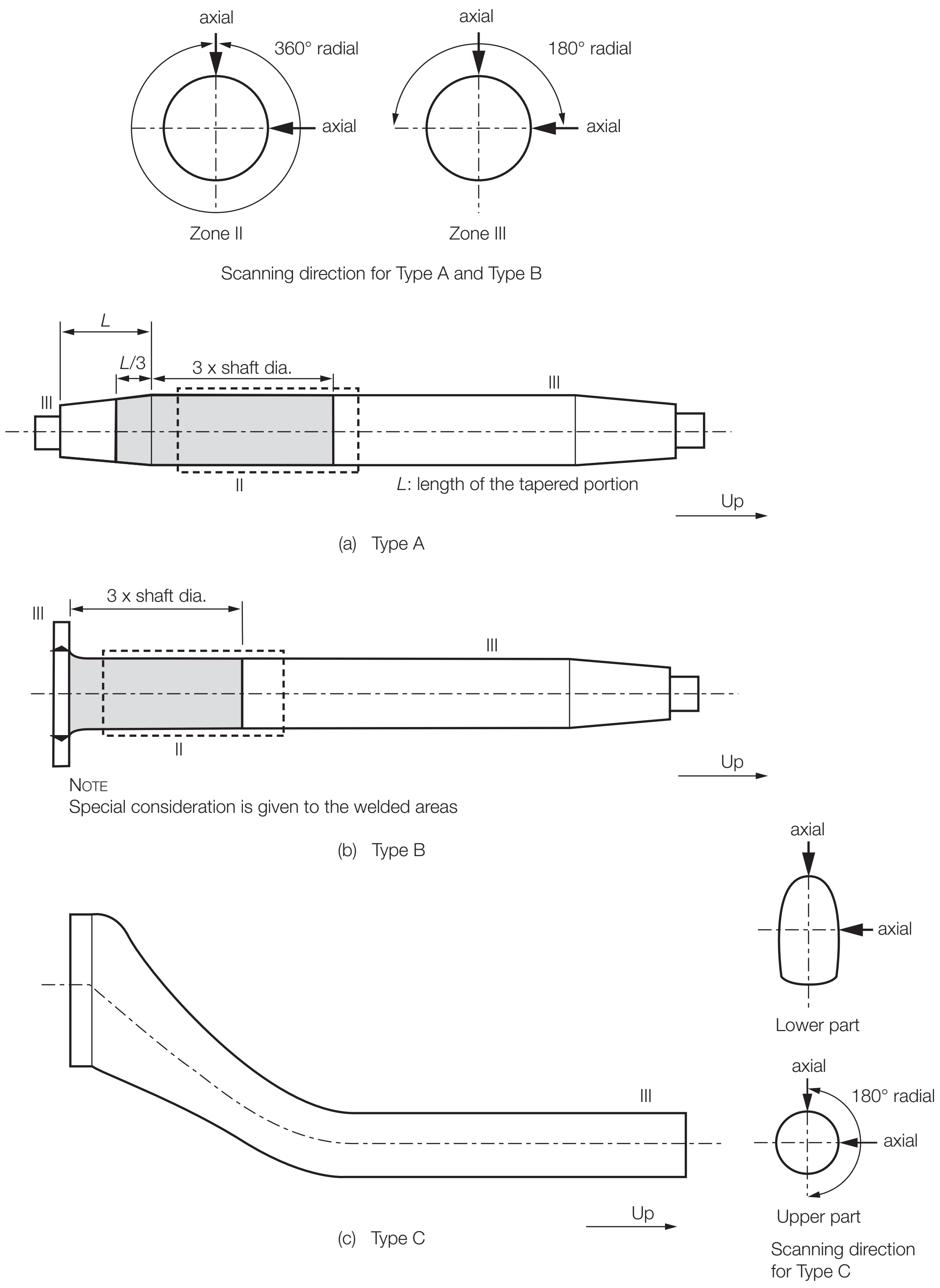


Fig. 5.2.1 Inspection zones for magnetic particle/dye penetrant testing on rudder stocks

2.5.8 Ultrasonic acceptance criteria are shown in Table 5.3.4, alternatively *see* Ch 1,5.



NOTE
Axial scan from end face also required for Type A and Type B

Fig. 5.2.2 Inspection zones for ultrasonic testing on rudder stocks

Section 3
Forgings for shafting and machinery

3.1 Scope

3.1.1 Detailed in this Section are the requirements for carbon-manganese steel forgings for shafting and other items of machinery which are not within the scope of Sections 4 to 8.

3.1.2 Where it is proposed to use alloy steel forgings, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. For main propulsion shafting in alloy steels, the specified minimum tensile strength is not to exceed 800 N/mm^2 (800–950 N/mm^2 acceptance range) and for other forgings is not to exceed 1100 N/mm^2 (1100–1300 N/mm^2 acceptance range).

3.2 Chemical composition

3.2.1 The chemical composition of ladle samples for carbon and carbon-manganese steels is to comply with the following overall limits:

Carbon	0,65% max.
Silicon	0,45% max.
Manganese	0,30–1,50%
Sulphur	0,035% max.
Phosphorus	0,035% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Molybdenum	0,15% max.
Nickel	0,40% max.
Total	0,85% max.

3.2.2 For alloy steels, *see* 1.4.3.

3.2.3 For forgings to which structural items are to be attached by welding, or which are intended for parts of a fabricated component, are to be of weldable quality, *see* 2.2.1.

3.3 Heat treatment

3.3.1 Forgings are to be:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered; or
(d) quenched and tempered.
The tempering temperature is to be not less than 550°C.

3.4 Mechanical tests

3.4.1 At least one tensile test is to be made on each forging, or each batch of forgings. Impact tests are not required except on screwshafts for ice service, *see* 3.4.12.

3.4.2 Where a forging exceeds both 4 tonnes in mass and 3 m in length, a tensile test is to be taken from each end. These limits refer to the 'as forged' mass and length but exclude the test material.

3.4.3 A batch testing procedure may be used for hot rolled bars not exceeding 250 mm diameter, which are intended for the manufacture (by machining operations only) of straight shafting, bolts, studs and other machinery components of similar shape. A batch is to consist of either:
(a) material from the same piece provided that where this is cut into individual lengths, these are all heat treated together in the same furnace; or
(b) bars of the same diameter and cast, heat treated together in the same furnace and with a total mass not exceeding 2,5 tonnes.

3.4.4 The test specimens are to be taken in the longitudinal direction but, at the discretion of the manufacturer and if agreed by the Surveyor, alternative directions or positions as shown in Figs. 5.3.1 to 5.3.3 may be used.

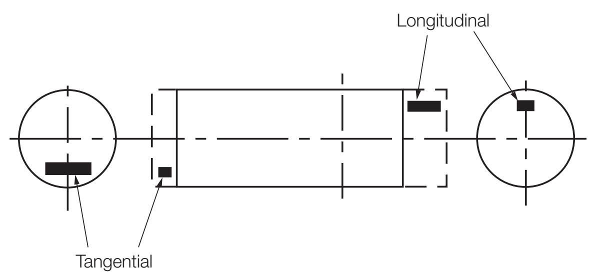


Fig. 5.3.1
Directions and positions of test specimens

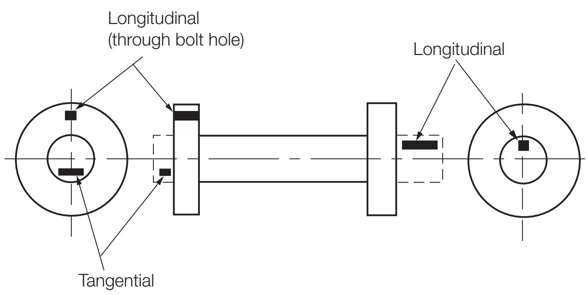


Fig. 5.3.2
Directions and positions of test specimens

3.4.5 For carbon-manganese steels, Table 5.3.1 gives the minimum requirements for yield stress, elongation and reduction of area, corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. Intermediate values for other specified minimum tensile strengths should be calculated by interpolation.

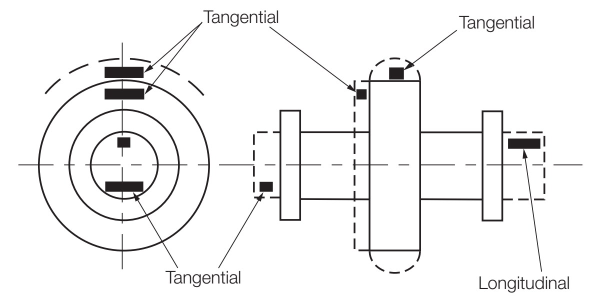


Fig. 5.3.3
Directions and positions of test specimens

3.4.6 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.3.1, except that for main propulsion shafting forgings the specified minimum tensile strength is to be not less than 400 N/mm^2 (400–520 N/mm^2 acceptance range) and not greater than 600 N/mm^2 (600–750 N/mm^2 acceptance range) *see* shaded area of Table 5.3.1.

3.4.7 The results of all tensile tests are to comply with the requirements given in Table 5.3.1 appropriate to the specified minimum tensile strength.

3.4.8 The minimum requirements for yield stress, elongation and reduction of area, corresponding to different strength levels in alloy steel forgings are given in Table 5.3.2.

Table 5.3.1 Mechanical properties for acceptance purposes: carbon and carbon-manganese steel forgings for machinery and shafting

Tensile strength N/mm^2	Yield stress N/mm^2	Elongation on $5,65\sqrt{S_o}$ min.%		Reduction of area min. %	
		Long.	Tang.	Long.	Tang.
360–480	180	28	20	50	35
400–520	200	26	19	50	35
440–560	220	24	18	50	35
470–590	235	23	17	45	35
480–600	240	22	16	45	30
520–640	260	21	15	45	30
560–680	280	20	14	40	27
600–750	300	18	13	40	27
640–790	320	17	12	40	27
680–830	340	16	12	35	24
700–850 [2]	350	15	11	35	24
720–870 [2]	360	15	11	35	24
760–910 [2]	380	14	10	35	24

NOTES
1. For main propulsion shafting forgings, the specified minimum tensile strength is to be between 400 and 600 N/mm^2 (shaded area of Table) *see* 3.4.6.
2. Where the specified minimum tensile strength exceeds 700 N/mm^2, forgings are to be supplied only in the quenched and tempered condition.

Table 5.3.2 Mechanical properties for acceptance purposes: alloy steel forgings for machinery and shafting

Tensile strength N/mm^2	Yield stress N/mm^2	Elongation on $5,65\sqrt{S_o}$ min.%		Reduction of area min. %	
		Long.	Tang.	Long.	Tang.
600–750	420	18	14	50	35
650–-800	450	17	13	50	35
700–850	480	16	12	45	30
750–900	530	15	11	45	30
800–950	580	14	10	40	27
850–1000	630	13	9	40	27
900–1100	690	13	9	40	27
950–1150	750	12	8	35	24
1000–1200	810	12	8	35	24
1050–1250	870	11	7	35	24
1100–1300	930	11	7	35	24

NOTE
For main propulsion shafting forgings, the minimum specified tensile strength is not to exceed 800 N/mm^2, *see* 3.4.9 (shaded area of Table).

3.4.9 Forgings in alloy steels may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.3.2, and minimum yield stress, elongation and reduction of area, obtained by interpolation, except that for main propulsion shafting forgings the specified minimum tensile strength is not to exceed 800 N/mm^2 (800–950 N/mm^2 acceptance range) *see* shaded area of Table 5.3.2.

3.4.10 The results of all tensile tests are to comply with the requirements given in Table 5.3.2 appropriate to the specified minimum tensile strength.

3.4.11 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm^2	Difference in tensile strength N/mm^2
<600	70
≥600 < 900	100
≥900	120

3.4.12 For screwshafts intended for ships with the notation **Ice Class 1AS** or **1A** and where the connection between the propeller and the screwshaft is by means of a key, a set of three Charpy V-notch impact tests (longitudinal test) is to be made on material from the propeller end of each shaft. The tests are to be carried out at –10°C and the average energy value is to be not less than 20 J.

3.5 Non-destructive examination

3.5.1 Magnetic particle or dye penetrant testing (where appropriate) is to be carried out on forgings for main propulsion shafting (including propeller shafts, intermediate shafts, and thrust shafts with minimum diameter not less than 100 mm), on all connecting rod forgings and on the following components when they are intended for engines having a bore diameter larger than 400 mm:

- Cylinder covers
- Piston crowns
- Piston rods
- Tie rods
- Gear wheels for camshaft drives
- Bolts and studs for:
  - Cylinder covers
  - Crossheads
  - Main bearings
  - Connecting rod bearings
  - Propeller blade fastening bolts
  - Crankpin bolts
  - Tie rod bolts
  - Additionally, bolts for engine bore diameters of less than 400 mm but having a minimum diameter 50 mm or greater (which are subjected to dynamic stress), are also to be subjected to surface examinations.

3.5.2 The areas to be tested by magnetic particle or dye penetrate testing are shown in Fig. 5.3.4 and Fig. 5.3.5. Areas of other components not shown in these figures are to be agreed with the Surveyor. For tie rods, only threaded portions and the adjacent material over a length equal to that of the thread need be tested.

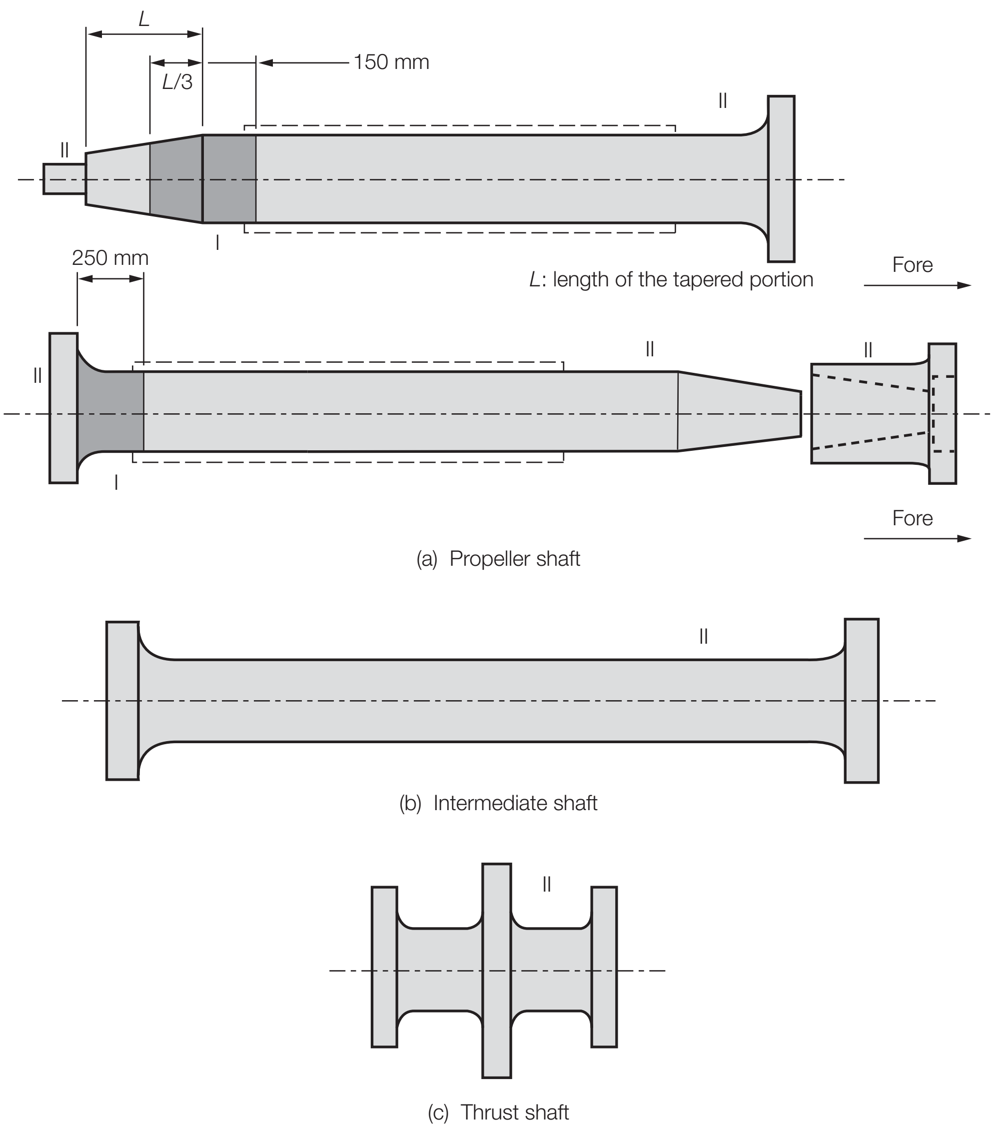
3.5.3 Surface inspection acceptance criteria are to be in accordance with 2.5. Other acceptance criteria may be applied, providing they meet these minimum criteria, and are to the satisfaction of the Surveyor.

3.5.4 Ultrasonic testing is to be carried out in accordance with 2.5 on the following items:

(a) Shafts having a finished diameter of 200 mm or larger when intended for main propulsion or other essential services.
(b) All piston crowns and cylinder covers.
(c) Piston rods and connecting rods for engines having a bore diameter greater than 400 mm.

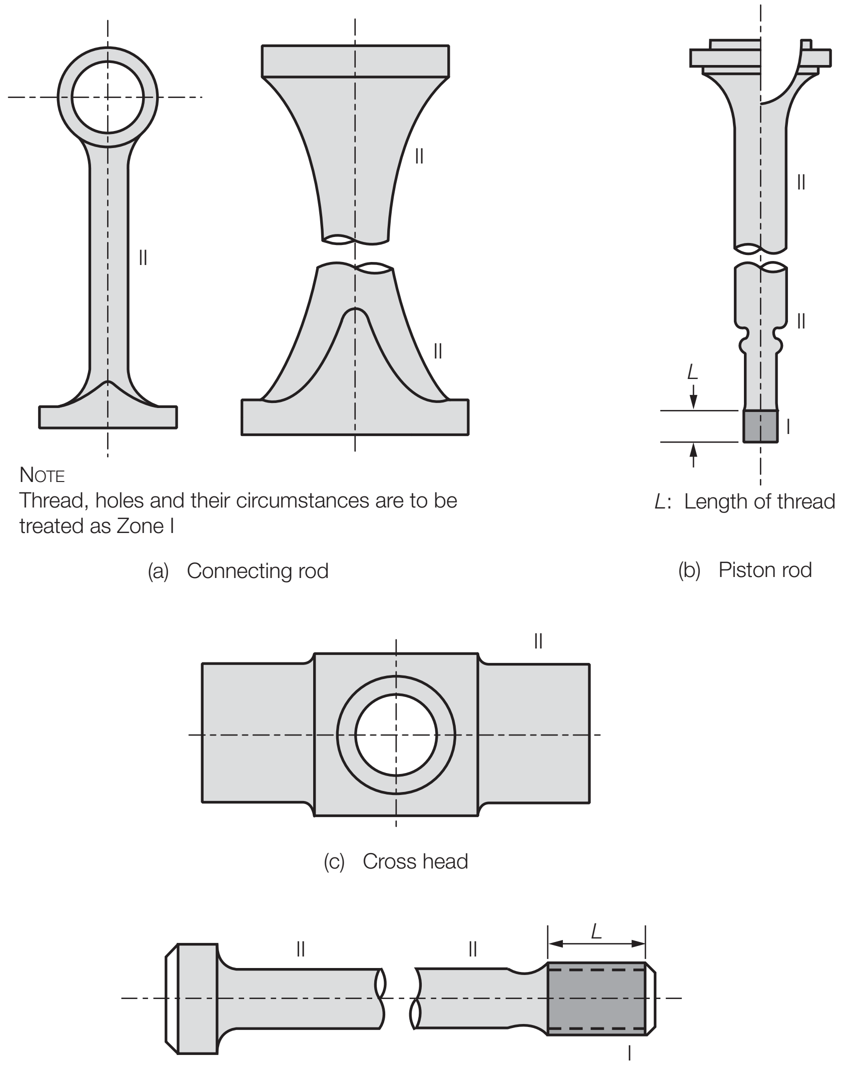
The areas to be tested are shown in Fig. 5.3.6 and Fig. 5.3.7. Areas of other components not shown in these drawings are to be agreed with the Surveyor.

3.5.5 Ultrasonic acceptance criteria are shown in Table 5.3.3. Other acceptance criteria may be applied, providing they meet these minimum criteria, and are to the satisfaction of the Surveyor.



Note
For propeller shaft, intermediate shafts and thrust shafts, all areas with stress raisers such as radial holes, slots and key ways are to be treated as Zone I.

Fig. 5.3.4 Zones for magnetic particle/dye penetrant testing on machinery components



NOTE
Thread, holes and their circumstances are to be treated as Zone I

(a) Connecting rod

L: Length of thread

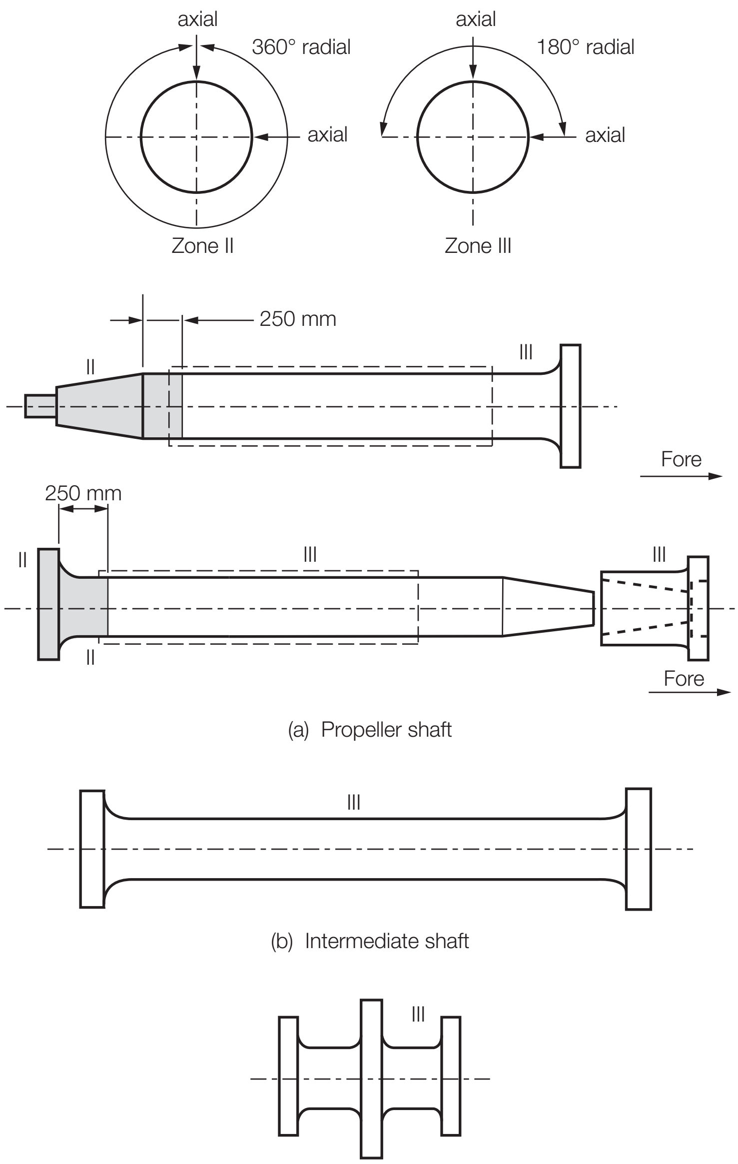
(b) Piston rod

(c) Cross head

L: Length of thread

(d) Bolt

Fig. 5.3.5 Zones for magnetic particle/dye penetrant testing on machinery components



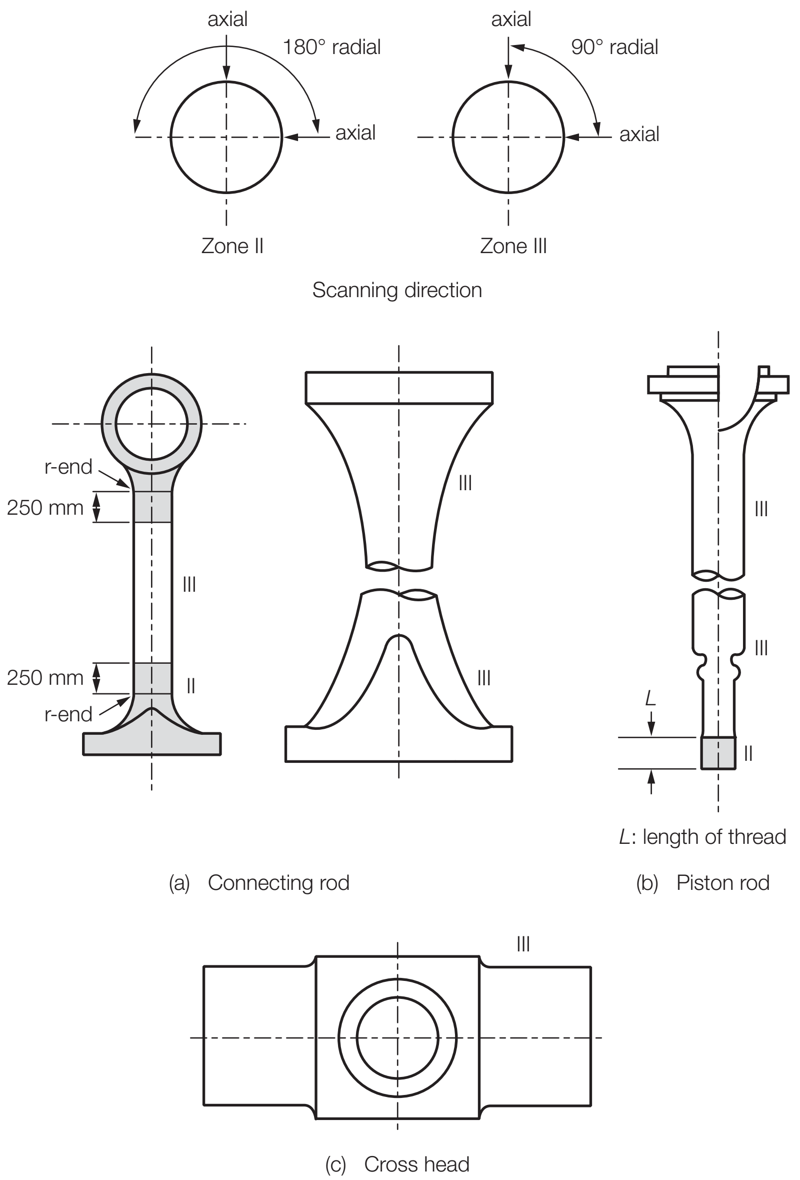
(a) Propeller shaft

(b) Intermediate shaft

(c) Thrust shaft

Notes
1. For hollow shafts, 360° radial scanning applies to Zone III
2. Circumferences of the bolt holes in the flanges are to be treated as Zone II
3. Axial scan from end face also required

Fig. 5.3.6 Zones for ultrasonic testing on shafts



NOTE
Axial scan from end face also required

Fig. 5.3.7 Zones for ultrasonic testing on machinery components

Table 5.3.3 Acceptance criteria for ultrasonic testing

Type of forging	Zone	Allowable disc shape according to Distance Gain Size (DGS), *see* Note 1, mm	Allowable length of indication, mm *see* Note 2
Propeller shaft Intermediate shaft	II	Outer $d \le 2$ Inner $d \le 4$	≤10 ≤15
Thrust shaft Rudder stock	III	Outer $d \le 3$ Inner $d \le 6$	≤10 ≤15
Connecting rod Piston rod	II	$d \le 2$	≤10
	III	$d \le 4$	≤10

NOTES
1. Outer part means the part beyond one third of the shaft radius from the centre. The inner part means the remaining core area.
2. For accumulations of two or more isolated indications which are subjected to registration, the minimum distance between two neighbouring indications is to be at least the length of the larger indication.

■ *Section 4* Forgings for crankshafts

4.1 Scope

4.1.1 The specific requirements for solid forged crankshafts and forgings for use in the construction of fully built and semi-built crankshafts are detailed in this Section.

4.1.2 Where it is proposed to use alloy steel forgings, particulars of the chemical composition (*see* 1.4.3), heat treatment and mechanical properties are to be submitted for approval. The specified minimum tensile strength is not to exceed 1000 N/mm^2 (1000–1200 N/mm^2 acceptance range).

4.2 Manufacture

4.2.1 For closed die and continuous grain flow crankshafts forgings, where an allowance is given for design purposes, full details of the proposed method of manufacture are to be submitted for approval. In such cases, tests will be required to demonstrate that a satisfactory structure and grain flow are obtained. The number and positions of test specimens are to be agreed with LR.

4.2.2 For the manufacture of welded crankshafts, approval is required for the welding procedure.

4.2.3 For combined crankweb and pin forgings, the proposed method of forging is to be submitted for approval. It is recommended that these forgings be made by a folding method. Other methods which can be shown to produce sound forgings with satisfactory mechanical properties will be considered, but where the gapping method is used for cranks having a pin diameter exceeding 510 mm this will only be accepted provided that an upsetting operation is included in the manufacturing sequence. In general, the amount of work during the upsetting operation is to be such that the reduction in the original length of the ingot (after discard) or bloom is not less than 50 per cent.

4.2.4 Where crankwebs are flame cut from forged or rolled slabs, the procedure used is to be in accordance with 1.2.13, and additionally, unless specially agreed, a depth of at least 7,5 mm is to be removed by machining from all flame-cut surfaces.

4.3 Chemical composition

4.3.1 The chemical composition of ladle samples is to comply with 3.2.1 for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

4.3.2 For alloy steel forgings which are to be nitrided, the phosphorus or sulphur contents are not to exceed 0,02 per cent.

4.4 Heat treatment

4.4.1 For forgings in all types of steels, heat treatment is to be either:
(a) normalising and tempering, or
(b) quenching and tempering.
The temperature used for tempering is to be not less than 550°C.

4.4.2 Where it is proposed to surface harden crankshaft forgings by nitriding or induction hardening, full details of the proposed procedure are to be submitted as required by 1.5.6.

4.5 Mechanical tests

4.5.1 At least one tensile test specimen is to be taken from each forging.

4.5.2 For solid forged crankshafts, tests are to be taken in the longitudinal direction from the coupling end of each forging (test position A in Fig. 5.4.1). Where the mass, as heat treated but excluding test material, exceeds 3 tonnes, a second set of tests is to be taken from the end opposite the coupling, in addition (test position B in Fig. 5.4.1). Where the crankthrows are formed by machining or flame cutting, the second set of tests is to be taken in a tangential direction from material removed from the crankthrow at the end opposite the coupling (test position C in Fig. 5.4.1).For continuous grain flow (CGF) crankshaft forgings, where insufficient material exists for a second longitudinal test, the second set of tests may be taken in a tangential direction from the crankthrow (test position C in Fig. 5.4.2).

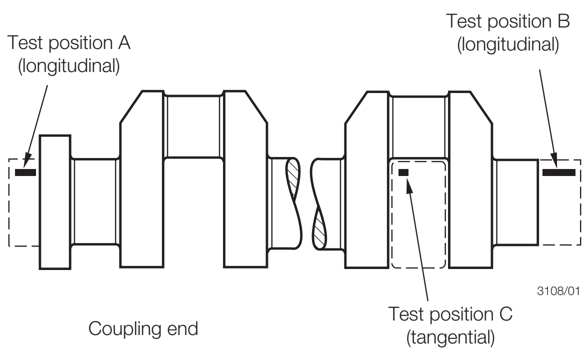


Fig. 5.4.1 Solid forged crankshaft

4.5.3 The number and position of test specimens from combined crankweb and pin forgings are to be in accordance with the requirements of the approved method of manufacture.

4.5.4 For other crankshaft forgings, tests are to be taken as detailed in Section 3, except that for crankwebs the test specimens are to be cut in a tangential direction.

4.5.5 As an alternative to 4.5.2, small solid forged crankshafts may be batch tested in accordance with 1.6.4, provided that, in addition, hardness tests are carried out on each forging.

4.5.6 Tables 5.4.1 to 5.4.3 give the minimum requirements for yield stress and elongation corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 in the case of alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 5.4.1 Mechanical properties for acceptance purposes: carbon-manganese steel forgings for crankshafts

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
400–520	200	26	19	110–150
440–560	220	24	18	125–160
480–600	240	22	16	135–175
520–640	260	21	15	150–185
560–680	280	20	14	160–200
600–750	300	18	13	175–215
640–790	320	17	12	185–230
680–830	340	16	12	200–240
720–870	350	15	11	210–250
760–910	380	14	18	225–265
Intermediate values may be obtained by interpolation.				

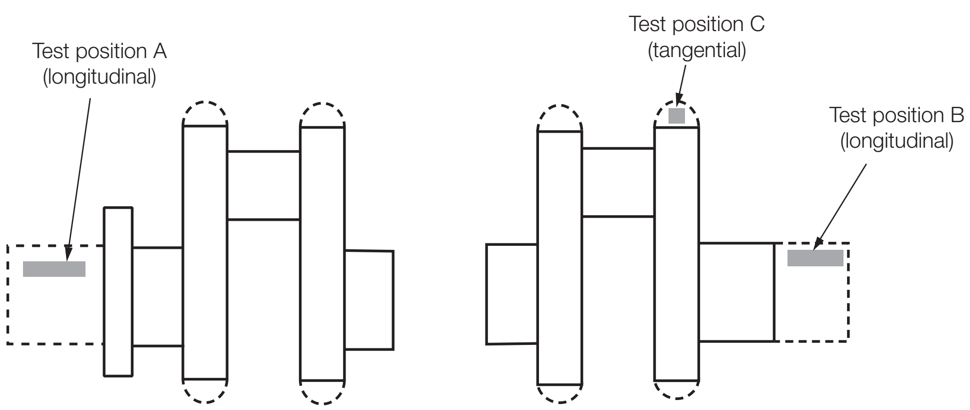


Fig. 5.4.2 CGF Crankshaft

Table 5.4.2 Mechanical properties for acceptance purposes: alloy steel forgings for crankshafts – Normalised and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
600–750	330	18	14	175–215
650–800	355	17	13	190–235
700–850	380	16	12	205–245
750–900	405	15	11	215–260
800–950	430	14	10	235–275
Intermediate values may be obtained by interpolation.				

Table 5.4.3 Mechanical properties for acceptance purposes: alloy steel forgings for crankshafts – Quenched and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
600–750	420	18	14	175–215
650–800	450	17	13	190–235
700–850	480	16	12	205–245
750–900	530	15	11	215–260
800–950	590	14	10	235–275
850–1000	640	13	9	245–290
900–1100	690	13	9	260–320
950–1150	750	12	8	275–340
1000–1200	810	12	8	290–365
Intermediate values may be obtained by interpolation.				

4.5.7 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 5.4.1 to 5.4.3.

4.5.8 The results of all tensile tests are to comply with the requirements of Table 5.4.1, 5.4.2 or 5.4.3 appropriate to the specified minimum tensile strength.

4.5.9 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm^2	Difference in tensile strength N/mm^2
<600	70
≥600 <900	100
≥900	120

4.5.10 For small crankshaft forgings which have been batch tested, the hardness values are to be not less than those given in Tables 5.4.1 to 5.4.3, as appropriate. The variation in hardness in each batch is to comply with the following:

Specified minimum tensile strength (N/mm^2)	Difference in hardness (Brinell number)
<600	not more than 25
≥600 <900	not more than 35
≥900	not more than 42

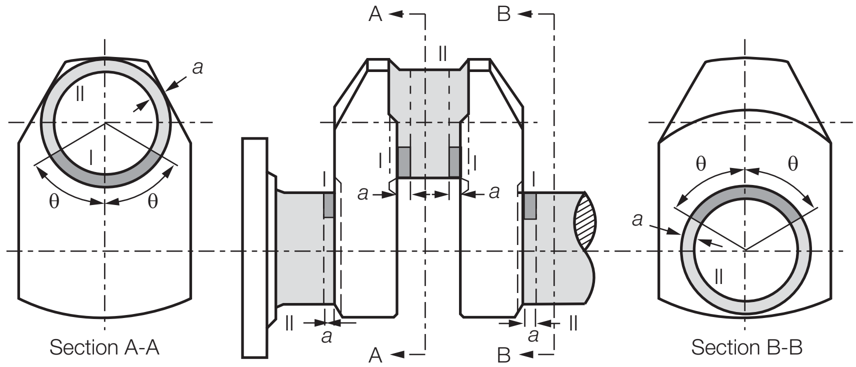
4.6 Non-destructive examination

4.6.1 Magnetic particle or dye penetrant testing as detailed in 1.8.5 and 2.5 is to be carried out on all forgings for crankshafts. Where applicable, this is to include all surfaces which have been flame-cut, but not subsequently machined during manufacture. Particular attention is to be given to the testing of the pins, journals and associated fillet radii of solid forged crankshafts and to the pins and fillet radii of combined web and pin forgings. The extent of testing is shown in Fig. 5.4.3.

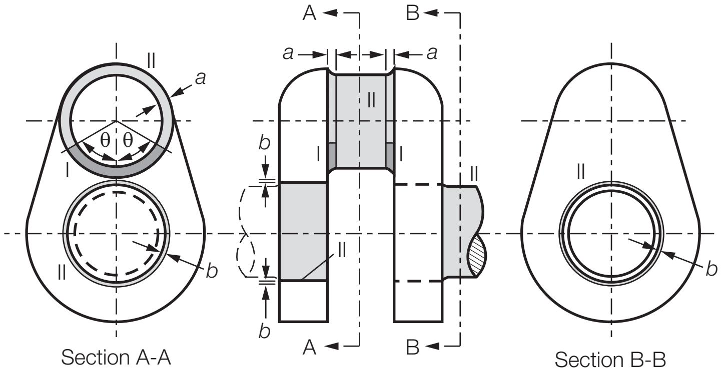
4.6.2 The manufacturer is to carry out an ultrasonic examination of all forgings as detailed in 1.8.8 and 2.5, except that for closed-die forgings this examination may, subject to approval, be confined to the initial production and to subsequent occasional checks. The extent of ultrasonic testing is shown in Fig. 5.4.4.

4.6.3 Surface inspection acceptance criteria are to be in accordance with 2.5 and with Table 5.4.4. Other acceptance criteria may be applied, providing they meet these minimum criteria, and is to the satisfaction of the Surveyor.

4.6.4 Ultrasonic acceptance criteria are shown in Table 5.4.5. Other acceptance criteria may be applied, providing they meet these minimum criteria, and is to the satisfaction of the Surveyor.



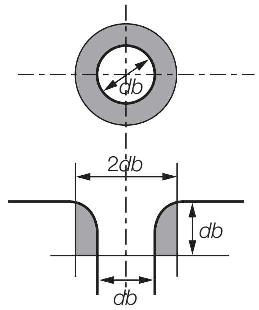
(a) Soild crankshaft



(b) Semi built-up crankshaft

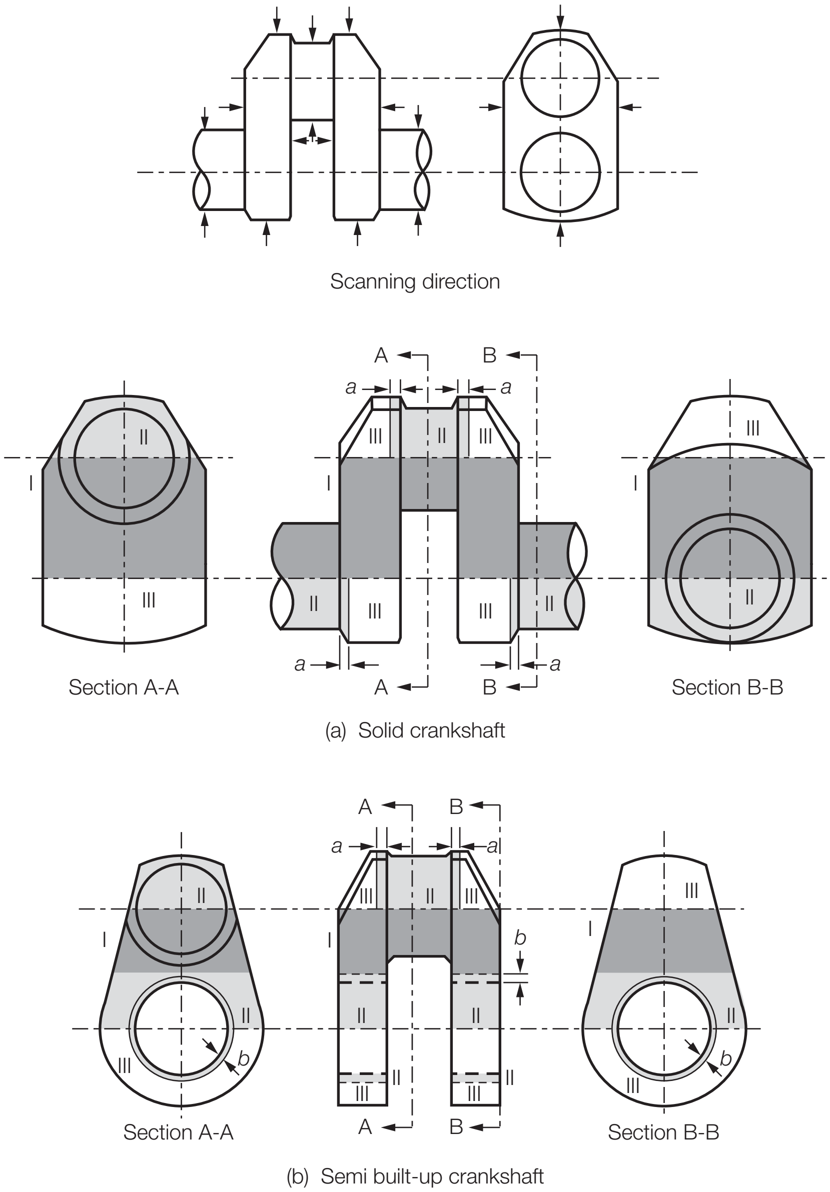
NOTES

1. Where the crankpin or journal has oil holes, the circumferential surfaces of the oil are to be treated as Zone I, (*see* the figure on the right)
2. In the above figures:
   θ = 60°
   a = 1,5*r*
   b = 0,05*d* (: circumferential surfaces of shrinkage fit)
   where
   r : fillet radius
   d : journal diameter
3. Identification of the Zones:
   : Zone I
   : Zone II



db: Oil hole bore diameter

Fig. 5.4.3 Zones for magnetic particle/dye penetrant testing on crankshafts



NOTES
1. In the above figures:
   a = 0,1*d* or 25 mm, whichever is greater
   b = 0,05*d* or 25 mm, whichever is greater (: circumstances of shrinkage fit)
   where
   d : pin or journal diameter
2. The mid third area of crank pins and/or journals within a raduis of 0,25*d* between the webs may generally be coordinated to Zone II
3. Identification of the Zones:
   : Zone I
   : Zone II
   : Zone III

Fig. 5.4.4 Zones for ultrasonic testing on crankshafts

Table 5.4.4 Surface inspection acceptance for crankshaft forgings – Allowable number and size of indications in a reference area of 225 cm²

Inspection zone	Maximum number of indication	Type of indication	Maximum number each type	Maximum dimension of single indication, mm
I Critical fillet area	0	Linear Non-linear Aligned	0 0 0	— — —
II Important fillet area	3	Linear Non-linear Aligned	0 3 0	— 3,0 —
III Journal surfaces	3	Linear Non-linear Aligned	0 3 0	— 5,0 —

Table 5.4.5 Ultrasonic acceptance criteria for crankshafts

Type of forging	Zone	Allowable disc shape according to Distance Gain Size (DGS), mm	Allowable length of indication, mm *see* Note
Crank shaft	I II III	$d \leq 2,0$ $d \leq 3,0$ $d \leq 4,0$	— ≤10 ≤15
NOTE For accumulations of two or more isolated indications which are subjected to registration, the minimum distance between two neighbouring indications is to be at least the length of the larger indication. This applies to the distance in axial direction as to the distance in depth. Isolated indications with less distance are to be determined as one single indication.			

■ *Section 5* Forgings for gearing

5.1 Scope

5.1.1 Provision is made in this Section for carbon-manganese and alloy steel forgings intended for use in the construction of gearing for main propulsion and for driving electric generators.

5.1.2 Gear wheel and rim forgings with a specified minimum tensile strength not exceeding 760 N/mm² (760–910 N/mm² acceptance range) may be made in carbon-manganese steel. Gear wheel or rim forgings where the specified minimum tensile strength is in excess of 760 N/mm², and all pinion or pinion sleeve forgings, are to be made in a suitable alloy steel. Specifications for alloy steel components and for quill shafts, giving chemical composition, heat treatment and mechanical properties, are to be submitted for approval.

5.1.3 Forgings for flexible couplings, quill shafts and gear wheel shafts are to comply with the requirements of Section 3.

5.1.4 Manufacturers' test certificates for forgings may be accepted where the transmitted power does not exceed 220 kW (300 shp) for main propulsion and 100 kW (150 shp) for auxiliary drives.

5.2 Manufacture

5.2.1 All forgings are to be made with sufficient material to allow an adequate machining allowance on all surfaces for the removal of unsound or decarburised material.

5.2.2 The hardenability of the forged material is to be checked at random intervals using an end quench test complying with a National or International Standard.

5.2.3 The grain size is to be checked on a random basis in accordance with the testing and reporting procedures of ASTM E 112, or an equivalent National Standard, and is to be within the range 5 to 8.

5.2.4 The microstructure of the hardened case is to be mainly martensite, with a maximum content of 15 per cent of retained austenite.

5.3 Chemical composition

5.3.1 The chemical composition of ladle samples is to comply with 3.2.1. for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

5.4 Heat treatment

5.4.1 Except as provided in 5.4.4 and 5.4.5, forgings may be either normalised and tempered or quenched and tempered in accordance with the approved specification. The tempering temperature is to be not less than 550°C.

5.4.2 Where forgings are machined prior to heat treatment, the allowance left for final machining is to be sufficient to remove the decarburised surface material, taking into account any bending or distortion which may occur.

5.4.3 When the teeth of a pinion or gear wheel are to be surface hardened, i.e, carburised, nitrided or induction hardened, the proposed specification together with details of the process and practice are to be submitted for approval. For purposes of initial approval, the gear manufacturer is required to demonstrate by test that the surface hardening of the teeth is uniform and of the required depth and that it does not impair the soundness and quality of the steel.

5.4.4 Where induction hardening of nitriding is to be carried out after machining of the gear teeth, the forgings are to be heat treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

5.4.5 Forgings for gears which are to be carburised after final machining are to be supplied in either the fully annealed or the normalised and tempered condition, suitable for subsequent machining and carburising.

5.5 Mechanical tests for through hardened, induction hardened or nitrided forgings

5.5.1 At least one tensile test specimen is to be taken from each forging in carbon or carbon-manganese steel, and at least one tensile test specimen from forgings in alloy steel. Sufficient test material is to be provided for this purpose and the test specimens are to be taken as follows:

(a) For pinion forgings where the finished diameter of the toothed portion exceeds 200 mm, tests are to be taken in a tangential direction and adjacent to the toothed portion (test position B in Fig. 5.5.1). Where the dimensions preclude the preparation of tests from this position, tests in a tangential direction are to be taken from the end of the journal (test position C in Fig. 5.5.1). If, however, the journal diameter is 200 mm or less, tests are to be taken in a longitudinal direction (test position A in Fig. 5.5.1). Where the finished length of the toothed portion exceeds 1250 mm, tests are to be taken from each end.

(b) For small pinion forgings where the finished diameter of the toothed portion is 200 mm or less, tests are to be taken in a longitudinal direction (test position A in Fig. 5.5.1).

(c) For gear wheel forgings, tests are to be taken in a tangential direction (from one of the test positions B in Fig. 5.5.2).

(d) For gear wheel rim forgings, tests are to be taken in a tangential direction (from one of the test positions A in Fig. 5.5.3). Where the finished diameter exceeds 2500 mm or the mass (as heat treated but excluding test material) exceeds 3 tonnes, tests are to be taken from two diametrically opposite positions (test positions A in Fig. 5.5.3).

(e) For pinion sleeve forgings, tests are to be taken in a tangential direction (from one of the test positions C in Fig. 5.5.4). Where the finished length exceeds 1250 mm, tests are to be taken from each end.

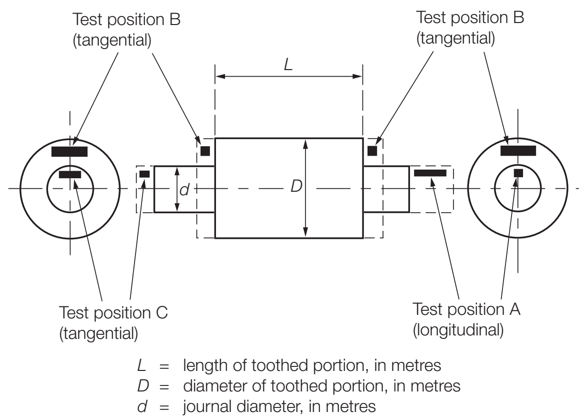


Fig. 5.5.1 Test positions for forgings for gearing

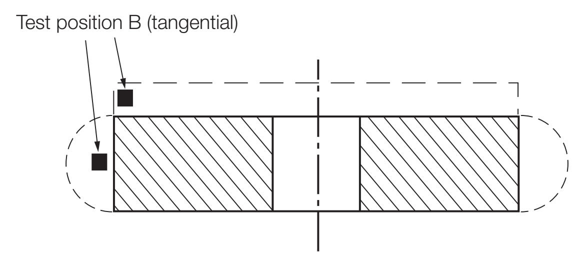


Fig. 5.5.2 Test position B

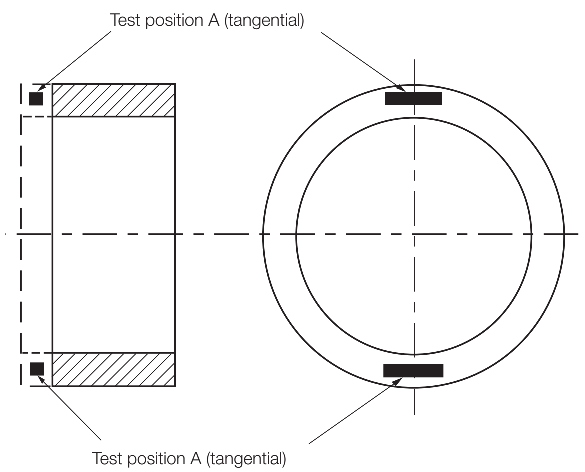


Fig. 5.5.3 Test position A

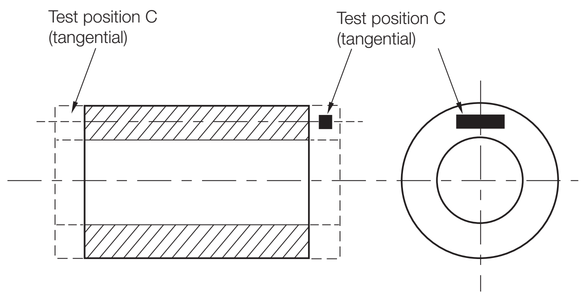


Fig. 5.5.4 Test position C

5.5.2 As an alternative to 5.5.1, small forgings may be batch tested in accordance with 1.6.4 provided that, in addition, hardness tests are carried out on each forging.

5.5.3 Tables 5.5.1 to 5.5.3 give the minimum requirements for yield stress and elongation corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 in the case of alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 5.5.1 Mechanical properties for acceptance purposes: carbon-manganese steels for gear wheel and rim forgings

Tensile strength N/mm^2 (*see* Note)	Yield stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum		Hardness Brinell
		Rims	Wheels	
400–520	200	26	22	110–150
440–560	220	24	21	125–160
480–600	240	22	19	135–175
520–640	260	21	18	150–185
560–680	280	20	17	160–200
600–750	300	18	15	175–215
640–790	320	17	14	185–230
680–830	340	16	14	200–240
720–870	360	15	13	210–250
760– 910	380	14	12	225–265

Intermediate values may be obtained by interpolation.

NOTE
When the specified minimum tensile strength exceeds 700 N/mm^2 forgings are to be supplied only in the quenched and tempered condition.

5.5.4 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 5.5.1 to 5.5.3.

5.5.5 The results of all tensile tests are to comply with the requirements of Table 5.5.1, 5.5.2 or 5.5.3, appropriate to the specified minimum tensile strength. Unless otherwise agreed, the specified minimum tensile strength is to be not less than 800 N/mm^2 (800–950 N/mm^2 acceptance range) for induction hardened or nitrided gear forgings.

Table 5.5.2 Mechanical properties for acceptance purposes: alloy steel gear wheel and rim forgings – Normalised and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum		Hardness Brinell
		Rims	Wheels	
600–750	330	18	16	175–215
650–800	355	17	15	190–235
700–850	380	16	14	205–245
750–900	405	15	13	215–260
800–950	430	14	12	235–275
850–1000	455	13	11	245–290

Intermediate values may be obtained by interpolation.

Table 5.5.3 Mechanical properties for acceptance purposes: alloy steel gear forgings – Quenched and tempered

Tensile strength N/mm^2 (*see* Notes 1 and 2)	Yield stress N/mm^2 minimum (*see* Note 2)	Elongation on $5,65\sqrt{S_o}$ % minimum			Hardness Brinell
		A	B	C	
600–750	420	18	16	14	175–215
650–800	450	17	15	13	190–235
700–850	480	16	14	12	205–245
750–900	530	15	13	11	215–260
800–950	590	14	12	10	235–275
850–1000	640	13	11	9	245–290
900–1050	690	13	11	9	260–310
950–1100	750	12	10	8	275–330
1000–1150	810	12	10	8	290–340
1050–1200	870	11	9	7	310–365

Column A is applicable to tests from gear rims and to longitudinal tests from pinions.
Column B is applicable to tests from gear wheels and to tangential tests from pinions.
Column C is applicable to tests from pinion sleeves.

Intermediate values may be obtained by interpolation.

NOTES
1. For gear wheel and rim forgings the specified minimum tensile strength is not to exceed 850 N/mm^2.
2. For carburised gear forgings the requirements for minimum yield stress and maximum tensile strength are not applicable.

5.5.6 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm^2	Difference in tensile strength N/mm^2
<600	70
≥600 <900	100
≥900	120

5.5.7 Hardness tests are to be carried out on all forgings after completion of heat treatment and prior to machining the gear teeth. The hardness is to be determined at four positions equally spaced around the circumference of the surface where teeth will subsequently be cut. Where the finished diameter of the toothed portion exceeds 2500 mm, the number of test positions is to be increased to eight. Where the width of a gear wheel rim forging exceeds 1250 mm, the hardness is to be determined at eight positions at each end of the forging.

5.5.8 For small gear forgings which are batch tested, at least one hardness test is to be carried out on each forging.

5.5.9 The results of all hardness tests are to comply with the appropriate requirements of Tables 5.5.1 to 5.5.3. The difference between the highest and lowest values on any one forging is not to exceed the following:

Specified minimum tensile strength (N/mm^2)	Difference in hardness (Brinell number)
<600	25
≥600 <900	35
≥900	42

5.5.10 On nitrided or induction hardened components, hardness tests are also to be made on the teeth when surface hardening and grinding have been completed. The results are to comply with the approved specification.

5.6 Mechanical tests for carburised forgings

5.6.1 Sufficient test material is to be provided for preliminary tests at the forge and for final tests after completion of carburising. For this purpose, duplicate sets of test material are to be taken from positions as detailed in 5.5.1, except that, irrespective of the dimensions or mass of the forging, tests are required from one position only, and in the case of forgings with integral journals are to be cut in a longitudinal direction. The test material which is to be used for measurements of case depth, hardness, grain size and residual austenite as well as mechanical properties is to be machined to a coupon of diameter of $\frac{D}{4}$ or 30 mm, whichever is less, where D is the finished diameter of the toothed portion.

5.6.2 For small forgings, where a system of batch testing is adopted, the test material may be prepared from surplus steel from the same cast provided that the forging reduction approximates to that of the actual gear forgings. The test samples are to be correctly identified and heat treated with the forgings they represent.

5.6.3 For preliminary tests at the forge, one set of test material is to be given a blank carburising and heat treatment cycle simulating that which will be subsequently applied to the forgings.

5.6.4 For final acceptance tests, the second set of test material is to be blank carburised and heat treated together with the forgings which it represents.

5.6.5 At the discretion of the forgemaster or gear manufacturer, test samples of larger cross-section than in 5.6.1 may be either carburised or blank carburised, but these are to be machined to the required diameter prior to the final quenching and stress relieving heat treatment.

5.6.6 At least one tensile specimen is to be prepared from each sample of test material.

5.6.7 Unless otherwise agreed, the specified minimum tensile strength is to be not less than 750 N/mm^2, and the results of all tensile tests are to comply with the requirements given in Table 5.5.3.

5.6.8 Where it is proposed to adopt alternatives to the requirements of 5.6.1 to 5.6.7, full details are to be submitted to the Surveyor for consideration.

5.7 Non-destructive examination

5.7.1 Magnetic particle or liquid penetrant testing is to be carried out on the teeth of all surface hardened forgings. This examination may also be requested on the finished machined teeth of through hardened gear forgings.

5.7.2 The manufacturer is to carry out an ultrasonic examination of all forgings where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm, and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

5.7.3 On gear forgings where the teeth have been surface hardened, additional test pieces may be required to be processed with the forgings and subsequently sectioned to determine the depth of the hardened zone. These tests are to be carried out at the discretion of the Surveyor, and for induction or carburised gearing the depth of the hardened zone is to be in accordance with the approved specification. For nitrided gearing, the full depth of the hardened zone, (i.e., depth to core hardness), is to be not less than 0,5 mm and the hardness at a depth of 0,25 mm is to be not less than 500 HV.

■ *Section 6* Forgings for turbines

6.1 Scope

6.1.1 Provision is made in this Section for ferritic steel forgings for turbine rotors, discs and spindles, turbine-driven generator rotors and compressor rotors.

6.1.2 Plans for rotor forgings are to state whether the rotor is intended for propulsion or auxiliary machinery and the shaft power of auxiliary turbines. In the case of a rotor which is to be tested for thermal stability, the maximum operating temperature and the proposed test temperature are also to be stated.

6.1.3 Specifications of alloy steel forgings giving the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval with the plans of the components.

6.1.4 Where it is proposed to use rotors of welded construction, the compositions of the steels for the forgings are to be submitted for special consideration, together with details of the proposed welding procedure. Welding procedure tests may be required.

6.2 Manufacture

6.2.1 Forgings are to be manufactured in accordance with the requirements of Section 1, except that for rotors the forging reduction is to be not less than 2,5 to 1. Where an upsetting operation is included in the manufacturing procedure, the above requirement applies to the cross-sectional area of the upset bloom and not to that of the ingot.

6.3 Chemical composition

6.3.1 The chemical composition of ladle samples is to comply with 3.2.1 for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

6.4 Heat treatment

6.4.1 Forgings are to be supplied in the heat treated condition, and the thermal treatment at all stages is to be such as to avoid the formation of hair-line cracks. At a suitable stage of manufacture, the forgings are to be reheated above the upper critical point to refine the grain, cooled in an approved manner and then tempered to produce the desired mechanical properties.

6.4.2 Where forgings receive their main heat treatment before machining, they are to be stress relieved after rough machining. Forgings which are heat treated in the rough machined condition need not be stress relieved provided that they have been slowly cooled from the tempering temperature.

6.4.3 The tempering and stress relieving temperatures are to be not less than 550°C for carbon and carbon-manganese steels, and not less than 600°C for alloy steels. The holding times and subsequent cooling rates are to be such that the forging in its final condition is free from harmful residual stresses.

6.4.4 Details of the proposed heat treatment for rotors of welded construction are to be submitted for approval.

6.5 Mechanical tests

6.5.1 At least one tensile test specimen, cut in a longitudinal direction, is to be taken from each rotor forging. For forgings exceeding both 3 tonnes in mass and 2000 mm in length, tests are to be taken from each end.

6.5.2 For rotor forgings of all main propulsion machinery and of auxiliary turbines exceeding 1100 kW, tangential and, where the dimensions permit, radial tensile tests are to be taken from the end of the body corresponding to the top end of the ingot, *see* Fig. 5.6.1.

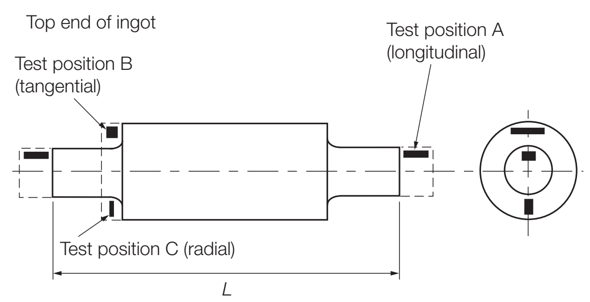


Fig. 5.6.1 Test positions for turbine rotor forgings

6.5.3 For each turbine disc, at least one tensile test specimen is to be cut in a tangential direction from material at the hub, *see* Fig. 5.6.2.

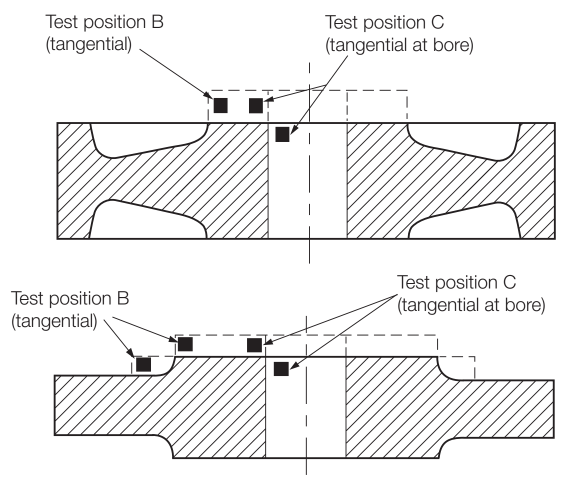


Fig. 5.6.2 Test positions for turbine disc forgings

6.5.4 For the tests required by 6.5.1 to 6.5.3, sufficient test material is to be left on each forging and is not to be removed until all heat treatment, including stress relieving, has been completed. In this connection, a thermal stability test does not form part of the heat treatment of a turbine forging. Any excess test material is not to be completely severed from a forging until all the mechanical tests have been completed with satisfactory results.

6.5.5 Tables 5.6.1 and 5.6.2 give the minimum requirements for yield stress, elongation and reduction of area corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 for alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 5.6.1 Mechanical properties for acceptance purposes: carbon-manganese steel forgings for turbines – Normalised and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation $5,65\sqrt{S_o}$ % minimum			Reduction of area % minimum		
		A	B	C	A	B	C
400–520	200	26	22	18	50	40	35
440–560	220	24	21	17	50	40	35
480–600	240	22	19	15	45	35	30
520–640	260	21	18	14	45	35	30
560–680	280	20	17	13	40	30	25
600–720	300	18	15	12	40	30	25

NOTES
Columns A are applicable to longitudinal tests from rotor and spindle forgings.
Columns B are applicable to tangential tests from rotor forgings.
Columns C are applicable to radial tests from rotor forgings.
Intermediate values may be obtained by interpolation.

6.5.6 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.6.1 or Table 5.6.2.

6.5.7 The results of all tensile tests are to comply with the requirements of Table 5.6.1 or Table 5.6.2 appropriate to the specified minimum tensile strength. For monobloc rotor forgings, the specified minimum tensile strength is not to exceed 800 N/mm^2.

6.6 Non-destructive examination

6.6.1 The end faces of the body of rotor forgings and the end faces of the boss and the bore surface of each turbine disc are to be machined to a fine smooth finish for visual and magnetic particle examination.

6.6.2 The manufacturer is to carry out an ultrasonic examination of each forging and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

6.6.3 Rotor forgings for propulsion machinery and for auxiliary turbines exceeding 1100 kW are to be hollow bored for internal examination. The surface of the bore is to have a fine smooth finish and is to be examined by means of an optical instrument of suitable magnification. Where the bore size permits, magnetic particle examination is also to be carried out. These examinations are to be confirmed by the Surveyor. Alternatively, an approved method of ultrasonic examination may be accepted instead of hollow boring. Details of the proposed method of ultrasonic examination are to be submitted for special consideration.

Table 5.6.2 Mechanical properties for acceptance purposes: alloy steel forgings for turbines – Quenched and tempered or normalised and tempered

Tensile strength N/mm^2 (*see* Note)	Yield stress N/mm^2 minimum Normalised and tempered	Yield stress N/mm^2 minimum Quenched and tempered	Elongation on $5,65\sqrt{S_o}$ % minimum			Reduction of area %minimum		
			A	B	C	A	B	C
500 – 650	275	—	22	20	18	50	40	35
550 – 700	300	—	20	18	16	50	40	35
600 – 750	330	410	18	16	14	50	40	35
650 – 800	355	450	17	15	13	50	40	35
700 – 850	385	490	16	14	12	45	35	30
750 – 900	—	530	15	13	11	45	35	30
800 – 950	—	590	14	12	10	45	35	30
850 – 1000	—	640	13	11	9	40	30	25
900 – 1050	—	690	13	11	9	40	30	25
950 – 1100	—	750	12	10	8	40	30	25
1000 – 1150	—	810	12	10	8	40	30	25

NOTES
Columns A are applicable to longitudinal tests from rotor and spindle forgings.
Columns B are applicable to tangential tests from rotor and spindle forgings, and to tangential tests from discs – test position B in Fig. 5.6.2.
Columns C are applicable to radial test from rotor forgings and to tangential tests from discs – test position C in Fig. 5.6.2.
Intermediate values may be obtained by interpolation.

6.7 Thermal stability tests

6.7.1 Thermal stability tests after heat treatment and rough machining of the turbine rotors, referred to in the relevant Rules dealing with design and construction, are to be undertaken in properly constructed furnaces, using accurate and reliable measuring equipment. Each test is to be carried out in accordance with the following recommended procedure:

(a) Five bands are to be machined concentric with the axis of rotation. Two of these are to be reference bands and are to be positioned at or near the locations of the bearings. The remaining three bands are to be test bands located one as near as possible to the mid-length, and the other two near each end of the body. Where the length of a rotor is such that five bands cannot be provided, alternative proposals are to be submitted to the Surveyor for his approval.
(b) Four positions, 90° apart, are to be stamped A, B, C and D on the coupling end of the rotor.
(c) The whole of the body, and as much of the shaft at either end as will include the positions of the glands, is to be enclosed in the furnace. In the case of a rotor having an overhung astern wheel, the astern wheel is also to be enclosed in the furnace during the first test.
(d) The rotor is to be rotated at a uniform and very low speed.
(e) The deflections at all bands are to be recorded at the A, B, C and D positions. Initial cold readings are to be taken prior to heating.
(f) The rotor is to be heated uniformly and slowly. Temperatures are to be recorded continuously at the surface of the rotor and, if practicable, in the bore at the mid-length of the body. In no circumstances is the surface temperature to exceed the temperature at which the rotor was tempered. During heating, the rate of rise of temperature is to be such as to avoid excessive temperature gradients in the rotor.
(g) The maximum or holding temperature is to be not less than 28°C above the maximum operating temperature of the rotor. For the purposes of the test, the holding period is to start when the rotor has attained a uniform and specified temperature. The rotor is to be held under the specified temperature conditions until not less than three consecutive hourly readings of deflections show the radial eccentricity to be constant within 0,006 mm on all test bands.
(h) The turbine rotor is to be rotated during cooling until the temperature is not more than 100°C. The rate of cooling is to be such as to avoid excessive temperature gradients in the rotor.
(j) Final cold readings are to be taken.

6.7.2 The movements of the axis of the rotor in relation to the reference bands are to be determined from polar plots of the deflection readings. The radial movement of the shaft axis, as determined by the difference between the final hot and the final cold movements, is not to exceed 0,025 mm on any one band. As verification that test equipment and conditions are satisfactory, it is required that similar determinations of differences between initial cold and final cold movements do not exceed 0,025 mm on any one band.

6.7.3 If the results of the test on a rotor fail to meet either or both of the requirements in 6.7.2, the test may be repeated if requested by the maker and agreed by the Surveyor. In the case of a rotor failing to meet the requirements of a thermal stability test, the rotor is deemed unacceptable. Proposals for the rectification of thermal instability of a rough machined rotor are to be submitted for special consideration.

■ *Section 7*
Forgings for boilers, pressure vessels and piping systems

7.1 Scope

7.1.1 Provision is made in this Section for carbon-manganese and low alloy steel forgings intended for use in the construction of boilers, pressure vessels and piping systems where the design temperature is not lower than 0°C.

7.1.2 In addition to specifying mechanical properties at ambient temperature for the purposes of acceptance testing, these requirements give details of appropriate mechanical properties at elevated temperatures to be used for design purposes.

7.1.3 Forgings used in the construction of equipment for the containment of liquefied gases are to comply with the requirements of Section 8, except for those used in piping systems, where the design temperature is not lower than 0°C. Forgings for other pressure vessels and piping systems, where the use of steels with guaranteed impact properties at low temperatures is required, are also to comply with Section 8.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the appropriate requirements of Table 5.7.1.

7.3 Heat treatment

7.3.1 Carbon-manganese steel forgings are to be normalised, normalised and tempered or quenched and tempered.

7.3.2 Alloy steel forgings are to be normalised and tempered or quenched and tempered.

7.3.3 No forging is to be fully heat treated more than twice.

7.4 Mechanical tests

7.4.1 Except as provided in 7.4.2 and 7.4.4, at least one tensile test is to be taken from each forging and, where the dimensions and shape allow, the test specimen is to be cut in the longitudinal direction.

Table 5.7.1 Chemical composition

Type of steel	Tensile strength N/mm^2	Chemical composition of ladle samples %							
		C max.	Si	Mn	P max.	S max.	Al	Residual elements	
Carbon-manganese	410–530	0,20		0,50–1,20					
	460–580	0,23	0,10–0,40	0,80–1,40	0,030	0,025	(*See* Notes 1 and 3)	Ni 0,40 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,80 max.	
	490–610	0,25		0,90–1,70					
Alloy steel								Cr	Mo
1Cr$^1/_2$Mo	440–590	0,18	0,15–0,40	0,40–0,70	0,030	0,025	0,020 max. (*See* Note 2)	0,85–1,15	0,45–0,65
2$^1/_4$ Cr1Mo	490–640	0,15						2,0–2,5	0,90–1,20

NOTES
1. Fine grained steels are to contain:
   aluminium (acid soluble) 0,015% min. or
   aluminium (total) 0,018% min.
2. For alloy steels, aluminium (acid soluble) 0,020% max.
   The determination of the aluminium (total) content is acceptable provided the above value is not exceeded.
3. Niobium may be used as a grain refiner in place of aluminium, in which case the content is to be in the range 0,01% to 0,06%.

7.4.2 On seamless drums and headers which are initially forged with open ends, test material is to be provided at each end of each forging. Where forged with one solid end, test material is to be provided at the open end only. Except where the ends are to be subsequently closed by forging, the test material is not to be removed until heat treatment has been completed. Where the ends are to be closed, rings of test material are to be cut off prior to the closing operation and are to be heat treated with the finished forging. In all cases, the test specimens are to be cut in the circumferential direction.

7.4.3 Unless otherwise agreed, tensile test specimens are to be taken with their axis at approximately 12,5 mm below the surface of the forging.

7.4.4 Small forgings may be batch tested in accordance with 1.6.4 provided that hardness tests are carried out on each forging. In such cases, the mass of each forging is not to exceed 1 tonne and that of the batch is not to exceed 10 tonnes and the hardness values are to accord with Table 5.7.2.

Table 5.7.2 Mechanical properties for acceptance purposes

Type of steel	Diameter or equivalent thickness mm	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Hardness Brinell
Carbon-manganese not specifically fine grained	≤100	215	410–530	20	110–155
	>100 ≤500	205			
	≤100	245	460–580	18	130–170
	>100	235			
	≤100	265	490–610	16	140–180
	>100	255			
Carbon-manganese, fine grained	≤100	235	410–530	20	110–155
	>100 ≤250	220			
	≤100	275	460–580	18	130–170
	>100 ≤250	255			
	≤100	305	490–610	16	140–180
	>100 ≤250	280			
Alloy steel 1Cr$^1/_2$Mo	–	275	440–590	19	110–160
2$^1/_4$Cr1Mo	–	275	490–640	18	140–185

7.4.5 If required by the Surveyors or by the Fabricators, test material may be given a simulated stress relieving heat treatment prior to the preparation of the test specimens. This has to be stated on the order, together with agreed details of the simulated heat treatment and the mechanical properties which can be expected.

7.4.6 Except as provided in 7.4.7, the results of all tensile tests are to comply with the requirements given in Table 5.7.2 appropriate to the specified minimum tensile strength.

7.4.7 Where tests are taken at a depth greater than 12,5 mm from the surface or where they are taken in a transverse direction, the mechanical properties which can be expected are to be agreed.

7.4.8 On seamless drums and headers where tests are taken from each end, the variation in tensile strength is not to exceed 70 N/mm^2.

7.4.9 For small batch-tested forgings, the hardness values are to comply with the requirements of Table 5.7.2 appropriate to the specified minimum tensile strength. If forgings of more than one thickness are to be supplied from one cast, then the test is to be made on the thickest forging.

7.5 Non-destructive examination

7.5.1 Non-destructive testing is to be carried out in accordance with the requirements of the approved forging drawing and specification, or as otherwise agreed between the manufacturer, purchaser and Surveyor.

7.6 Pressure tests

7.6.1 Where applicable, pressure tests are to be carried out in accordance with the requirements of the relevant Rules.

7.7 Mechanical properties for design purposes

7.7.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Table 5.7.3. These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than those given in Table 5.7.3.

Table 5.7.3 Mechanical properties for design purposes

Type of steel	Diameter or equivalent thickness mm	Tensile strength N/mm^2	Nominal minimum lower yield or 0,2% proof stress N/mm^2											
			Temperature °C											
			50	100	150	200	250	300	350	400	450	500	550	600
Carbon-manganese not specifically fine grained	≤100	410–530	196	192	188	181	168	150	142	138	136	—	–	—
	>100		183	178	175	170	162	150	142	138	136	—	—	—
	≤100	460–580	227	222	218	210	194	176	168	162	158	—	—	—
	>100		212	206	203	197	188	176	168	162	158	—	—	—
	≤100	490–610	245	240	236	227	210	192	183	177	172	—	—	—
	>100		229	222	219	212	203	192	183	177	172	—	—	—
Carbon-manganese fine grained	≤100	410–530	222	215	204	188	171	152	141	134	130	—	—	—
	>100		207	200	190	175	164	152	141	134	130	—	—	—
	≤100	460–580	262	251	236	217	198	177	167	158	153	—	—	—
	>100		244	233	220	202	190	177	167	158	153	—	—	—
	≤100	490–610	286	272	256	234	213	192	182	173	168	—	—	—
	>100		266	253	238	218	205	192	182	173	168	—	—	—
Alloy steel 1Cr$^1/_2$Mo	—	410–560	254	241	224	213	197	184	170	162	157	151	146	145
2$^1/_4$Cr1Mo	—	490–640	268	261	253	245	236	230	224	218	205	189	167	145

7.7.2 Where verification is required, at least one tensile test at the proposed design or other agreed temperature is to be made on each forging or each batch of forgings. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature, and the test procedure is to be in accordance with the requirements of Chapter 2. The results of all tests are to comply with the requirements of the National or proprietary specification.

7.7.3 Values for the estimated average stress to rupture in 100 000 hours are given in Table 5.7.4 and may be used for design purposes.

Table 5.7.4 Mechanical properties for design purposes: estimated average values for stress to rupture in 100 000 hours (units N/mm²)

Temperature °C	Grades of steel		
	Carbon-manganese	1 Cr 1/2 Mo	2 1/4 Cr 1Mo
380	227	—	—
390	203	—	—
400	179	—	—
410	157	—	—
420	136	—	—
430	117	—	—
440	100	—	—
450	85	290	—
460	73	262	—
470	63	235	210
480	55	208	186
490	—	181	165
500	—	155	145
510	—	129	128
520	—	103	112
530	—	80	98
540	—	62	84
550	—	49	72
560	—	42	61
570	—	36	49
580	—	32	—
590	—	29	—

■ *Section 8* Ferritic steel forgings for low temperature service

8.1 Scope

8.1.1 The requirements for carbon-manganese and nickel steels suitable for low temperature service are detailed in this Section. They are applicable to all forgings used for the construction of cargo tanks, storage tanks and process pressure vessels for liquefied gases and, where the design temperature is less than 0°C, to forgings for the piping systems.

8.1.2 The requirements are also applicable to forgings for other pressure vessels and pressure piping systems where the use of steels with guaranteed impact properties at low temperatures is required.

8.1.3 In all cases, details of the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval.

8.1.4 In addition to the steels in this Section, the austenitic stainless steels detailed in Section 9 may also be used for low temperature applications.

8.2 Chemical composition

8.2.1 The chemical composition of ladle samples is, in general, to comply with the requirements given in Table 5.8.1.

8.3 Heat treatment

8.3.1 Forgings are to be normalised, normalised and tempered or quenched and tempered in accordance with the approved specification.

8.4 Mechanical tests

8.4.1 At least one tensile and three Charpy V-notch impact test specimens are to be taken from each forging or each batch of forgings. Where the dimensions and shape allow, the test specimens are to be cut in a longitudinal direction.

8.4.2 The impact tests are to be carried out at a temperature appropriate to the type of steel and for the proposed application. Where forgings are intended for ships for liquefied gases, the test temperature is to be in accordance with the requirements given in Table 3.6.3 in Chapter 3.

8.4.3 The results of all tensile tests are to comply with the approved specification.

8.4.4 The average energy values for impact tests are also to comply with the approved specification and generally with the requirements of Ch 3,6. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value. *See* Ch 2,1.4 for re-test procedures.

Table 5.8.1 Chemical composition of ferritic steel forgings

Grade of steel	C %	Si %	Mn %	Ni %	P %	S %	Residual elements %	Grain refiners % Al	Grain refiners % Other
LT–AH (AH40) LT–DH (DH40) LT–EH (EH40)	0,18 max.	0,50 max.	0,90–1,60	0,40 max.	0,035 max.	0,030 max.	Cu 0,35 max. Cr 0,20 max. Mo 0,08 max. Total 0,60 max.	Total 0,020 min. Acid soluble 0,015 min.	(*See* Note) Nb 0,02 – 0,05 V 0,03 – 0,10 Ti 0,02 max.
LT–FH (FH40)	0,16 max.			0,80 max.	0,025 max.	0,025 max.			
$1^1/_2$Ni	0,18 max.	0,10 – 0,35	0,30–1,50	1,30–1,70		0,020 max.	Cu 0,35 max. Cr 0,25 max. Mo 0,08 max. Total 0,60 max.		
$3^1/_2$Ni	0,15 max.		0,30–0,90	3,20–3,80					
5Ni	0,12 max.			4,70–5,30					
9 Ni	0,10 max.			8,50–10,0					

NOTE
The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of each element is not applicable.

8.5 Non-destructive examination

8.5.1 Non-destructive testing is to be carried out in accordance with the requirements of the approved forging drawing and specification, or as otherwise agreed between the manufacturer, purchaser and Surveyor.

8.6 Pressure tests

8.6.1 When applicable, pressure tests are to be carried out in accordance with the requirements of the relevant Rules.

■ *Section 9* Stainless steel forgings

9.1 General

9.1.1 Forgings in austenitic and duplex stainless steels are acceptable for use in the construction of cargo tanks, storage tanks and piping systems for chemicals and liquefied gases. They may also be accepted for elevated temperature service in boilers.

9.1.2 Where it is proposed to use forgings in these types of steels, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval. These are to comply, in general, with the requirements of Ch 3,7 for austenitic steel plates.

9.2 Chemical composition

9.2.1 The chemical composition of ladle samples is to comply with the requirements given in Table 5.9.1.

9.2.2 Consideration will be given to the use of steels whose compositions are outside the scope of Table 5.9.1.

9.3 Heat treatment

9.3.1 All materials are to be supplied in the solution treated condition.

9.4 Mechanical tests

9.4.1 Tensile test specimens are to be taken in accordance with the appropriate requirements of 1.7.

9.4.2 The results of all tensile tests and impact tests are to comply with the requirements of Table 5.9.2 or the approved specification.

9.4.3 For austenitic stainless steel forgings, impact tests may be omitted subject to prior agreement with LR.

Table 5.9.1 Chemical composition of stainless steel forgings

Type of steel	Chemical composition % (*see* Note)								
	C	Si	Mn	S	P	Cr	Mo	Ni	Others
Austenitic									
304L	0,03	1,00	2,00	0,030	0,045	18,0–20,0	–	8,0–13,0	—
304	0,08					18,0–20,0	–	8,0–11,0	—
316L	0,03					16,0–18,0	2,0–3,0	10,0–15,0	—
316	0,08					16,0–18,0	2,0–3,0	10,0–14,0	—
317	0,08					18,0–20,0	3,0–4,0	11,0–15,0	—
347	0,08					17,0–20,0	–	9,0–13,0	Nb ≥ 10 x C ≤ 1,10
Duplex									
UNS S 31803	0,03	1,00	2,00	0,020	0,030	21,0–23,0	2,5–3,5	4,5–6,5	N 0,08–0,20
UNS S 32750	0,03	0,80	1,20	0,020	0,035	24,0–26,0	3,0–5,0	6,0–8,0	N 0,24–0,32 Cu 0,50

NOTE
Where a single value is shown (and not a range of values), the value is to be taken as maximum.

Table 5.9.2 Mechanical properties for acceptance purposes: stainless steel forgings

Type of steel	Tensile strength N/mm^2 minimum	1,0% proof stress N/mm^2 minimum	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests	
					Test temperature °C	Average energy J minimum
Austenitic						
304L	485	170	30	50	–196	41
304	515	205				
316L	485	170				
316	515	205				
317	515	205				
347	515	205				
Duplex						
UNS S 31803	620	450	25	45	–20	41
UNS S 32750	800	550	15	40		

9.5 Mechanical properties for design purposes

9.5.1 Where austenitic stainless steel forgings are intended for service at elevated temperatures, the nominal values for the minimum one per cent proof stress at temperatures of 100°C and higher given in Table 5.9.3 may be used for design purposes. Verification of these values is not required except for material complying with a National or proprietary specification in which the elevated temperature properties proposed for design purposes are higher than those given in Table 5.9.3.

9.6 Non-destructive examination

9.6.1 Non-destructive examination is to be carried out in accordance with the requirements of the approved forging drawing and specification or as otherwise agreed between the manufacturer, purchaser and Surveyor.

9.7 Corrosion tests

9.7.1 Where corrosive conditions are anticipated in service, for grades 304, 316 and 317 intergranular corrosion tests are required in accordance with Ch 2,8.1. Such tests may also be required for grades 304L, 316L and 347.

9.7.2 Where corrosive conditions are anticipated in service, for duplex stainless grades pitting corrosion tests are required in accordance with ASTM G48 Method C. For UNS S 31803 duplex stainless steels the test temperature is to be 25°C. Following the test, no pitting corrosion is to be observed at 20x magnification. The use of a weight loss method may be accepted subject to special consideration.

Table 5.9.3 Mechanical properties for design purposes: austenitic stainless steels

Grade	Nominal 1% proof stress (N/mm^2) at a temperature of												
	100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C	650°C	700°C
304L	168	150	137	128	122	116	110	108	106	102	100	96	93
316L	177	161	149	139	133	127	123	119	115	112	110	107	105
316LN	238	208	192	180	172	166	161	157	152	149	144	142	138
321	192	180	172	164	158	152	148	144	140	138	135	130	124
347	204	192	182	172	166	162	159	157	155	153	151	—	—

Section

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for boiler tubes, superheater tubes and pipes intended for use in the construction of boilers, pressure vessels and pressure piping systems.

1.1.2 In addition to specifying mechanical properties for the purpose of acceptance testing, these requirements give details of appropriate mechanical properties at elevated temperatures to be used for design purposes.

1.1.3 Except for pipes for Class III pressure systems (as defined in the relevant Rules), all pipes and tubes are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2, the general requirements of this Section and the appropriate specific requirements given in Sections 2, 3, 4, 5 and 6.

1.1.4 Steels intended for the piping systems for liquefied gases where the design temperature is less than 0°C are to comply with the specific requirements of Section 4 or 5.

1.1.5 As an alternative to 1.1.3 and 1.1.4, pipes or tubes which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.6 At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of materials. In such cases, these may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

1.1.7 Pipes for Class III pressure systems are to be manufactured and tested in accordance with the requirements of an acceptable National specification. The manufacturer's test certificate will be acceptable and is to be provided for each consignment of material. Forge butt welded pipes are not acceptable for oil fuel systems, heating coils in oil tanks, primary refrigerant systems and other applications where the pressure exceeds 4,0 bar (4,1 kgf/cm^2).

1.2 Manufacture

1.2.1 Pipes for Class I and II pressure systems, boiler and superheater tubes are to be manufactured at works approved by Lloyd's Register (hereinafter referred to as 'LR'). The steel used is to be manufactured and cast in ingot moulds or by an approved continuous casting process as detailed in Ch 3,1.4.

1.2.2 Unless a particular method is requested by the purchaser, pipes and tubes may be manufactured by any of the following methods:

- Hot finished seamless.
- Cold finished seamless.
- Electric resistance or induction welded.
- Cold finished electric resistance or induction welded.
- Electric fusion welded.

1.2.3 Care is to be taken during manufacture that the pipe or tube surfaces coming in contact with any non-ferrous metals or their compounds are not contaminated to such an extent as could prove harmful during subsequent fabrication and operation.

1.3 Quality

1.3.1 All pipes and tubes are to have a workmanlike finish and are to be clean and free from such surface and internal defects as can be established by the specified tests.

1.3.2 All pipes and tubes are to be reasonably straight. The ends are to be cut nominally square with the axis of the pipe or tube, and are to be free from excessive burrs.

1.4 Dimensional tolerances

1.4.1 The tolerances on the wall thickness and diameter of pipes and tubes are to be in accordance with an acceptable National specification.

1.5 Chemical composition

1.5.1 The requirements for the chemical composition of ladle samples and acceptable methods of deoxidation are detailed in subsequent Sections in this Chapter.

1.6 Heat treatment

1.6.1 All pipes and tubes are to be supplied in the condition detailed in the relevant specific requirements.

1.7 Test material

1.7.1 Pipes and tubes are to be presented for test in batches. The size of a batch and the number of tests to be performed are dependent on the application.

1.7.2 Where heat treatment has been carried out, a batch is to consist of pipes or tubes of the same size, manufactured from the same types of steel and subjected to the same finishing treatment in a continuous furnace, or heat treated together in the same batch type furnace.

1.7.3 Where no heat treatment has been carried out, a batch is to consist of pipes or tubes of the same size manufactured by the same method from material of the same type of steel.

1.7.4 For pipes for Class I pressure systems and boiler and superheater tubes, at least two per cent of the number of lengths in each batch is to be selected at random for the preparation of tests at ambient temperature.

1.7.5 For pipes for Class II pressure systems, each batch is to contain not more than the number of lengths given in Table 6.1.1. Tests are to be carried out on at least one pipe selected at random from each batch or part thereof.

Table 6.1.1 Batch sizes for pipes for Class II pressure systems

Outside diameter mm	Number in batch
≤323,9	200 pipes as made
>323,9	100 pipes as made

1.8 Dimensions of test specimens and test procedures

1.8.1 The procedures for mechanical tests and the dimensions of the test specimens are to be in accordance with Chapter 2.

1.9 Visual and non-destructive testing

1.9.1 All pipes for Class I and II pressure systems, boiler and superheater tubes, are to be presented for visual examination and verification of dimensions. The manufacturer is to provide adequate lighting conditions to enable an internal and external examination of the pipes and tubes to be carried out.

1.9.2 For welded pipes and tubes, the manufacturer is to employ suitable non-destructive methods for the quality control of the welds. It is preferred that this examination is carried out on a continuous basis.

1.10 Hydraulic test

1.10.1 Each pipe and tube is to be subjected to a hydraulic test at the manufacturer's works.

1.10.2 The hydraulic test pressure is to be determined from the following formula, except that the maximum test pressure need not exceed 140 bar (143 kgf/cm^2):

$$P = \frac{20st}{D} \left(P = \frac{200st}{D}\right)$$

where

P = test pressure, in bar (kgf/cm^2)
D = nominal outside diameter, in mm
t = nominal wall thickness, in mm
s = 80 per cent of the specified minimum yield stress, in N/mm^2 (kgf/mm^2), for ferritic steels and 70 per cent of the specified minimum, 1,0 per cent proof stress, in N/mm^2 (kgf/mm^2), for austenitic steels. These relate to the values specified for acceptance testing at ambient temperature.

1.10.3 The test pressure is to be maintained for sufficient time to permit proof and inspection. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test will be accepted. Where it is proposed to adopt a test pressure other than that determined as in 1.10.2, the proposal will be subject to special consideration.

1.10.4 Subject to special approval, either an ultrasonic or eddy current test can be accepted in lieu of the hydraulic test.

1.11 Rectification of defects

1.11.1 Surface imperfections may be removed by grinding provided that the thickness of the pipe or tube after dressing is not less than the required minimum thickness. The dressed area is to be blended into the contour of the tube.

1.11.2 By agreement with the Surveyor, the repair of minor defects by welding can be accepted, subject to welding procedure tests which demonstrate acceptable properties appropriate for the grade of pipe to be repaired. Weld procedure tests are to be subjected to the same heat treatment as will be applied to the actual pipes after weld repair.

1.11.3 The repaired area is to be tested by magnetic particle examination, or, for austenitic steels, by liquid penetrant examination on completion of welding, heat treatment and surface grinding.

1.12 Identification

1.12.1 Pipes and tubes are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:

(a) LR or Lloyd's Register.
(b) Manufacturer's name or trade mark.
(c) Identification mark for the specification or grade of steel.
(d) Identification number and/or initials which will enable the full history of the item to be traced.
(e) The personal stamp of the Surveyor responsible for the final inspection.

1.12.2 It is recommended that hard stamping be restricted to the end face, but it may be accepted in other positions in accordance with National Standards and practices.

1.13 Certification of materials

1.13.1 Unless a LR certificate is specified in other parts of the Rules, a manufacturer's certificate validated by LR is to be issued, *see* Ch 1,3.1.

1.13.2 The manufacturer is to provide LR with the following information:

(a) Purchaser's name and order number.
(b) If known, the contract number for which the material is intended.
(c) Address to which material is despatched.
(d) Specification or the grade of material.
(e) Description and dimensions.
(f) Identification number and/or initials.
(g) Cast number and chemical composition of ladle samples.
(h) Mechanical test results, and results of the intercrystalline corrosion tests where applicable.
(j) Condition of supply.

1.13.3 As a minimum, the chemical composition stated on the certificate is to include the content of all the elements detailed in the specific requirements. Where rimming steel is supplied, this is to be stated on the certificate.

1.13.4 When steel is not produced at the pipe or tube mill, a certificate is to be supplied by the steelmaker stating the process of manufacture, the cast number and the ladle analysis.

1.13.5 The steel manufacturer's works is to be approved by LR.

■ *Section 2*
Seamless pressure pipes

2.1 Scope

2.1.1 Provision is made in this Section for seamless pressure pipes in carbon, carbon-manganese and low alloy steels.

2.1.2 Where pipes are used for the manufacture of pressure vessel shells and headers, the requirements for forgings in Ch 5,7 are applicable where the wall thickness exceeds 40 mm.

2.2 Manufacture and chemical composition

2.2.1 Pipes are to be manufactured by a seamless process and may be hot or cold finished.

2.2.2 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.2.1.

Table 6.2.1 Chemical composition of seamless pressure pipes

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle samples %											
			C	Si	Mn	S max.	P max.	Residual elements						
Carbon and carbon-manganese	320	Semi-killed or killed	≤0,16	–	0,40–0,70	0,050	0,050	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,70 max.						
	360		≤0,17	≤0,35	0,40–0,80	0,045	0,045							
	410	Killed	≤0,21	≤0,35	0,40–1,20	0,045	0,045							
	460		≤0,22	≤0,35	0,80–1,40	0,045	0,045							
	490		≤0,23	≤0,35	0,80–1,50	0,045	0,045							
								Ni	Cr	Mo	Cu	Sn	V	Al
1Cr$^1/_2$Mo	440	Killed	0,10–0,18	0,10–0,35	0,40–0,70	0,040	0,040	0,30 max.	0,70–1,10	0,45 – 0,65	0,25 max.	0,03 max.	—	≤0,020
2$^1/_4$Cr1Mo	410 490	Killed	0,08–0,15	0,10–0,50	0,40–0,70	0,040	0,040	0,30 max.	2,0–2,5	0,90–1,20	0,25 max.	0,03 max.	—	≤0,020
$^1/_2$Cr$^1/_2$Mo$^1/_4$V	460	Killed	0,10–0,18	0,10–0,35	0,40–0,70	0,040	0,040	0,30	0,30–0,60	0,50–0,70	0,25 max.	0,03 max.	0,22–0,32	≤0,020

2.3 Heat treatment

2.3.1 Pipes are to be supplied in the condition given in Table 6.2.3.

2.4 Mechanical tests

2.4.1 All pipes are to be presented in batches as defined in Section 1.

2.4.2 Each pressure pipe selected for test is to be subjected to tensile and flattening or bend tests.

2.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.2.2.

2.5 Mechanical properties for design

2.5.1 Values for nominal minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Table 6.2.4 and are intended for design purposes only. Verification of these values is not required, except for materials complying with National or proprietary specification where the elevated temperature properties used for design are higher than those given in Table 6.2.4.

2.5.2 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on each cast. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature and tested in accordance with the procedures given in Chapter 2. If tubes or pipes of more than one thickness are supplied from one cast, the test is to be made on the thickest tube or pipe.

Table 6.2.3 Heat treatment

Type of steel		Condition of supply
Carbon and carbon-manganese		
Hot finished		Hot finished (*see* Note 1) Normalised (*see* Note 2)
Cold finished		Normalised (*see* Note 2)
Alloy steel		
1Cr$^{1}/_{2}$Mo		Normalised and tempered
2$^{1}/_{4}$Cr1Mo	Grade 410	Fully annealed
	Grade 490	Normalised and tempered 650—780°C
	Grade 490	Normalised and tempered 650—750°C
$^{1}/_{2}$Cr$^{1}/_{2}$Mo$^{1}/_{4}$V		Normalised and tempered

NOTES
1. Provided that the finishing temperature is sufficiently high to soften the material.
2. Normalised and tempered at the option of the manufacturer.

2.5.3 As an alternative to 2.5.2, a manufacturer may carry out an agreed comprehensive test program for a stated grade of steel to demonstrate that the specified minimum mechanical properties at elevated temperatures can be consistently obtained. This test program is to be carried out under the supervision of the Surveyors, and the results submitted for assessment and approval. When a manufacturer is approved on this basis, tensile tests at elevated temperatures are not required for acceptance purposes, but at the discretion of the Surveyors occasional check tests of this type may be requested.

2.5.4 Values for the estimated average stress to rupture in 100 000 hours are given in Table 6.2.5 and may be used for design purposes.

Table 6.2.2 Mechanical properties for acceptance purposes: seamless pressure pipes (maximum wall thickness 40 mm), *see* 2.1.2

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_0}$ % minimum	Flattening test constant C	Bend test diameter of former (t = thickness)
Carbon and carbon-manganese	320	195	320—440	25	0,10	4t
	360	215	360—480	24	0,10	
	410	235	410—530	22	0,08	
	460	265	460—580	21	0,07	
	490	285	490—610	21	0,07	
1Cr$^{1}/_{2}$Mo	440	275	440—590	22	0,07	4t
2$^{1}/_{4}$Cr1Mo	410 (*see* Note 1)	135	410—560	20	0,07	
	490 (*see* Note 2)	275	490—640	16		4t
$^{1}/_{2}$Cr$^{1}/_{2}$Mo$^{1}/_{4}$V	460	275	460—610	15	0,07	4t

NOTES
1. Annealed condition.
2. Normalised and tempered condition.

Table 6.2.4 **Mechanical properties for design purposes: seamless pressure pipes**

Type of steel	Grade	Nominal minimum lower yield or 0,2% proof stress N/mm^2											
		Temperature °C											
		50	100	150	200	250	300	350	400	450	500	550	600
Carbon and carbon-manganese	320	172	168	158	147	125	100	91	88	87	—	—	—
	360	192	187	176	165	145	122	111	109	107	—	—	—
	410	217	210	199	188	170	149	137	134	132	—	—	—
	460	241	234	223	212	195	177	162	159	156	—	—	—
	490	256	249	237	226	210	193	177	174	171	—	—	—
1Cr$^1/_2$Mo	440	254	240	230	220	210	183	169	164	161	156	151	—
2$^1/_2$Cr1Mo	410 (*see* Note 1)	121	108	99	92	85	80	76	72	69	66	64	62
	490 (*see* Note 2)	268	261	253	245	236	230	224	218	205	189	167	145
$^1/_2$Cr$^1/_2$Mo$^1/_4$V	460	266	259	248	235	218	192	184	177	168	155	148	—

NOTES
1. Annealed condition.
2. Normalised and tempered condition.

Table 6.2.5 **Mechanical properties for design purposes: seamless pressure pipes – Estimated values for stress to rupture in 100 000 hours (units N/mm^2)**

Temperature °C	Carbon and carbon-manganese		1Cr$^1/_2$Mo	2$^1/_4$Cr1Mo		$^1/_2$Cr$^1/_2$Mo$^1/_4$V
	Grade 320 360 410	Grade 460 490	Grade 440	Grade 410 Annealed	Grade 490 Normalised and tempered (*see* Note)	Grade 460
380	171	227	—	—	—	—
390	155	203	—	—	—	—
400	141	179	—	—	—	—
410	127	157	—	—	—	—
420	114	136	—	—	—	—
430	102	117	—	—	—	—
440	90	100	—	—	—	—
450	78	85	—	196	221	—
460	67	73	—	182	204	—
470	57	63	—	168	186	—
480	47	55	210	154	170	218
490	36	47	177	141	153	191
500	—	41	146	127	137	170
510	—	—	121	115	122	150
520	—	—	99	102	107	131
530	—	—	81	90	93	116
540	—	—	67	78	79	100
550	—	—	54	69	69	85
560	—	—	43	59	59	72
570	—	—	35	51	51	59
580	—	—	—	44	44	46

NOTE
When the tempering temperature exceeds 750°C, the values for Grade 410 are to be used.

■ *Section 3*
Welded pressure pipes

3.1 Scope

3.1.1 Provision is made in this Section for welded pressure pipes in carbon, carbon-manganese and low alloy steels.

3.2 Manufacture and chemical composition

3.2.1 Pipes are to be manufactured by the electric resistance or induction welding process and, if required, may be subsequently hot reduced or cold finished.

3.2.2 Where it is proposed to use other welding processes, details of the welding processes and procedures are to be submitted for review.

3.2.3 In all cases, welding procedure tests are required. Test samples are to be subjected to the same heat treatment as the pipe.

3.2.4 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.3.1.

3.3 Heat treatment

3.3.1 Pipes are to be supplied in the heat treated condition given in Table 6.3.3.

3.4 Mechanical tests

3.4.1 All pipes are to be presented in batches as defined in Section 1.

3.4.2 Each pressure pipe selected for test is to be subjected to tensile and flattening or bend tests.

3.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.3.2.

3.5 Mechanical properties for design

3.5.1 The mechanical properties at elevated temperature for carbon and carbon-manganese steels in Grades 320 to 460 and $1Cr^{1}/_{2}Mo$ steel can be taken from the appropriate Tables in Section 2.

Table 6.3.1 Chemical composition of welded pressure pipes

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle samples %										
			C	Si	Mn	S max.	P max.	Residual elements					
Carbon and carbon-manganese	320	Any method	≤0,16	—	0,30–0,70	0,050	0,050	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,70 max.					
	360	(see Note)	≤0,17	≤0,35	0,40–1,00	0,045	0,045						
	410	Killed	≤0,21	≤0,35	0,40–1,20	0,045	0,045						
	460		≤0,22	≤0,35	0,80–1,40	0,045	0,045						
								Ni	Cr	Mo	Cu	Sn	Al
$1Cr^{1}/_{2}Mo$	440	Killed	0,10–0,18	0,10–0,35	0,40–0,70	0,040	0,040	0,30 max.	0,70–1,10	0,45–0,65	0,25 max.	0,03 max.	≤0,020

NOTE
For rimming steels, the carbon content may be increased to 0,19% max.

Table 6.3.2 Mechanical properties for acceptance purposes: welded pressure pipes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Flattening test constant *C*
Carbon and carbon-manganese	320 360 410 460	195 215 235 265	320 – 440 360 – 480 410 – 530 460 – 580	25 24 22 21	0,10 0,10 0,08 0,07
1Cr$^1/_2$Mo	440	275	440 – 590	22	0,07

Table 6.3.3 Heat treatment: welded pressure pipes

Type of steel	Condition of supply
Carbon and carbon-manganese, *see* Note	Normalised (Normalised and tempered at the option of the manufacturer)
1Cr$^1/_2$Mo	Normalised and tempered
NOTE Subject to special approval, electric resistance welded (ERW) pipes and tubes in grades 320 and 360 may be supplied without heat treatment for the following applications: (a) Class 2 piping systems, except for liquefied gases or other low temperature applications. (b) Class 3 piping systems.	

■ *Section 4*
Ferritic steel pressure pipes for low temperature service

4.1 Scope

4.1.1 Provision is made in this Section for carbon, carbon-manganese and nickel pipes intended for use in the piping arrangements for liquefied gases where the design temperature is less than 0°C. These requirements are also applicable for other types of pressure piping systems where the use of steels with guaranteed impact properties at low temperatures is required.

4.2 Manufacture and chemical composition

4.2.1 Carbon and carbon-manganese steel pipes are to be manufactured by a seamless, electric resistance or induction welding process.

4.2.2 Nickel steel pipes are to be manufactured by a seamless process.

4.2.3 Seamless pipes may be hot finished or cold finished. Welded pipes may be as-welded, hot finished or cold finished. The terms ‘hot finished’, ‘cold finished’ and ‘as-welded’ apply to the condition of the pipes before final heat treatment.

4.2.4 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.4.1.

4.3 Heat treatment

4.3.1 Pipes are to be supplied in the condition given in Table 6.4.3.

4.4 Mechanical tests

4.4.1 All pipes are to be presented for test in batches as defined in Section 1 for Class 1 pressure piping systems, but in addition the material in each batch is to be from the same cast.

4.4.2 At least two per cent of the number of lengths in each batch is to be selected at random for the preparation of tests.

4.4.3 Each pressure pipe selected for test is to be subjected to tensile, flattening or bend test at room temperature and, where the wall thickness is 6 mm or greater, an impact test at the test temperature specified in Table 6.4.2.

4.4.4 The impact tests are to consist of a set of three Charpy V-notch test specimens cut in the longitudinal direction with the notch perpendicular to the original surface of the pipe. The dimensions of the test specimens are to be in accordance with the requirements of Chapter 2.

4.4.5 The results of all tensile, flattening and bend tests are to comply with the appropriate values in Table 6.4.2.

4.4.6 The average value for impact test specimens is to comply with the appropriate requirements of Table 6.4.2. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value. *See* Ch 2,1.4.1 for re-test procedures.

Table 6.4.1 Chemical composition

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle sample %							
			C max.	Si	Mn	P max.	S max.	Ni	Al_{sol} *see* Note	Residual elements
Carbon	360	Fully killed	0,17	0,10—0,35	0,40—1,00	0,030	0,025	—	0,015 min.	Cr 0,25 Cu 0,30 Mo 0,10 Ni 0,30 Total 0,70
Carbon-manganese	410 and 460		0,20	0,10—0,35	0,60—1,40	0,030	0,025	—	0,015 min.	
$3^1/_2$Ni	440		0,15	0,15—0,35	0,30—0,90	0,025	0,020	3,25—3,75	—	Cr 0,25 Cu 0,30 Mo 0,10 Total 0,60
9Ni	690		0,13	0,15—0,30	0,30—0,90	0,025	0,020	8,50—9,50	—	

NOTE
Where a minimum Al_{sol} of 0,015% is specified, the determination of the total aluminium is acceptable provided that the result is not less than 0,020%.

Table 6.4.2 Mechanical properties for acceptance purposes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)	Charpy V-notch impact tests	
							Test temperature °C	Average energy J minimum
Carbon	360	210	360—480	24	0,10	4*t*	–40	27
Carbon-manganese	410 460	235 260	410—530 460—580	22 21	0,08 0,07	4*t*	–50	27
$3^1/_2$Ni	440	245	440—590	16	0,08	4*t*	–95	34
9Ni	690	510	690—840	15	0,08	4*t*	–196	41

For standard subsidiary impact test specimens, the minimum energy values are to be as follows:

Required average energy value for standard 10 mm x 10 mm	Subsidiary 10 mm x 7,5 mm	Subsidiary 10 mm x 5 mm
	Average energy	Average energy
27 J	22 J	18 J
34 J	28 J	23 J
41 J	34 J	27 J

Table 6.4.3 Heat treatment

Type of steel	Condition of supply
Carbon and carbon-manganese	Hot finished Normalised Normalised and tempered
$3^1/_2$ Ni	Normalised Normalised and tempered
9Ni	Double normalised and tempered Quenched and tempered

Section 5
Austenitic stainless steel pressure pipes

5.1 Scope

5.1.1 Provision is made in this Section for austenitic stainless steel pipes suitable for use in the construction of the piping systems for chemicals and for liquefied gases where the design temperature is not less than minus 165°C and for bulk chemical tankers.

5.1.2 Austenitic stainless steels are also suitable for service at elevated temperatures. Where such applications are proposed, details of the chemical composition, heat treatment and mechanical properties are to be submitted for consideration and approval.

5.1.3 Where it is intended to supply seamless pipes in the direct quenched condition, a programme of tests for approval is to be carried out under the supervision of the Surveyors, and the results are to be to the satisfaction of LR, *see* Ch 1,2.2.

5.2 Manufacture and chemical composition

5.2.1 Pipes are to be manufactured by a seamless or a continuous automatic electric fusion welding process.

5.2.2 Welding is to be in a longitudinal direction, with or without the addition of filler metal.

5.2.3 The chemical composition of the ladle samples is to comply with the appropriate requirements of Table 6.5.1.

5.3 Heat treatment

5.3.1 Pipes are generally to be supplied by the manufacturer in the solution treated condition over their full length.

5.3.2 Alternatively, seamless pipes may be direct quenched immediately after hot forming, while the temperature of the pipes is not less than the specified minimum solution treatment temperature.

5.4 Mechanical tests

5.4.1 All pipes are to be presented in batches as defined in Section 1 for Class I and II piping systems.

5.4.2 Each pipe selected for test is to be subjected to tensile and flattening or bend tests.

5.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.5.2.

Table 6.5.1 Chemical composition

Type of steel	Grade	Chemical composition of ladle sample %								
		C max.	Si	Mn	P max.	S max.	Cr	Mo	Ni	Others
304L	490	0,03	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	—
316L	490	0,03	<1,00	<2,00	0,045	0,030	16,0 – 18,5	2,0–3,0	11,0 – 14,5	—
321	510	0,08	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	Ti ≥5 x C ≤0,80
347	510	0,08	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	Nb ≥10 x C ≤1,00

Table 6.5.2 Mechanical properties for acceptance purposes

Type of steel	Grade	0,2% proof stress N/mm^2 (*see* Note)	1,0% proof stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)
304L	490	175	205	490 – 690	30	0,09	3*t*
316L	490	185	215	490 – 690	30	0,09	3*t*
321	510	195	235	510 – 710	30	0,09	3*t*
347	510	205	245	510 – 710	30	0,09	3*t*

NOTE
The 0,2% proof stress values given for information purposes and unless otherwise agreed are not required to be verified by test.

5.5 Intergranular corrosion tests

5.5.1 For materials used for piping systems for chemicals, intercrystalline corrosion tests are to be carried out on one per cent of the number of pipes in each batch, with a minimum of one pipe.

5.5.2 For pipes with an outside diameter not exceeding 40 mm, the test specimens are to consist of a full cross-section. For larger pipes, the test specimens are to be cut as circumferential strips of full wall thickness and having a width of not less than 12,5 mm. In both cases, the total surface area is to be between 15 and 35 cm^2.

5.5.3 Unless otherwise agreed or required for a particular chemical cargo, the testing procedure is to be in accordance with Ch 2,9.

5.5.4 After immersion, the full cross-section test specimens are to be subjected to a flattening test in accordance with the requirements of Chapter 2. The strip test specimens are to be subjected to a bend test through 90° over a mandrel of diameter equal to twice the thickness of the test specimen.

5.6 Fabricated pipework

5.6.1 Fabricated pipework is to be produced from material manufactured in accordance with 5.2, 5.3, 5.4 and 5.5.

5.6.2 Welding is to be carried out in accordance with an approved and qualified procedure by suitably qualified welders.

5.6.3 Fabricated pipework may be supplied in the as-welded condition without subsequent solution treatment provided that welding procedure tests have demonstrated satisfactory material properties including resistance to intercrystalline corrosion.

5.6.4 In addition, butt welds are to be subjected to 5 per cent radiographic examination for Class I, and 2 per cent for Class II pipes.

5.6.5 Fabricated pipework in the as-welded condition and intended for systems located on deck is to be protected by a suitable corrosion control coating.

5.7 Certification of materials

5.7.1 Each test certificate is to be of the type and give the information detailed in Ch 1,3.1 together with general details of heat treatment and, where applicable, the results obtained from intercrystalline corrosion tests. As a minimum, the chemical composition is to include the content of all the elements detailed in Table 6.5.1.

■ *Section 6*
Boiler and superheater tubes

6.1 Scope

6.1.1 Provision is made in this Section for boiler and superheater tubes in carbon, carbon-manganese and low alloy steels.

6.1.2 Austenitic stainless steels may also be used for this type of service. Where such applications are proposed, details of the chemical composition, heat treatment and mechanical properties are to be submitted for consideration and approval.

6.2 Manufacture and chemical composition

6.2.1 Tubes are to be seamless or welded and are to be manufactured in accordance with the requirements of Sections 2 and 3, respectively.

6.2.2 The method of deoxidation and the chemical composition of ladle samples are to comply with the requirements given in Table 6.2.1 or 6.3.1, as appropriate.

6.3 Heat treatment

6.3.1 All tubes are to be supplied in accordance with the requirements given in Table 6.2.3 or 6.3.3 as appropriate, except that 1Cr$^{1}/_{2}$Mo steel may be supplied in the normalised only condition when the carbon content does not exceed 0,15 per cent.

6.4 Mechanical tests

6.4.1 Tubes are to be presented for test in batches as defined in Section 1.

6.4.2 Each boiler and superheater tube selected for test is to be subjected to at least the following:
(a) Tensile test.
(b) Flattening or bending test.
(c) Expanding or flanging test.

6.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.6.1.

6.5 Mechanical properties for design

6.5.1 The mechanical properties at elevated temperature for carbon and carbon-manganese steels in Grades 320 to 460, 1Cr$^{1}/_{2}$Mo and 2$^{1}/_{4}$Cr1Mo steels can be taken from the appropriate Tables in Section 2.

6.5.2 Where rimming steel is used, the design temperature is limited to 400°C.

Table 6.6.1 Mechanical properties for acceptance purposes: boiler and superheater tubes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)	Drift expanding and flanging test minimum % increase in outside diameter		
							Ratio $\frac{\text{Inside diameter}}{\text{Outside diameter}}$		
							≤0,6	>0,6 ≤0,8	>0,8
Carbon and carbon-manganese	320 360 410 460	195 215 235 265	320–440 360–480 410–530 460–580	25 24 22 21	0,10 0,10 0,08 0,07	4*t*	12 12 10 8	15 15 12 10	19 19 17 15
$1Cr^1/_2Mo$	440	275	440–590	22	0,07	4*t*	8	10	15
$2^1/_2Cr1Mo$	410 (*see* Note 1) 490 (*see* Note 2)	135 275	410–560 490–640	20 16	0,07	4*t*	8	10	15

NOTES
1. Annealed condition.
2. Normalised and tempered condition.

Section

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for grey (flake), spheroidal (nodular) graphite and compacted (vermicular) graphite iron castings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems.

1.1.2 Where required by the relevant Rules dealing with design and construction, castings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the requirements given in this Section and either Section 2 for grey iron castings, Section 3 for spheroidal graphite iron castings or Section 4 for compacted graphite iron castings. Castings for crankshafts are additionally to comply with the requirements detailed in Section 5.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted, provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Where small castings are produced in large quantities, or where castings of the same type are produced in regular quantities, alternative survey procedures, in accordance with Ch 1,2.2, may be adopted subject to approval by Lloyd's Register (hereinafter referred to as 'LR').

1.2 Manufacture

1.2.1 Castings as designated in 1.1.2 are to be made at foundries approved by LR.

1.2.2 Suitable mechanical methods are to be employed for the removal of surplus material from castings. Thermal cutting processes are not acceptable, except as a preliminary operation to mechanical methods.

1.3 Quality of castings

1.3.1 Castings are to be free from surface or internal defects which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved plan.

1.4 Chemical composition

1.4.1 The chemical composition of the iron used is left to the discretion of the manufacturer, who is to ensure that it is suitable to obtain the mechanical properties specified for the castings.

1.5 Heat treatment

1.5.1 Except as required by 1.5.2, castings may be supplied in either the as cast or heat treated condition.

1.5.2 For some applications, such as elevated temperature service, or where dimensional stability is important, castings may require to be given a suitable tempering or stress relieving heat treatment. This is to be carried out after any refining heat treatment and before machining.

1.5.3 Where it is proposed to carry out local hardening of the surface of a casting, full details of the proposed procedure are to be submitted for approval.

1.6 Test material

1.6.1 At least one test sample is to be provided for each casting or batch of castings. For large castings, where more than one ladle of metal is used, one test sample is to be provided, from each ladle used.

1.6.2 A batch testing procedure may be adopted for castings with a fettled mass of 1 tonne or less. All castings in a batch are to be of similar type and dimensions, and cast from the same ladle of metal. One test sample is to be provided for each multiple of two tonnes of fettled castings in the batch.

1.6.3 Where separately cast test samples are used, they are to be cast in moulds made from the same type of material as used for the castings and are not to be stripped from the moulds until the temperature is below 500°C.

1.6.4 All test samples are to be suitably marked to identify them with the castings which they represent.

1.6.5 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent. For cast-on test samples, the sample is not to be separated from the casting until after heat treatment.

1.7 Mechanical tests

1.7.1 One tensile specimen is to be prepared from each test sample. The dimensions of the test specimens and the testing procedures used are to be in accordance with Chapter 2.

1.7.2 The results of all tensile tests are to comply with the requirements given in Section 2, 3, 4 or 5, as appropriate.

1.7.3 In the case of castings supplied in the as cast condition which initially do not meet the requirements of 1.7.2, the manufacturer, by agreement with the purchaser, has the right to heat treat the castings, together with the representative test samples, and re-submit them for acceptance.

1.7.4 In the case of a batch of castings supplied in the heat treated condition which initially do not meet the requirements of 1.7.2, the manufacturer has the right to re-heat treat the batch together with the representative test samples, and re-submit the castings for acceptance. The number of reheat treatments and retestings will be restricted to two.

1.8 Visual and non-destructive examination

1.8.1 All castings are to be cleaned and adequately prepared for examination. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.8.2 The accuracy and verification of dimensions are the responsibility of the manufacturer, unless otherwise agreed.

1.8.3 All castings are to be presented to the Surveyor for visual examination and this is to include the examination of internal surfaces where applicable.

1.8.4 The non-destructive examination of castings is not required unless otherwise stated in the approved plan or where there is reason to suspect the soundness of the casting.

1.8.5 In the event of any casting proving defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

1.9 Rectification of defective castings

1.9.1 At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

1.9.2 Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by vacuum impregnation with a suitable plastic filler, provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

1.9.3 Repairs by welding are not permitted on grey cast iron castings or compacted graphite iron castings and generally not permitted for spheroidal or nodular graphite iron castings, but may be considered in special circumstances for spheroidal or nodular graphite iron castings. In such cases, full details of the proposed repair procedure are to be submitted for approval prior to the commencement of the proposed rectification.

1.10 Pressure testing

1.10.1 When required by the relevant Rules, castings are to be pressure tested before final acceptance. These tests are to be carried out in the presence and to the satisfaction of the Surveyor.

1.11 Identification of castings

1.11.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities for tracing the castings when required.

1.11.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following particulars:

(a) Type and grade of cast iron.
(b) Identification number, cast number or other marking which will enable the full history of the casting to be traced.
(c) Manufacturer's name or trade mark.
(d) LR or Lloyd's Register and the abbreviated name of LR's local office.
(e) Personal stamp of Surveyor responsible for inspection.
(f) Test pressure, where applicable.
(g) Date of final inspection.

1.11.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

1.12 Certification of materials

1.12.1 A LR certificate is to be issued, *see* Ch 1,3.1.

1.12.2 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting or batch of castings which has been accepted:

(a) Purchaser's name and order number.
(b) Description of castings and quality of cast iron.
(c) Identification number.
(d) General details of heat treatment, where applicable.
(e) Results of mechanical tests.
(f) Test pressure, where applicable.
(g) When specially required, the chemical analysis of ladle samples.

1.12.3 Where applicable, the manufacturer is to provide a signed statement regarding non-destructive testing as required by 1.8, together with a statement and/or a sketch detailing the extent and position of all weld repairs made to each casting as required by 1.9.

■ *Section 2* Grey iron castings

2.1 Scope

2.1.1 This Section gives the specific requirements for grey cast iron castings.

2.2 Test material

2.2.1 Separately cast test samples in the form of cylindrical bars, 30 mm diameter and of a suitable length, are to be used unless otherwise agreed by LR. Test samples of other dimensions may be specially required for some components as may cast-on samples. In these circumstances, the tensile strength requirements are to be agreed.

2.2.2 When two or more test samples are cast simultaneously in a single mould, the bars are to be at least 50 mm apart.

2.2.3 Test samples may be cast integrally when a casting is both more than 20 mm thick and its mass exceeds 200 kg, subject to agreement between the manufacturer and the purchaser. The type and location of the samples are to be such as to provide approximately the same cooling conditions as for the casting it represents and are also subject to agreement.

2.2.4 For continuous melting of the same grade of cast iron in large tonnages the mass of a batch may be taken as the output of two hours of pouring.

2.2.5 Where 2.2.4 applies and production is carefully monitored by systematic checking of the melting process by, for example, chill testing, chemical analysis or thermal analysis, test samples may be taken at longer intervals as agreed by the Surveyor.

2.3 Mechanical tests

2.3.1 Only the tensile strength is to be determined, and the results obtained from tests are to comply with the minimum value specified for the castings being supplied. Except for crankshaft castings (*see* Section 5), the specified tensile strength is to be not less than 200 N/mm^2 subject to any additional requirements of the relevant Rules. The fractured surfaces of all tensile test specimens are to be granular and entirely grey in appearance.

■ *Section 3* Spheroidal or nodular graphite iron castings

3.1 Scope

3.1.1 This Section gives the specific requirements for spheroidal or nodular graphite iron castings.

3.1.2 These requirements are generally applicable to castings intended for use at ambient temperatures. Additional requirements will be necessary when the castings are intended for service at either low or elevated temperatures. Impact test requirements are given for low temperature service in 3.4.2.

3.2 Heat treatment

3.2.1 The special qualities with 350 N/mm^2 and 400 N/mm^2 nominal tensile strength and impact test are to undergo a ferritising heat treatment, *see* 3.4.2.

3.3 Test material

3.3.1 The test samples are to be as detailed in Figs. 7.3.1, 7.3.2 or 7.3.3 The dimensions of the test specimens and testing procedures used are to be in accordance with Chapter 2. Test samples of other dimensions may be specially required for some castings and these are to be agreed with the Surveyor.

3.3.2 The test samples may be either gated to the casting or separately cast.

3.3.3 Where separately cast test samples are used, they are to be taken towards the end of pouring of the castings.

3.4 Mechanical tests

3.4.1 The tensile strength and elongation are to be determined and are to comply with the requirements of Table 7.3.1. Minimum values for the 0,2 per cent proof stress are also included in this Table but are to be determined only if included in the specification. Typical ranges of hardness values are also given in Table 7.3.1 and are intended for information purposes.

3.4.2 Impact tests may be required for some applications in which case the selection of the grade is to be confined to those listed in Table 7.3.2. These castings are to be given a ferritising heat treatment. The mechanical test results are to comply with Table 7.3.2.

3.4.3 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 7.3.1 and 7.3.2 but subject to any additional requirements of the relevant Rules.

Dimension	Standard sample, mm	Alternative samples when specially required, mm		
u *v* *x* *y*	25 55 40 100	12 40 30 80	50 90 60 150	75 125 65 165
Z *Rs*	To suit testing machine Approximately 5			

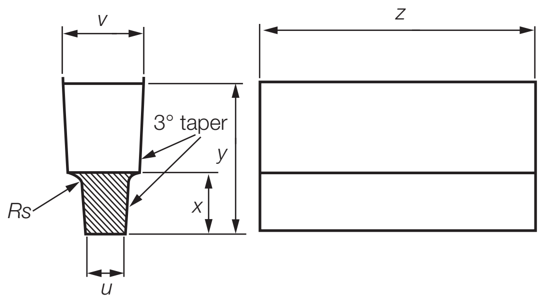


Fig. 7.3.1 Type A (U-type) test samples

Dimension	Standard sample, mm
u *v* *x* *y*	25 90 40 100
Z *Rs*	To suit testing machine Approximately 5

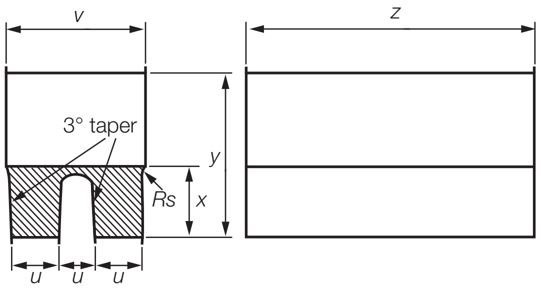


Fig. 7.3.2 Type B (Double U-type) test samples

3.5 Metallographic examination

3.5.1 Samples for metallographic examination are to be prepared for spheroidal or nodular graphite iron castings. These samples are to be representative of each ladle used and may conveniently be taken from the tensile test specimens. Alternative arrangements for the provision of these samples may, however, be adopted subject to the concurrence of the Surveyor. They are, however, to be taken towards the end of the pour.

3.5.2 Examination of the samples is to show that at least 90 per cent of the graphite is in a dispersed spheroidal or nodular form. Details of typical matrix structures are given in Table 7.3.1 and are intended for information purposes.

Dimension	Standard sample, mm	Alternative samples when specially required, mm		
u *v* *x* *y*	25 55 40 140	12 40 25 135	50 100 50 150	75 125 65 175
Z	To suit testing machine			
Minimum thickness of mould surrounding test sample	40	40	80	80

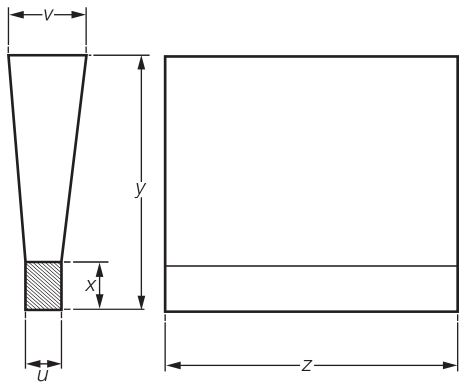


Fig. 7.3.3 Type C (Y-type) test samples

Table 7.3.1 Mechanical properties for acceptance purposes: spheroidal or nodular graphite iron castings

Specified minimum tensile strength N/mm^2	0,2% proof stress (*see* Note) N/mm^2 minimum	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Typical hardness value HB (*see* 3.4.1)	Typical structure of matrix (*see* 3.5.2)
370	230	17	120 – 180	Ferrite
400	250	12	140 – 200	Ferrite
500	320	7	170 – 240	Ferrite/pearlite
600	370	3	190 – 270	Pearlite/ferrite
700	420	2	230 – 300	Pearlite
800	480	2	250 – 350	Pearlite or tempered structure

NOTE
Proof stresses need only be determined if specifically requested.

Table 7.3.2 Mechanical properties: special qualities

Specified minimum tensile strength N/mm^2	0,2% proof stress minimum (*see* Note 1) N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ minimum % (*see* Note 2)	Typical hardness value	Charpy V-notch impact tests	
				Test temperature °C (*see* Note 3)	Average energy J minimum (*see* Note 4)
350	220	22	110 – 170	20 –40	17 (14) 12 (10)
400	250	18	140 – 200	20 –20	14 (11) 12 (10)

NOTES
1. Proof stresses need only be determined if specifically requested.
2. In the case of integrally cast samples, the acceptable elongation may be taken as 2 percentage points less.
3. Tests need only be made at either of the temperatures listed, as appropriate.
4. The average value measured on three Charpy V-notch specimens. One of the three values may be below the specified minimum average value, but not less than the value shown in brackets.
5. Typical structure of the matrix is ferrite.

■ *Section 4* Compacted or vermicular graphite iron castings

4.1 Scope

4.1.1 This Section gives the specific requirements for compacted or vermicular graphite iron castings.

4.1.2 These requirements are generally applicable to castings intended for use at ambient temperatures.

4.2 Heat treatment

4.2.1 Where castings do not meet the specified mechanical property requirements in the as-cast condition, a corrective heat treatment may be carried out. This is to be restricted to a single heat treatment and the test coupons must be heat treated with the castings.

4.3 Test material

4.3.1 The test samples are to be as detailed in Figs. 7.3.1, 7.3.2 or 7.3.3. The dimensions of the test specimens and testing procedures used are to be in accordance with Chapter 2. Test samples of other dimensions may be specially agreed with the Surveyor.

4.3.2 The test samples may be either gated to the casting or separately cast.

4.4 Mechanical tests

4.4.1 The tensile strength and elongation are to be determined and are to comply with the requirements of Table 7.4.1. Minimum values for the 0,2 per cent proof stress are also included in this Table but are to be determined only if included in the specification. Typical ranges of hardness values are also given in Table 7.4.1 and are intended for information purposes.

4.4.2 Castings may be supplied to any specified minimum tensile strength grade.

Table 7.4.1 Mechanical properties for acceptance purposes: compacted or vermicular graphite iron castings

Specified minimum tensile strength N/mm^2	0,2% proof stress (*see* Note) N/mm^2 minimum	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Typical hardness value HB (*see* 4.4.1)	Typical structure of matrix (*see* 4.5.2)
300	210	2	140 – 210	Ferrite
350	245	1,5	160 – 220	Ferrite/pearlite
400	280	1	180 – 240	Pearlite/ferrite
450	315	1	200 – 250	Pearlite
500	350	0,5	220 – 260	Fully pearlitic

NOTE
Proof stresses need only be determined if specifically requested.

4.5 Metallographic examination

4.5.1 Samples for metallographic examination are to be prepared for compacted or vermicular graphite iron castings. These samples are to be representative of each ladle used and may conveniently be taken from the tensile test specimens. Alternative arrangements for the provision of these samples may, however, be adopted subject to the concurrence of the Surveyor. They are, however, to be taken towards the end of the pour.

4.5.2 Examination of the samples is to show that at least 80 per cent of the graphite is in a dispersed, compacted or vermicular form. The remaining 20 per cent of the graphite may be in spheroidal forms. Details of typical matrix structures are given in Table 7.4.1 and are intended for information purposes.

■ *Section 5* **Iron castings for crankshafts**

5.1 Scope

5.1.1 This Section gives additional requirements for cast iron crankshafts intended for diesel engines and compressors. For both of these applications, details of the proposed specification are to be submitted for approval.

5.1.2 Crankshaft castings in grey iron and compacted graphite iron are acceptable only for compressors, and the specified minimum tensile strength is to be not less than 300 N/mm^2.

5.1.3 For crankshaft castings in spheroidal or nodular graphite iron, the specified minimum tensile strength is to be not less than 370 N/mm^2.

5.2 Manufacture

5.2.1 Details of the method of manufacture, including the arrangements proposed for the provision of test material, are to be submitted for approval.

5.2.2 Tests to demonstrate the soundness of prototype castings and the mechanical properties at important locations will be required.

5.3 Heat treatment

5.3.1 In general, crankshaft castings other than those which are fully annealed, normalised or oil quenched and tempered, are to receive a suitable stress relief heat treatment before machining.

5.3.2 Where it is proposed to harden the surfaces of machined pins and/or journals of cast iron crankshafts, details of the process are to be submitted for approval. Before such a process is applied to a crankshaft it is to be demonstrated by procedure tests, and to the satisfaction of the Surveyor, that the process is suitably controlled and does not impair the strength or soundness of the material.

5.4 Test material

5.4.1 Unless otherwise approved, the dimensions of the test samples are to be such as to ensure that they have mechanical properties representative of those of the average section of the crankshaft casting.

5.4.2 For large crankshaft castings, the test samples are to be cast integral with, or gated from, each casting.

5.4.3 The batch testing procedure detailed in 1.6.2 may be adopted only where small and identical crankshaft castings are produced in quantity. Generally, the fettled mass of each casting in a batch is not to exceed 100 kg, and in addition to tensile tests, the hardness of each casting is to be determined. For this purpose, a small flat is to be ground on each crankshaft, and Brinell hardness tests are to be carried out. The results obtained from these tests are to comply with the approved specification.

5.5 Non-destructive examination

5.5.1 Cast crankshafts are to be subjected to a full magnetic particle or dye penetrant examination after final machining and completion of any surface hardening operations.

5.5.2 Particular attention is to be given to the testing of the pins, journals and associated fillet radii.

5.5.3 Cracks and crack-like defects are not acceptable. Fillet radii are to be free from any indications.

5.6 Rectification of defective castings

5.6.1 Cast iron crankshafts are not to be repaired by welding, and blemishes are not to be plugged with a filler.

5.7 Certification of materials

5.7.1 The chemical composition of ladle samples is to be given in addition to the other particulars detailed in 1.12.2.

Section

Section 1
Plates, bars and sections

1.1 Scope

1.1.1 This Section makes provision for aluminium alloy plates, bars and sections intended for use in the construction of ships and other marine structures and for cryogenic applications.

1.1.2 Except as provided in 1.1.4, all items are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and those detailed in this Section.

1.1.3 The thickness of plates, sections and bars described by these requirements will be in the range between 3 and 50 mm. Plates and sections less than 3,0 mm thick may be manufactured and tested in accordance with the requirements of an acceptable national specification.

1.1.4 Plates less than 3,0 mm thick and sections less than 40 mm x 40 mm x 3,0 mm may be manufactured and tested in accordance with the requirements of an acceptable National specification.

1.1.5 Where the section thickness exceeds 50 mm, the requirements will be subject to special consideration.

1.1.6 Materials intended for the construction of cargo tanks or storage for liquefied gases, and for other low temperature applications, are to be manufactured in the 5083 alloy in the annealed condition.

1.1.7 As an alternative to 1.1.2 and 1.1.4, materials which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section and are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.2 Manufacture

1.2.1 Aluminium alloys are to be manufactured at works approved by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 The alloys may be cast either in ingot moulds or by an approved continuous casting process. Plates are to be formed by rolling and may be hot or cold finished. Bars and sections may be formed by extrusion, rolling or drawing.

1.2.3 All melts are to be suitably degassed prior to casting such that the aim hydrogen content is less than 0,2 ml per 100 g.

1.3 Quality of materials

1.3.1 Materials are to be free from surface or internal defects of such a nature as would be harmful in service.

1.3.2 The manufacturer is to verify the integrity of pressure welds of closed extrusion profiles in accordance with 1.10.

Table 8.1.1 Underthickness tolerances for rolled products for marine construction

Nominal thickness range, mm	Underthickness tolerance for nominal width range, mm		
	≤1500	>1500 ≤2000	>2000 ≤3500
≥3,0 <4,0	0,10	0,15	0,15
≥4,0 <8,0	0,20	0,20	0,25
≥8,0 <12	0,25	0,25	0,25
≥12 <20	0,35	0,40	0,50
≥20 <50	0,45	0,50	0,65

1.4 Dimensional tolerances

1.4.1 Underthickness tolerances for rolled products for marine construction are given in Table 8.1.1.

1.4.2 Underthickness tolerances for extruded products are to comply with an acceptable National or International Standard.

1.4.3 There are to be no underthickness tolerances for materials for application in cryogenic process pressure vessels.

1.4.4 Dimensional tolerances other than permitted underthicknesses are to comply with an acceptable National or International Standard.

1.4.5 Verification of dimensions is the responsibility of the manufacturer. Acceptance by Surveyors of material which is later found to be defective does not absolve the manufacturer from this responsibility.

Table 8.1.2 Chemical composition, percentage

Element	5083	5383	5059	5086	5754	5456	6005–A (*see* Note 1)	6061 (*see* Note 1)	6082
Copper	0,10 max.	0,20 max.	0,25 max.	0,10 max.	0,10 max.	0,10 max.	0,30 max.	0,15—0,40	0,10 max.
Magnesium	4,0—4,9	4,0—5,2	5,0—6,0	3,5—4,5	2,6—3,6	4,7—5,5	0,40—0,70	0,80—1,20	0,60—1,20
Silicon	0,40 max.	0,25 max.	0,45 max.	0,40 max.	0,40 max.	0,25 max.	0,50—0,90	0,40—0,80	0,70—1,30
Iron	0,40 max.	0,25 max.	0,50 max.	0,50 max.	0,40 max.	0,40 max.	0,35 max.	0,70 max.	0,50 max.
Manganese	0,40—1,00	0,7—1,0	0,6—1,2	0,20—0,70	0,50 max. (*see* Note 2)	0,50—1,00	0,50 max. (*see* Note 3)	0,15 max.	0,40—1,00
Zinc	0,25 max.	0,40 max.	0,40—0,90	0,25 max.	0,20 max.	0,25 max.	0,20 max.	0,25 max.	0,20 max.
Chromium	0,05—0,25	0,25 max	0,25 max.	0,05—0,25	0,30 max. (*see* Note 2)	0,05—0,20	0,30 max. (*see* Note 3)	0,04—0,35	0,25 max.
Titanium	0,15 max.	0,15 max.	0,20 max.	0,15 max.	0,15 max.	0,20 max.	0,10 max.	0,15 max.	0,10 max.
Zirconium		0,20 max.	0,05—0,25						
Other elements: each	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.
total	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.

NOTES
1. These alloys are not normally acceptable for application in direct contact with sea-water.
2. Mn + Cr = 0,10 min., 0,60 max.
3. Mn + Cr = 0,12 min., 0,50 max.

1.5 Chemical composition

1.5.1 Samples for chemical analysis are to be taken representative of each cast, or the equivalent where a continuous melting process is involved.

1.5.2 The chemical composition of these samples is to comply with the requirements of Table 8.1.2.

1.6 Heat treatment

1.6.1 The Aluminium 5000 series alloys, capable of being strain hardened, are to be supplied in any of the following temper conditions:

- O annealed
- H111 annealed with slight strain hardening
- H112 strain hardened from working at elevated temperatures
- H116 strain hardened and with specified resistance to exfoliation corrosion for alloys where the magnesium content is 4 per cent or more
- H321 strain hardened and stabilised.

1.6.2 The H116 temper is specially developed for use in a marine environment.

1.6.3 The Aluminium 6000 series alloys, capable of being age hardened, are to be supplied in either of the following temper conditions:

- T5 hot worked and artificially aged
- T6 solution treated and artificially aged.

1.7 Test material

1.7.1 Materials of the same product form, (i.e., plates, sections or bars) and thickness and from a single cast or equivalent, are to be presented for test in batches of not more than 2 tonnes, with the exceptions of those given in 1.7.2, 1.7.3 and 1.7.4.

1.7.2 For single plates or coils weighing more than 2 tonnes, only one tensile specimen per plate or coil is to be taken.

1.7.3 A tensile test specimen is required from each plate to be used in the construction of cargo tanks, secondary barriers and process pressure vessels with design temperatures below –55°C.

1.7.4 Extrusions, bars and sections of less than 1 kg/m in nominal weight are to be tested in batches of 1 tonne. Where the nominal weight is greater than 5 kg/m, one tensile test is to be carried out for every three tonnes produced, or fractions thereof.

1.7.5 If the material is supplied in the heat treated condition, each batch is to be treated together in the same furnace or subjected to the same finishing treatment when a continuous furnace is used.

1.7.6 For plates over 300 mm in width, tensile test specimens are to be cut with their length transverse to the principal direction of rolling. For narrow plates and for sections and bars, the test specimens are to be cut in the longitudinal direction. Longitudinal tensile test specimens are accepted for the strain hardenable 5000 series alloys.

Table 8.1.3 Minimum mechanical properties for acceptance purposes of selected rolled aluminium alloy products

Alloy and temper condition, *see* Note 3	Thickness, *t*, mm	0,2% proof stress R_p, N/mm^2	Tensile strength R_m N/mm^2	Elongation 4*d*, %	Elongation on $5{,}65 \sqrt{S_o}$ 5*d*,%
5083-O	$3 \le t \le 50$ (*see* Note 2)	125	275–350	16	14
5083-H111	$3 \le t \le 50$	125	275–350	16	14
5083-H112	$3 \le t \le 50$	125	275	12	10
5083-H116	$3 \le t \le 50$	215	305	10	10
5083-H321	$3 \le t \le 50$	215–295	305–380	12	10
5086-O	$3 \le t \le 50$	100	240–305	16	14
5086-H111	$3 \le t \le 50$	100	240–305	16	14
5086-H112	$3 \le t \le 12{,}5$ $12{,}5 < t \le 50$	125 105	250 240	8 —	— 9
5086-H116	$3 \le t \le 50$	195	275	10 (*see* Note 1)	9
5059-O	$3 \le t \le 50$	160	330	24	24
5059-H111	$3 \le t \le 50$	160	330	24	24
5059-H116	$3 \le t \le 20$ $20 < t \le 50$	270 260	370 360	10 10	10 10
5059-H321	$3 \le t \le 20$ $20 < t \le 50$	270 260	370 360	10 10	10 10
5383-O	$3 \le t \le 50$	145	290	17	17
5383-H111	$3 \le t \le 50$	145	290	17	17
5754-H111	$3 \le t \le 50$	80	190–240	18	17
5383-H116	$3 \le t \le 50$	220	305	10	10
5383-H321	$3 \le t \le 50$	220	305	10	10
5456-O	$3 \le t \le 6{,}3$ $6{,}3 \le t \le 50$	130–205 125–205	290–365 285–360	16 16	— 14
5456-H116	$3 \le t \le 30$ $30 < t \le 40$ $40 < t \le 50$	230 215 200	315 305 285	10 — —	10 10 10
5456-H321	$3 \le t \le 12{,}5$ $12{,}5 \le t \le 40$ $40 \le t \le 50$	230–315 215–305 200–295	315–405 305–385 285–370	12 — —	— 10 10
5754-O	$3 \le t \le 50$	80	190–240	18	17

NOTES
1. 8% for thickness up to and including 6,3 mm.
2. For application to liquefied natural gas carriers or liquefied natural gas tankers where thicknesses are in excess of 50 mm, the mechanical properties given in this table are, in general, to be complied with.
3. The mechanical properties for the O and H111 tempers are the same for all alloys shown in this Table. However, they are separated in this Table as they are made using different manufacturing processes.

Table 8.1.4 Minimum mechanical properties for acceptance purposes of selected extruded aluminium alloy products

Alloy and temper condition, *see* Note 2	Thickness, t, mm	0,2% proof stress R_p, N/mm^2	Tensile strength R_m N/mm^2	Elongation 4d, %	Elongation on $5{,}65\sqrt{S_o}$ 5d,%
5083-O	$3 \le t \le 50$	110	270–350	14	12
5083-H111	$3 \le t \le 50$	165	275	12	10
5083-H112	$3 \le t \le 50$	110	270	12	10
5086-O	$3 \le t \le 50$	95	240–315	14	12
5086-H111	$3 \le t \le 50$	145	250	12	10
5086-H112	$3 \le t \le 50$	95	240	12	10
5059-H112	$3 \le t \le 50$	200	330	10	10
5383-O	$3 \le t \le 50$	145	290	17	17
5383-H111	$3 \le t \le 50$	145	290	17	17
5383-H112	$3 \le t \le 50$	190	310	13	13
6005A-T5	$3 \le t \le 50$	215	260	9	8
6005A-T6	$3 \le t \le 10$ $10 < t \le 50$	215 200	260 250	8 8	6 6
6061-T6	$3 \le t \le 50$	240	260	10	8
6082-T5	$3 \le t \le 50$	230	270	8	6
6082-T6	$3 \le t \le 5$ $5 < t \le 50$	250 260	290 310	6 10	— 8

NOTES
1. The values are applicable for longitudinal and transverse tensile test specimens as well.
2. The mechanical properties for the O and H111 tempers are the same for all alloys shown in this Table. However, they are separated in this Table as they are made using different manufacturing processes.

1.7.7 Longitudinal tensile test specimens from a plate are to be taken at 1/3 width from the longitudinal edge. Longitudinal tensile test specimens taken from extruded sections should be taken in the range from 1/3 to 1/2 of the distance from the edge to the centre of the thickest region of the section.

1.8 Mechanical tests

1.8.1 At least one tensile test specimen is to be prepared from each batch of material submitted for acceptance.

1.8.2 Tensile test specimens are to be machined to the dimensions given in Fig. 2.2.3 in Chapter 2. Alternatively, machined proportional test specimens of circular cross-section in accordance with Fig. 2.2.2 in Chapter 2 may be used provided that the diameter is not less than 10 mm. Round bars may be tested in full section, or test specimens may be machined in accordance with the dimensions given in Fig. 2.2.2 in Chapter 2.

1.8.3 The results of all tensile tests are to comply with the values given in Tables 8.1.3 and 8.1.4, as applicable.

1.9 Corrosion tests

1.9.1 Rolled 5000 series alloys of type 5083, 5383, 5059, 5456 and 5086 in the H116 and H321 tempers intended for use in marine hull construction or in marine applications with frequent direct contact with seawater are to be corrosion tested with respect to exfoliation and intergranular corrosion resistance.

1.9.2 The manufacturer is to establish the relationship between microstructure and resistance to corrosion when the above alloys are approved. A reference photomicrograph taken at 500x under the conditions specified in ASTM B928 Section 9.4.1, is to be prepared for each of the alloy-tempers and thickness ranges relevant. The reference photographs are to be taken from samples which have exhibited no evidence of exfoliation corrosion and a pitting rating of PB or better, when subjected to the test described in ASTM G66 (ASSET).The samples are also to have exhibited resistance to

intergranular corrosion at a mass loss no greater than 15 mg/cm^2, when subjected to the test described in ASTM G67 (NAMLT). Upon satisfactory establishment of the relationship between microstructure and resistance to corrosion, the master photomicrographs and the results of the corrosion tests are to be approved by LR. Production practices are not to be changed after approval of the reference micrographs.

1.9.3 For batch acceptance of 5000 series alloys in the H116 and H321 tempers, metallographic examination of one sample selected from mid width at one end of a coil or random sheet or plate is to be carried out. The microstructure of the sample is to be compared to the reference photomicrograph of acceptable material in the presence of the Surveyor. A longitudinal section perpendicular to the rolled surface is to be prepared for metallographic examination, under the conditions specified in ASTM B928 Section 9.6.1. If the microstructure shows evidence of continuous grain boundary network of aluminium-magnesium precipitate in excess of the reference photomicrographs of acceptable material, the batch is either to be rejected or tested for exfoliation corrosion resistance and intergranular corrosion resistance subject to the agreement of the Surveyor. The corrosion tests are to be in accordance with ASTM G66 and G67 or equivalent standards. Acceptance criteria are that the sample shall exhibit no evidence of exfoliation corrosion and a pitting rating of PB or better when test subjected to ASTM G66 (ASSET) test, and the sample is to exhibit resistance to intergranular corrosion at a mass loss no greater than 15 mg/cm^2 when subjected to ASTM G67 (NAMLT) test. If the results from testing satisfy the acceptance criteria stated in 1.9.2, the batch is accepted, otherwise it is to be rejected.

1.9.4 As an alternative to metallographic examination, each batch may be tested for exfoliation corrosion resistance and intergranular corrosion resistance, in accordance with ASTM G66 and G67 under the conditions specified in ASTM B298, or equivalent standards. If this alternative is used, then the results of the test must satisfy the acceptance criteria stated in 1.9.2.

1.9.5 Tempers that are corrosion tested in accordance with 1.9.3 are to be marked ‘M’ after the temper condition, e.g., 5083 H321 M.

1.10 Pressure weld tests

1.10.1 The integrity of pressure welds of closed profile extrusions is to be verified by examination of macrosections or drift expansion tests.

1.10.2 Every closed profile extrusion is to be sampled, except where the closed profile extrusions are equal to or shorter than 6,0 m long, in which case a batch is to comprise five profiles. Every sample is to be tested at both ends after final heat treatment.

1.10.3 Where verification is by examination of macrosections, no indication of lack of fusion is permitted.

1.10.4 Where verification of fusion at pressure welds of closed profile extrusions is by drift expansion test, testing is to be generally in accordance with Ch 2,4.3. The minimum included angle of the mandrel is to be 60°, and the minimum specimen length, 50 mm. For acceptance, there is to be no failure by a clean split along the weld line.

1.11 Visual and non-destructive examination

1.11.1 Surface inspection and verification of dimensions are the responsibility of the manufacturer, and acceptance by the Surveyors of material later found to be defective shall not absolve the manufacturer from this responsibility.

1.11.2 In general, the non-destructive examination of materials is not required for acceptance purposes. Manufacturers are expected, however, to employ suitable methods of non-destructive examination for the general maintenance of quality standards.

1.11.3 For applications where the non-destructive examination of materials is considered to be necessary, the extent of this examination, together with appropriate acceptance standards, are to be agreed between the purchaser, manufacturer and Surveyor.

1.12 Rectification of defects

1.12.1 Slight surface imperfections may be removed by mechanical means, provided that the prior agreement of the Surveyor is obtained, that the work is carried out to his satisfaction and that the final dimensions are acceptable. The repair of defects by welding is not allowed.

1.13 Identification

1.13.1 The manufacturer is to adopt a system of identification which will ensure that all finished material in a batch presented for test is of the same nominal chemical composition.

1.13.2 Products are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:

(a) Manufacturer’s name or trade mark.
(b) Alloy grade and temper condition.
(c) Identification mark which will enable the full history of the item to be traced.
(d) The stamp of the LR brand, ℞.

1.14 Certification of materials

1.14.1 A manufacturer’s certificate validated by LR is to be issued, *see* Ch 1,3.1.

1.14.2 Each test certificate is to include the following particulars:

(a) Purchaser's name and order number.
(b) Contract number.
(c) Address to which material is to be despatched.
(d) Description and dimensions.
(e) Alloy grade and temper condition.
(f) Identification mark which will enable the full history of the item to be traced.
(g) Chemical composition.
(h) Mechanical test results (not required on shipping statement).
(j) Details of temper condition and heat treatment, where applicable.
(k) Corrosion test results (as applicable).

1.14.3 Where the alloy is not produced at the works at which it is wrought, a certificate is to be supplied by the manufacturer of the alloy stating the cast number and chemical composition. The works at which the alloy was produced must be approved by LR.

■ *Section 2* Aluminium alloy rivets

2.1 Scope

2.1.1 Provision is made in this Section for aluminium alloy rivets intended for use in the construction of marine structures.

2.1.2 They are to be manufactured and tested in accordance with the appropriate requirements of Section 1 and those detailed in this Section.

2.2 Chemical composition

2.2.1 The chemical composition of bars used for the manufacture of rivets is to comply with the requirements of Table 8.2.1.

Table 8.2.1 Chemical composition, percentage

Element	5154A	6082
Copper	0,10 max.	0,10 max.
Magnesium	3,1 – 3,9	0,6 – 1,2
Silicon	0,50 max.	0,7 – 1,3
Iron	0,50 max.	0,50 max.
Manganese	0,1 – 0,5	0,4 – 1,0
Zinc	0,20 max.	0,20 max.
Chromium	0,25 max.	0,25 max.
Titanium	0,20 max.	0,10 max.
Other elements: each	0,05 max.	0,05 max.
total	0,15 max.	0,15 max.
Aluminium	Remainder	Remainder

2.3 Heat treatment

2.3.1 Rivets are to be supplied in the following condition:

5154A – annealed
6082 – solution treated.

2.4 Test material

2.4.1 Bars intended for the manufacture of rivets are to be presented for test in batches of not more than 250 kg. The material in each batch is to be the same diameter and nominal chemical composition.

2.4.2 At least one test sample is to be selected from each batch and, prior to testing, is to be heat treated in full cross-section and in a manner simulating the heat treatment applied to the finished rivets.

2.5 Mechanical tests

2.5.1 At least one tensile and one dump test specimen are to be prepared from each test sample.

2.5.2 The tensile test specimen may be either a suitable length of bar tested in full cross-section or a specimen machined to the dimensions given in Fig. 2.2.2 in Chapter 2.

2.5.3 The dump test specimen is to consist of a section cut from the bar with the ends perpendicular to the axis. The length of this section is to be equal to the diameter of the bar.

2.5.4 The results of tensile tests are to comply with the appropriate requirements of Table 8.2.2.

Table 8.2.2 Mechanical properties for acceptance purposes

Mechanical properties	5154A	6082
0,2% proof stress N/mm^2 min.	90	120
Tensile strength N/mm^2 min.	220	190
Elongation on $5{,}65\sqrt{S_o}$ % min.	18	16

2.5.5 The dump test is to be carried out at ambient temperature and is to consist of compressing the specimen until the diameter is increased to 1,6 times the original diameter. After compression, the specimen is to be free from cracks.

2.6 Tests from manufactured rivets

2.6.1 At least three samples are to be selected from each consignment of manufactured rivets. Dump tests as detailed in 2.5 are to be carried out on each sample.

2.7 Identification

2.7.1 Each package of manufactured rivets is to be identified with attached labels giving the following details:
(a) Manufacturer's name or trade mark.
(b) Alloy grade.
(c) Rivet size.

2.8 Certification of materials

2.8.1 A manufacturer's certificate is to be issued (*see* Ch 1,3.1) and for each consignment of manufactured rivets is to include the following particulars:
(a) Purchaser's name and order number.
(b) Description and dimensions.
(c) Specification.

■ *Section 3*
Aluminium alloy castings

3.1 Scope

3.1.1 Provision is made in this Section for aluminium alloy castings intended for use in the construction of ships, ships for liquid chemicals and other marine structures and liquefied gas piping systems where the design temperature is not lower than minus 165°C. These materials should not be used for piping systems outside cargo tanks except for short lengths of pipes attached to the cargo tanks in which case fire-resisting insulation should be provided.

3.1.2 Castings are to be manufactured and tested in accordance with Chapters 1 and 2 and also with the requirements of this Section.

3.1.3 As an alternative to 3.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

3.2 Manufacture

3.2.1 Castings are to be manufactured at foundries approved by LR.

3.3 Quality of castings

3.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

3.4 Chemical composition

3.4.1 The chemical composition of a sample from each cast is to comply with the requirements given in Table 8.3.1. Suitable grain refining elements may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

Table 8.3.1 Chemical composition, percentage

Alloy / Element		Al–Mg 3	Al–Si 12	Al–Si 10 Mg	Al–Si 7 High purity
Copper		0,1 max.	0,1 max.	0,1 max.	0,1 max.
Magnesium		2,5—4,5	0,1 max.	0,15—0,4	0,25—0,45
Silicon		0,5 max.	11,0—13,5	9,0—11,0	6,5—7,5
Iron		0,5 max.	0,7 max.	0,6 max.	0,2 max.
Manganese		0,6 max.	0,5 max.	0,6 max.	0,1 max.
Zinc		0,2 max.	0,1 max.	0,1 max.	0,1 max.
Chromium		0,1 max.	—	—	—
Titanium		0,2 max.	0,2 max.	0,2 max.	0,2 max.
Others	each	0,05 max.	0,05 max.	0,05 max.	0,05 max.
	Total	0,15 max.	0,15 max.	0,15 max.	0,15 max.
Aluminium		Remainder	Remainder	Remainder	Remainder

3.4.2 Where it is proposed to use alloys not specified in Table 8.3.1, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

3.4.3 When a cast is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional checks as required by the Surveyor.

3.5 Heat treatment

3.5.1 Castings are to be supplied in the following conditions:

Grade Al-Mg 3	–	as-manufactured
Grade Al-Si 12	–	as-manufactured
Grade Al-Si 10 Mg	–	as-manufactured or solution heat treated and precipitation hardened
Grade Al-Si 7 Mg (high purity)	–	solution heat treated and precipitation hardened.

3.6 Mechanical tests

3.6.1 At least one tensile specimen is to be tested from each cast and, where heat treatment is involved, for each heat treatment batch from each cast. Where continuous melting is employed, 500 kg of fettled castings may be regarded as a cast.

3.6.2 The test samples are to be separately cast in moulds made from the same type of material as used for the castings. These moulds should conform to National Standards.

3.6.3 The method and procedures for the identification of the test specimens, and the castings they represent, are to be agreed with the Surveyor. The identification marks are to be maintained during the preparation of test specimens.

3.6.4 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent prior to testing.

3.6.5 The results of all tensile tests are to comply with the appropriate requirements given in Table 8.3.2 and/or Table 8.3.3.

Table 8.3.2 Minimum mechanical properties for acceptance purposes of sand-cast and investment cast reference test pieces

Alloy	Temper (*see* Note)	Tensile strength N/mm^2	Elongation %
Al–Mg 3	M	150	5
Al–Si 12	M	150	3
Al–Si 10 Mg	M	150	2
Al–Si 10 Mg	TF	220	1
Al–Si 7 Mg	TF	230	5

NOTE
M refers to as cast condition.
TF refers to solution heat treated and precipitation hardened condition.

Table 8.3.3 Minimum mechanical properties for acceptance purposes of chill-cast reference test piece

Alloy	Temper (*see* Note)	Tensile strength N/mm^2	Elongation %
Al–Mg 3	M	150	5
Al–Si 12	M	170	3
Al–Si 10 Mg	M	170	3
Al–Si 10 Mg	TF	240	1,5
Al–Si 7 Mg	TF	250	5

NOTE
M refers to as cast condition.
TF refers to solution heat treated and precipitation hardened condition.

3.6.6 Where the results of a test do not comply with the requirements, the re-test procedure detailed in Ch 2,1.4 is to be applied. Where castings are to be used in the heat treated condition, the re-test sample must have been heat treated together with the castings it represents.

3.7 Visual examination

3.7.1 All castings are to be cleaned and adequately prepared for inspection.

3.7.2 The accuracy and verification of dimensions are the responsibility of the manufacturer, unless otherwise agreed.

3.7.3 Before acceptance, all castings are to be presented to the Surveyor for visual examination.

3.8 Rectification of defective castings

3.8.1 At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

3.8.2 Where appropriate, repair by welding may be accepted at the discretion of the Surveyor. Such repair is to be made in accordance with an approved procedure.

3.9 Pressure testing

3.9.1 Where required by the relevant Rules, castings are to be pressure tested before final acceptance. Unless otherwise agreed, these tests are to be carried out in the presence and to the satisfaction of the Surveyor.

3.10 Identification

3.10.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast and the Surveyor is to be given full facilities for tracing the casting when required.

3.10.2 All castings which have been tested and inspected with satisfactory results are to be clearly marked with the following details:

(a) Identification number, cast number or other markings which will enable the full history of the casting to be traced.
(b) LR or Lloyd's Register and the abbreviated name of LR's local office.
(c) Personal stamp of the Surveyor responsible for the inspection.
(d) Test pressure where applicable.
(e) Date of final inspection.

3.10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

3.11 Certification of materials

3.11.1 A LR certificate is to be issued (*see* Ch 1,3.1) giving the following particulars for each casting or batch of castings which have been accepted:

(a) Purchaser's name and order number.
(b) Description of castings and alloy type.
(c) Identification number.
(d) Ingot or cast analysis.
(e) General details of heat treatment, where applicable.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

Section 4
Aluminium/steel transition joints

4.1 Scope

4.1.1 Provision is made in this Section for explosion bonded composite aluminium/steel transition joints used for connecting aluminium structures to steel plating.

4.1.2 Each individual application is to be separately approved as required by the relevant Rules dealing with design and construction.

4.2 Manufacture

4.2.1 Transition joints are to be manufactured by an approved producer in accordance with an approved specification which is to include the maximum temperature allowable at the interface during welding.

4.2.2 The aluminium material is to comply with the requirements of Section 1 and the steel is to be of an appropriate grade complying with the requirements of Ch 3,2.

4.2.3 Alternative materials which comply with International, National or proprietary specifications may be accepted provided that they give reasonable equivalence to the requirements of 4.2.2 or are approved for a specific application.

4.2.4 Intermediate layers between the aluminium and steel may be used, in which case the material of any such layer is to be specified by the manufacturer and is to be recorded in the approval certificate. Any such intermediate layer is then to be used in all production transition joints.

4.3 Visual and non-destructive examination

4.3.1 Each composite plate is to be subjected to 100 per cent visual and ultrasonic examination in accordance with a relevant National Standard to determine the extent of any unbonded areas. Unbonded areas are unacceptable and any such area plus 25 mm of surrounding sound material is to be discarded.

4.4 Mechanical tests

4.4.1 Two shear test specimens and two tensile test specimens are to be taken from each end of each composite plate for tests to be made on the bond strength. One shear and one tensile test specimen from each end are to be tested at ambient temperature after heating to the maximum allowable interface temperature, *see* 4.2.1; the other two specimens are to be tested without heat treatment.

4.4.2 Shear tests may be made on a specimen as shown in Fig. 8.4.1 or an appropriate equivalent. Tensile tests may be made across the interface by welding extension pieces to each surface or by the ram method shown in Fig. 8.4.2 or by an appropriate alternative method.

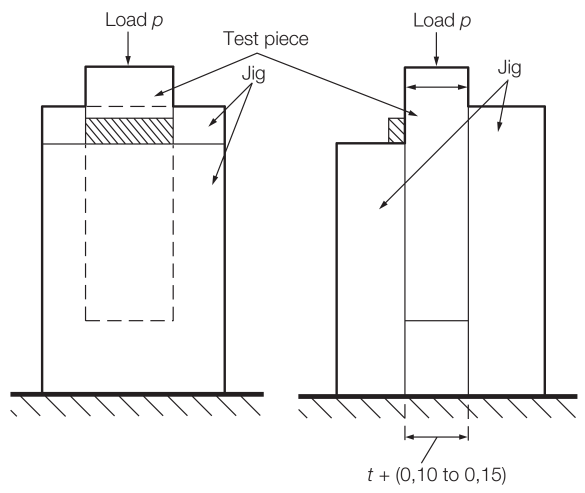


Fig. 8.4.1 Specimen and procedure for shear tests

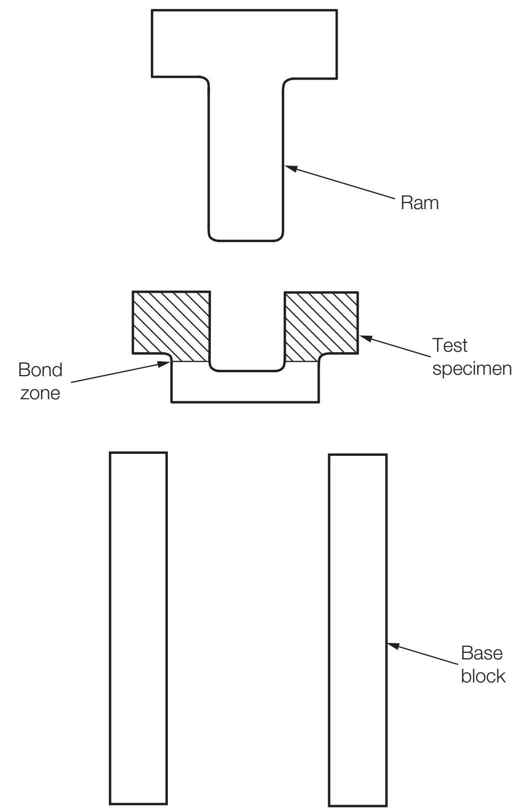


Fig. 8.4.2 Ram tensile test

4.4.3 The shear and tensile strengths of all the test specimens are to comply with the requirements of the manufacturing specification.

4.4.4 If either the shear or tensile strength of the bond is less than the specified minimum but not less than 70 per cent of the specified minimum, two additional shear and two tensile test specimens from each end of the composite plate are to be tested and, in addition, bend tests as described in 4.4.6 and Table 8.4.1 are to be made.

Table 8.4.1 Bend tests on explosion bonded aluminium/steel composites

Type of test	Minimum bend, degrees	Diameter of former
Aluminium in tension	90	3*T*
Steel in tension	90	3*T*
Side bend	90	6*T*
NOTE *T* is the total thickness of the composite plate.		

4.4.5 If either the shear or tensile strength of the bond is less than 70 per cent of the specified minimum the cause is to be investigated. After evaluation of the results of this investigation, LR will consider the extent of composite plate which is to be rejected.

4.4.6 Bend tests, when required, are to be made under the following conditions, as listed in Table 8.4.1:
(a) The aluminium plate is in tension.
(b) The steel plate is in tension.
(c) A side bend is applied.

4.5 Identification

4.5.1 Each acceptable transition strip is to be clearly marked with the following particulars:
(a) LR or Lloyd's Register and the abbreviated name of LR's local office.
(b) Manufacturer's name or trade mark.
(c) Identification mark for the grade of aluminium.
(d) Identification mark for the grade of steel.
The particulars are to be stamped on the aluminium surface at one end of the strip.

4.6 Certification of materials

4.6.1 A manufacturer's certificate validated by LR is to be issued (*see* Ch 1,3.1) and as a minimum is to include the following particulars:
(a) Purchaser's name and order number.
(b) The contract number for which the material is intended, if known.
(c) Address to which the material is dispatched.
(d) Description and dimensions of the material.
(e) Specifications or grades of both the aluminium alloy and the steel and any intermediate layer.
(f) Cast numbers of the steel and aluminium plates.
(g) Identification number of the composite plate.
(h) Mechanical test results (not required on shipping statement).

■ *Section 1* Castings for propellers

1.1 Scope

1.1.1 This Section gives the requirements for copper alloy castings for one-piece propellers and separately cast blades and bosses for fixed pitch and controllable pitch propellers (CPP). These include contra-rotating propellers and propulsors fitted to podded drives and azimuth units.

1.1.2 These castings are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and the specific requirements of this Section.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application.

1.1.4 The appropriate requirements of this Section may also be applied to the repair and inspection of propellers which have been damaged during service.

1.1.5 Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.2 Manufacture

1.2.1 All castings are to be manufactured at foundries approved by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 The pouring is to be carried out into dried moulds using degassed liquid metal. The pouring is to avoid turbulent flow. Special devices and/or procedures are to be used to prevent slag flowing into the mould.

1.3 Quality of castings

1.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

1.3.2 The removal and repair of defects are dealt with in 1.9 and 1.10.

1.4 Chemical composition

1.4.1 The chemical compositions of samples from each melt are to comply with the manufacturing specification approved by LR and also with the overall limits given in Table 9.1.1. In addition to carrying out chemical analysis for the elements given in the Table, it is expected that manufacturers will ensure that any harmful residual elements are within acceptable limits.

1.4.2 The use of alloys whose chemical compositions are different from those detailed in Table 9.1.1 will be given special consideration by LR.

1.4.3 The manufacturer is to maintain records of all chemical analyses, which are to be made available to the Surveyor so that he can satisfy himself that the chemical composition of each casting is within the specified limits.

Table 9.1.1 Chemical composition of propeller and propeller blade castings

Alloy designation	Chemical composition of ladle samples %							
	Cu	Sn	Zn	Pb	Ni	Fe	Al	Mn
Grade Cu 1 Manganese bronze (high tensile brass)	52–62	1,5 max.	35–40	0,5 max.	1,0 max.	0,5–2,5	0,5–3,0	0,5–4,0
Grade Cu 2 Ni-manganese bronze (high tensile brass)	50–57	0,1–1,5	33–38	0,5 max.	3,0–8,0	0,5–2,5	0,5–2,0	1,0–4,0
Grade Cu 3 Ni-aluminium bronze	77–82	0,1 max.	1,0 max.	0,03 max.	3,0–6,0 (*see* Note)	2,0–6,0 (*see* Note)	7,0–11,0	0,5–4,0
Grade Cu 4 Mn–aluminium bronze	70–80	1,0 max.	6,0 max.	0,05 max.	1,5–3,0	2,0–5,0	6,5–9,0	8,0–20,0

NOTE
For Naval ships, the nickel content is to be higher than the iron content.

1.4.4 When a melt is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional checks as required by the Surveyor. If any foundry returns are added to the melts, the ingot manufacturer's chemical analyses are to be supplemented by frequent checks as required by the Surveyor.

1.4.5 For alloys Grade Cu 1 and Cu 2, the zinc equivalent shall not exceed 45 per cent, and is to be calculated using the following formula:

$$\text{zinc equivalent \%} = 100 - \frac{100 \times \%\text{Cu}}{100 + A}$$

where A is the algebraic sum of the following:

1 x % Sn
5 x % Al
–0,5 x % Mn
–0,1 x % Fe
–2,3 x % Ni

1.4.6 Samples for metallographic examination are to be prepared from the ends of test bars cast from every melt of Grade Cu 1 and Cu 2 alloys. The proportion of alpha-phase determined from the average of at least five counts is to be not less than 25 per cent.

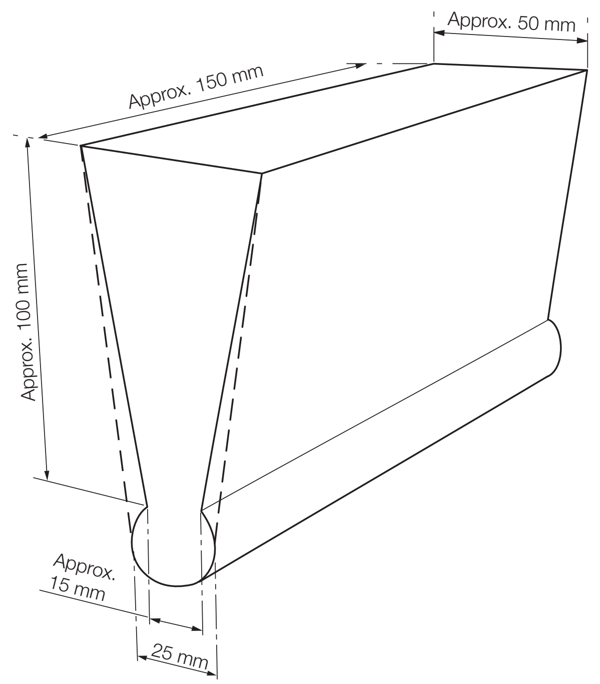


Fig. 9.1.1 Keel block type test sample

1.5 Heat treatment

1.5.1 At the option of the manufacturer, castings may be supplied in the 'as-cast' or heat treated condition. However, if heat treatment is to be applied, full details are to be included in the manufacturing specification.

1.5.2 If any welds are made in the propeller casting, stress relief heat treatment is required in order to minimise the residual stresses. Requirements concerning such heat treatment are given in 1.10.

1.6 Test material

1.6.1 Test samples are to be cast separately from each melt used for the manufacture of propeller or propeller blade castings.

1.6.2 The test samples are to be of the keel block type, generally in accordance with the dimensions given in Fig. 9.1.1 and are to be cast in moulds made from the same type of material as used for the castings.

1.6.3 The method and procedures for the identification of the test specimens, and the castings they represent, are to be agreed with the Surveyor. The identification marks are to be transferred and maintained during the preparation of test specimens.

1.6.4 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent.

1.7 Mechanical tests

1.7.1 At least one tensile test specimen representative of each cast is to be prepared. The dimensions of this test specimen are to be in accordance with Fig. 2.2.1 in Chapter 2.

1.7.2 The results of all tensile tests are to comply with the requirements given in Table 9.1.2.

1.7.3 The mechanical properties of alloys whose chemical compositions do not accord with Table 9.1.1 are to comply with a manufacturing specification approved by LR.

Table 9.1.2 Mechanical properties for acceptance purposes: propeller and propeller blade castings

Alloy designation	0,2% proof stress N/mm^2 minimum	Tensile strength N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum
Grade Cu 1 Manganese bronze (high tensile brass)	175	440	20
Grade Cu 2 Ni-manganese bronze (high tensile brass)	175	440	20
Grade Cu 3 Ni-aluminium bronze	245	590	16
Grade Cu 4 Mn-aluminium bronze	275	630	18

1.8 Inspection and non-destructive examination

1.8.1 Propeller castings should be visually inspected at all stages of manufacture. The manufacturer is to draw any significant imperfections to the attention of the Surveyor. Such imperfections are to be verified in accordance with 1.9.

1.8.2 All finished castings are to be subjected to a comprehensive visual examination by the Surveyor, including internal surfaces such as the bore and bolt holes. Where unauthorised weld repairs are suspected by the Surveyor, the area is to be etched (e.g., by iron chloride) for the purpose of confirmation.

1.8.3 For the purpose of these requirements, the blades of propellers, including CPP blades, are divided into three severity Zones A, B and C as shown in Fig. 9.1.2 and detailed in 1.8.4 for blades having skew angles of 25° or less and 1.8.5 for blades having skew angles of greater than 25°.

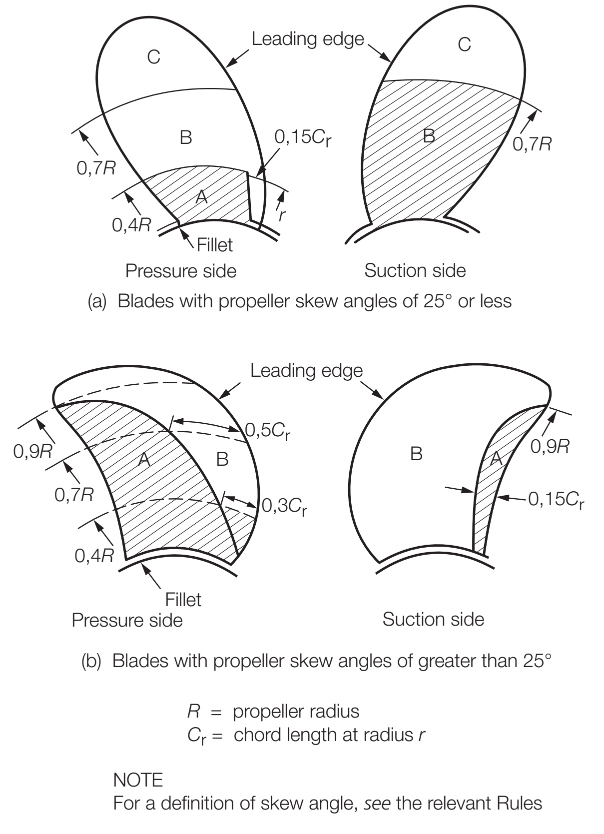


Fig. 9.1.2 Severity zones in all propeller blades

1.8.4 **Skew angles of 25° or less:**

- Zone A is the area on the pressure side of the blade from and including the root fillet to 0,4*R* and bounded by the trailing edge and by a line at a distance 0,15 times the chord length from the leading edge.
- Zone B includes the areas inside 0,7*R* on both sides of the blade, excluding Zone A.
- Zone C includes the areas outside 0,7*R* on both sides of the blade.

1.8.5 **Skew angles of greater than 25°**:

- Zone A is the area on the pressure side of the blade bounded by, and including, the root fillet and a line running from the junction of the leading edge with the root fillet to the trailing edge at 0,9*R* and passing through the mid-point of the chord at 0,7*R* and a point situated at 0,3 of the chord length from the leading edge at 0,4*R*.
- Zone A also includes the area along the trailing edge on the suction side of the blade from the root to 0,9*R* and with its inner boundary at 0,15 of the chord length tapering to meet the trailing edge at 0,9*R*.
- Zone B constitutes the whole of the remainder of the blade surfaces.

1.8.6 In propeller blades with continuously loaded tips (CLT), the whole of the tip plate and the adjoining blade to a distance of 100 mm is to be regarded as severity Zone B, *see* Fig. 9.1.3. For propellers with diameters less than 2 m, the width of this zone may be reduced to one tenth of the propeller radius.

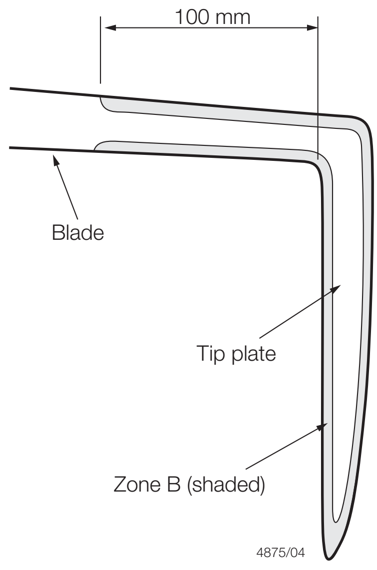
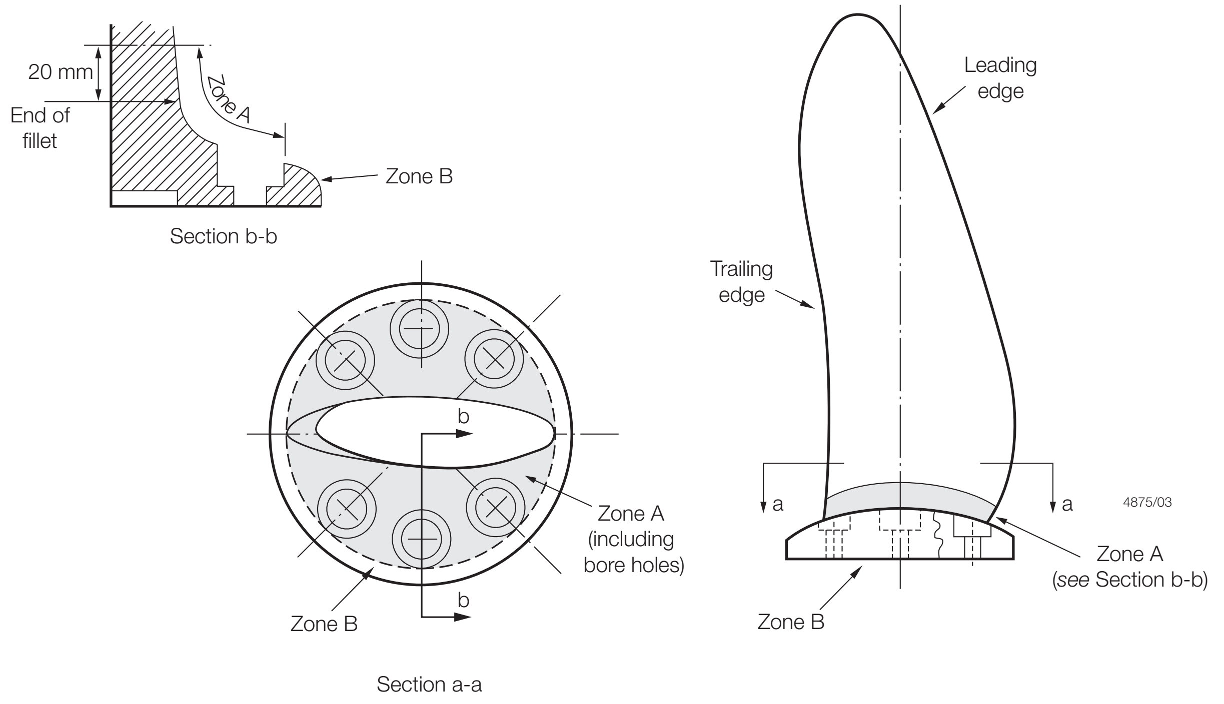


Fig. 9.1.3
Severity Zone B at Continuously loaded blade tip

1.8.7 In addition, the palm of a CPP blade is divided into severity Zones A and B as shown in Fig. 9.1.4.

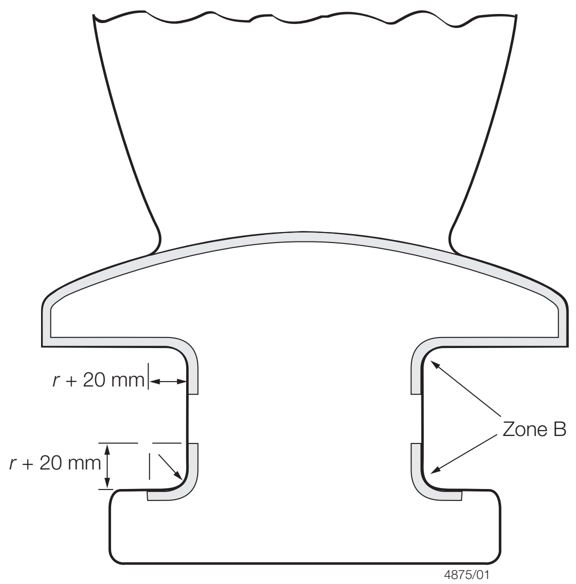
1.8.8 If a CPP blade has an integrally cast journal, the fillets of the journal and the adjoining material up to a distance of 20 mm from the fillet run-outs are to be regarded as Zone B, as indicated in Fig. 9.1.5. The remainder of the surface of the journal may be regarded as Zone C.

1.8.9 Hubs of controllable pitch propellers are to contain a Zone A region at each blade port as shown in Fig. 9.1.6. The remainder may be regarded as Zone C.



The surfaces of blades are to be divided into severity zones in accordance with Fig. 9.1.2

Fig. 9.1.4 Severity zones for controllable pitch propeller blades



The surfaces of the journal which are not shaded are to be regarded as severity Zone C

Fig. 9.1.5
Severity zones in integrally cast CPP blade journals

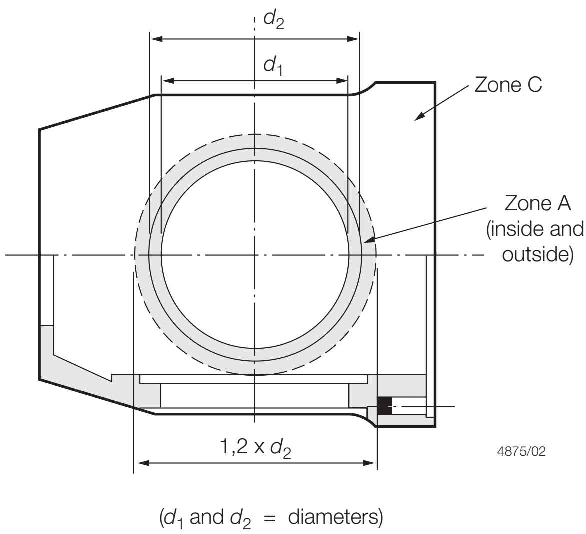


Fig. 9.1.6
Severity zones for controllable pitch propeller hub

1.8.10 On completion of machining and grinding, the whole surface of each casting is to be subjected to a dye penetrant inspection in accordance with a procedure acceptable to LR.

1.8.11 All dye penetrant inspections on Zone A areas in the finished condition are to be made in the presence of the Surveyor.

1.8.12 Dye penetrant inspections on Zones B and C are to be performed by the manufacturer and may be witnessed at the Surveyor's request.

1.8.13 The surface to be inspected shall be divided into reference areas of 100 cm^2. The indications detected shall, with respect to their size and number, not exceed the values given in Table 9.1.3. The area shall be taken in the most unfavourable location relative to the indication being evaluated.

1.8.14 Indications exceeding the acceptance standard in Table 9.1.3 shall be repaired in accordance with 1.9.

1.8.15 All defects requiring repair by welding in new propeller castings are to be recorded on sketches showing their locations and dimensions. Copies of these sketches are to be presented to the Surveyor prior to repair.

1.8.16 Where repairs have been made either by grinding or welding, the repaired areas are to be subjected to dye penetrant inspection in the presence of the Surveyor, regardless of their location.

1.8.17 Where no welds have to be made on a casting, the manufacturer is to provide the Surveyor with a statement that this is the case.

1.8.18 Where it is suspected that a casting contains internal defects, radiographic and/or ultrasonic examination may be required by the Surveyor. The acceptance criteria are to be agreed between the manufacturer and LR in accordance with a recognised standard. The standard ASTM E272-99 (Severity Level 2) or equivalent is to be the radiographic acceptance standard for copper alloy castings. Ultrasonic testing of Cu 1 and Cu 2 is not considered in these Rules. For Cu 3 and Cu 4, ultrasonic inspection of defects may be possible and is to comply with the requirements for steel castings.

1.8.19 The measurement of dimensional accuracy is the responsibility of the manufacturer but the report on dimensional inspection is to be presented to the Surveyor who may require checks to be made and to witness such checks.

1.8.20 Static balancing is to be carried out on all propellers in accordance with the approved plan. Dynamic balancing is necessary for propellers running above 500 rpm.

1.9 Rectification of defective castings

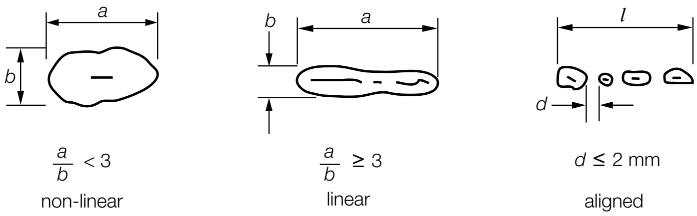
1.9.1 The rectification of defective propeller and propeller blade castings is to be carried out in accordance with the requirements given in 1.9.2 to 1.9.12.

1.9.2 The rectification of small indications within the acceptance standard of Table 9.1.3 is not generally required except where they occur in closely spaced groups.

Table 9.1.3 Allowable number and size of dye penetrant indications in a reference area of 100 cm^2 (*see* Note 1)

Severity Zones	Max. total number of indications	Type of indications (*see* Note 2)	Max. number of each type (*see* Notes 3 and 4)	Max. acceptable value for 'a' or '*l*' of indications (mm) (*see* Note 2)
A	7	Non-linear Linear Aligned	5 2 2	4 3 3
B	14	Non-linear Linear Aligned	10 4 4	6 6 6
C	20	Non-linear Linear Aligned	14 6 6	8 6 6

NOTES
1. The reference area is defined as an area of 0,1 m^2, which may be square or rectangular, with the major dimension not exceeding 250 mm. The area shall be taken in the most unfavourable location relative to the indication being evaluated.
2. Non-linear, linear and aligned indications are defined as follows:



3. Only indications that have any dimension greater than 1,5 mm shall be considered relevant.
4. Single non-linear indications less than 2 mm in Zone A and less than 3 mm in other zones may be disregarded.
5. The total number of non-linear indications may be increased to the maximum total number, or part thereof, represented by the absence of linear or aligned indications.

1.9.3 Where, in the surface of the end face or bore of a propeller boss, local pores are present which do not themselves adversely affect the strength of the casting, they may be filled with a suitable plastic filler after the appropriate preparation of the defective area. The foundry is to maintain records and details of all castings which have been so rectified.

1.9.4 Where unacceptable defects are found in a casting, they are to be removed by mechanical means, and the surfaces of the resulting depressions are subsequently to be ground smooth. Complete elimination of the defects is to be proved by adequate dye penetrant inspection.

1.9.5 Shallow grooves or depressions resulting from the removal of defects may, at the discretion of the Surveyor, be accepted provided that they will cause no appreciable reduction in the strength of the castings and that they are suitably blended by grinding.

1.9.6 Welded repairs are to be undertaken only when they are considered to be necessary and approved by the Surveyor. In general, welds having an area less than 5 cm^2 are to be avoided.

1.9.7 All weld repairs are to be carried out in accordance with qualified procedures by suitably qualified welders, and are to be completed to the satisfaction of the Surveyor. Records are to be made available to the Surveyor.

1.9.8 Welding is generally not permitted in Zone A and will only be allowed after special consideration.

1.9.9 Prior approval by the Surveyor is required for any welds in Zone B. Complete details of the repair procedure are to be submitted for each case.

1.9.10 Repair by welding is allowed in Zone C provided that there is compliance with 1.9.6 and 1.9.7.

1.9.11 The maximum area of any single repair and the maximum total area of repair in any one zone or region are given in Table 9.1.4.

1.9.12 Where it is proposed to exceed the areas given in Table 9.1.4, the nature and extent of the repair work are to be approved by the Surveyor before commencement of the repair.

1.10 Weld repair procedure

1.10.1 Welding is to be carried out under cover in positions free from draughts and adverse weather conditions.

1.10.2 The manufacturer is to submit a detailed welding procedure specification covering the weld preparation, welding parameters, filler metal, preheating, post-weld heat treatment and inspection procedures.

1.10.3 Before welding is started, Welding Procedure Qualification tests are to be carried out and witnessed by the Surveyor. Each welder is to be qualified to carry out the proposed welding using the same process, consumable and position which are to be used for the repair.

Table 9.1.4 Permissible rectification of new propellers by welding

Severity zone or region	Maximum individual area of repair	Maximum total area of repairs
Zone A	Weld repairs not generally permitted	
Zone B	Defects that are not deeper than (*t*/40) mm or 2 mm, whichever is greater, below the minimum local thickness are to be removed by grinding. Defects which are deeper than allowable for removal by grinding may be repaired by welding.	
Zone C	60 cm^2 or 0,6% x *S* whichever is the greater	200 cm^2 or 2% x *S*, whichever is the greater in combined Zones B and C but not more than 100 cm^2 or 0,8% x *S*, whichever is the greater, in Zone B on the pressure side
Other regions (*see* Note)	17 cm^2 or 1,5% area of the region whichever is the greater	50 cm^2 or 5% x area of the region whichever is the greater

where t = minimum local thickness in mm

S = area of one side of a blade = $0{,}79 \dfrac{D^2 B}{N}$

D = finished diameter of propeller
B = developed area ratio
N = number of blades

NOTE
Other regions include:
(a) the bore;
(b) the forward and aft faces of the boss;
(c) the outer surface of the boss to the start of the blade root fillets;
(d) the inner face of a CPP blade palm;
(e) all surfaces of CPP nose cones;
(f) the surfaces of integral journals to CPP blades other than the fillets.

1.10.4 Defects to be repaired by welding are to be removed completely by mechanical means (e.g. grinding, chipping or milling). Removal of defects in accordance with the requirements for Zone A is to be demonstrated by dye penetrant inspection in the presence of the Surveyor. The excavation is to be prepared in a manner which will allow good fusion and is to be clean and dry.

1.10.5 Metal arc welding with the electrodes or filler wire used in the procedure tests is to be used for all types of repairs. Welds should preferably be made in the downhand (flat) position. Where necessary, suitable preheat is to be applied before welding, and the preheat temperature is to be maintained until welding is completed.

1.10.6 When flux coated electrodes are used they are to be dried immediately before use, in accordance with the manufacturer's instructions.

1.10.7 All slag, undercuts and other defects are to be removed before the subsequent run is deposited.

1.10.8 With the exception given in 1.10.9, all weld repairs in areas of solid propellers exposed to sea-water, and all repairs to separately cast blades, are to be stress relief heat treated.

1.10.9 Stress relief heat treatment is not mandatory after welding Grade Cu 3 castings in Zone C unless a welding consumable susceptible to stress corrosion (e.g. complying with the composition range of Grade Cu 4) is used. All welds in Zones A and B however, must be stress relieved by heat treatment, regardless of alloy.

1.10.10 Propeller and propeller blades are to be stress relieved within the following temperature ranges:

alloy Grades Cu 1 and Cu 2	350°C to 550°C
alloy Grade Cu 3	450°C to 500°C
alloy Grade Cu 4	450°C to 600°C

Soaking times are to be in accordance with Table 9.1.5, and subsequent cooling from the soaking temperature is to be suitably controlled to minimise residual stresses and is not to exceed 50°C per hour until the temperature is below 200°C. Care should be taken to avoid heating castings in the Grade Cu 3 alloy at temperatures between 300° and 400°C for prolonged periods.

Table 9.1.5 Soaking times for stress relief heat treatment of copper alloy propellers

Stress relief temperature °C (*see* Notes)	Alloy Grade Cu1 and Cu2		Alloy Grade Cu3 and Cu4	
	Hours per 25 mm of thickness	Maximum recommended total time hours	Hours per 25 mm of thickness	Maximum recommended total time hours
350	5	15	—	—
400	1	5	—	—
450	1/2	2	5	15
500	1/4	1	1	5
550	1/4	1/2	1/2	2
600	—	—	1/4	1

NOTES
1. Treatment at 550°C is not applicable to alloy Grade Cu3.
2. Treatment at 600°C is only applicable to alloy Grade Cu4.

1.10.11 Stress relief heat treatment is to be carried out, where possible, in furnaces having suitable atmosphere and temperature control. Sufficient thermocouples are to be attached to the casting to measure the temperature at positions of extremes of thickness.

1.10.12 As an alternative to 1.10.11, local stress relief heat treatment may be accepted, provided that the Surveyor is satisfied that the technique will be effective and that adequate precautions are taken to prevent the introduction of detrimental temperature gradients. Where local stress relief heat treatment is approved, adequate temperature control is to be provided. The area of the propeller or blade adjacent to the repair is to be suitably monitored and insulated to ensure that the required temperature is maintained and that temperature gradients are moderate. Care should be taken to select the shape of an area to be heat treated which will minimise residual stresses.

1.10.13 On completion, welds are to be ground smooth for visual examination and dye penetrant inspection. Where a propeller or propeller blade is to be stress relief heat treated, a visual examination is to be made before heat treatment, and both visual and dye penetrant examinations are to be made after the stress relief heat treatment. Irrespective of location, all weld repairs are to be assessed according to Zone A in Table 9.1.3.

1.10.14 The foundry is to maintain full records detailing the weld procedure, heat treatment and extent and location on drawings of repairs made to each casting. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

1.10.15 LR reserves the right to restrict the amount of repair work accepted from a manufacturer when it appears that repetitive defects are the result of improper foundry techniques or practices.

1.11 Identification

1.11.1 Castings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all castings which have been accepted:

(a) Identification mark which will enable the full history of the item to be traced.
(b) Alloy grade.
(c) LR or Lloyd's Register and the abbreviated name of LR local office.
(d) Personal stamp of Surveyor responsible for the final inspection.
(e) Date of final inspection.
(f) Skew angle, if in excess of 25°. *See* Pt 5, Ch 7,1 of the Rules for Ships for the definition of skew angle.

1.12 Certification of materials

1.12.1 A LR certificate is to be issued for each propeller, *see* Ch 1,3.1.

1.12.2 The manufacturer is to provide the Surveyor with the following particulars for each casting:

(a) Purchaser's name and order number.
(b) Description of casting.
(c) Alloy designation and/or trade name.
(d) Identification number of casting.
(e) Cast identification number if different from (d).
(f) Details of heat treatment, where applicable.
(g) Skew angle, if in excess of 25°. *See* the relevant Rules for the definition of skew angle.
(h) Final weight of casting.
(j) Results of non-destructive tests and details of test procedures.
(k) Proportion of alpha-structure for Cu1 and Cu2 alloys.
(l) Results of mechanical tests.
(m) A sketch showing the location and extent of welding repairs (if any).

Section 2 Castings for valves, liners and bushes

2.1 Scope

2.1.1 This Section makes provision for copper alloy castings for valves, liners, bushes and other fittings intended for use in the construction of ships, other marine structures, machinery and pressure piping systems.

2.1.2 Castings are to be manufactured and tested in accordance with Chapters 1 and 2, and also with the requirements given in this Section.

2.1.3 As an alternative to 2.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

2.2 Manufacture

2.2.1 Castings are to be manufactured at foundries approved by LR.

2.3 Quality of castings

2.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

2.4 Chemical composition

2.4.1 The chemical composition is to comply with the requirements of a National or International Standard and, where appropriate, with the limits for the principal elements of the preferred alloys listed in Tables 9.2.1 and 9.2.2.

2.4.2 With the exception given in 2.4.3, chemical analysis is required on each cast.

2.4.3 Where a cast is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional check tests as requested by the Surveyor. The frequency of these check tests should, as a minimum, be one in every ten casts. If one of these check analyses fails to comply with the specification, checks are to be made on the previous and subsequent melts. If one or both of these further analyses is unsatisfactory, chemical analysis is to be carried out on all further melts until the Surveyor is satisfied that a return can be made to the use of occasional check tests.

2.5 Heat treatment

2.5.1 Where required by the specification, castings may be supplied in either the 'as-cast' or heat treated condition.

2.5.2 Where castings are supplied in a heat treated condition, the test samples are to be heat treated with the castings they represent prior to the preparation of the tensile test specimens.

2.6 Test material

2.6.1 Test material sufficient for the tests specified in 2.6.4 and for possible re-test purposes is to be provided for each cast of material.

2.6.2 The test material is to be separately cast into moulds made of the same material as that used for the castings they represent.

2.6.3 For the alloys listed in Table 9.2.1, sand cast test bars are generally to be in accordance with Fig. 9.2.1.

2.6.4 For the alloys listed in Table 9.2.2, keel block type test samples are to be in accordance with Fig. 9.1.1.

Table 9.2.1 Chemical compositions of long freezing range alloys: principal elements only

Alloy type	Designation	Chemical composition						Typical applications
		Cu	Sn	Zn	Pb	Ni	P	
Phosphor bronze	Cu Sn11P Cu Sn12	87,0 – 89,5 85,0 – 88,5	10,0 – 11,5 11,0 – 13,0	0,05 max. 0,50 max.	0,25 max. 0,7 max.	0,10 max. 2,0 max.	0,5 – 1,0 0,60 max.	Liners, bushes, valves and fittings
Gunmetal	Cu Sn10 Zn2	Remainder	9,5 – 10,5	1,75 – 2,75	1,5 max.	1,0 max.	—	Liners, valves and fittings
Leaded gunmetal	Cu Sn5 Zn5 Pb5 Cu Sn7 Zn2 Pb3 Cu Sn7 Zn4 Pb7 Cu Sn6 Zn4 Pb2	83,0 – 87,0 85,0 – 89,0 81,0 – 85,0 86,0 – 90,0	4,0 – 6,0 6,0 – 8,0 6,0 – 8,0 5,5 – 6,5	4,0 – 6,0 1,5 – 3,0 2,0 – 5,0 3,0 – 5,0	4,0 – 6,0 2,5 – 3,5 5,0 – 8,0 1,0 – 2,0	2,0 max. 2,0 max. 2,0 max. 1,0 max.	0,10 max. 0,10 max. 0,10 max. 0,05 max.	Bushes, valves and fittings
Leaded bronze	Cu Sn10 Pb10 Cu Sn5 Pb9 Cu Sn7 Pb15 Cu Sn5 Pb20	78,0 – 82,0 80,0 – 87,0 74,0 – 80,0 70,0 – 78,0	9,0 – 11,0 4,0 – 6,0 6,0 – 8,0 4,0– 6,0	2,0 max. 2,0 max. 2,0 max. 2,0 max.	8,0 – 11,0 8,0 – 10,0 13,0 – 17,0 18,0 – 23,0	2,0 max. 2,0 max. 0,5 – 2,0 0,5 – 2,5	0,10 max. 0,10 max. 0,10 max. 0,10 max.	Bushes

Table 9.2.2 Chemical compositions of short freezing range alloys: principal elements only

Alloy type	Designation	Chemical composition								Typical applications
		Cu	Ni	Fe	Mn	Cr	Nb	Si	Al	
Copper 30% nickel	Cu Ni30 Fe1 Mn1 Cu Ni30 Fe1 Mn1 Nb Si Cu Ni30 Cr2 Fe Mn Si (*see* Note 1)	64,5 min. Remainder Remainder	29,0–31,0 29,0–31,0 29,0–32,0	0,5–1,5 0,5–1,5 0,5–1,0	0,6–1,2 0,6–1,2 0,5–1,0	– – 1,5–2,0	– 0,5–1,0 –	0,1 max. 0,3–0,7 0,15–0,50	– – –	Flanges, valves and fittings
Copper 10% nickel	Cu Ni10 Fe1 Mn1	84,5 min.	9,0–11,0	1,0–1,8	1,0–1,5	–	1,0 max.	0,10 max.	–	Flanges, valves and fittings
Aluminium bronze	Cu Al10 Fe5 Ni5 Cu Al11 Fe6 Ni6	76,0–83,0 72,0–78,0	4,0–6,0 (*see* Note 2) 4,0–7,5 (*see* Note 2)	4,0–5,5 (*see* Note 2) 4,0–7,0 (*see* Note 2)	3,0 max. 2,5 max.	– –	– –	0,1 max. 0,1 max.	8,5–10,5 10,0–12,0	Bushes, valves and fittings

NOTES
1. Normally alloy Cu Ni30 Cr2 Fe Mn Si contains 0,1 to 0,25% titanium and 0,05 to 0,15% zirconium.
2. For Naval ships, the nickel content is to be higher than the iron content.

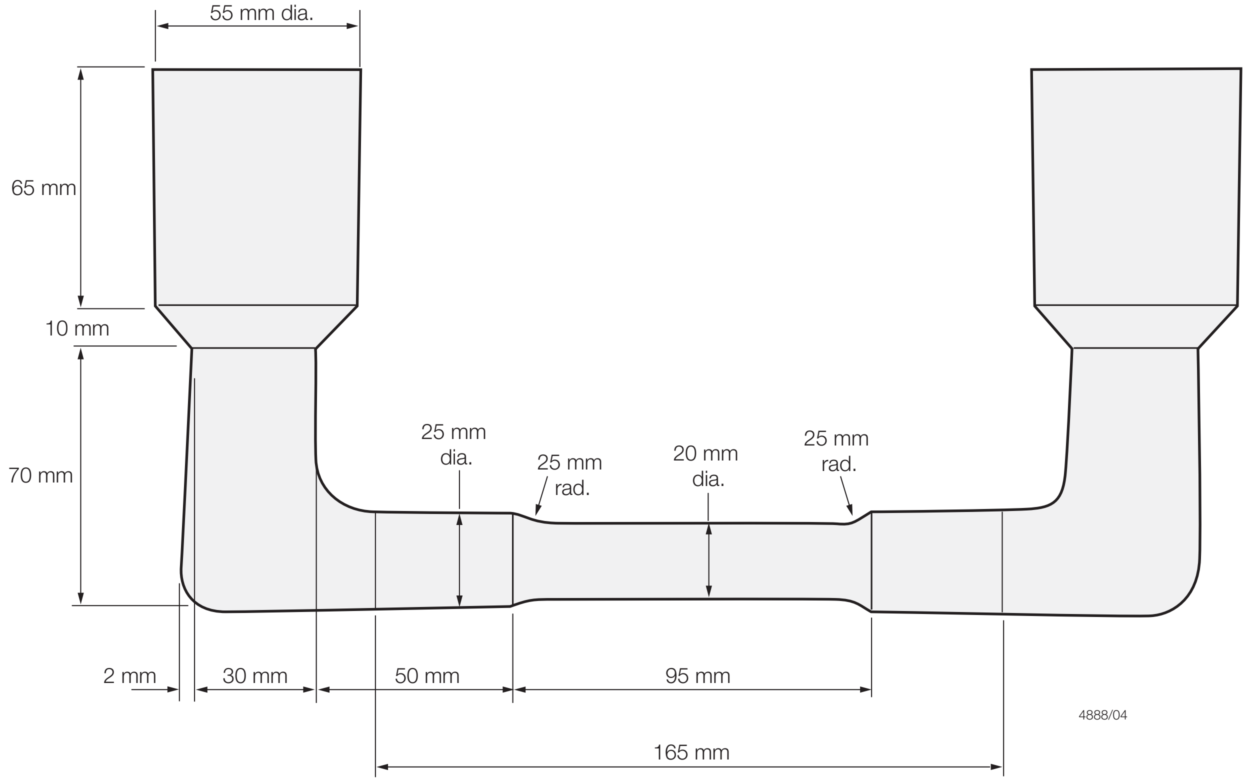


Fig. 9.2.1 Sand cast test bars for long freezing range alloys

2.6.5 If it is proposed to use any other form of test bar, this is to be agreed in advance with the Surveyor.

2.6.6 As an alternative, for liners and bushes, the test material may be taken from the ends of the castings.

2.7 Mechanical tests

2.7.1 A tensile test specimen is to be prepared from each test sample. The dimensions of the specimens are to comply with Fig. 2.2.1 or Fig. 2.2.2 in Chapter 2.

2.7.2 The results of all tests are to comply with the appropriate requirements given in Tables 9.2.3 and 9.2.4.

Table 9.2.3 Mechanical properties of long freezing range alloys for acceptance purposes

Alloy type	Designation	0,2% proof stress N/mm^2 minimum (*See* Note 1)		Tensile strength N/mm^2 minimum		Elongation on 5,65 $\sqrt{S_o}$ % minimum	
		Sand	Centrifugal	Sand	Centrifugal	Sand	Centrifugal
Phosphor bronze	Cu Sn11 P Cu Sn12	130 140	170 150	250 260	330 280	5 7	4 5
Gunmetal	Cu Sn10 Zn2	130	130	270	250	13	5
Leaded gunmetal	Cu Sn5 Zn5 Pb5 Cu Sn7 Zn2 Pb3 Cu Sn7 Zn4 Pb7 Cu Sn6 Zn4 Pb2	90 130 120 110	110 130 120 110	200 230 230 220	250 260 260 240	13 14 15 15	13 12 12 12
Leaded bronze	Cu Sn10 Pb10 Cu Sn5 Pb9 Cu Sn7 Pb15 Cu Sn5 Pb20	80 60 80 70	110 90 90 80	180 160 170 150	220 200 200 170	8 7 8 5	6 6 7 6

NOTES
1. The 0,2% proof stress values are given for information purposes only and, unless otherwise agreed, are not required to be verified by test.
2. Castings may be supplied in the chill cast condition in which case the mechanical properties requirements are to be in accordance with a specification agreed by LR.

Table 9.2.4 Mechanical properties of short freezing range alloys for acceptance purposes

Alloy type	Designation	0,2% proof stress N/mm^2 minimum (*See* Note 1)		Tensile strength N/mm^2 minimum		Elongation on 5,65 $\sqrt{S_o}$ % minimum	
		Sand	Centrifugal	Sand	Centrifugal	Sand	Centrifugal
Copper 30% Nickel	Cu Ni30 Fe1 Mn1 Cu Ni30 Fe1 Mn1 Nb Si Cu Ni30 Cr2 Fe Mn Si	120 230 250	120 — —	340 440 440	340 — —	18 18 18	18 — —
Copper 10% Nickel	Cu Ni10 Fe1 Mn1	120	100	280	280	20	25
Aluminium Bronze	Cu Al10 Fe5 Ni5 Cu Al11 Fe6 Ni6	250 320	280 380	600 680	650 750	13 5	13 5

2.8 Inspection

2.8.1 All castings are to be cleaned and adequately prepared for inspection. Before acceptance, all castings are to be presented to the Surveyor for visual examination. This is to include the examination of internal surfaces, where applicable.

2.8.2 For valves and other pressure components, dye penetrant inspection is required and the Surveyor is to witness the tests. Unless otherwise agreed, the acceptance criteria to be applied are to meet the requirements of Table 9.2.5, or equivalent.

2.8.3 The accuracy and verification of dimensions are the responsibility of the manufacturer. However, the report on dimensional inspection is to be presented to the Surveyor who may request to witness confirmatory measurements.

Table 9.2.5 Visual and surface NDE acceptance criteria for valves and pressure components

Defect type	Acceptance criteria for visual and surface NDE, *see* Note
Linear indications	Not permitted
Porosity	Individual pores are not to exceed 3 mm diameter bleed out, and the sum of the diameters of all indications in an area of 70 x 70 mm is not to exceed 24 mm^2

NOTE
Inspection is to be in accordance with a procedure acceptable to LR.

2.9 Rectification of defective castings

2.9.1 Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by impregnation with a suitable plastic filler provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

2.9.2 Proposals to repair a defective casting by welding are to be submitted to the Surveyor before this work is commenced. The Surveyor is to be satisfied that the number, position and size of the defects are such that the castings can be efficiently repaired.

2.9.3 Where approval is given for the repair by welding, complete elimination of the defects is to be proven by adequate non-destructive testing.

2.9.4 All welding is to be in accordance with an approved and qualified weld procedure and carried out by a qualified welder.

2.9.5 A statement and/or sketch detailing the extent and position of all weld repairs is to be prepared by the manufacturer as a permanent record. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

2.9.6 The alloys listed in Table 9.2.1 are not satisfactory for repair by welding which is generally not permitted. Weld repairs may, however, be considered in special circumstances provided that a suitable procedure, with proof of previous satisfactory repairs is submitted to the Surveyor.

2.9.7 The welding during manufacture of liners is not permitted in any alloy containing more than 0,5 per cent lead.

2.10 Pressure testing

2.10.1 Where required by the relevant Rules, castings are to be pressure tested before final acceptance. Unless otherwise agreed, these tests are to be carried out in the presence of the Surveyors and are to be to their satisfaction.

2.11 Identification

2.11.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities for tracing the casting when required.

2.11.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following details:

(a) Identification number, cast number or other markings which will enable the full history of the casting to be traced.
(b) LR or Lloyd’s Register and the abbreviated name of LR’s local office.
(c) Personal stamp of the Surveyor responsible for inspection.
(d) Test pressure, where applicable.
(e) Date of final inspection.

2.11.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

2.12 Certification of materials

2.12.1 A LR certificate is to be issued, *see* Ch 1,3.1.

2.12.2 The manufacturer is to provide the Surveyor with the following particulars for each casting or batch of castings which has been accepted:

(a) Purchaser’s name and order number.
(b) Description of castings and alloy grade.
(c) Identification number.
(d) Ingot or cast analysis.
(e) Full details of heat treatment, where applicable.
(f) Mechanical test results.
(g) Test pressure, where applicable.

2.12.3 In addition to 2.12.2, the manufacturer is to provide, where applicable, a statement and/or sketch detailing the extent and position of all weld repairs made to each casting.

■ *Section 3* **Tubes**

3.1 Scope

3.1.1 Provision is made in this Section for seamless copper and copper alloy tubes intended for use in condensers, heat exchangers and pressure piping systems.

3.1.2 Tubes for Class I and II pressure systems (as defined in the relevant Rules) are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2 and the requirements of this Section.

3.1.3 As an alternative to 3.1.2, tubes which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

3.1.4 Tubes for Class III pressure systems are to be manufactured and tested in accordance with the requirements of a National or International Standard recognised by LR. The manufacturer’s test certificate will be acceptable and is to be provided for each batch of material.

3.2 Manufacture

3.2.1 Tubes for Class I and II pressure systems are to be manufactured at a works approved by LR for the grade of material being supplied.

3.2.2 Tubes for Class III pressure systems are not required to be manufactured at a works approved by LR.

3.3 Quality

3.3.1 Tubes are to be clean and free from surface and internal defects and residues from manufacturing operations.

3.3.2 The tubes are to be supplied in smooth, round, straight lengths and the manufacturer is to guarantee freedom from deleterious films in the bore. The ends are to be cut clean and square with the axis of the tube and are to be de-burred.

3.4 Dimensional tolerances

3.4.1 The tolerances on the wall thickness and diameter of the tubes are to be in accordance with a National or International Standard recognised by LR.

3.4.2 The measurement of dimensional accuracy and compliance with the specification are the responsibility of the manufacturer, but the reports are to be made available to the LR Surveyors, who may require checks to be made in their presence.

3.5 Chemical composition

3.5.1 The chemical composition is to comply with the requirements of a National or International Standard recognised by LR and comply with the base limits for the principal elements given in Table 9.3.1.

3.6 Heat treatment

3.6.1 Copper-phosphorus and aluminium brass tubes are to be supplied in the annealed condition. Aluminium brass tubes may additionally be required to be given a suitable stress relieving heat treatment when subjected to a cold straightening operation after annealing.

3.6.2 Tubes in the copper-nickel iron alloys are to be supplied in a solution heat treated condition to ensure that no iron rich phases are present.

3.7 Mechanical tests

3.7.1 Tubes are to be presented for test in batches of 300 lengths. A batch is to consist of tubes of the same size, manufactured from the same material grade.

3.7.2 At least one length is to be selected at random from each batch and subjected to the following tests:
(a) Tensile test.
(b) Flattening test.
(c) Drift expanding test.

3.7.3 The procedures for mechanical tests and the dimensions of the test specimens are to be in accordance with Chapter 2.

3.7.4 The flattening test is to be continued until the interior surfaces of the tube meet.

3.7.5 For the drift expanding test, the mandrel is to have an included angle of 45°.

3.7.6 The results of all mechanical tests are to comply with the appropriate requirements given in Table 9.3.2.

3.7.7 At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of materials. In such cases, these may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

Table 9.3.1 Chemical composition of principal elements only

Designation	Chemical composition %								
	Cu	As	P	Fe	Pb	Ni	Al	Mn	Zn
Copper-phosphorus deoxidised–non-arsenical	99,85 min.	–	0,013–0,050	—	—	—	—	—	—
Copper-phosphorus deoxidised–arsenical	99,2 min.	0,30–0,50	0,013–0,050		—	—	—	—	—
Aluminium brass	76,0–79,0	0,02–0,06	—	0,06 max.	0,07 max.	—	1,8–2,5	—	Remainder
90/10 Copper-nickel-iron (*see* Note)	Remainder	—	—	1,0-2,0	—	9,0–11,0	—	0,5–1,0	—
70/30 Copper-nickel-iron (*see* Note)	Remainder	—	—	0,40–1,00	—	29,0–33,0	—	0,5–1,5	—

NOTE
Where the purchaser specifies that the product is intended for subsequent welding applications, the following limits will apply:

Zn	0,50% max.	S	0,02% max.
Pb	0,02% max.	C	0,05% max.
P	0,02% max.		

Table 9.3.2 Mechanical properties for acceptance purposes

Designation	0,2% proof stress N/mm^2 minimum	Tensile strength N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum	Drift expansion test % minimum	Grain size mm maximum (*see* Note)
Copper-phosphorus deoxidised–non-arsenical	65	220	40	40	—
Copper-phosphorus deoxidised–arsenical	65	220	40	40	—
Aluminium brass	125	320	40	30	0,045
90/10 Copper-nickel-iron	100	270	30	30	0,045
70/30 Copper-nickel-iron	120	360	30	30	0,045
NOTE When a maximum grain size is specified, the structure is to be completely re-crystallised. The manufacturer is to guarantee the grain size, but testing of each batch will not be required.					

3.8 Visual examination

3.8.1 All tubes are to be visually examined. The manufacturer is to provide adequate lighting conditions to enable an internal and external examination of the tubes to be carried out.

3.8.2 The inner and outer surfaces are to be clean and smooth but may have a superficial, dull iridescent film on both the inner and outer surfaces.

3.9 Hydraulic test

3.9.1 Each tube is to be subjected to a hydraulic test at the manufacturer's works.

3.9.2 The hydraulic test pressure is to be determined from the following formula, except that the maximum test pressure need not exceed 70 bar:

$$P = \frac{20st}{D}$$

where

P = test pressure, in bar
D = nominal outside diameter, in mm
t = nominal wall thickness, in mm
s = 40 for copper-phosphorus
60 for Al-brass and
90/10 copper nickel iron
75 for 70/30 copper nickel iron.

3.9.3 The test pressure is to be maintained for sufficient time to permit proof that the tubes do not weep, leak or undergo a permanent increase in diameter. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test will be accepted.

3.9.4 Where it is proposed to adopt a test pressure other than that determined in 3.10.2, the proposal will be subject to special consideration.

3.9.5 Subject to special approval, an automated eddy current test can be accepted in lieu of the hydraulic test. Discontinuous irregularities on the external and internal surfaces of the tubes are permitted if they are within the agreed dimensional tolerances, with the exception of cracks, which are not permitted.

3.10 Rectification of defects

3.10.1 The repair of defects by welding is not permitted.

3.11 Identification

3.11.1 Tubes are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:

(a) LR or Lloyd's Register.
(b) Manufacturer's name or trade mark.
(c) Grade of material or designation code.
(d) Identification number and/or initials which will enable the full history of the item to be traced.

3.11.2 Identification is to be by rubber stamp or stencils. Hard stamping is not permitted.

3.12 Certification of materials

3.12.1 A manufacturer's certificate validated by LR is to be issued (*see* Ch 1,3.1), giving the following particulars for each casting or batch of castings which has been accepted:

(a) Purchaser's name and order number.
(b) Specification or grade of material.
(c) Description and dimensions.
(d) Cast number and chemical composition.
(e) Mechanical test results.
(f) Results of stress corrosion cracking test, where applicable.
(g) Hydraulic test report.

■ *Section 1* Anchors

1.1 Scope

1.1.1 This Section makes provision for the manufacture and testing of anchors constructed from cast, forged and fabricated components.

1.1.2 This Section is applicable to the following types of anchor:
(a) Ordinary.
(b) High holding power (HHP).
(c) Super high holding power (SHHP).

1.1.3 In the context of this Section, the reference to swivels refers to those directly attached to the anchor shank in lieu of the conventional 'D' shackle. For other mooring equipment swivels, *see* 2.13.

1.2 Manufacture

1.2.1 All anchors are to be of an approved design.

1.3 Cast steel anchors

1.3.1 Cast steel anchor heads, shanks, shackles and swivels are to be manufactured and tested in accordance with the requirements of Ch 4,1 and Ch 4,2. The Special grade quality is to be used for anchor heads, shanks and shackles.

1.3.2 Special consideration will be given to the use of other grades of steel for the manufacture of swivels.

1.3.3 To confirm the quality of cast anchor components, the Surveyor is to witness drop and hammering tests.

1.3.4 When drop and hammering tests are required, they are to be carried out as follows:
(a) Each anchor, or the components of an anchor made from more than one piece, is to be dropped from a clear height of 4 m onto a steel slab laid on a solid foundation.
(b) Separately cast flukes, shanks and shackles are to be suspended horizontally from a clear height of 4 m before being dropped.
(c) Anchors cast in one piece are to be drop tested twice from a clear height of 4 m. For the first test, the shank and flukes are to be horizontal. For the second test, two steel blocks are to be placed on the slab, arranged so that the middle of each fluke makes contact with the blocks without the crown making contact with the slab, and the orientation of the anchor is to be vertical with the crown nearest the slab.
(d) If the slab is broken by the impact, the test is to be repeated on a new slab.

1.3.5 When hammering tests are required, they are to be carried out after the drop test on each anchor head and shank, which is slung clear of the ground, using a non-metallic sling, and hammered to check the soundness of the component. A hammer of at least 3 kg mass is to be used.

1.3.6 As part of the manufacturer's works approval, consideration may be given to carrying out drop tests in alternative locations to the manufacturer's when the facilities and location are not suitable.

1.3.7 Repair of fractures or unsoundness detected during the drop or hammering tests are not permitted and the component is to be rejected.

1.4 Forged steel anchors

1.4.1 Forged steel anchor pins, swivels, shanks and shackles are to be manufactured and tested in accordance with the requirements of Ch 5,1 and Ch 5,2 carbon and carbon-manganese steel for welded construction. Rolled steel bar may be used provided that the requirements of Ch 5,1.2.9 are met.

1.4.2 Special consideration will be given to other grades of steel for the manufacture of swivels.

1.5 Fabricated steel anchors

1.5.1 Where it is proposed to use plate material for fabricated steel anchors, it is to comply with the requirements of Ch 3,2 or Ch 3,3, and the proposed manufacturing procedure is to be submitted for approval.

1.5.2 Fabricated anchors are to be manufactured in accordance with Chapter 13.

1.5.3 Stress relief is to be carried out as required in the approved welding procedure.

1.6 Rectification

1.6.1 All rectification is to be agreed with the Surveyor.

1.6.2 Rectification of defective castings is to be carried out in accordance with Ch 4,1.9.

1.6.3 Rectification of defective forgings is to be carried out in accordance with Ch 5,1.9.

1.6.4 Rectification of defective fabricated anchors is to be carried out by suitably qualified welders within the parameters of the approved welding procedure used in construction.

1.6.5 Rectification of defective castings, forgings or fabricated anchors by welding is to be carried out using qualified weld procedures in accordance with Ch 12,1 and Ch 12,2, and in accordance with Ch 13,1 and Ch 13,2.

1.7 Super high holding power (SHHP) anchors

1.7.1 The impact test requirements for SHHP anchor shackles are to be in accordance with the requirements for Grade U3 in Table 10.2.1.

1.8 Assembly

1.8.1 Assembly and fitting is to be carried out in accordance with the approved design.

1.8.2 Securing of anchor pins, shackle pins or swivels by welding is to be carried out by suitably qualified welders in accordance with an approved welding procedure.

1.9 Proof test of anchors

1.9.1 Anchors having a mass of 75 kg or more inclusive of stock (56 kg in the case of high holding power anchors) are to be tested in the presence of the Surveyor at a proving establishment recognised by LR. A list of recognised proving establishments is published separately by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship or mobile offshore unit is to be registered.

1.9.2 The anchor is to be visually examined before application of the proof test load to ensure that it is free from cracks, notches, inclusions and other surface defects that would impair the performance of the product.

1.9.3 As required by 1.9.1, each anchor is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.1.1 for the appropriate mass of the anchor. The proof load is to be applied on the arm or on the palm at a spot which, measured from the extremity of the bill, is one-third of the distance between it and the centre of the crown. For stocked anchors, each arm is to be tested individually. For stockless anchors, both arms are to be tested at the same time, first on one side of the shank, then reversed and tested on the other.

Table 10.1.1 Proof load tests for anchors
(*see* Notes 1 and 2)

Mass of anchor (1.6.5) kg	Proof test load kN	Mass of anchor (1.6.5) kg	Proof test load kN	Mass of anchor (1.6.5) kg	Proof test load kN
50	23,2	2200	376,0	7800	861,0
55	25,2	2300	388,0	8000	877,0
60	27,1	2400	401,0	8200	892,0
65	28,9	2500	414,0	8400	908,0
70	30,7	2600	427,0	8600	922,0
75	32,4	2700	438,0	8800	936,0
80	33,9	2800	450,0	9000	949,0
90	36,3	2900	462,0	9200	961,0
100	39,1	3000	474,0	9400	975,0
120	44,3	3100	484,0	9600	987,0
140	49,0	3200	495,0	9800	998,0
160	53,3	3300	506,0	10 000	1010,0
180	57,4	3400	517,0	10 500	1040,0
200	61,3	3500	528,0	11 000	1070,0
225	65,8	3600	537,0	11 500	1090,0
250	70,4	3700	547,0	12 000	1110,0
275	74,9	3800	557,0	12 500	1130,0
300	79,5	3900	567,0	13 000	1160,0
325	84,1	4000	577,0	13 500	1180,0
350	88,8	4100	586,0	14 000	1210,0
375	93,4	4200	595,0	14 500	1230,0
400	97,9	4300	604,0	15 000	1260,0
425	103,0	4400	613,0	15 500	1280,0
450	107,0	4500	622,0	16 000	1300,0
475	112,0	4600	631,0	16 500	1330,0
500	116,0	4700	638,0	17 000	1360,0
550	125,0	4800	645,0	17 500	1390,0
600	132,0	4900	653,0	18 000	1410,0
650	140,0	5000	661,0	18 500	1440,0
700	149,0	5100	669,0	19 000	1470,0
750	158,0	5200	677,0	19 500	1490,0
800	166,0	5300	685,0	20 000	1520,0
850	175,0	5400	691,0	21 000	1570,0
900	182,0	5500	699,0	22 000	1620,0
950	191,0	5600	706,0	23 000	1670,0
1000	199,0	5700	713,0	24 000	1720,0
1050	208,0	5800	721,0	25 000	1770,0
1100	216,0	5900	728,0	26 000	1800,0
1150	224,0	6000	735,0	27 000	1850,0
1200	231,0	6100	740,0	28 000	1900,0
1250	239,0	6200	747,0	29 000	1940,0
1300	247,0	6300	754,0	30 000	1990,0
1350	255,0	6400	760,0	31 000	2030,0
1400	262,0	6500	767,0	32 000	2070,0
1450	270,0	6600	773,0	34 000	2160,0
1500	278,0	6700	779,0	36 000	2250,0
1600	292,0	6800	786,0	38 000	2330,0
1700	307,0	6900	794,0	40 000	2410,0
1800	321,0	7000	804,0	42 000	2490,0
1900	335,0	7200	818,0	44 000	2570,0
2000	349,0	7400	832,0	46 000	2650,0
2100	362,0	7600	845,0	48 000	2730,0

Proof loads for intermediate mass are to be determined by linear interpolation

NOTES

1. Where ordinary anchors have a mass exceeding 48 000 kg, the proof loads are to be taken as 2,059 (mass of anchor in kg)$^{2/3}$ kN.
2. Where high holding power anchors have a mass exceeding 36 000 kg, the proof loads are to be taken as 2,452 (actual mass of anchor in kg)$^{2/3}$ kN.

1.9.4 The general arrangements for the test are to be such that the complete anchor, including the shackle, shackle pins and any welded or bolted connections are included in the test. If a replacement shackle is needed which requires welding or heating for fitting, the combined anchor and shackle are to be proof load tested. If welding or heating is not involved in fitting, the shackle may be proof load tested separately from the anchor.

1.9.5 The mass to be used in Table 10.1.1 is:

(a) For stockless anchors, the total mass of the anchor.
(b) For stocked anchors, the mass of the anchor excluding the stock.
(c) For high holding power anchors, a nominal mass equal to 1,33 times the actual total mass of the anchor.
(d) For mooring anchors, including positional mooring anchors, a nominal mass equal to 1,33 times the actual total mass of the anchor, unless specifically agreed otherwise.
(e) For super high holding power anchors, a nominal mass equal to twice the actual total mass of the anchor.

1.9.6 For positional mooring anchors, the proof test loading is to be that required by 1.9.3 or 50 per cent of the minimum break strength of the intended anchor line, whichever is the greater.

1.9.7 The gauge length is to be measured with 10 per cent of the required load applied, before and after proof test. The two measurements shall differ by no more than 1 per cent. The gauge length is the distance between the tip of each fluke and a point on the shank adjacent to the shackle pin, *see* Fig. 10.1.1.

1.9.8 After proof testing, all accessible surfaces are to be visually inspected by the Surveyor.

1.9.9 Following proof testing, NDE is to be conducted as described in Table 10.1.2 for ordinary and HHP anchors and Table 10.1.3 for SHHP anchors.

1.9.10 Each casting is to be subjected to ultrasonic inspection in the region of runners and risers, or where excess material has been removed by thermal methods. This examination is to extend around the whole periphery of the casting and for a distance of t/3 beyond the area affected, where t is the maximum thickness. In addition, random areas are to be selected by the Surveyor and examined.

1.9.11 Acceptance criteria for castings are to be in accordance with Chapter 4.

1.9.12 Acceptance criteria for forgings are to be in accordance with Chapter 5.

1.9.13 Paint or anti-corrosive coatings are not to be applied until these inspections are completed to the satisfaction of the Surveyor.

Table 10.1.2 NDE requirements following proof testing for Ordinary and HHP anchors

Location	Method of NDE
Feeder heads, runners and risers of castings	Magnetic particle inspection and ultrasonic test, *see* Note 1
All welds	Magnetic particle inspection
Forged components	Not required
Fabrication welds	Magnetic particle inspection

NOTES
1. *See also* 1.9.10.
2. Penetrant testing is to be used in lieu of magnetic particle testing for stainless steel, aluminium and copper alloy anchors.

Table 10.1.3 NDE requirements following proof testing for SHHP anchors

Location	Method of NDE
Feeder heads, runners and risers of castings	Magnetic particle inspection and ultrasonic test, *see* Note 1
All surfaces of castings	Magnetic particle inspection
All welds	Magnetic particle inspection
Forged components	Not required
Fabrication welds	Magnetic particle inspection

NOTES
1. *See also* 1.9.10.
2. Additionally, all surfaces of all SHHP anchors are to be surface inspected by the magnetic particle or penetrant method as appropriate.
3. Penetrant is to be used in lieu of magnetic particle testing for stainless steel, aluminium and copper alloy anchors.

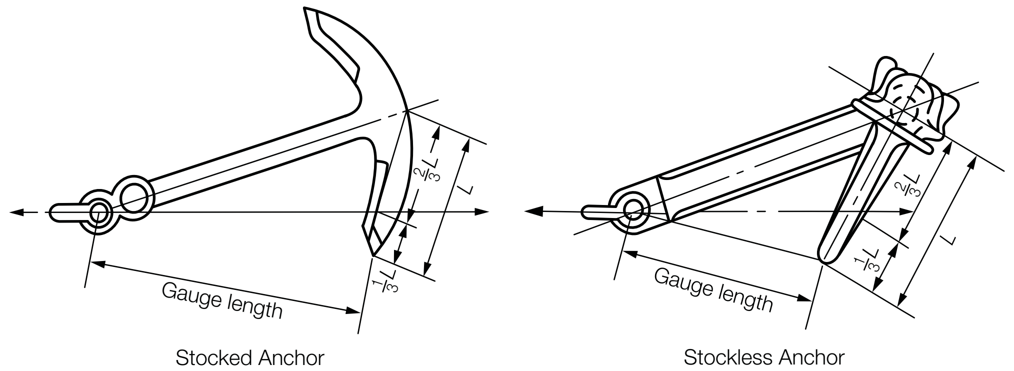


Fig. 10.1.1 Location of gauge length measurement during proof load

1.9.14 On completion of the proof testing, anchors made in more than one piece are to be examined for free movement of their heads over the complete range of rotation.

1.10 Clearances and tolerances

1.10.1 Where no fitting tolerances are specified on the approved plans the following assembly and fitting tolerance are to be applied.

1.10.2 The clearance either side of the shank within the shackle jaws and the shackle pin in the shank end hole is to be no more than 3 mm for small anchors up to 3 tonnes, 4 mm for anchors up to 5 tonnes, 6 mm for anchors up to 7 tonnes and is not to exceed 12 mm for larger anchors.

1.10.3 The shackle pin to hole tolerance is to be no more than 0,5 mm for pins up to 57 mm and 1,0 mm for pins of larger diameter and the eyes of the shackle are to be chamfered on the outside to ensure a good tightness when the pin is fitted. The shackle pin is to mate with the shackle such that it can be inserted with moderate hand pressure, allowing disassembly if required.

1.10.4 The trunnion pin is to fit within the chamber such that it will achieve the closest fit which can be carried out by hand. The pin is to be long enough to prevent horizontal movement. The gap is to be no more than 1 per cent of the chamber length.

1.10.5 The lateral movement of the shank is not to exceed 3 degrees from the centreline datum, *see* Fig. 10.1.2.

1.10.6 Unless otherwise agreed, the verification of mass and dimensions is the responsibility of the manufacturer. The Surveyor is only required to monitor this inspection. The mass of the anchor is to exclude the mass of the swivel, unless the swivel is in lieu of the conventional 'D' shackle.

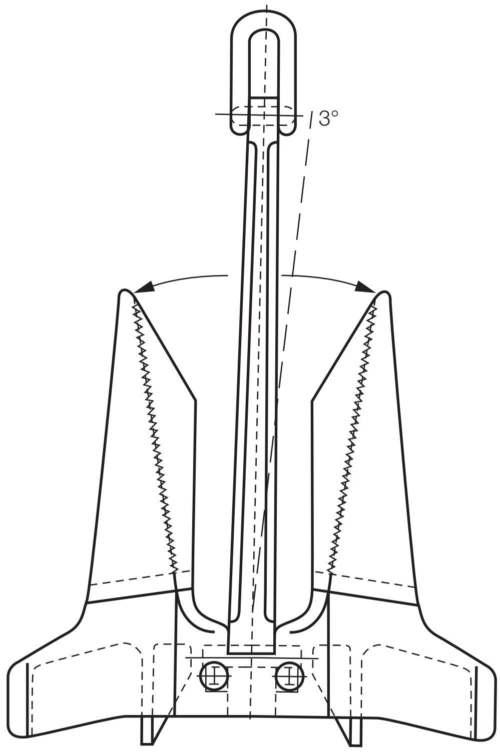


Fig. 10.1.2 Allowable lateral movement of shank

1.11 Identification

1.11.1 Identification marks on the shank are to be approximately level with the fluke tips. On the fluke, these markings are to be approximately at a distance of two thirds from the tip of the bill to the centre line of the crown on the right hand fluke, looking from the crown towards the shank.

1.11.2 The following details are to be shown on all anchors:

(a) LR or Lloyd's Register and abbreviated name of LR's local office issuing the certificate.
(b) Number of the certificate.
(c) Month and year of test.

(d) Mass (also the letters 'HHP' when approved as high holding power anchors or 'SHHP' when approved as super high holding power anchors).
(e) Mass of stock (in the case of stocked anchors).
(f) National Authority requirements, as applicable.
(g) Manufacturer's mark.

1.11.3 In addition to 1.11.2, each important part of an anchor is to be plainly marked by the maker with the words 'forged steel' or 'cast steel' as appropriate. Fabricated steel anchor heads do not require special marking.

1.12 Certification

1.12.1 The manufacturer is to provide the Surveyor with a written statement that the anchor has been manufactured and tested in accordance with LR Rules together with the following particulars:
(a) Purchaser's name and order number.
(b) Type of anchor and principal dimensions.
(c) Mass of anchor.
(d) Identification mark which will enable the full history of manufacture to be traced.
(e) Chemical composition.
(f) Details of heat treatment.
(g) Mechanical test results.
(h) Proof load.
(j) Results of the non-destructive examination.
(k) Weld location maps (cast steel anchors only).

1.12.2 Shanks, heads, pins, shackles and swivels are to be certified by LR in accordance with the relevant sections of Chapters 3, 4 and 5.

1.12.3 An LR Anchor Certificate is to be issued for the completed anchor which will include the following particulars:
(a) Manufacturer's name.
(b) Type of anchor.
(c) Mass of anchor.
(d) Grade of materials.
(e) Proof test load.
(f) Heat treatment.
(g) Marking applied to anchor.
(h) Dimensions.
(j) General Approval of an Anchor Design Certificate Number.
(k) Fluke and shank identification numbers.

■ *Section 2*
Stud link chain cables for ships

2.1 Scope

2.1.1 Provision is made in this Section for a range of grades, U1, U2 and U3, of stud link chain and fittings intended for anchor cables for ships.

2.1.2 The requirements for mooring chain cables are given in Section 3.

2.1.3 The design of chain cables is to be to a Standard recognised by LR, such as ISO 1704.

2.2 Manufacture

2.2.1 All grades of chain cable and accessories are to be manufactured by approved procedures at works approved by LR. A list of approved manufacturers of stud link chain cables and fittings is published separately by LR.

2.2.2 The links may be made by the flash-butt or other approved welding process, or in the case of Grades U2 and U3 they may be flash-butt welded or drop forged, designated U2(a) or U3(a), or cast steel designated U2(b) or U3(b), *see* Table 10.2.5.

2.2.3 As far as practicable, consecutive links in all chain cable should originate from a single cast or batch of bar stock (*see* Ch 3,9.6.1), and indicating marks should be stamped on the final link formed from one cast or batch and the first link formed from a separate cast or batch.

2.2.4 A length of chain cable is to measure not more than 27,5 m and is to comprise an odd number of links. In this context, a length is a statutory term and is the basis for the number of test samples.

2.2.5 Where end links or enlarged links are manufactured and heat treated as part of and at the same time as the chain cable and are of the same cast heat of steel, they may be excluded from separate mechanical tests and break load tests.

2.3 Flash butt welded chain cable

2.3.1 Bar material is to comply with the requirements of Ch 3,9 and may be heated either by electrical resistance or in a furnace. For electrical resistance heating, the process is to be controlled by an optical heat sensor. For furnace heating, thermocouples in close proximity to the bars are to be used for control. The temperature is to be continuously recorded. In both cases, the controls are to be checked at least once every eight hours and checks are to be recorded.

2.3.2 Mechanical properties testing of U1 cable is not required. For Grade U2 cable supplied in the as-welded condition, and Grade U3 in all conditions, one tensile and one set of three Charpy V-notch impact test specimens are to be taken at the side of a link opposite the weld from at least every fourth 27,5 m length of cable. A further set of three impact test specimens is to be taken with the notch positioned at the centre of the weld, *see* Table 10.2.3. The test specimens are not to be selected from the same length as that from which the breaking test sample is taken, unless breaking test samples are to be taken from every length of the batch. All test samples are to be correctly identified with the lengths of cable represented.

2.3.3 The test links from which the mechanical test specimens are prepared are to be made as part of the chain cable and are to be heat treated with it. They may be removed from the cable prior to heat treatment provided that each sample is heat treated with, and in the same manner as, the chain it represents prior to preparation of the mechanical test specimens.

2.3.4 The results of tests on specimens taken from the non-welded areas are to comply with the appropriate requirements of Table 10.2.1. The results of tests on the welds are to comply with the requirements of Table 10.2.6.

2.4 Cast chain cables

2.4.1 The manufacture of cast steel chain cable is generally to be in accordance with the requirements of Ch 4,1, as appropriate.

2.4.2 The chemical composition of ladle samples is to comply with the specification approved by LR.

2.4.3 Separately cast test samples are to be provided from each cast. They are to be of similar dimensions to the links they represent and are to be heat treated together with, and in the same manner as, the completed chain cable, *see* Table 10.2.3.

2.4.4 Tensile and Charpy V-notch impact test specimens are to be taken from each test sample and machined to the dimensions given in Ch 2,3.

2.4.5 The results of all tests are to comply with the requirements given in Table 10.2.1 for the relevant grade.

2.5 Forged chain cables

2.5.1 The procedure for the manufacture and testing of drop forgings for chain cable will be specially considered, but is generally to be in accordance with the appropriate requirements of Ch 5,1.

2.5.2 The chemical composition is to comply with Table 10.2.2.

2.5.3 The completed forgings are to be heat treated in accordance with Table 10.2.3.

2.5.4 Test samples are to be provided in the form of forgings of similar dimensions to the links they represent. These test samples are to be from the same steel-making heat and heat treated together with the links they represent.

2.5.5 One tensile and three Charpy V-notch specimens are to be taken from each test sample.

Table 10.2.1 Mechanical properties of finished chain cable and fittings

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests	
					Test temperature °C	Average energy J minimum
U2	295	490 – 690	22	—	0 (*see* Note 1)	27
U3	410	690 minimum	17	40	0 –20 (*see* Note 2)	60 35

NOTES
1. When required *see* Table 10.2.3.
2. Testing may be carried out at either 0°C or –20°C.
3. Mechanical testing is not required for finished chain cables and fittings in Grade U1.

Table 10.2.2 Chemical composition of butt welded and forged chain cable

Grade	Chemical composition %												
	C max.	Si	Mn	P max.	S max.	Al	N max.	Cr max.	Cu max.	Nb max.	Ni max.	V max.	Mo max.
U1	0,20	0,15 – 0,35	0,40 min.	0,04	0,04	—	—	—	—	—	—	—	—
U2	0,24	0,15 – 0,55	1,60 max.	0,035	0,035	0,02 min. *see* Note 1	—	—	—	—	—	—	—
U3	0,33	0,15 – 0,35	1,90 max.	0,04	0,04	0,065 max. *see* Note 2	0,015	0,25	0,35	0,05 *see* Note 2	0,40	0,10 *see* Note 2	0,08

NOTES
1. Aluminium may be partly replaced by other grain refining elements.
2. To obtain fine grain steel, at least one of these grain refining elements must be present in sufficient amount.

Table 10.2.3 Condition of supply and scope of mechanical tests for finished chain cables and fittings

Grade	Manufacturing method	Condition of supply	Number of test specimens on every four lengths of chain cable of 27,5 m or less, or on each batch of fittings		
			Tensile test on base materials	Charpy V-notch impact test	
				Base material	Weldment
U1 cable	Flash butt welded	As welded Normalised	— —	— —	— —
U2 cable	Flash butt welded	As welded Normalised	1 —	3 —	3 —
U3 cable	Flash butt welded	Normalised Normalised and Tempered Quenched and Tempered	1	3	3
U2 cable	Cast or drop forged	Normalised	1	3	—
U3 cable	Cast or drop forged	Normalised Normalised and Tempered Quenched and Tempered	1	3	—
U2 fittings	Cast or drop forged	Normalised	1	3	—
U3 fittings	Cast or drop forged	Normalised Normalised and Tempered Quenched and Tempered	1	3	—

2.5.6 The results of mechanical tests are to comply with the requirements of Table 10.2.1 for the relevant grade.

2.6 Stud material

2.6.1 Steel studs are to be used for all grades of welded chain cable. In general, the carbon content should not exceed 0,23 per cent but mechanical tests for acceptance purposes are not required.

2.7 Welding of studs

2.7.1 Where studs are welded into the links this is to be completed before the chain cable is heat treated.

2.7.2 The stud ends must be a good fit inside the link, and the weld is to be confined to the stud end opposite the flash-butt weld. The full periphery of the stud end is to be welded. If, however, it can be demonstrated to the Surveyor that the quality of welding is of a high standard then partial peripheral welding may be accepted provided that welds are made only at the sides of the stud and that each run extends continuously for at least 25 per cent of the stud periphery. Weld start/stop positions are not to be located in the plane of the chain cable.

2.7.3 The welds are to be made by qualified welders using an approved procedure and consumables approved to Grade 3 and low hydrogen, in accordance with Chapter 11.

2.7.4 The welds are to be of good quality and free from defects liable to impair the proper use of the chain. Undercuts, end craters and similar stress raising defects shall, where necessary, be ground off.

2.7.5 At least one stud weld within each length of cable is to be inspected using dye penetrant testing in accordance with Ch 1,5 after the chain has been proof loaded. If a crack is found, the stud welds in the adjoining links are to be inspected; if a crack is found in either link, all the stud welds in that length are to be inspected using dye penetrant.

2.8 Heat treatment of completed chain cables

2.8.1 The completed chain cable is to be heat treated in accordance with Table 10.2.3 for the appropriate grade of cable.

2.8.2 Special consideration will be given to the heat treatment of certain types of drop forged chain cable.

2.8.3 In all cases, heat treatment is to be carried out prior to the proof loading and breaking tests.

2.8.4 All test samples are to be heat treated with, and in the same way as, the chain cables they represent.

2.9 Testing of completed chain cables

2.9.1 All chain cables are to be subjected to a Proof Load test and a Breaking Load test. In addition, mechanical tests should be carried out where required, *see* Table 10.2.3.

2.9.2 All chain cables are to be tested in the presence of a Surveyor, at a proving establishment recognised by LR. A list of recognised proving establishments is published separately by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

2.10 Proof load tests

2.10.1 Each length of chain cable is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.2.4 for the appropriate grade and size of cable.

2.10.2 On completion of the test, each link is to be visually examined and is to be free from significant defects. Special attention is to be given to welds.

2.10.3 Should any link be found to be defective it is to be replaced by an approved connecting link (joining shackle or substitute link as detailed in 2.14). The chain is then to be subjected to a repeat of the proof load test followed by re-examination.

2.10.4 If a link breaks during proof load testing, a sample consisting of three common links is to be taken from each side of the broken link and subjected to a breaking test as detailed in 2.12. If either of these samples fails, the length of cable is not to be accepted. A thorough examination of all broken links is to be made to determine the cause of failure and, after evaluation, LR will consider the extent of cable which is to be rejected.

2.11 Dimensional inspection

2.11.1 The measurement of dimensions in 2.11.2 and 2.11.3 is to take place after the proof load has been applied to the chain and subsequently reduced to the load of 10 per cent of the proof load. All other dimensional checks are to be carried out without application of load.

2.11.2 On every 27,5 m length of chain, five links are to be selected for measurement of length to ensure that the maximum allowable tolerance on a length of five links is plus 2,5 per cent. No under-tolerance is permitted.

2.11.3 If a five-link length of chain exceeds the tolerance given in 2.11.2, then the entire chain is to be checked for length, five links at a time with an overlap of two links, which is to include the first five links. Oversize links are to be removed and an approved connecting link inserted.

2.11.4 Checks of all other dimensions are to be made on three links from every four 27,5 m lengths. All measurements are to be made on links selected by the Surveyor and are to be carried out to the Surveyor's satisfaction.

2.11.5 If one of the links detailed in 2.11.4 fails to comply with the required tolerances, measurements are to be made on all four 27,5 m lengths.

2.11.6 If more than one link in a 27,5 m length of chain cable fails to meet the tolerance requirements, all the links in that length are to be measured.

2.11.7 Links that fail to comply with tolerance requirements are to be removed and approved connecting links inserted. Where a significant number of links fail to comply with the tolerance requirements the chain is to be rejected.

2.11.8 The form and proportion of links and shackles are to be in accordance with a standard recognised by LR, such as ISO 1704; alternatively, the design may be specifically approved by LR.

2.11.9 Manufacturing tolerances on stud link chain are to be within ±2,5 per cent (taking into account that all components of the chain are to be a good fit with one another), except for those detailed in 2.11.10.

2.11.10 The nominal diameter, d, is to be the average of the diameters, measured in the plane of the link, d_c, and perpendicular to the plane of the link, d_p, *see* Fig. 10.2.1. The negative tolerance on the nominal diameter is not to exceed the following:

Minus 1 mm when $d \leq 40$ mm
Minus 2 mm when 40 mm $< d \leq 84$ mm
Minus 3 mm when 84 mm $< d \leq 122$ mm
Minus 4 mm when $d > 122$ mm

The plus tolerance on the diameter at the crown measured out of the plane of the link, d_p, is not to exceed 5 per cent.

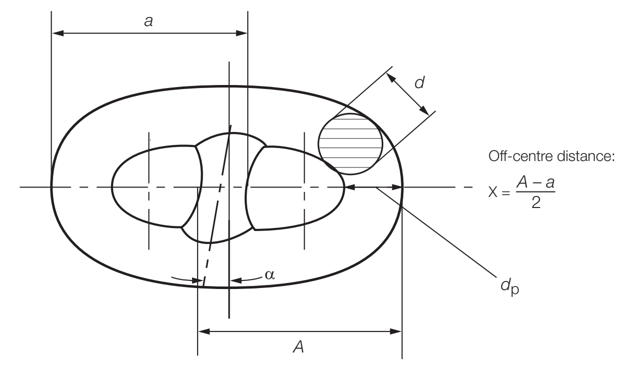


Fig. 10.2.1 Manufacturing tolerances

2.11.11 The cross-sectional area is to be calculated using the nominal diameter, d. The cross-sectional area at the crown of the link is to have no negative tolerance.

2.11.12 The diameter measured at locations other than the crown is to have no negative tolerance. The plus tolerance is to be in accordance with Table 3.9.3 in Chapter 3 except at the butt weld where it is to be in accordance with the manufacturer's specification, which is to be agreed by LR.

Table 10.2.4 Test loads for stud link anchor chain cables

Chain diameter	Grade U1		Grade U2		Grade U3	
	Proof load kN	Breaking load kN	Proof load kN	Breaking load kN	Proof load kN	Breaking load kN
d mm	$0{,}00686d^2 (44-0{,}08d)$	$0{,}00981d^2 (44-0{,}08d)$	$0{,}00981d^2 (44-0{,}08d)$	$0{,}01373d^2 (44-0{,}08d)$	$0{,}01373d^2 (44-0{,}08d)$	$0{,}01961d^2 (44-0{,}08d)$
12,5	46	66	66	92	—	—
14	58	82	82	115	—	—
16	75	107	107	150	—	—
17,5	89	128	128	179	—	—
19	105	150	150	211	—	—
20,5	122	175	175	244	244	349
22	140	201	201	281	281	401
24	166	238	238	333	333	475
26	194	278	278	389	389	556
28	225	321	321	450	450	642
30	257	367	367	514	514	734
32	291	416	416	583	583	832
34	327	468	468	655	655	936
36	366	523	523	732	732	1045
38	406	580	580	812	812	1160
40	448	640	640	896	896	1280
42	492	703	703	984	984	1406
44	538	769	769	1076	1076	1537
46	585	837	837	1171	1171	1673
48	635	908	908	1270	1270	1814
50	686	981	981	1373	1373	1961
52	739	1057	1057	1479	1479	2113
54	794	1135	1135	1589	1589	2269
56	850	1216	1216	1702	1702	2430
58	908	1299	1299	1818	1818	2597
60	968	1384	1384	1938	1938	2767
62	1029	1472	1472	2060	2060	2943
64	1092	1562	1562	2187	2187	3123
66	1157	1655	1655	2316	2316	3308
68	1223	1749	1749	2448	2448	3496
70	1291	1846	1846	2583	2583	3690
73	1395	1995	1995	2792	2792	3988
76	1503	2149	2149	3007	3007	4295
78	1576	2254	2254	3154	3154	4505
81	1689	2415	2415	3380	3380	4827
84	1805	2580	2580	3612	3612	5158
87	1923	2750	2750	3849	3849	5498
90	2045	2924	2924	4093	4093	5845
92	2127	3042	3042	4258	4258	6081
95	2254	3223	3223	4510	4510	6442
97	2339	3345	3345	4682	4682	6687
100	2470	3532	3532	4943	4943	7060
102	2558	3658	3658	5120	5120	7312
105	2692	3850	3850	5389	5389	7697
107	2783	3980	3980	5571	5571	7957
111	2968	4245	4245	5941	5941	8486
114	3110	4447	4447	6224	6224	8889
117	3253	4652	4652	6511	6511	9299
120	3398	4859	4859	6801	6801	9714
122	3496	4999	4999	6997	6997	9994
124	3595	5141	5141	7195	7195	10276
127	3744	5354	5354	7494	7494	10703
130	3895	5571	5571	7796	7796	11135
132	3997	5716	5716	8000	8000	11426
137	4254	6083	6083	8514	8514	12161
142	4515	6456	6456	9036	9036	12906
147	4779	6834	6834	9565	9565	13662
152	5046	7217	7217	10100	10100	14426
157	5316	7602	7602	10640	10640	15197
162	5588	7991	7991	11185	11185	15975

2.11.13 Studs must be located in the links centrally and at right angles to the sides of the link, although the studs at each end of any length may also be located off-centre to facilitate the insertion of the joining shackle. The following tolerances in Fig. 10.2.1 will be accepted provided that the stud fits snugly and its ends lie practically flush against the inside of the link:

Maximum off-centre distance 'X': 10 per cent of the nominal diameter *d*
Maximum deviation 'α' from the 90° – position: 4°.

2.11.14 All individual parts must have a clean surface consistent with the method of manufacture and the surface is to be free from cracks, notches, inclusions and other defects which could impair the performance of the product. Crack-like imperfections less than 3 mm in length can be ignored. The flash produced by upsetting or drop forging must be properly removed.

2.11.15 Minor surface imperfections may be ground off so as to leave a gentle transition to the surrounding surface provided that the cross-sectional area remains equal to or greater than the nominal cross-sectional area. Remote from the crown, local grinding up to 5 per cent of the nominal diameter may be permitted.

2.11.16 Paint or anti-corrosive coatings are not to be applied until these inspections are completed to the satisfaction of the Surveyor.

2.12 Breaking load tests

2.12.1 Breaking load tests are to be carried out on three-link samples selected by the Surveyor from the completed (including heat treatment) chain. The test links may be removed from the chain prior to heat treatment provided that each sample is heat treated with, and in the same manner as the chain it represents. They are to be properly identified with the lengths of chain they represent.

2.12.2 The number of tests required is to be in accordance with Table 10.2.5 except that for chafing chain for Emergency Towing Arrangements (ETA), *see* Pt 3, Ch 13,10.2, one test is to be carried out on each 110 m of finished chains.

2.12.3 Breaking test specimens are to withstand the load given in Table 10.2.4 for the appropriate grade and size of cable. The specimen is considered to have passed this test if it has shown no sign of fracture after application of the required load for a minimum of 30 seconds.

2.12.4 Where a breaking test specimen fails, a further specimen is to be cut from the same length of cable and subjected to test. If this re-test fails, the length of cable from which it was taken is to be rejected. When this test is also representative of other lengths, each of the remaining lengths is to be individually tested by taking a breaking test specimen from each length of the batch. If one of these further tests fails, the entire set of lengths represented by the original test is to be rejected.

2.12.5 For large diameter cables where the required breaking load is greater than the capacity of the testing machines, special consideration will be given to acceptance of an alternative testing procedure.

Table 10.2.5 Number of breaking tests from completed cables

Designation	Method of manufacture	Number of breaking test specimens
Grade U1	Flash-butt welded and heat treated	One from every four lengths of 27,5 m or less
Grade U2(a) U3(a)	Flash-butt welded, or drop forged and heat treated	One from every four lengths of 27,5 m or less
Grade U1 U2(a)	Flash-butt welded but not heat treated	One from each length of 27,5 m or less
Grade U2(b) U3(b)	Cast and heat treated	One per heat treatment batch with a minimum of one from every four lengths of 27,5 m or less

Table 10.2.6 Mechanical properties of welds in chain cables

Grade	Charpy V-notch impact test	
	Test temperature °C	Average energy J min
U1	—	—
U2	0 (*see* Note 1)	27
U3	0	50
	–20 (*see* Note 2)	27

NOTES
1. Impact tests are only required if the chain cable is not heat treated.
2. Impact testing may be carried out at 0°C or minus 20°C.

2.13 Fittings for chain cables

2.13.1 Cable fittings are to be manufactured at an approved works.

2.13.2 The materials from which the fittings are made are to be manufactured at approved works, in accordance with the appropriate requirements of Ch 4,1 or Ch 5,1 respectively. Alternative arrangements may be agreed provided that full details concerning the manufacturer are submitted to LR.

2.13.3 All fittings are to be manufactured to an approved manufacturing specification, and provision is to be made for tensile specimens and, where applicable, impact test specimens, *see* Table 10.2.3. The mechanical test requirements are the same as those for the relevant grade of chain cable, *see* Table 10.2.1.

2.13.4 The test samples are to be prepared in accordance with 2.4.3 or 2.5.4 as applicable. The test specimens are to be subjected to heat treatment with the fittings they represent.

2.13.5 For mechanical testing, a batch is defined as fittings of the same grade, size and heat treatment furnace load and is to have originated from a single cast heat of steel.

2.13.6 Mechanical tests of pins are to be taken in accordance with 3.8.15.

2.13.7 Fittings such as shackles, swivels and swivel shackles are to be forged or cast in steel of at least Grade U2. The welded construction of fittings may also be approved providing that full details of the manufacturing process and the heat treatment are submitted.

2.13.8 All chain cable accessories, including spares, are to be subjected to the proof loads appropriate to the grade and size of cable for which they are intended. These include shackles, swivels, swivel shackles, enlarged links and end links. Anchor shackles, however, are to be tested in combination with the anchor, *see* 1.4.

2.13.9 The appropriate breaking load is to be applied for a minimum of 30 seconds to at least one item out of every batch of up to 25 detachable links, shackles, swivels, swivel shackles, enlarged end links and end links and at least one item out of every batch of up to 50 for lugless (Kenter) shackles. The item tested is to be destroyed and not used as part of an outfit. For the purposes of break load testing, a batch of accessories is to consist of:

(a) the same accessory type, grade and size;
(b) the same rolling or forging or casting process; and
(c) accessories that are heat treated together in the same furnace.

2.13.10 Where a break load batch as defined in 2.13.9 requires a normalise or normalise and temper heat treatment, the size of accessories may vary within a batch provided that the heat treatment cycle is chosen to satisfy the accessory with the largest cross-section size. The batch may consist of more than one steel-making heat provided that the two accessories are break tested, one with the largest cross-section size and one with the smallest cross-section size.

2.13.11 Where a break load batch as defined in 2.13.9 requires a quench and temper heat treatment, the size of the accessories within the batch is to be the same and is limited to the same steel-making heat.

2.13.12 If the sample fails to withstand the breaking load without fracture, two more samples from the same batch may be tested. If either of these samples fails, the batch is to be rejected.

2.13.13 Fittings of increased dimensions or higher grade material may be used subject to approval by LR.

2.13.14 Where items of increased dimensions are used or if material of a higher grade than is specified is used, the breaking load is to be applied to each item, and the items so tested included with the outfit. For the purpose of this paragraph, items of increased dimensions are those so designed that their breaking strength is not less than 1,4 times the Rule minimum breaking load of the chain cable with which they are to be used.

2.13.15 LR may waive the breaking load test provided that:

(a) the breaking load test has been completed satisfactorily during approval testing, and
(b) the tensile and impact properties of each manufacturing batch are proved and
(c) the accessories are subjected to suitable non-destructive testing.

2.13.16 All testing is to be carried out in the presence of the Surveyor and to his satisfaction.

2.13.17 The following tolerances are applicable to accessories:

Nominal diameter: plus 5 per cent, minus 0 per cent
Other dimensions: ±2,5 per cent
The radii of all machined corners are to be not less than 0,03 times the nominal chain diameter.

2.13.18 All fittings are to be stamped in accordance with 2.15.

2.14 Substitute single links

2.14.1 Single links to connect lengths of chain cable or to substitute for defective links, without the necessity for re-heat treatment of the whole cable length, are to be made by the chain manufacturer in accordance with an approved procedure. Separate approvals are required for each grade of chain cable and the tests are to be made on the maximum size of chain for which approval is sought. Re-approval is required annually.

2.14.2 Manufacture and heat treatment of the substitute link are not to affect the strength of the adjoining links. The temperature reached by these links is nowhere to exceed 250°C.

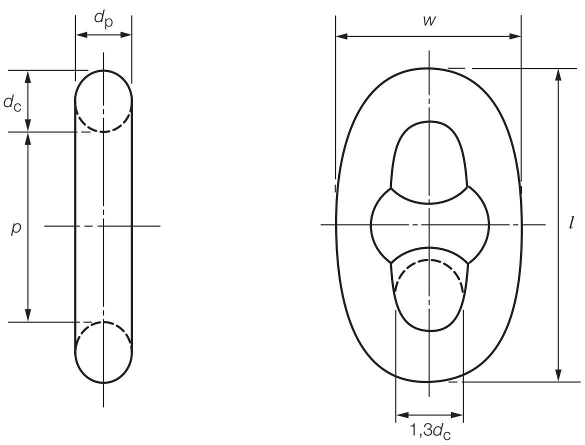
2.14.3 The steel bar used is to conform with the specification for the chain in accordance with Ch 3,9.

2.14.4 Details of the method of manufacture, including heat treatment, are to be submitted for approval, together with the results of a series of tests laid down by LR.

2.14.5 All links involved in the approval tests are to be destroyed and are not to be used as part of a chain cable.

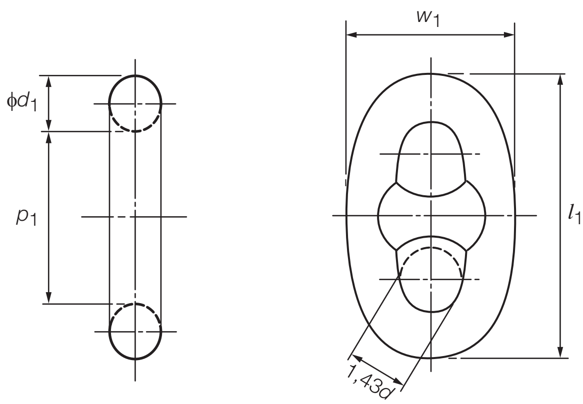
2.14.6 Every substitute link included in a chain cable is to be subjected to the proof load appropriate to the grade and size of chain in which it is incorporated, as detailed in Table 10.2.4.

2.14.7 Each substitute link is to be stamped on the stud with the identification marks listed in 2.15.1 plus a unique number for the link. The adjoining links are also to be stamped on the studs.



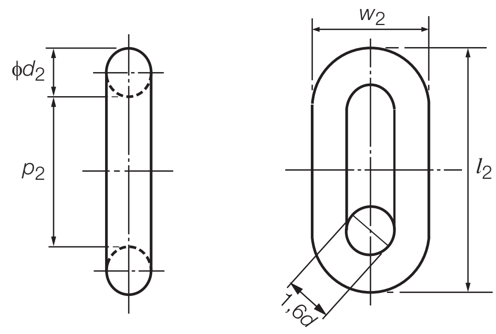
d = nominal diameter $\left(\frac{d_c + d_p}{2}\right)$
d_c = nominal diameter at crown measured in plane of link
d_p = nominal diameter at crown measured perpendicular to plane of link
l = $6d_c$
p = $4d_c$
w = $3{,}6d_c$ to the nearest millimetre

Fig. 10.2.2 Common link



d = nominal diameter of common stud link
d_1 = nominal diameter of enlarged stud link = $1{,}1d$
l_1 = $6d_1 \approx 6{,}6d$
p_1 = $4d_1 \approx 4{,}4d$
w_1 = $3{,}6d_1 \approx 3{,}96d$

Fig. 10.2.3 Enlarged link



d = nominal diameter of common stud link
d_2 = nominal diameter of end link = $1{,}2d$ ($d_2 = 1{,}2d$)
l_2 = $p_2 + 2d_2 \approx 6{,}75d$
p_2 = $3{,}65d_2 \approx 4{,}35d$
w_2 = $3{,}3d_2 \approx 4d$

Fig. 10.2.4 End link

2.15 Identification

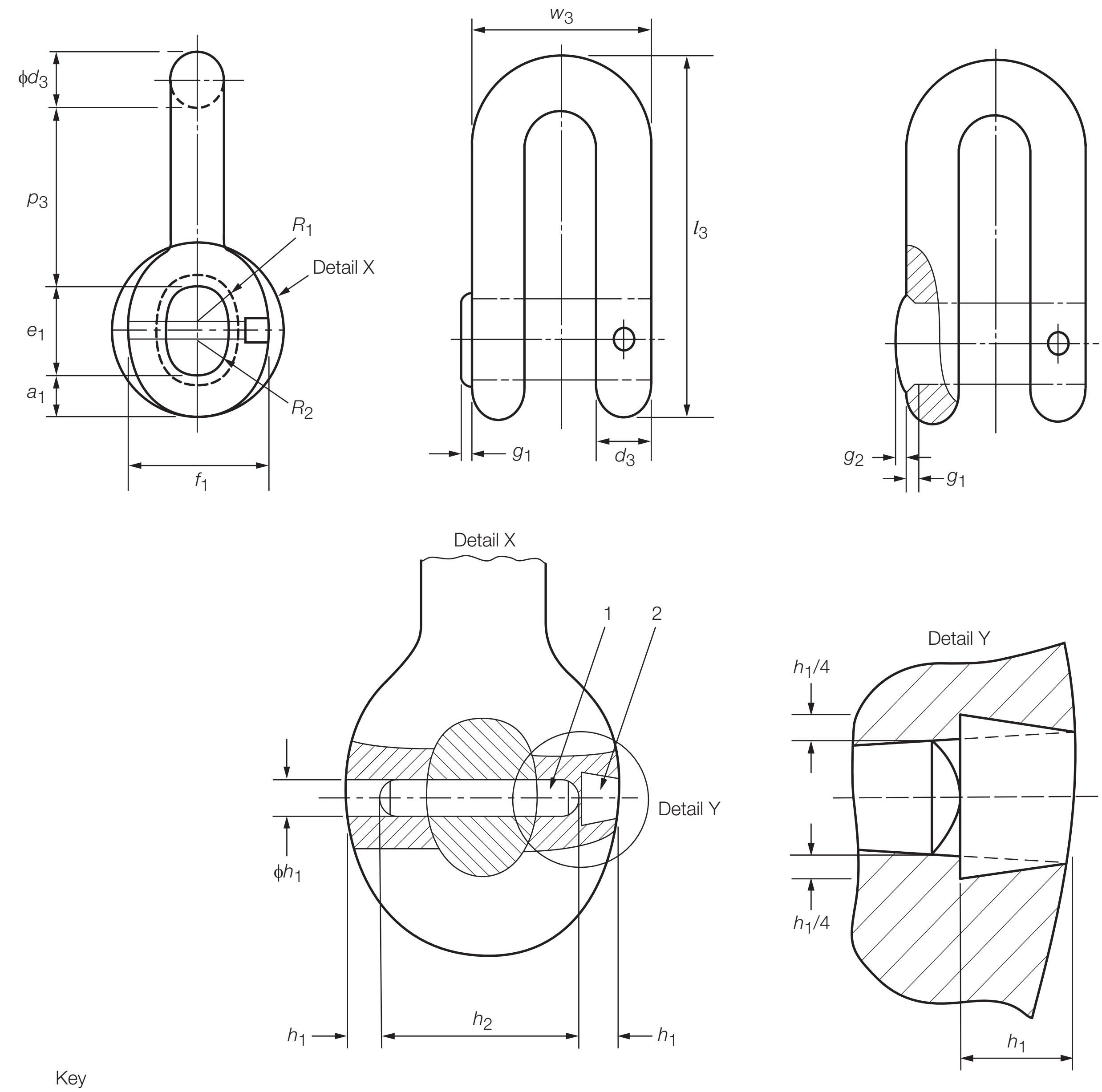
2.15.1 All lengths of Grades U1, U2 and U3 cable and all fittings are to be stamped with the following identification marks:
(a) LR or Lloyd's Register and abbreviated name of LR's local office issuing the certificate.
(b) Number of certificate.
(c) Proof load and grade of chain.
(d) Surveyor's personal stamp.
(e) Each length of chain cable is to be stamped on both ends.

2.16 Certification

2.16.1 An LR certificate is to be issued for chain cable only, fittings only or chain cable with associated fittings.

2.16.2 Each test certificate is to include the following particulars for all items included on the certificate:
(a) Manufacturer's name.
(b) Purchaser's name and order number.
(c) Description and dimensions.
(d) Grade of chain cable.
(e) Identification mark which will enable the full history of the chain or fitting to be traced.
(f) Chemical composition.
(g) Details of heat treatment.
(h) Mechanical test results.
(j) Breaking test load.
(k) Proof load.

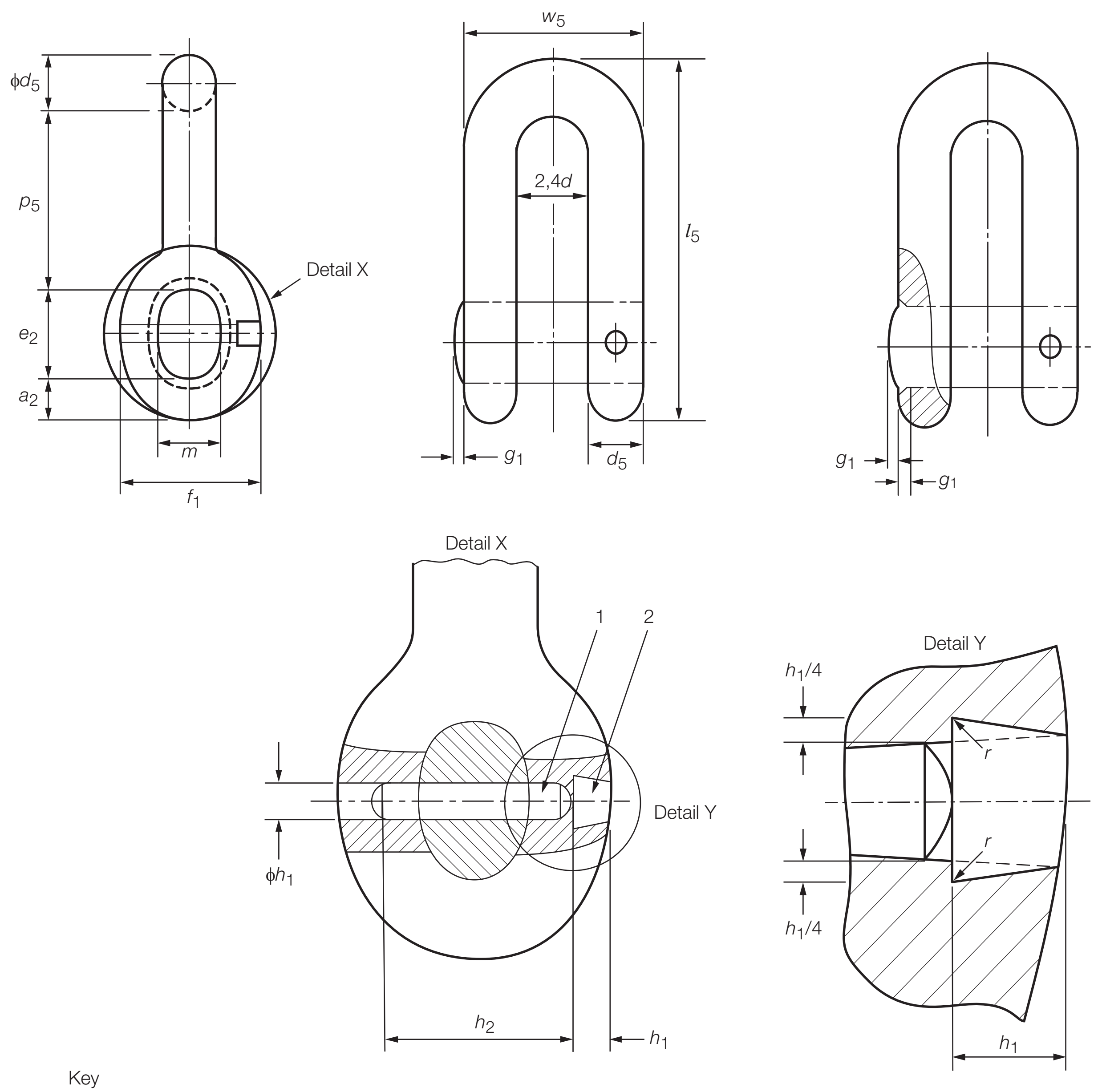
2.16.3 Where appropriate, the certificate is to include a list of all substitute links together with their grade of steel, the name of the steelmaker, the heat number and the purchase order number.



Key
1 retaining pin
2 dovetail chamber

d	=	nominal diameter of common stud link	f_1	=	2,8d
d_3	=	nominal diameter of joining shackle = 1,3d	g_1	=	0,2d
l_3	=	7,1d	g_2	=	0,1d
p_3	=	$l_3 - (d_3 + a_1 + e_1)$ = 3,4d	h_1	=	nominal diameter of taper pin
w_3	=	4d	h_2	=	nominal length of taper pin
a_1	=	0,8d	R_1	=	0,6d
e_1	=	1,6d	R_2	=	0,5d

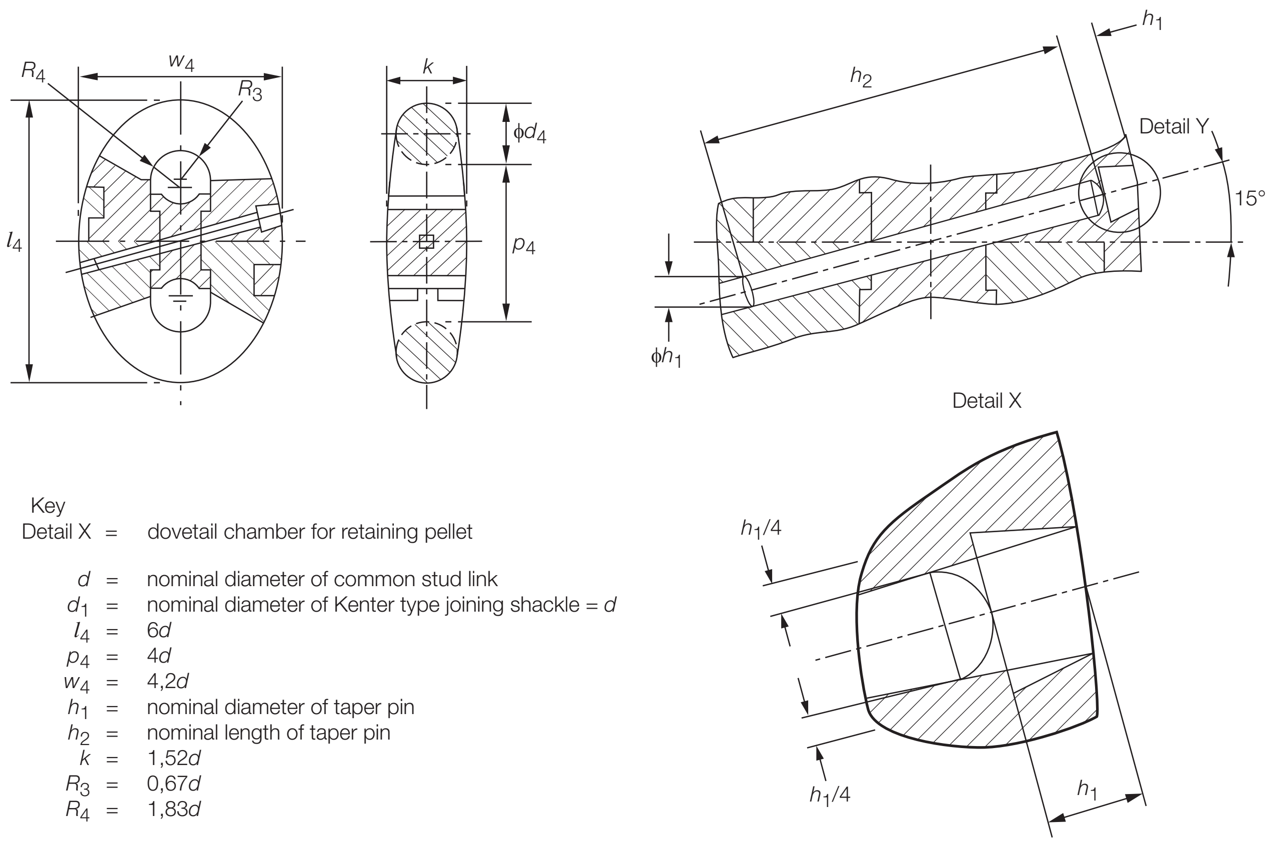
Fig. 10.2.5 Dee shackle



Key
1 retaining pin
2 dovetail chamber

d = nominal diameter of common stud link
d_5 = nominal diameter of end shackle = 1,4d
l_5 = 8,7d
p_5 = $l_5 - (d_5 + a_2 + e_2)$ = 4,5d
w_5 = 5,2d
a_2 = 0,9d
e_2 = 1,8d
f_2 = 3,1d
g_1 = 0,2d
g_2 = 0,1d
m = 1,4d
h_1 = nominal diameter of taper pin
h_2 = nominal length of taper pin

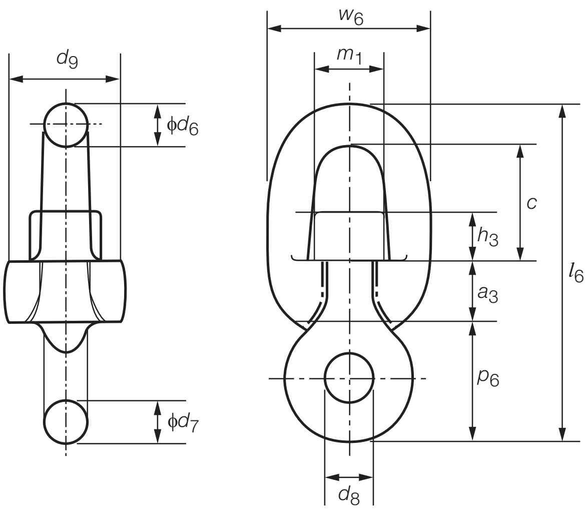
Fig. 10.2.6 End shackle



Key

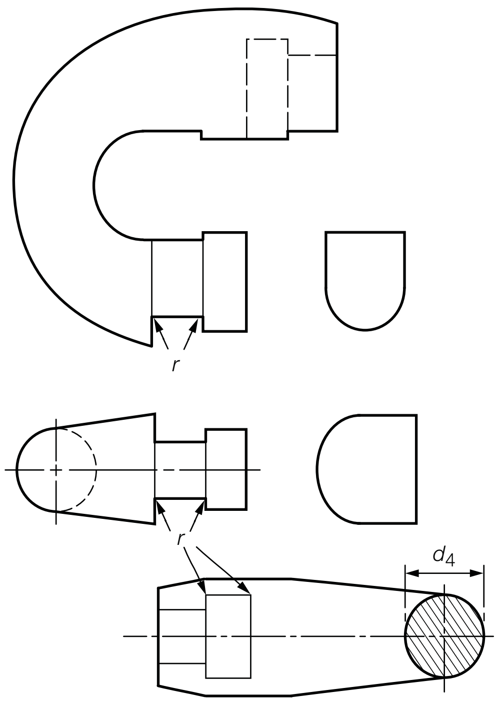
Detail X	=	dovetail chamber for retaining pellet
d	=	nominal diameter of common stud link
d_1	=	nominal diameter of Kenter type joining shackle = d
l_4	=	$6d$
p_4	=	$4d$
w_4	=	$4{,}2d$
h_1	=	nominal diameter of taper pin
h_2	=	nominal length of taper pin
k	=	$1{,}52d$
R_3	=	$0{,}67d$
R_4	=	$1{,}83d$

Fig. 10.2.7 Lugless shackle



d	=	nominal diameter of common stud link
d_6	=	nominal diameter of swivel = $1{,}2d$
l_6	=	$9{,}7d$
p_6	=	$d_9 = 3{,}4d$
w_6	=	$4{,}7d$
d_7	=	$1{,}1d$
a_3	=	$1{,}75d$
m_1	=	$2d$
h_3	=	$d_8 = 1{,}4d$
c	=	$3{,}35d$

Fig. 10.2.8 Swivel



The radii indicated by r are to be not less than 0,03 x d_4

Fig. 10.2.9 Lugless shackle of the Kenter type

Section 3
Stud link mooring chain cables

3.1 Scope

3.1.1 Provision is made in this Section for five grades, R3, R3S, R4, R4S and R5, of stud link chain intended for offshore mooring applications such as mooring of mobile offshore units, offshore loading systems and gravity based structures during fabrication.

3.1.2 Design of chain cables must be to a recognised Standard, such as ISO 1704; alternatively, the design may be specifically approved by LR.

3.1.3 In addition, chain cable conforming to the requirements of the current edition of API specification 2F is acceptable provided that it has been manufactured, inspected and tested under Survey by LR, and that the bar stock has also been certified by LR in accordance with Ch 3,9.

3.2 Manufacture

3.2.1 All grades of chain cable and accessories are to be manufactured by approved procedures at works approved by LR. A list of approved manufacturers for stud link chain cables is published separately by LR.

3.2.2 The works in which the chain is manufactured is to have a quality system approved by LR. The provision of such a quality system is required in addition to and not in lieu of the witnessing of tests by a Surveyor.

3.2.3 Approval is confined to a single works and is limited to one grade of cable made from bar from a nominated and approved supplier. Separate approvals are required if steel bar is supplied from more than one works and for other grades of cable, *see also* Ch 3,9.

3.2.4 Details of the method of manufacture and the specification of the steel, are to be submitted.

3.2.5 Offshore mooring chains are to be made in continuous lengths by flash-butt welding.

3.2.6 Bar material may be heated either by electric resistance or in a furnace. For electrical resistance heating, the process is to be controlled by an optical heat sensor. For furnace heating, thermocouples in close proximity to the bars are to be used for control and the temperature is to be continuously recorded. In both cases, the controls are to be checked at least once every eight hours and records taken.

3.2.7 The following welding parameters (as approved in the weld procedure) are to be controlled during welding of each link:
(a) platen motion;
(b) current as a function of time; and
(c) hydraulic pressure.
The controls are to be checked at least once every four hours.

3.2.8 The records of bar heating, flash-butt welding and heat treatment are to be made available to the Surveyor when required.

3.2.9 As far as practicable, consecutive links in all chain cable should originate from a single batch of bar stock (*see* Ch 3,9.6.1) and indicating marks should be stamped on the final link formed from one batch and the first link formed from a separate batch.

3.3 Dimensions and tolerances

3.3.1 The form and proportions of links and shackles are to be in accordance with ISO/1704, *see* Figs. 10.2.2 to 10.2.9. Link tolerances are to be in accordance with 3.3.2 to 3.3.6.

3.3.2 Diameter measured at the crown:
Minus 1 mm when $d_c \le 40$ mm
Minus 2 mm when 40 mm < $d_c \le 84$ mm
Minus 3 mm when 84 mm < $d_c \le 122$ mm
Minus 4 mm when 122 mm < $d_c \le 152$ mm
Minus 6 mm when 152 mm < $d_c \le 184$ mm
Minus 7,5 mm when 184 mm < $d_c \le 210$ mm
The plus tolerance must not exceed 5 per cent of the nominal diameter, and the cross-sectional area at the crown is to have no negative tolerance.

3.3.3 The diameter measured at locations other than the crown is to have no negative tolerance. The plus tolerance is to be in accordance with Table 3.9.3 except at the butt weld where it is to be in accordance with the manufacturer's specification, which is to be agreed by LR.

3.3.4 The maximum allowable tolerance on a length of five links measured in accordance with 2.11.1 is +2,5 per cent. No under-tolerance is permitted.

3.3.5 A manufacturing tolerance on all other dimensions of ±2,5 per cent is acceptable subject to all parts fitting properly together.

3.3.6 The tolerances for common links are to be measured in accordance with Fig. 10.3.2.

3.3.7 All measurements are to be made on links selected by the Surveyor and are to be carried out to the Surveyor's satisfaction.

3.3.8 Studs are to be located in the links centrally, and at right angles to the sides of the link, although the studs of the final link at each end of any length may also be located off-centre to facilitate the insertion of the joining shackle. The tolerances in accordance with Fig. 10.3.2 are acceptable provided that the stud fits snugly and its ends lie flush against the inside of the link.

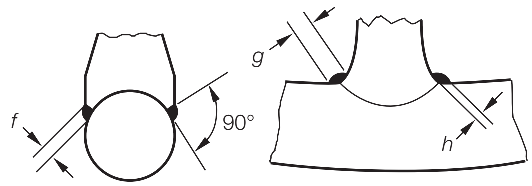
3.4 Studs

3.4.1 The studs are to be made of steel corresponding to that of the chain or in compliance with a specification approved by LR. In general, the carbon content should not exceed 0,23 per cent if the studs are to be welded in place.

3.4.2 Studs may be welded into grade R3 and R3S chains. The welding of studs into grade R4, R4S and R5 chain is not permitted unless specially approved.

3.4.3 In all cases where studs are welded into links, this is to be carried out in accordance with 2.7.

3.4.4 The size of the stud welds is to be in accordance with Fig. 10.3.1.



Dimension Designation	Nominal Dimension	Minus Tolerance
f	0,10*d*	0,01*d*
g	0,20*d*	0,02*d*
h	0,09*d*	0,01*d*

d = Nominal diameter of barstock

3450/02

Fig. 10.3.1
Dimensions and tolerances of stud welds

3.4.5 All stud welds are to be visually inspected. At least 10 per cent of all stud welds within each length of chain are to be examined by magnetic particle inspection after proof load testing. Stress raising defects such as cracks, lack of fusion, gross porosity, and undercuts exceeding 1 mm are not permitted; if any such defects are found, then all stud welds in that length of chain are to be examined by means of magnetic particle inspection.

3.4.6 Where plastic straining is used to set studs, the applied load is not to be greater than that qualified in approval tests. The combined effect of shape and depth of the impression of the stud in the link is not to cause any harmful notch effect or stress concentration.

3.5 Heat treatment of completed chain cables

3.5.1 The chain is to be normalised, normalised and tempered or quenched and tempered in accordance with the specification approved by LR.

3.5.2 The chains are to be heat treated in a continuous furnace; batch heat treatment is not permitted.

3.5.3 The temperature and time, or temperature and chain speed, are to be controlled and continuously recorded.

3.5.4 Heat treatment is to be carried out prior to the proof loading and breaking tests.

3.5.5 Calibration of furnaces is to be verified by measurement and recording of actual link temperature (surface and internal).

3.6 Testing of completed chain cables

3.6.1 All chain cables are to be tested in the presence of a Surveyor, at a proving establishment recognised by LR. A list of recognised proving establishments is published by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

3.6.2 The entire length of chain cable is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.3.1 for the appropriate grade and size of cable.

3.6.3 Care should be taken to obtain a uniform stress distribution in the links being tested.

3.6.4 The chain is to be shot or sand blasted prior to testing in order to ensure that its surfaces are free from scale, paint or other coating for inspection.

3.6.5 On completion of the proof load test, each link is to be visually examined and is to be free from significant defects such as mill defects, surface cracks, dents and cuts, especially where gripped by clamping dies during flash butt welding. Studs are to be securely fastened and any burrs, irregularities and rough edges are to be removed by careful grinding.

3.6.6 All flash butt welds, including the area gripped by the clamping dies, are to be examined by magnetic particle inspection. The area is to be free from cracks, lack of fusion, gross porosity and any other stress concentrations.

3.6.7 Surface defects in the region of the flash butt welds may be removed by grinding, provided that the depth of grinding does not exceed five per cent of the link diameter and is smoothly contoured into the surrounding material. The final dimensions are still to conform with the agreed standard.

3.6.8 All flash butt welds are also to be examined by ultrasonic inspection and are to be free from defects such as internal cracks or lack of fusion.

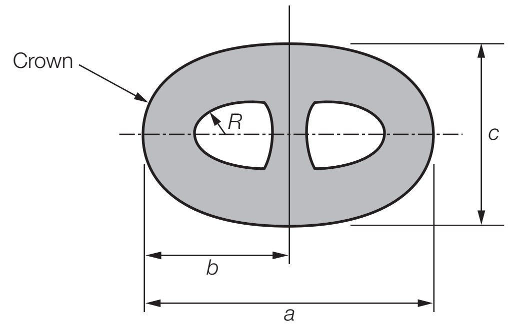
3.6.9 All non-destructive examination is to be carried out in accordance with approved procedures, in accordance with Ch 1,5.

3.6.10 All non-destructive examination operators are to be qualified to a minimum Level II, qualified in accordance with a recognised standard.

3.6.11 After proof testing, the entire chain is to be checked for length, five links at a time with an overlap of two links, which is to include the first five links, to ensure that the chain meets the tolerances given in 2.11.12. The measurements are to be made while the chain is loaded to about 10 per cent of the proof load.

Fig. 10.3.2 Stud link chain cable common link tolerances

The internal link radii (*R*) and external radii should be uniform



Designation	Description	Nominal dimension of the link	Minus tolerance	Plus tolerance
a	Link length	6*d*	0,15*d*	0,15*d*
b	Link half length	*a**/2	0,10*d*	0,10*d*
c	Link width	3,6*d*	0,09*d*	0,09*d*
e	Stud angular misalignment	0 degrees	4 degrees	4 degrees
R	Inner radius	0,65*d*	0	—

Symbols

d = nominal diameter of chain
*a** = actual link length

3.6.12 The links held in the end blocks may be excluded from these measurements.

3.6.13 If the length over five links is less than the nominal, the chain may be stretched by loading above the specified proof test load provided that the applied load is not greater than ten per cent above the proof test load, and that only random lengths of the chain need to be stretched.

3.6.14 Loads used for plastic straining to set studs are not to exceed those approved in qualification tests.

3.6.15 Checks of all other dimensions are to be made on at least five per cent of the links in the cable.

3.6.16 If any link fails to meet the dimensional tolerance requirements (*see* 3.3), measurements are to be made on 20 more links on each side of the incorrect one. If failure to meet any particular dimensional requirements occurs in more than two of the measured links, then all the links are to be dimensionally checked.

3.6.17 Should any link be found to be defective or fail to meet the dimensional tolerance requirements or if a five link length of chain exceeds the specified tolerance, the unsatisfactory links are to be removed from the chain, and connecting common links complying with the requirements of 3.7 inserted in their places.

3.6.18 The chain is then to be subjected to a further proof load test and re-examined.

3.6.19 The number of connecting common links which may be used to replace defective links is not to exceed three in any 100 m length of chain. The number and type of joining shackles which may be used are to be subject to the written agreement of the end user.

3.6.20 If a link breaks during proof load testing, a sample consisting of three common links is to be taken from each side of the broken link and subjected to a breaking test as detailed in 3.6.21 and 3.6.22. If either of these samples fails, the proof loaded length of cable is not to be accepted. A thorough examination of all broken links is to be made to determine the cause of failure and, after evaluation, LR will consider the extent of cable which is to be rejected and also the possibility that similar factors to those which caused the failure may also be present in other parts of the cable, or other chain cables. The Surveyor is to be advised in advance of all examinations, with reasonable notice being given.

3.6.21 In addition to the requirements of 3.6.2, three link samples are to be selected by the Surveyors from the completed chain for breaking tests. The number of tests required is to be in accordance with Table 10.3.2. Extra links are to be provided for the mechanical tests detailed in 3.6.25. All test links are to be made as part of the chain cable and are to be heat treated with it. These may be removed from the cable prior to heat treatment provided that each sample is heat treated with, and in the same manner as, the chain it represents prior to selection of the mechanical test specimens. They are to be properly identified with the length of chain they represent.

Table 10.3.1 Test loads for mooring chain cables *(continued)*

Nominal diameter *d*	Grade R3			Grade R3S			Grade R4			Grade R4S			Grade R5		
	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load
	Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain	
mm	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN
50	1480	1480	2230	1800	1740	2490	2160	1920	2740	2400	2130	3040	2510	2230	3200
52	1594	1594	2402	1939	1874	2682	2327	2068	2952	2585	2295	3275	2704	2402	3447
54	1712	1712	2580	2083	2013	2881	2499	2222	3170	2777	2465	3517	2904	2580	3703
56	1834	1834	2764	2231	2156	3086	2677	2380	3396	2974	2640	3768	3111	2764	3966
58	1960	1960	2953	2383	2304	3297	2860	2542	3628	3178	2820	4025	3323	2953	4237
60	2089	2089	3147	2540	2455	3514	3048	2710	3867	3387	3006	4290	3542	3147	4516
62	2221	2221	3347	2701	2611	3737	3242	2881	4112	3602	3196	4562	3767	3347	4802
64	2357	2357	3551	2867	2771	3965	3440	3058	4364	3822	3392	4841	3997	3551	5096
66	2496	2496	3761	3036	2935	4200	3643	3238	4621	4048	3593	5127	4233	3761	5397
68	2639	2639	3976	3209	3102	4440	3851	3423	4885	4279	3798	5420	4475	3976	5706
70	2785	2785	4196	3387	3274	4685	4064	3613	5156	4516	4008	5720	4723	4196	6021
73	3010	3010	4535	3660	3538	5064	4392	3904	5572	4881	4331	6182	5104	4535	6507
76	3242	3242	4884	3942	3811	5454	4731	4205	6001	5257	4665	6658	5498	4884	7009
78	3400	3400	5123	4135	3997	5720	4962	4411	6295	5514	4893	6984	5766	5123	7351
81	3643	3643	5490	4431	4283	6130	5317	4726	6745	5908	5243	7484	6179	5490	7877
84	3893	3893	5866	4735	4577	6550	5682	5051	7208	6313	5603	7997	6602	5866	8418
87	4149	4149	6252	5046	4878	6981	6056	5383	7682	6729	5972	8523	7037	6252	8971
90	4412	4412	6647	5365	5187	7422	6439	5723	8167	7154	6349	9062	7482	6647	9539
92	4590	4590	6916	5582	5396	7722	6699	5954	8497	7443	6606	9428	7784	6916	9924
95	4862	4862	7326	5913	5716	8180	7096	6307	9001	7884	6997	9987	8246	7326	10512
97	5047	5047	7604	6138	5933	8490	7365	6547	9343	8184	7263	10366	8559	7604	10911
100	5328	5328	8028	6480	6264	8964	7776	6912	9864	8640	7668	10944	9036	8028	11520
102	5519	5519	8315	6712	6488	9285	8054	7159	10217	8949	7942	11336	9359	8315	11932
105	5809	5809	8753	7065	6829	9773	8478	7536	10754	9420	8360	11932	9851	8753	12560
107	6005	6005	9048	7304	7060	10103	8764	7790	11118	9738	8643	12335	10184	9048	12984
111	6404	6404	9650	7789	7529	10775	9347	8308	11856	10385	9217	13154	10861	9650	13847
114	6709	6709	10109	8159	7887	11287	9791	8703	12420	10879	9655	13780	11378	10109	14506
117	7018	7018	10574	8535	8251	11807	10242	9104	12993	11380	10100	14415	11902	10574	15174
120	7331	7331	11047	8916	8619	12334	10700	9511	13573	11889	10551	15059	12434	11047	15852
122	7542	7542	11365	9173	8868	12690	11008	9785	13964	12231	10855	15493	12792	11365	16308
124	7755	7755	11686	9432	9118	13048	11319	10061	14358	12576	11161	15930	13153	11686	16768
127	8078	8078	12171	9824	9497	13591	11789	10479	14955	13099	11626	16592	13700	12171	17466
130	8404	8404	12663	10221	9880	14139	12265	10903	15559	13628	12095	17262	14253	12663	18171
132	8623	8623	12993	10488	10138	14508	12585	11187	15965	13984	12411	17713	14625	12993	18645
137	9178	9178	13829	11162	10790	15441	13395	11906	16992	14883	13209	18852	15565	13829	19844

Table 10.3.1 Test loads for mooring chain cables *(conclusion)*

Nominal diameter *d*	Grade R3			Grade R3S			Grade R4			Grade R4S			Grade R5		
	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load
	Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain	
mm	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN
142	9741	9741	14677	11847	11452	16388	14216	12637	18033	15796	14019	20008	16520	14677	21061
147	10311	10311	15536	12540	12122	17347	15048	13376	19089	16720	14839	21179	17487	15536	22294
152	10887	10887	16405	13241	12800	18317	15890	14124	20156	17655	15669	22363	18464	16405	23540
157	11469	11469	17282	13949	13484	19297	16739	14879	21234	18599	16507	23559	19452	17282	24799
162	12056	12056	18166	14663	14174	20284	17596	15641	22320	19551	17351	24764	20447	18166	26068
167	12647	12647	19056	15381	14869	21278	18458	16407	23414	20508	18201	25977	21448	19056	27345
172	13240	13240	19950	16103	15566	22276	19324	17177	24513	21471	19055	27196	22455	19950	28628
177	13836	13836	20847	16827	16267	23278	20193	17949	25615	22437	19912	28420	23465	20847	29915
182	14433	14433	21746	17553	16968	24282	21064	18723	26720	23404	20771	29645	24477	21746	31205
187	15029	15029	22646	18279	17670	25286	21935	19498	27825	24372	21630	30871	25489	22646	32496
192	15626	15626	23544	19004	18371	26289	22805	20271	28929	25339	22488	32096	26500	23544	33785
197	16220	16220	24440	19727	19070	27290	23673	21043	30029	26303	23344	33317	27509	24440	35071
202	16813	16813	25332	20448	19766	28286	24537	21811	31126	27264	24196	34534	28513	25332	36351
207	17401	17401	26220	21164	20459	29277	25397	22575	32216	28219	25044	35744	29512	26220	37625
210	17753	17753	26749	21591	20872	29868	25910	23031	32867	28788	25550	36465	30108	26749	38385

Grade R3		
Proof test load	Stud link chain	$0{,}0148d^2 (44 - 0{,}08d)$
	Studless chain	$0{,}0148d^2 (44 - 0{,}08d)$
Break test load		$0{,}0223d^2 (44 - 0{,}08d)$
Grade R3S		
Proof test load	Stud link chain	$0.0180d^2 (44 - 0{,}08d)$
	Studless chain	$0{,}0174d^2 (44 - 0{,}08d)$
Break test load		$0{,}0249d^2 (44 - 0{,}08d)$
Grade R4		
Proof test load	Stud link chain	$0{,}0216d^2 (44 - 0{,}08d)$
	Studless chain	$0{,}0192d^2 (44 - 0{,}08d)$
Break test load		$0{,}0274d^2 (44 - 0{,}08d)$
Grade R4S		
Proof test load	Stud link chain	$0{,}0240d^2 (44 - 0{,}08d)$
	Studless chain	$0{,}0213d^2 (44 - 0{,}08d)$
Break test load		$0{,}0304d^2 (44 - 0{,}08d)$
Grade R5		
Proof test load	Stud link chain	$0{,}0251d^2 (44 - 0{,}08d)$
	Studless chain	$0{,}0223d^2 (44 - 0{,}08d)$
Break test load		$0{,}0320d^2 (44 - 0{,}08d)$

3.6.22 Breaking test specimens are to withstand the load given in Table 10.3.1 for the appropriate grade and size of cable for a period of 30 seconds. The specimen is considered to have passed this test if it has shown no sign of fracture after application of the required load.

3.6.23 If a breaking test specimen fails, two further specimens are to be cut from the same sampling length and both are to be subjected to the breaking test load. If one of the re-test specimens fails the length is to be rejected. All the broken links are to be subjected to an investigation into the cause of failure. LR will then decide which lengths of chain can be accepted and on further action.

3.6.24 For large diameter cables where the required breaking load is greater than the capacity of the testing machines, special consideration will be given to acceptance of an alternative testing procedure.

3.6.25 One tensile and three sets of Charpy V-notch impact test specimens are to be taken from links cut from the heat treated and proof loaded chain at intervals no greater than those indicated in Table 10.3.2 provided that every cast is sampled. The tensile specimen and one set of impact specimens are to be taken from the side of the link opposite the weld. One set of impact test specimens is to have the notches positioned at the centre of the flash butt weld and the third set is to be taken from the bend. All the specimens are to be taken from positions in accordance with Fig. 10.3.3.

3.6.26 The frequency of testing at the link bends may be reduced at the discretion of LR provided it can be verified that the required toughness is achieved consistently.

3.6.27 The results of the mechanical tests are to comply with the requirements of Table 10.3.3.

3.6.28 If the tensile test requirements are not achieved, two further specimens from the same sample are to be tested. The related length of chain will be considered acceptable if both re-test specimens meet the requirements but failure of either of the re-test specimens will result in rejection of the sampling length of chain represented by the tests.

3.6.29 If the impact test requirements are not achieved, re-tests may be carried out in accordance with Ch 1,2.4. Failure to meet the re-test requirements will result in rejection of the sampling length of chain represented by the tests.

3.6.30 The mass per unit length of stud link mooring cable is to comply with Table 10.3.4.

3.7 Connecting common links or substitute links

3.7.1 Single links to connect lengths of heat treated chain cable or to substitute for test links or defective links without the necessity for re-heat treatment of the whole length of cable are to be made by the chain manufacturer in accordance with an approved procedure. Separate approvals are required for each grade of chain cable and tests are to be made on the maximum size of chain for which approval is sought.

Table 10.3.2 Frequency of break and mechanical tests

Nominal chain diameter mm	Maximum sampling interval m (*See* Note)
Min. — 48	91
49 — 60	110
61 — 73	131
74 — 85	152
86 — 98	175
99 — 111	198
112 — 124	222
125 — 137	250
138 — 149	274
150 — 162	297
163 — 175	322
176 — 186	346
187 — 199	370
199 — 210	395

NOTE
If the sampling interval contains links made from more than one cast, extra break and mechanical tests are required so that tests are made on every cast.

3.7.2 Manufacture and heat treatment of the connecting common link is not to affect the strength of the adjoining links. The temperature reached by these links is nowhere to exceed 250°C.

3.7.3 The steel bar used is to conform with the specification for the chain and approved by LR in accordance with Ch 3,9.

3.7.4 Details of the method of manufacture, including heat treatment, are to be submitted for approval, together with the results of a series of tests laid down by LR.

3.7.5 All links involved in the approval tests are to be destroyed and are not to be used as part of a chain cable.

3.7.6 Every connecting common link included in a chain cable is to be subjected to the proof load appropriate to the grade and size of chain in which it is incorporated as detailed in Table 10.3.1.

3.7.7 Every connecting common link is to be inspected in accordance with 3.6.5 to 3.6.10.

3.7.8 A second identical link is to be made for mechanical tests which are to be in accordance with 3.6.25. This test link is also to be inspected in accordance with 3.7.7.

3.7.9 Each connecting common link is to be stamped on the stud with the identification marks listed in 3.9.1 plus a unique number for the link. The adjoining links are also to be stamped on the studs.

3.8 Fittings for offshore mooring chain

3.8.1 Cable fittings are to be manufactured at an approved works. Fittings include, but are not limited to, shackles, triplates, end shackles, swivels, and swivel shackles.

Table 10.3.3 Mechanical properties of chain cable materials

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation % minimum	Reduction of area % minimum (*See* Note 3)	Charpy V-notch impact tests		
					Test temperature °C	Average energy J minimum	Average energy flash weld J minimum
R3	410 (*See* Note 1)	690 minimum (*See* Note 1)	17	50	0 –20 (*See* Note 2)	60 40	50 30
R3S	490 (*See* Note 1)	770 minimum (*See* Note 1)	15	50	0 –20 (*See* Note 2)	65 45	53 33
R4	580 (*See* Note 1)	860 minimum (*See* Note 1)	12	50	–20	50	36
R4S (*See* Note 4)	700 (*See* Note 1)	960 (*See* Note 1)	12	50	–20	56	40
R5 (*See* Note 4)	760 (*See* Note 1)	1000 (*See* Note 1)	12	50	–20	58	42

NOTES
1. The ratio of yield strength to tensile strength should not exceed 0,92.
2. Testing may be carried out at either 0°C or –20°C.
3. For cast fittings, the minimum values for reduction of area are to be 40% for Grades R3 and R3S and 35% for Grades R4, R4S and R5.
4. The maximum hardness for Grade R4S is to be HB330, and for Grade R5 is to be HB340.

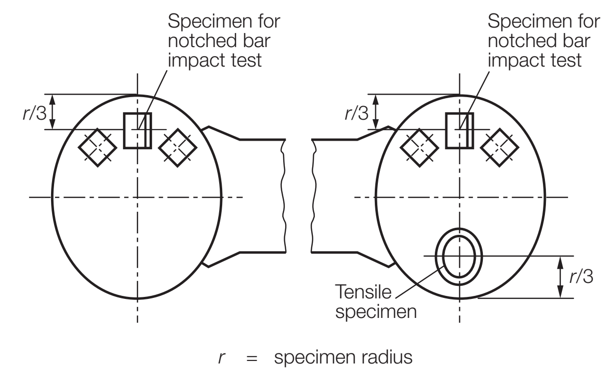


Fig. 10.3.3 Sampling of chain links

3.8.2 The materials from which the fittings are made are to be manufactured at approved works, in accordance with the appropriate requirements of Ch 4,1 or Ch 5,1, and 3.8.3 to 3.8.6. Alternative arrangements may be agreed provided that full details concerning the manufacturer are submitted to LR.

3.8.3 Steel used for fittings must be manufactured by an approved process, and be killed and fine grain treated.

3.8.4 The austenite grain size of steel used for fittings must be 6 or finer as measured in accordance with ASTM E112.

3.8.5 Steel used for forgings or castings for grades R4S and R5 must be vacuum degassed.

Table 10.3.4 Mass per unit length of chain cable

Nominal chain diameter (mm)	Mass per unit length $0{,}0291d^2$ (kg/m)
50	73
55	88
60	105
65	123
70	143
75	164
80	186
85	210
90	236
95	263
100	291
105	321
110	352
115	385
120	419
125	455
130	492
135	530
140	570
145	612
150	655
155	699
160	745
165	792
170	841
175	891
180	943
185	996
190	1051
195	1107
200	1164
205	1223
210	1283

3.8.6 For steel used for forgings or castings for grades R4S and R5 the following tests are to be carried out on each heat:

(a) Assessment and quantification of the level of non-metallic micro inclusions. These must be acceptable for the final product.

(b) Macro etching on representative sample, in accordance with ASTM E381 or equivalent, this must be free from any injurious segregation or porosity.

(c) Jominy hardenability tests in accordance with ASTM A255 or equivalent.

The results of these tests are to be supplied by the steel manufacturer, and the results are to be included in the final accessory documentation.

3.8.7 Fittings for chain are to be heat treated in accordance with procedures that have been approved by LR.

3.8.8 All fittings are to be manufactured to a manufacturing specification approved by LR, and provision is to be made for tensile and impact test specimens. The test samples are to be subjected to heat treatment with the fittings they represent. The mechanical test requirements are the same as those for the relevant grade of chain cable, *see* Table 10.3.3.

3.8.9 For fittings for mooring chain, a batch is defined as fittings from the same steel-making heat that have been heat treated together in the same furnace.

3.8.10 Mechanical tests for fittings are to be taken from full size fittings that have been heat treated with the production batch they represent, and the tests are to be taken after the fitting has been proof load tested. It is not permitted to use separate representative coupons unless approved by LR in accordance with 3.8.14.

3.8.11 Forged shackle bodies and forged Kenter shackles are to have a set of three Charpy impact tests and a tensile test taken from the crown of the shackle. For smaller diameter shackles, where the geometry does not allow for the tensile test to be taken from the crown, this may be taken from the straight portion from the locations specified in Fig. 10.3.4, with the Charpy impact test specimens on the outside radius.

3.8.12 The test pieces for cast shackle bodies and cast Kenter shackles can be taken from the straight portion of the fitting from the locations shown in Fig. 10.3.4.

3.8.13 For fittings with complex geometries the locations of test pieces taken are to be approved by LR.

3.8.14 Where fittings are produced in small batches (less than 5) alternative testing may be approved; a proposal must be submitted in a written procedure for consideration.

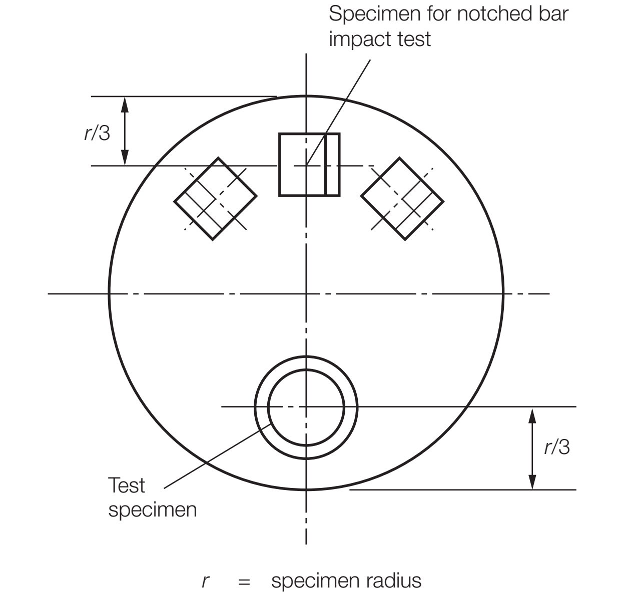


Fig. 10.3.4
Sampling of steel bars, forgings and castings

3.8.15 Mechanical tests of pins are to be taken as shown in Fig. 10.3.5 from the mid length of a sacrificial pin of the same diameter as the final pin. For oval pins, the diameter taken is to represent the smaller dimension. Mechanical tests may be taken from an extended pin of the same diameter as the final pin that incorporates a test prolongation and a heat treatment buffer prolongation, where equivalence with mid length test values have been established. The length of the buffer is to be at least equal to 1 pin diameter which is removed after the heat treatment cycle is finished. The test coupon can then be removed from the pin. The buffer and test are to come from the same end of the pin, as shown in Fig. 10.3.5.

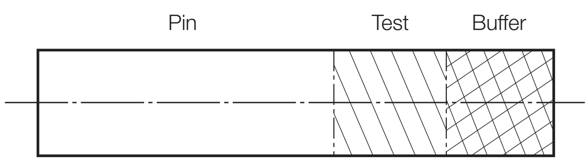


Fig. 10.3.5
Buffer and test piece location for pins

3.8.16 Manufacturers intending to supply accessories in the machined condition (e.g. Kenter type shackles) are to submit detailed drawings for approval by LR.

3.8.17 All chain cable accessories, including spares, are to be subjected to the proof loads appropriate to the grade and size of cable for which they are intended, *see* Table 10.3.1. Prior to this test, the accessories are to be shot or sand blasted to ensure that their surfaces are free from scale, paint or any other coating which could interfere with any subsequent inspection.

3.8.18 The appropriate breaking load as required by Table 10.3.1 is to be applied to at least one item out of every batch of up to 25, and this item is to be destroyed and not used as part of an outfit.

3.8.19 If the sample fails to withstand the breaking load without fracture, or in the event of failure of any other test, then the entire batch is to be rejected unless the cause of failure has been determined and it can be demonstrated that the condition causing failure is not present in any of the other accessories in the batch. If this can be demonstrated then two more samples from the same batch may be tested. If either of these samples fails, the batch is to be rejected.

3.8.20 For very large fittings where the required breaking load is greater than the capacity of the testing machine and for individually produced accessories or accessories produced in small batches, proposals for an alternative method of testing will be given special consideration. All proposals for alternative testing methods are to be detailed in writing and submitted.

3.8.21 At least one accessory from each batch is to be checked dimensionally after proof load testing. The manufacturer is to provide a statement that the dimensions comply with the specified requirements.

3.8.22 The following tolerances apply of the unmachined dimensions of all fittings;
(a) nominal diameter plus 5 per cent, minus 0 per cent; and
(b) other dimensions plus or minus 2,5 per cent.

3.8.23 All accessories are to be subjected to close visual examination after proof load testing, particular attention being paid to machined surfaces and highly stressed regions. All accessories are also to be examined by magnetic particle or dye penetrant inspection and ultrasonic testing. All NDE is to be carried out in accordance with 3.6.9 and 3.6.10. The manufacturer is to provide a statement that the non-destructive examination has been carried out with satisfactory results; this statement is to include reference to the techniques used and the operator's qualifications.

3.8.24 All testing is to be carried out to the satisfaction and in the presence of the Surveyor.

3.8.25 Fittings of increased dimensions or higher grade material may be used subject to approval by LR.

3.8.26 Where fittings with increased dimensions, or fittings of a higher material grade are included in an outfit:
(a) each item must be successfully tested at the required breaking load for the chain cable for which it is intended; and
(b) items of increased dimensions are so designed that their breaking strength is not less than 1,4 times the Rule minimum breaking load for the chain cable for which they are intended, and this has been verified by procedure tests.

3.9 Identification

3.9.1 Each length of chain is to be permanently marked with the following:
(a) LR and abbreviated name of LR's local office issuing the certificate.
(b) Certificate number (this may be abbreviated provided it is stated in the certificate).
(c) Grade and proof load of chain.

3.9.2 The chain is to be marked as follows:
(a) at each end (the marking should identify the leading and tail end of each chain),
(b) at intervals not exceeding 100 m,
(c) on all connecting common links or shackles and the immediately adjacent links,
(d) on the first and last common link of each individual heat used in the continuous length.

3.9.3 All identification marks are to be made on the studs and are to be permanent and legible throughout the expected service life of the chain.

3.10 Documentation

3.10.1 A complete Chain Inspection and Testing Report, in booklet form, is to be provided by the chain manufacturer for each continuous chain length, and for each order for chain and fittings. It is to include all dimensional checks, test and inspection reports, non-destructive test reports, process records, as well as any non-conformity, together with corrective action and repair work.

3.10.2 All documents, including reports and appendices, are to contain a reference to the relevant certificate number.

3.10.3 The chain manufacturer is responsible for storing all the documentation in a safe and retrievable manner for a period of at least 10 years.

3.11 Certification

3.11.1 An LR certificate is to be issued for each continuous single length of chain, and each type of fitting, *see* Ch 1,3.1.

3.11.2 Each test certificate is to include the following particulars:
(a) Purchaser's name and order number.
(b) Description and dimensions.
(c) Grade of chain cable.
(d) Identification mark which will enable the full history of the chain to be traced.
(e) Chemical composition.
(f) Details of heat treatment.
(g) Mechanical test results.
(h) Breaking test load.
(j) Proof load.
(k) The number and locations of all connecting common links and all marked links.

■ *Section 4* Studless mooring chain cables

4.1 Scope

4.1.1 Provision is made in this Section for five grades, R3, R3S, R4, R4S and R5 of studless flash butt welded chain cable intended for long term mooring applications.

4.1.2 The chain is generally expected to be deployed only once for a pre-determined service life.

4.1.3 Each studless chain link design will require to be approved by LR. The plan submitted for this approval is to include the minimum proof and breaking test loads, and the chain mass calculations.

4.2 Manufacture

4.2.1 All the requirements of 3.2, with the exception of that relating to studs, apply to the manufacture of studless mooring chain cables.

4.3 Shape and dimensions of links

4.3.1 The shape and dimensions of the links are to be in accordance with the approved design.

4.4 Dimensional tolerances

4.4.1 The dimensional tolerances of studless links are to be in accordance with the requirements of 3.3.1 to 3.3.7.

4.4.2 The tolerances for common links are to be measured in accordance with Fig. 10.4.1.

4.5 Heat treatment

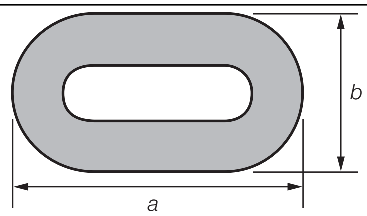
4.5.1 Heat treatment of the chain is to be in accordance with the requirements of 3.5.

4.6 Testing of completed chain

4.6.1 All chain cables are to be tested in the presence of a Surveyor, at a proving establishment recognised by LR. A list of recognised proving establishments is published by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

Fig. 10.4.1 Studless chain cable common link tolerances

The internal link radii (*R*) and external radii should be uniform



Designation	Description	Nominal dimension of the link	Minus tolerance	Plus tolerance
a	Link length	6*d*	0,15*d*	0,15*d*
b	Link width	3,35*d*	0,09*d*	0,09*d*
R	Inner radius	0,60*d*	0	–

Symbols

d = nominal diameter of chain

NOTE
Other dimensional ratios are subject to special approval.

4.6.2 The entire length of chain cable is to be subjected to a proof load test in an approved testing machine and is to withstand the load given in Table 10.3.1 for the appropriate grade and diameter of the chain, *see also* 4.1.3.

4.6.3 Inspection after proof load testing is to be in accordance with the requirements given in 3.6.3 to 3.6.20, excluding that related to checking of studs in 3.6.5.

4.6.4 In addition to the inspection of the flash butt welded areas as required in 3.6.6, the surfaces of the bends of at least 10 per cent of the links are to be examined by magnetic particle inspection and are to be free from cracks or other defects.

4.6.5 If stretching of links is required in order to maintain dimensional tolerances, the load applied is not to exceed the proof load by more than 10 per cent, and only random lengths of the chain need to be stretched.

4.6.6 Breaking load tests are to be carried out in accordance with 3.6.21 to 3.6.23 and Tables 10.3.1 and 10.3.2.

4.6.7 Alternative procedures to breaking load testing (*see* 3.6.24) are not permissible unless prior agreement is given by LR after special consideration.

4.6.8 Mechanical testing is to be carried out in accordance with 3.6.25 to 3.6.30 and Table 3.3.4.

4.6.9 The weight of the chain cable is to be in accordance with the approved plan.

4.7 Connecting or substitute links

4.7.1 Connecting links and substitute links are to be in accordance with the requirements of 3.7.

4.8 Fittings

4.8.1 Fittings for studless chain are to comply with the requirements of 3.8.

4.9 Identification

4.9.1 All chain and each fitting is to be identified in accordance with 3.9.1 and 3.9.2.

4.9.2 Identification marks are to be made on the outside of the straight part of the link, opposite the flash butt weld.

4.10 Certification

4.10.1 Certificates are to be issued in accordance with 3.11.

4.11 Documentation

4.11.1 Documentation in accordance with 3.11 is to be provided by the manufacturer.

■ *Section 5*
Short link chain cables

5.1 Scope

5.1.1 This Section gives the requirements for electrically welded steel short link chain cable for marine use but excluding those applications covered by the *Code for Lifting Appliances in a Marine Environment*.

5.1.2 Provision is made for grade M(4), as defined in ISO 1834.

5.2 Manufacture

5.2.1 Short link chain cables are to be manufactured at works approved by LR. A list of approved manufacturers for short link chain cable is published separately by LR.

5.2.2 The chain is to be supplied in either the normalised or quenched and tempered condition. Heat treatment is to be carried out prior to proof and breaking load testing.

5.2.3 The chain may be galvanised using a hot dipping process provided that this is carried out prior to proof and breaking load testing. If galvanised, it is recommended that the thickness of the zinc coating be not less than 70 microns.

5.2.4 Unless otherwise agreed, the finished chain is to be free from coatings other than zinc.

5.3 Bar material

5.3.1 Bars for the manufacture of short link chain cable are to be made and tested in accordance with the appropriate requirements of Ch 3,1 and to the requirements of an International or acceptable National Standard.

5.3.2 The bars are to be made at a works approved by LR.

5.3.3 The steel is to be fully killed and fine grain treated.

5.3.4 The steel is to have mechanical properties which will allow the chain to meet the mechanical test requirements of 5.4.7 and Table 10.5.1.

Table 10.5.1 Mechanical test requirements for short link chain cables

Chain diameter mm	Grade M(4)	
	Proof load kN	Breaking load minimum kN
5	7,9	15,8
6,3	12,5	25
7,1	15,9	31,8
8	20,2	40,4
9	25,5	51
10	29,5	63
11,2	31,5	79
12,5	49,1	98,2
14	63	126
16	81	162
18	102	204
20	126	252
22,4	158	316
25	197	394
28	247	494
32	322	644
36	408	816
40	503	1006
45	637	1274

5.4 Testing and inspection of chain cables

5.4.1 All chain cable of 12,5 mm diameter and above, and all steering chains irrespective of diameter, are to be tested in the presence of a Surveyor at a proving establishment recognised by LR. A list of recognised proving establishments is published by LR. In addition to the requirements stated in this Chapter, attention is to be given to any relevant statutory requirements of the National Authority of the country in which the ship or other marine structure is to be registered.

5.4.2 For chain of diameter less than 12,5 mm, other than steering chains, the manufacturer's tests will be acceptable.

5.4.3 After completion of all manufacturing processes, including heat treatment and galvanising, the whole of the chain is to be subjected to the appropriate proof load specified in Table 10.5.1.

5.4.4 The whole of the chain is to be inspected after the proof load test and is to be free from significant defects.

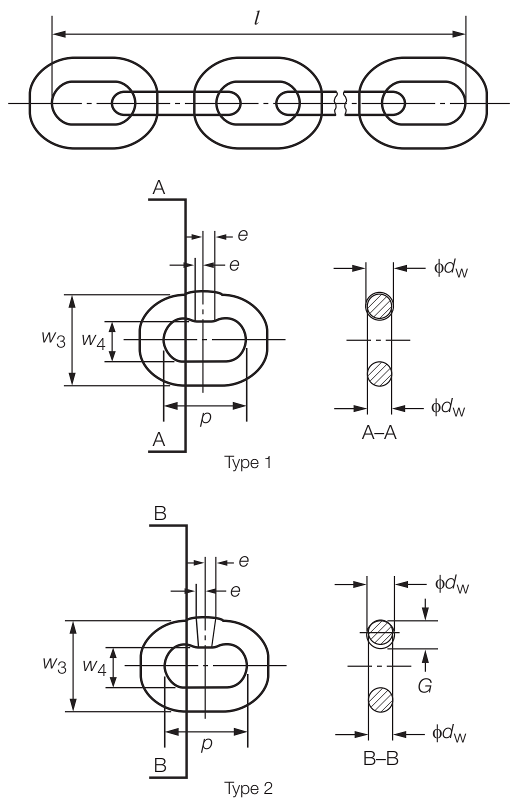
5.4.5 At least one sample, consisting of seven or more links, is to be selected by the Surveyor from each 200 m or less of chain for breaking load tests. Two additional links may be required for engagement in the jaws of the testing machine. These extra links are not to be taken into account in determining the total elongation, *see* 5.4.7.

5.4.6 The breaking load is to comply with the appropriate requirements of Table 10.5.1.

5.4.7 The total elongation of the breaking load sample at fracture, expressed as a percentage of the original inside length of the sample after proof loading, is to be not less than 20 per cent.

5.5 Dimensions and tolerances

5.5.1 The form and proportions of links are to be in accordance with Fig. 10.5.1.



l = multiple pitch length
p = pitch (internal link length)
d_n = measured diameter of the material, except at the weld
d_w = measured diameter of the material at the weld (Type 1) or weld dimension perpendicular to the plane of the link (Type 2)
G = dimension in other planes as per individual chain specification (Type 2)
e = length affected by welding, on either side of the centre link
w_1 = internal link width away from the weld
w_2 = external link width away from the weld
w_3 = external link width over the weld
w_4 = internal link width at the weld

Fig. 10.5.1 Form and proportions of links

5.5.2 Manufacturing tolerances are to be within the following limits:

Nominal diameter, d_n	± 5%
Pitch of chain, p_1	± 3%
Length measured over 11 links, l	± 2%
Inside width, w_1	$1{,}35d_n$ minimum
Outside width, w	$3{,}6d_n$ maximum

The tolerances are to apply after galvanising. All measurements are to be taken after proof testing.

5.6 Identification

5.6.1 All lengths of cable are to be stamped with the following identification marks:

(a) Inspector's mark and date.
(b) Reference mark or number of certificate.
(c) Manufacturer's mark or name.
(d) Chain cable quality mark, M, is to be stamped on at least each twentieth link or at intervals of one metre, whichever is the lesser distance.

5.6.2 Where the inspection is performed under LR's supervision, the inspector's mark and date are to be replaced by LR and the abbreviated name of LR's local office issuing the certificate.

5.7 Certification

5.7.1 The manufacturer is to supply the Surveyor with a certificate stating compliance with an appropriate ISO standard, and also, in the event of the requirements of 5.4 being undertaken other than in the presence of the Surveyor, stating that the test and inspection requirements have been complied with at a recognised proving establishment.

5.7.2 Each test certificate is to include the following particulars:

(a) the quality and description of chain,
(b) identification mark,
(c) nominal size of chain,
(d) proof load,
(e) breaking load,
(f) total elongation at fracture,
(g) where appropriate, the name of the proving establishment.

■ *Section 6* Steel wire ropes

6.1 Scope

6.1.1 Provision is made in this Section for the requirements for the manufacture, testing and certification of steel wire ropes intended to be used for general marine purposes, as well as permanent anchoring, mooring and marine lifting applications.

6.2 General requirements

6.2.1 For general marine purposes, such as stream wires, towlines and ship mooring lines, the construction is to be in accordance with Table 10.6.1. The construction, diameter and strength of steel wire ropes for permanent offshore applications, such as mooring, anchoring and lifting, are covered by other LR Rules. Alternative applications of wire ropes may be accepted, subject to special consideration.

6.2.2 The manufacturer's plant and method of production are to be approved by LR. A list of approved manufacturers of steel wire ropes is published annually in the *List of Approved Manufacturers of Materials*.

6.2.3 For shaped wire, for example, for large diameter ropes for permanent mooring, where there are no established Standards, the manufacturer is to provide evidence by way of test reports that specifications have been developed and agreed with the purchaser and LR for the purposes intended.

6.3 Steel wire for ropes

6.3.1 Steel wire is to be of homogeneous quality, uniform strength and free of defects likely to impair the manufacture and performance of the rope.

6.3.2 For all ropes, the specified minimum tensile strength of the wire is to be 1420, 1570, 1770 or 1960 N/mm^2. The specified minimum tensile strength of the wire is the designated grade for the rope, unless otherwise defined by the purchaser's specification. The actual tensile strength of the wire is not to exceed 120 per cent of the specified minimum tensile strength.

Table 10.6.1 Recommended rope construction

Purpose	Construction of rope			Construction of strands
	Strands	Wires	Core	
Stream wires, towlines and mooring lines	6	24	Fibre	15 over 9 over fibre core
	6	37	Fibre	18 over 12 over 6 over 1
	6	26	Fibre	10 over (5 + 5) over 5 over 1
	6	31	Fibre	12 over (6 + 6) over 6 over 1
	6	36	Fibre	14 over (7 + 7) over 7 over 1
	6	41	Fibre	16 over (8 + 8) over 8 over 1
	6	30	Fibre	18 over 12 over fibre core
Towlines and mooring lines used in association with mooring winches	6	31	7 x 7 wire rope	12 over (6 + 6) over 6 over 1
	6	36	7 x 7 wire rope	14 over (7 + 7) over 7 over 1
	6	41	7 x 7 wire rope	16 over (8 + 8) over 8 over 1

6.3.3 For new rope construction, the manufacturer is to carry out prototype testing suitable for the application of the rope and this is to include tests on wire used for the construction.

6.3.4 Tensile and torsion tests, coating, and adhesion (wrap) tests are to be carried out on wire used for the manufacture of rope.

6.3.5 At least 10 per cent of the spools used for the manufacture of the strand are to be tested. The manufacturer is to demonstrate that tests have been carried out on at least one wire intended for each of the outer and inner strands, and for each diameter and grade used.

6.3.6 The heat number, wire diameter and strength of wire used for a particular construction are to be recorded by the manufacturer.

6.3.7 Torsion tests are to be carried out on the wire by causing one or both of the securing vices to be revolved until fracture occurs (a tensile load not exceeding two per cent of the breaking load of the wire may be applied to keep the wire stretched).

6.3.8 The uncoated wire is to withstand, without fracture, the number of complete twists given for Grades 1 or 3 in Table 10.6.2.

6.3.9 The galvanised wire is to withstand, without fracture, the number of complete twists given in the specification, as agreed with the purchaser and LR. In the absence of a suitable specification, the results are to comply with Table 10.6.2.

Table 10.6.2 Torsion test

Diameter coated wire mm	Minimum number of twists					
	Grade 2		Grade 1 or 3			
	Minimum strength N/mm^2		Minimum strength N/mm^2			
	1570	1770	1420	1570	1770	1960
<1,3	19	18	29	26	23	23
≥1,3 <2,3	18	17	26	24	21	21
≥2,3 <3,0	16	14	24	22	—	19
≥3,0 <4,0	12	10	20	18	—	17
≥4,0 <4,6	—	—	18	16	—	—
≥4,6 <5,0	—	—	16	14	—	—
≥5,0 <6,0	—	—	14	11	—	—

NOTE
The minimum test length is 100*d* or 300 mm, where *d* is the wire diameter.

6.3.10 Hot dipped galvanised steel wire is to be used for the manufacture of ropes for marine applications. Depending upon the application, the coating may comply with any of the grades in Table 10.6.3. Grades 1 and 2 are heavy coatings. Grade 3 is the minimum coating weight where the galvanising is carried out prior to final wire drawing. Uncoated wire may be considered for approved applications.

Table 10.6.3 Zinc coating

Diameter of coated wire mm	Zinc coating, minimum g/m^2		
	Grade1	Grade 2	Grade 3
≥0,20 <0,25	—	30	20
≥0,25 <0,33	—	45	30
≥0,33 <0,40	—	60	30
≥0,40 <0,50	60	75	40
≥0,50 <0,60	70	90	50
≥0,60 <0,80	85	110	60
≥0,80 <1,00	95	130	70
≥1,00 <1,20	110	150	80
≥1,20 <1,50	120	165	90
≥1,50 <1,90	130	180	100
≥1,90 <2,50	—	205	110
≥2,50 <3,20	—	230	125
≥3,20 <4,00	—	250	135

6.3.11 The mass per unit area of the zinc coating is to be determined in accordance with a recognised National or International Standard.

6.3.12 Zinc coating tests are to be carried out for each designated grade of wire. The manufacturer is to demonstrate that the coatings are continuous and uniform and suitable for the intended purpose.

6.3.13 Unless otherwise specified by the purchaser, zinc coating tests are to be carried out on the wire prior to stranding.

6.3.14 The adhesion of the coating is to be tested by wrapping the wire round a cylindrical mandrel for 10 complete turns. The ratio between the diameter of the mandrel and that of the wire is to be as in Table 10.6.4. After wrapping on the appropriate mandrel, the zinc coating is to have neither flaked nor cracked to such an extent that any zinc can be removed by rubbing with a cloth.

Table 10.6.4 Wrap test for adhesion of coating

Coating	Diameter of coated wire mm	Maximum ratio of mandrel to wire diameter
Grade 1 and 2	<1,5	4
	≥1,5	6
Grade 3	<1,5	2
	≥1,5	3

6.4 Tests on completed ropes

6.4.1 Every length of wire rope is to be subjected to a breaking strength test.

6.4.2 A sample of sufficient length is to be provided for the breaking load test. The rope ends are to be enclosed in a suitable socket. Testing is to be carried out in accordance with a recognised National or International Standard.

6.4.3 The rope may be subject to cyclic loading for bedding purposes prior to testing. The rope is to be tested at a suitable strain rate in accordance with a recognised National or International Standard.

6.4.4 The load is to be applied until one wire break is witnessed or 130 per cent of the minimum breaking load is recorded. The maximum recorded load is to be reported by the manufacturer.

6.4.5 Tests in which a breakage occurs adjacent to and as a result of damage from the grips are to be rejected, if the applied load is less than the specified minimum requirement. The rope is to be retested to withstand the agreed minimum breaking load.

6.4.6 With the exception of offshore mooring ropes, consideration may be given to determining the breaking load by summation or aggregating actual test results on individual wires, if facilities are not available for undertaking a breaking test on a production basis. A suitable spin factor or lay-up deduction allowance in accordance with a recognised National or International Standard for the applicable rope diameter, designated grade and construction is to be applied.

6.4.7 Where spin factors or lay-up deduction allowances are proposed by the manufacturer, a report on suitable cyclic load testing of prototype ropes of the same construction, strength and diameter is to be approved by LR. In addition, the manufacturer is to show that a satisfactory breaking load test has been carried out in the previous two years, and witnessed by LR for the same rope construction, diameter and designated grade.

6.4.8 LR may give special consideration to spin factors or lay deductions based on data extrapolated from smaller diameter ropes of the same construction, provided that these ropes have been tested in accordance with 6.4.7.

6.4.9 All data arising from smaller diameter ropes for the extrapolation in 6.4.8 are to have been derived from tests carried out within two years of the manufacture of the larger diameter rope.

6.4.10 The finished rope is to have no more than one wire connecting weld in any length of 18*d*, where *d* is the diameter of the rope.

6.5 Inspection

6.5.1 A report on dimensional and visual examination is to be presented to the Surveyor by the manufacturer. The dimensions and discard criteria are to comply with an agreed National or International Standard.

6.6 Identification

6.6.1 All completed ropes are to be identified with attached labels detailing the rope type, diameter and length.

6.7 Certification

6.7.1 A manufacturer's certificate, in accordance with Ch1,3.1.3(c), is to be issued. The certificate is to be validated by the manufacturer's representative, who is to be independent of the production process and LR.

6.7.2 Each test certificate is to contain the following particulars:

- Purchaser's name and order number.
- Details of the rope construction.
- Core material.
- Grade of zinc coating.
- Mechanical test results.
- Adhesion test results.
- Dimensions.
- Method of breaking load testing.
- Breaking load.

■ *Section 7* Fibre ropes

7.1 Manufacture

7.1.1 Fibre ropes intended as mooring lines may be made of coir, hemp, manila or sisal, or may be composed of synthetic (man-made) fibres. They may be three-strand (hawser laid), four-strand (shroud laid) or nine-strand (cable laid), but other constructions will be specially considered.

7.1.2 Each length of rope is to be manufactured from suitable material of good and consistent quality. Rope materials should, in general, comply with a recognised National Standard.

7.1.3 Synthetic fibre ropes are to be suitable for the purpose intended and should comply with a recognised standard.

7.1.4 Weighting and loading matter is not to be added, and any lubricant is to be kept to a minimum. Any rot-proofing or water repellancy treatment is not to be deleterious to the fibre nor is it to add to the weight or reduce the strength of the rope.

7.2 Tests of completed ropes

7.2.1 The breaking load is to be determined by testing to destruction a sample cut from the completed rope.

7.2.2 The minimum test length and the initial test load are to be as given in Table 10.7.1. After application of the initial load, the diameter and evenness of lay up of the sample are to be checked. The sample is then to be uniformly strained at the rate given in Table 10.7.1 until it breaks.

7.2.3 The actual breaking load is to be not less than that given in an appropriate National Standard.

Table 10.7.1 Breaking load test

Material	Test length mm minimum	Initial load % (*see* Note)	Rate of straining mm/min
Natural fibre	1800	2	150 ± 50
Synthetic fibre	900	1	100 max.

NOTE
Percentage of specified minimum breaking load.

7.2.4 If the sample is held by grips and the break occurs within 150 mm of the grips, the test may be repeated, but not more than two tests may be made on any one coil.

7.2.5 Where difficulty is experienced in testing a sample of a completed synthetic fibre rope, LR will consider alternative methods of testing.

7.3 Identification

7.3.1 Each coil of rope is to be identified with an attached label detailing the material, construction, diameter and length.

7.4 Certification

7.4.1 A manufacturer's certificate, in accordance with Ch1,3.1.3(c), is to be issued. The certificate is to be validated by the manufacturer's representative, who is to be independent of the production process and LR.

7.4.2 Each test certificate is to include the following particulars:

- Manufacturer's name.
- Purchaser's name and order number.
- Rope type.
- Dimensions.
- Test length.
- Rate of straining.
- Breaking load.

■ *Section 1* General

1.1 Scope

1.1.1 Provision is made in this Chapter for the approval by Lloyd's Register (hereinafter referred to as 'LR') of electrodes, wires, fluxes and other consumables intended for use in the welding of the following types of materials:

(a) Steel of various grades as represented by Grade A through to Grade FH69, *see* Sections 3 to 7.
(b) A wide range of low-temperature service steels, *see* Sections 3 to 7.
(c) Stainless steels including nitrogen strengthened grades and some of the duplex varieties, *see* Section 8.
(d) Aluminium alloys, *see* Section 9.

1.1.2 For this purpose, welding, consumables are categorised and subject to the special requirements of different Sections of this Chapter.

(a) Covered electrodes for manual welding and gravity welding.
(b) Combinations of wire and flux for automatic submerged-arc welding.
(c) Combinations of wire and gas for gas metal-arc welding and wires for self-shielding welding.
(d) Combinations for electro-slag and electro-gas welding.
(e) Combinations with temporary backing materials for one-side welding.
(f) Consumables for welding austenitic and duplex stainless steels.
(g) Combinations for welding aluminium.

1.2 Grading

1.2.1 Consumables for welding structural steels are graded into ten strength levels, and each of these is further subdivided into several levels in respect of notch toughness. The five basic levels of toughness are indicated by a number (1 to 5). Normal tensile strength is indicated by 'N'. Higher tensile strength is indicated by 'Y', and if the yield strength is higher than 375 N/mm^2 the Y is followed by a number (40 to 69), as shown in Table 11.1.1.

1.2.2 In addition to the grade, consumables are also allocated a suffix indicating the welding technique used. These are defined in the context of the following Sections of this Chapter.

1.2.3 Consumables for structural and low temperature service steels may be controlled low hydrogen and approved as such. Grade marking H15, H10 or H5 will be applied, as appropriate.

1.2.4 For joining higher strength steels, approval granted for 1Y consumables will be limited to maximum material thickness of 25 mm.

1.2.5 Test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress relieved (tempered) condition. In those cases, the code 'sr' will be added to the approval grade.

1.2.6 Further details of grading are given in subsequent Sections of this Chapter.

1.3 Manufacture

1.3.1 The manufacturer's plant and method of production of welding consumables are to be such as to ensure reasonable uniformity in manufacture.

1.4 Approval procedures

1.4.1 Welding consumables will be approved subject to a satisfactory inspection of the works by the Surveyor for compliance with the test requirements detailed in subsequent Sections in this Chapter.

1.4.2 The test assemblies are to be prepared under the supervision of the Surveyor, and using samples selected by him. All tests are to be carried out in his presence.

1.4.3 For Charpy V-notch tests, a set of three test specimens is to be prepared and the average energy value is to comply with the requirements of subsequent Sections in this Chapter. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value.

1.4.4 Where chemical analysis is required for approval, the results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

Table 11.1.1 Welding consumable grades appropriate to structural and low temperature service steel grades

Consumable grade	Suitable for steel grades (*see* Notes)			
1. Ship Grade Steels (Ch 3,2 and Ch 3,3)				
1N	A	***AH27S***	—	—
2N	B, D	***DH27S***	—	—
3N	E	***EH27S***	—	—
1Y	A	***AH27S***	***AH32***	***AH36***
2Y	B, D	***DH27S***	***DH32***	***DH36***
3Y	E	***EH27S***	***EH32***	***EH36***
4Y	—	***FH27S***	***FH32***	***FH36***
2Y40	***AH32***	***AH36***	***AH40***	—
2Y40	***DH32***	***DH36***	***DH40***	—
3Y40	***EH32***	***EH36***	***EH40***	—
4Y40	***FH32***	***FH36***	***FH40***	—
5Y40	***FH32***	***FH36***	***FH40***	—
3Y47	—	—	***EH40***	***EH47***
2. High Strength Steels (Ch 3,10) *see* Note 3				
3Y42	***AH36***	***AH40***	AH42	—
3Y42	***DH36***	***DH40***	DH42	—
4Y42	***EH36***	***EH40***	EH42	—
5Y42	***FH36***	***FH40***	FH42	—
3Y46	***AH40***	AH42	AH46	—
3Y46	***DH40***	DH42	DH46	—
4Y46	***EH40***	EH42	EH46	—
5Y46	***FH40***	FH42	FH46	—
3Y50	AH42	AH46	AH50	—
3Y50	DH42	DH46	DH50	—
4Y50	EH42	EH46	EH50	—
5Y50	FH42	FH46	FH50	—
3Y55	AH50	AH55	—	—
3Y55	DH50	DH55	—	—
4Y55	EH50	EH55	—	—
5Y55	FH50	FH55	—	—
3Y62	AH55	AH62	—	—
3Y62	DH55	DH62	—	—
4Y62	EH55	EH62	—	—
5Y62	FH55	FH62	—	—
3Y69	AH62	AH69	—	—
3Y69	DH62	DH69	—	—
4Y69	EH62	EH69	—	—
5Y69	FH62	FH69	—	—
3. Ferritic Low Temperature Service Steels (Ch 3,6)				
$1^1/_2$ Ni	$1^1/_2$ Ni	—	—	—
$3^1/_2$ Ni	$3^1/_2$ Ni	—	—	—
5 Ni	5 Ni	—	—	—
9 Ni	9 Ni	—	—	—

NOTES
1. Steel grades shown in bold italic type include the equivalent (LT-xxxx) low temperature service grades referenced in Ch 3,6.
2. The Table applies to the multi-run welding techniques (i.e. m, S, M).
3. Approval of consumables intended for welding high strength steels in Ch 3,10 also includes the standard ship steel grades as shown in bold italic type and equivalent low temperature service steel grades referenced in Ch 3,6.

1.4.5 LR may require, in any particular case, such additional tests or requirements as may be necessary.

1.4.6 A *List of Approved Welding Consumables* is published by LR.

1.4.7 LR is to be notified of any alteration proposed to be made in the process of manufacture subsequent to approval. Sufficient detail is to be provided to determine the need for further testing to maintain the approval.

1.4.8 Consideration will be given to alternative procedures for approval in the case of manufacturers producing consumables under the control of another manufacturer or plant already having approval of one or more products.

1.5 Annual inspection and tests

1.5.1 All establishments where approved welding consumables are manufactured, and the associated quality control procedures, are to be subjected to annual inspection. On these occasions, samples of the approved consumables are to be selected by the Surveyor and subjected to the tests detailed in subsequent Sections in this Chapter. These are to be completed and reported before the end of the one year period beginning at the initial approval date, and repeated annually so as to provide at least an average of one annual test per year.

1.6 Changes in grading

1.6.1 Changes in grading of welding consumables will be considered only at the manufacturer's request, preferably at the time of annual testing. For upgrading in connection with impact properties, and uprating in connection with tensile properties, tests from butt weld assemblies will be required in addition to the normal annual approval tests. For upgrading in connection with hydrogen testing, specific tests will be required in accordance with ISO 3690. Downgrading and downrating may be imposed by LR where tests and re-tests fail to meet the requirements of this Chapter.

1.7 Manufacturers' Quality Assurance Systems

1.7.1 As an alternative to 1.5, manufacturers may seek maintenance of approval based on acceptance by LR of their 'in house' quality assurance system, and by regular audit of that system carried out in accordance with procedures approved by LR.

1.8 Certification

1.8.1 Each carton or package of approved consumables is to contain a certificate from the manufacturer, generally in accordance with the following: 'The <*insert name of manufacturer*> company certifies that the composition and quality of these consumables conform with those of the consumables used in making the test pieces submitted to and approved by the approval bodies nominated on the label of this package.'

Section 2
Mechanical testing procedures

2.1 Dimensions of test specimens

2.1.1 Dimensions of test pieces for deposited metal tensile tests, butt weld tensile tests, bend tests and Charpy V-notch impact test are to machined to the dimensions and tolerances detailed in Chapter 2.

2.2 Testing procedures

2.2.1 The procedures used for all tensile and impact tests are to comply with the requirements of Chapter 2.

2.2.2 Butt weld bend test specimens are to be tested at ambient temperature and are to be bent through an angle of 120° over a former having a diameter which relates to the thickness of the test specimen as detailed in subsequent Sections. For each pair of bend test specimens, one specimen is to be tested with the face of the weld in tension and the other with the root of the weld in tension.

2.2.3 Macro examinations are to be carried out on polished and etched specimens at a maximum magnification not exceeding x10. The examination is to ensure complete fusion, inter-run penetration and freedom of defects.

2.3 Re-testing procedures

2.3.1 Re-testing procedures are to comply with Ch 2,1.4.

Section 3
Electrodes for manual and gravity welding

3.1 General

3.1.1 Dependent on the results of the mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

3.1.2 Approval of an electrode will be given in conjunction with a welding technique indicated by a suffix ‘m’ for manual welding, ‘G’ for gravity or contact electrode and ‘p’ for deep penetration electrode.

3.1.3 If the electrodes are in compliance with the requirements of the hydrogen test given in 3.4, a suffix ‘H15’ or ‘H10’ or ‘H5’ will be added to the grade mark. Table 11.3.1 shows the mandatory levels of low hydrogen approval for the various approval grades.

3.1.4 For each strength level, electrodes which have satisfied the requirements for a higher toughness grade are considered as complying with the requirements for a lower grade.

Table 11.3.1 Minimum low hydrogen approval requirements for manual and gravity electrodes

Approval grades	Low hydrogen grade required
1 (1N), 2 (2N), 3 (3N)	NR
2Y, 3Y, 4Y	H15 (*see* Note 2)
2Y40 to 5Y40	H15
3Y47	H10
3Y42 to 5Y42	H10
3Y46 to 5Y46	H10
3Y50 to 5Y50	H10
3Y55 to 5Y55	H5
3Y62 to 5Y62	H5
3Y69 to 5Y69	H5
1½ Ni	H15
3½ Ni	H15
5 Ni	NR (*see* Note 3)
9 Ni	NR (*see* Note 3)

NOTES
1. NR – Not required. Approval may be obtained when requested.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes use of an austenitic, non-transformable, filler material.

3.1.5 Electrodes approved for normal and higher strength levels up to and including ‘Y’ are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

3.1.6 Electrodes approved for strength levels Y40 to Y50, but excluding Y47 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

3.1.7 Electrodes approved for strength levels Y47, Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

3.1.8 The welding current used is to be within the range recommended by the manufacturer and, where an electrode is stated to be suitable for both a.c. and d.c., a.c. is to be used for the preparation of the test assemblies.

3.1.9 Where an electrode is submitted only for approval for fillet welding and to which the butt weld test provided in 3.3 is not considered applicable, approval tests are to consist of the fillet weld tests as given in 3.5 and deposited metal tests with chemical analyses as given in 3.2.

3.2 Deposited metal test assemblies

3.2.1 The deposited metal test assemblies are to be prepared in the downhand position as shown in Fig. 11.3.1, one with 4 mm diameter electrodes and the other with 8 mm diameter electrodes, or the largest size manufactured if this is less than 8 mm diameter. If an electrode is available in one diameter only, one test assembly is sufficient. Any of the grades of steel in Table 11.1.1 may be used for the preparation of these assemblies, up to a strength level which is not more than two levels above that for which approval is sought.

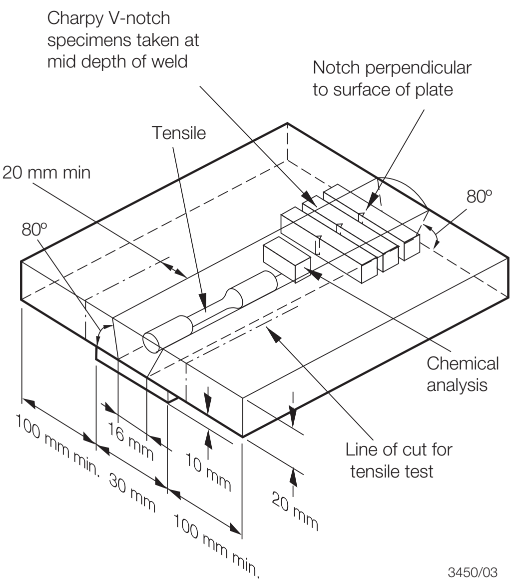


Fig. 11.3.1 Deposited metal test assembly

3.2.2 For Y47 grades, as an alternative to Fig. 11.3.1, the thickness of the plate used for the test assembly may be taken as 50 mm.

3.2.3 The weld metal is to be deposited in single- or multi-run layers according to normal practice, and the direction of deposition of each layer is to alternate from each end of the plate, each run of weld metal being not less than 2 mm and not more than 4 mm thick. Between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress-relieved (tempered) condition. In those cases, the code 'sr' will be added to the approval grading.

3.2.4 The chemical analysis of the deposited weld metal in each deposited metal test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

3.2.5 One tensile and three impact test specimens are to be taken from each test assembly as shown in Fig. 11.3.1. Care is to be taken that the axis of the tensile test specimen coincides with the centre of the weld and the mid-thickness of the plates. The impact test specimens are to be cut perpendicular to the weld, with their axes 10 mm from the upper surface. The notch is to be positioned in the centre of the weld and cut in the face of the test specimen perpendicular to the surface of the plate.

3.2.6 The results of all tests are to comply with the requirements of Table 11.3.2 as appropriate.

3.3 Butt weld test assemblies

3.3.1 Butt weld assemblies, as shown in Fig. 11.3.2, are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward, vertical-downward, and overhead) for which the electrode is recommended by the manufacturer. In the case of electrodes for normal strength and higher strength steels (up to 355 N/mm^2 minimum specified yield strength), electrodes satisfying the requirements for downhand and vertical-upward positions will be considered as also complying with the requirements for the horizontal-vertical position. In all other cases, approval for the horizontal-vertical position will require a butt weld to be made in that position and fully tested.

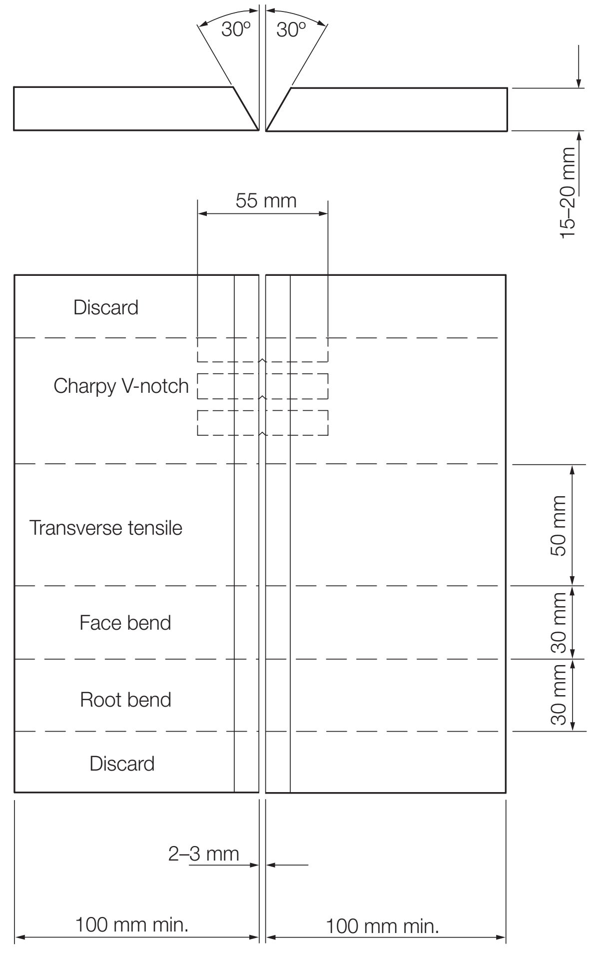


Fig. 11.3.2 Butt weld test assembly

3.3.2 For Y47 grades, as an alternative to Fig. 11.3.2 the thickness of the plate used for the test assembly may be taken as 50 mm.

3.3.3 Where the electrode is to be approved only in the downhand position, an additional test assembly is to be prepared in that position.

Table 11.3.2 Requirements for deposited metal tests (covered electrodes)

Grade (*see* Note 3)	Yield stress N/mm^2 minimum	Tensile strength N/mm^2 (*see* Note 1)	Elongation on 50 mm % minimum	Charpy V-notch impact tests	
				Test temperature °C	Average energy (*see* Note 2) J minimum
1N, 2N, 3N	305	400 – 560	22	+20, 0, –20	47
1Y, 2Y, 3Y, 4Y	375	490 – 660	22	+20, 0, –20, –40	47
2Y40, 3Y40, 4Y40, 5Y40	400	510 – 690	22	0, –20, –40, –60	47
3Y47	460	570 – 720	19	–20	53
3Y40	400	510 – 690	22	–20	47
3Y42	420	530 – 680	20	–20	47
3Y46	460	570 – 720	20	–20	47
3Y50	500	610 – 770	18	–20	50
3Y55	550	670 – 830	18	–20	55
3Y62	620	720 – 890	18	–20	62
3Y69	690	770 – 940	17	–20	69
4Y40	400	510 – 690	22	–40	47
4Y42	420	530 – 680	20	–40	47
4Y46	460	570 – 720	20	–40	47
4Y50	500	610 – 770	18	–40	50
4Y55	550	670 – 830	18	–40	55
4Y62	620	720 – 890	18	–40	62
4Y69	690	770 – 940	17	–40	69
5Y40	400	510 – 690	22	–60	47
5Y42	420	530 – 680	20	–60	47
5Y46	460	570 – 720	20	–60	47
5Y50	500	610 – 770	18	–60	50
5Y55	550	670 – 830	18	–60	55
5Y62	620	720 – 890	18	–60	62
5Y69	690	770 – 940	17	–60	69
$1^1/_2$ Ni	375	460	22	–80	34
$3^1/_2$ Ni	375	420	25	–100	34
5 Ni	375	500	25	–120	34
9 Ni	375	600	25	–196	34

NOTES
1. Single values are the minimum requirements.
2. Energy values from individual impact test specimens are to comply with 1.4.3.
3. Grade 1Y is not applicable to SMAW consumables referenced in Section 3.

3.3.4 The grades of steel used for the preparation of the test assemblies are to be as follows:

Grade 1 (1N) electrodes	A
Grade 2 (2N) electrodes	A, B or D
Grade 3 (3N) electrodes	A, B, D or E
Grade 2Y electrodes	AH32, AH36, DH32 or DH36
Grade 3Y electrodes	AH32, AH36, DH32, DH36, EH32 or EH36
Grade 4Y electrodes	AH32 AH36, DH32, DH36, EH32, EH36, FH32 or FH36
Grade 2Y40 electrodes	AH40 or DH40
Grade 3Y40 electrodes	AH40, DH40 or EH40
Grade 4Y40 electrodes	AH40, DH40, EH40 or FH40
Grade 5Y40 electrodes	AH40, DH40, EH40 or FH40
Grade 3Y47 electrodes	EH47

Where Grade 32 higher tensile steel is used, the tensile strength is to be not less than 490 N/mm^2. The chemical composition, including the content of grain refining elements, is to be reported in all cases where higher tensile steel is used.

3.3.5 For all other grades, the steel plates used are to be selected by reference to Table 11.1.1, and are to have at least their chemical composition and tensile properties within the limits specified for that grade in Chapter 3. The strength grade used is to be the same as that for which approval is sought, and the toughness grade is to be no higher than that for which approval is also sought.

3.3.6 The test assemblies are to be made by welding together two plates of equal thickness (15 to 20 mm), not less than 100 mm in width and of sufficient length to allow the cutting out of test specimens of the prescribed number and size. The plate edges are to be prepared to form a single V-joint, the included angle between the fusion faces being 60° and the root gap 2 to 3 mm. The root face is to be 0 to 2 mm.

3.3.7 The following welding procedure is to be adopted in making the test assemblies:

Downhand (a). The first run with 4 mm diameter electrode. Remaining runs (except the last two layers) with 5 mm diameter electrodes or above according to the normal welding practice with the electrodes. The runs of the last two layers with the largest diameter of electrode manufactured or 8 mm whichever is the lesser.

Downhand (b) (where a second downhand test is required). First run with 4 mm diameter electrode. Next run with an electrode of intermediate diameter of 5 mm or 6 mm, and the remaining runs with the largest diameter of electrode manufactured or 8 mm whichever is the lesser.

Horizontal-vertical. First run with 4 mm or 5 mm diameter electrode. Subsequent runs with 5 mm diameter electrodes.

Vertical-upward and overhead. First run with 3,25 mm diameter electrode. Remaining runs with 4 mm diameter electrodes or possibly with 5 mm if this is recommended by the manufacturer for the positions concerned.

Vertical-downward. If the electrode being tested is intended for vertical welding in the downward direction, this technique is to be adopted for the preparation of the test assembly using electrode diameters as recommended by the manufacturer.

3.3.8 For all assemblies, the back sealing runs are to be made with 4 mm diameter electrodes in the welding position appropriate to each test sample, after cutting out the root run to clean metal. For electrodes suitable for downhand welding only, the test assemblies may be turned over to carry out the back sealing run.

3.3.9 Normal welding practice is to be used and, between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress-relieved (tempered) condition. In those cases, the code 'sr' will be added to the approval grading.

3.3.10 It is recommended that the welded assemblies be subjected to a radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

3.3.11 The test specimens as shown in Figs. 11.3.2 and 11.3.3 are to be prepared from each test assembly.

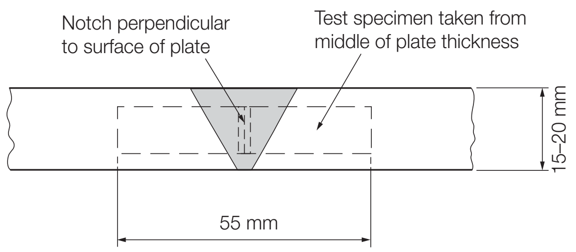


Fig. 11.3.3
Butt weld test assembly position of impact test specimens

3.3.12 The results of all tensile and impact tests are to comply with the requirements of Table 11.3.3 as appropriate. The position of fracture in the transverse tensile test is to be reported.

3.3.13 The bend test specimens can be considered as complying with the requirements if, after bending, no crack or other open defect exceeding 3 mm in dimensions can be seen on the outer surface.

3.4 Hydrogen test

3.4.1 The hydrogen gradings are specified in 3.1.3. The hydrogen grading required determines the method of testing permitted as shown in Table 11.3.4. Where ISO 3690 is used as the testing method, three test specimens are to be prepared and tested, and all three hydrogen test results must be below the maximum value for the hydrogen mark required.

3.5 Fillet weld test assemblies

3.5.1 Fillet weld assemblies as shown in Fig. 11.3.4 are to be prepared for each welding position (horizontal-vertical, vertical-upward, vertical-downward or overhead) for which the electrode is recommended by the manufacturer. The grade of steel used for the test assemblies is to be as detailed in 3.3.4. The length of the test assembly, *L*, is to be sufficient to allow at least the deposition of the entire length of the largest diameter electrode being tested. Where an electrode is submitted for approval of both butt and fillet welding, approval tests are to include the deposited metal tests as given in 3.2, the butt weld tests as given in 3.3, and only one fillet weld test as given in subsequent paragraphs of this sub-Section welded in the horizontal-vertical position.

3.5.2 For Y47 grades, as an alternative to Fig. 11.3.4, the thickness of the plate used for the test assembly may be taken as 50 mm.

Table 11.3.3 Requirements for butt weld tests (covered electrodes)

Grade (see Note 3)	Tensile strength N/mm^2	Bend test ratio: $\frac{D}{t}$	Charpy V-notch impact tests: Test temperature °C	Charpy V-notch impact tests: Average energy (see Note 1) J minimum — All positions (see Note 2)
1N, 2N, 3N	400	3	+20, 0, –20	47 (34)
1Y, 2Y, 3Y, 4Y	490	3	+20, 0, –20, –40	47 (34)
2Y40, 3Y40, 4Y40, 5Y40	510	3	0, –20, –40, –60	47 (39)
3Y47	570 – 720	4	–20	53
3Y40	510	3	–20	47 (39)
3Y42	530 – 680	4	–20	47
3Y46	570 – 720	4	–20	47
3Y50	610 – 770	4	–20	50
3Y55	670 – 830	5	–20	55
3Y62	720 – 890	5	–20	62
3Y69	770 – 940	5	–20	69
4Y40	510	3	–40	47 (39)
4Y42	530 – 680	4	–40	47
4Y46	570 – 720	4	–40	47
4Y50	610 – 770	4	–40	50
4Y55	670 – 830	5	–40	55
4Y62	720 – 890	5	–40	62
4Y69	770 – 940	5	–40	69
5Y40	510	3	–60	39
5Y42	530 – 680	4	–60	47
5Y46	570 – 720	4	–60	47
5Y50	610 – 770	4	–60	50
5Y55	670 – 830	5	–60	55
5Y62	720 – 890	5	–60	62
5Y69	770 – 940	5	–60	69
$1^1/_2$ Ni	490	3	–80	27
$3^1/_2$ Ni	450	3	–100	27
5 Ni	540	4	–120	27
9 Ni	640	4	–196	27

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. Values in ( ) apply only to welds made in the vertical position with upward progression.
3. Grade 1Y is not applicable to SMAW consumables referenced in Section 3.

Table 11.3.4 Permitted methods for obtaining low hydrogen grading

Hydrogen Grade	Permitted Method
H15	ISO 3690 (or Glycerine) (*See* Note)
H10	ISO 3690
H5	ISO 3690

NOTE
ISO method preferred.

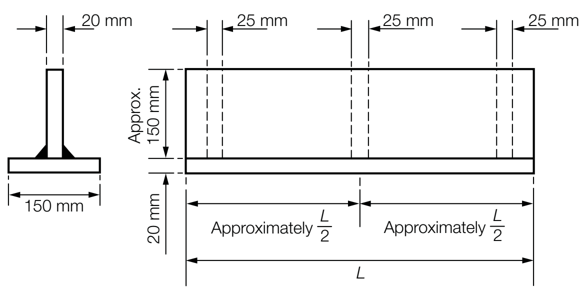


Fig. 11.3.4 Fillet weld test assembly

3.5.3 The electrode sizes to be used are the maximum and minimum diameters recommended by the manufacturer for fillet welding. The first side is to be welded using the maximum diameter. The second side is to be welded only after the assembly has been allowed to cool below 50°C using the minimum diameter. The size of these single run fillet welds will, in general, be determined by the electrode size and the welding current employed during testing and should represent the range of fillet weld bead sizes recommended by the manufacturer.

3.5.4 Each test assembly is to be sectioned to form three macro-sections, each about 25 mm thick. These are to be examined for root penetration, satisfactory profile, freedom from cracking and reasonable freedom from porosity and slag inclusions. Any undercut is not to exceed 0,5 mm in depth. Convexity or concavity of the profile is not to exceed one-tenth of the fillet bead throat dimension. All such observations are to be reported.

3.5.5 Hardness measurements are to be made on the central macro-section only, as shown in Fig. 11.3.5. The results are to be reported.

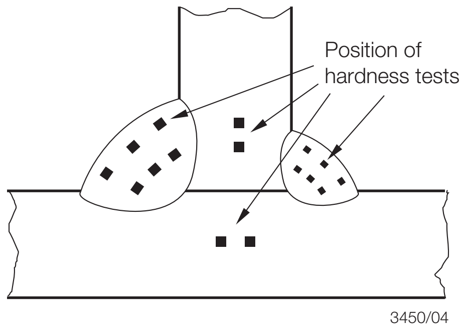


Fig. 11.3.5
Hardness tests for fillet weld test assembly

3.5.6 One of the remaining sections of the assembly is to have the weld on the first side gouged or machined to facilitate breaking the fillet weld on the second side by closing the two plates together, subjecting the root of the weld to tension. On the other remaining section, the weld on the second side is to be gouged or machined and the section fractured using the same procedure. The fractured surfaces are to be examined. They are to show satisfactory penetration, freedom from cracks and reasonable freedom from porosity and this should be reported.

3.6 Electrodes designed for deep penetration welding

3.6.1 Where an electrode is designed solely for the deep penetration welding of downhand butt joints and horizontal-vertical fillets in normal tensile strength steel, only the tests detailed in 3.7 and 3.8 are required for approval purposes.

3.6.2 Electrodes designed solely for the deep penetration welding technique will be approved as complying with Grade 1 requirements only and will be given the suffix 'p'.

3.6.3 Where a manufacturer recommends that an electrode having deep penetrating properties can also be used for downhand butt welding of thicker plates with prepared edges, the electrode will be treated as a normal penetration electrode, and the full series of tests in the downhand position is to be carried out, together with the deep penetration tests given in 3.7 and 3.8.

3.6.4 Where a manufacturer desires to demonstrate that an electrode, in addition to its use as a normal penetration electrode, also has deep penetrating properties when used for downhand butt welding and horizontal fillet welding, the additional tests given in 3.7 and 3.8 are to be carried out.

3.6.5 Electrodes approved for both normal and deep penetration welding will have the suffix 'p' added after the appropriate grade mark for normal penetration welding.

3.6.6 Where the manufacturer prescribes a different welding current and procedure for the electrode when used as a deep penetration electrode and a normal penetration electrode, the recommended current and procedure are to be used when making the test assemblies in each case.

3.7 Deep penetration butt weld test assemblies

3.7.1 Two plates of thickness equal to twice the diameter of the core of the electrode plus 2 mm are to be butt welded together with one downhand run of welding from each side. The plates are to be not less than 100 mm wide and of sufficient length to allow the cutting out of the test specimens of the correct number and size as shown in Fig. 11.3.6. Grade A steel is to be used for these test assemblies. The joint edges are to be prepared square and smooth and, after tacking, the gap is not to exceed 0,25 mm. The test assembly is to be welded using an 8 mm diameter electrode, or the largest diameter manufactured if this is less than 8 mm and the assembly is to be allowed to cool below 50°C between runs.

3.7.2 The test specimens as shown in Figs. 11.3.3 and 11.3.6 are to be prepared from each test assembly.

3.7.3 The results of tensile and impact tests are to comply with the requirements of Table 11.3.3 for Grade 1 electrodes. The position of fracture in the tensile test is to be reported. The bend test specimens are to be in accordance with 3.3.13.

3.7.4 The discards at the end of the welded assemblies are to be not more than 35 mm wide. The joints of these discards are to be polished and etched and must show complete fusion and inter-penetration of the weld beads. At each cut in the test assembly, the joints are also to be examined to ensure that complete fusion has taken place.

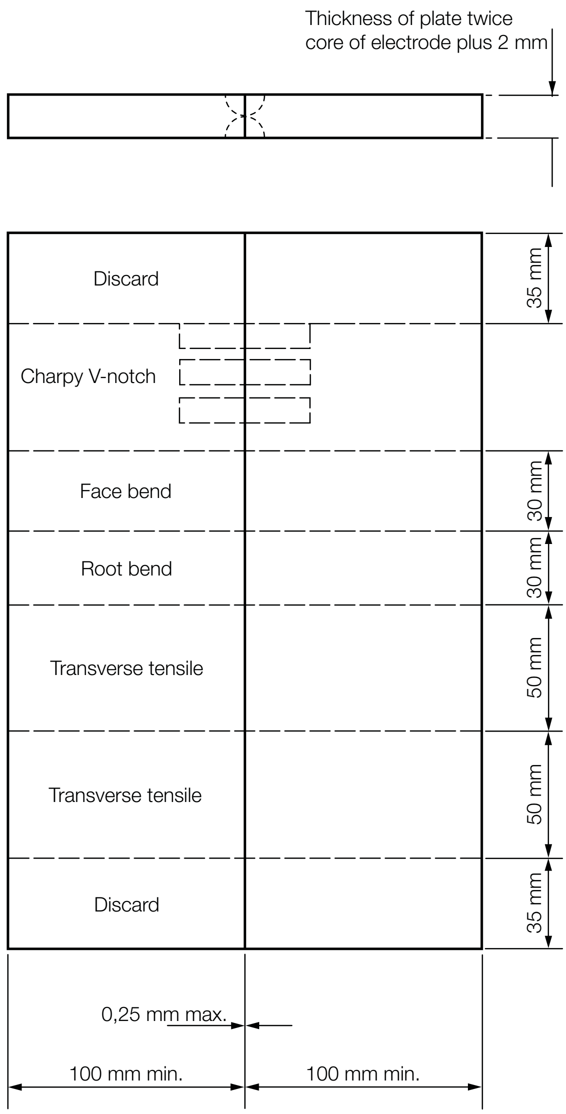


Fig. 11.3.6
Deep penetration butt weld test assembly

3.8 Deep penetration fillet weld test assemblies

3.8.1 A fillet weld assembly is to be prepared as shown in Fig. 11.3.7 with plates about 12,5 mm in thickness. The welding is to be carried out with one run for each fillet with plate A in the horizontal plane during the welding operations. The length of the fillet is to be 160 mm and the gap between the plates is to be not more than 0,25 mm. Grade A steel is to be used for these test assemblies.

3.8.2 The fillet weld on one side of the assembly is to be carried out with a 4 mm diameter electrode, and that on the other side with the maximum diameter of electrode manufactured. The welding current used is to be within the range recommended by the manufacturer, and the welding is to be carried out using normal welding practice except that the assembly is to be allowed to cool below 50°C between runs.

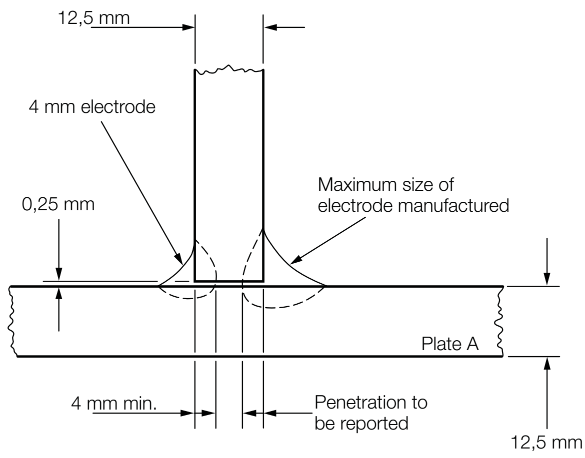


Fig. 11.3.7
Deep penetration fillet weld test assembly

3.8.3 The welded assembly is to be cut by sawing or machining within 35 mm of the ends of the fillet welds, and the joints are to be polished and etched. The welding of the fillet made with a 4 mm diameter electrode is to show a penetration of 4 mm (*see* Fig. 11.3.7) and the corresponding penetration of the fillet made with the maximum diameter of electrode manufactured is to be reported.

3.9 Electrodes designed for gravity or contact welding

3.9.1 Approval for welding using the gravity, 'G', technique is available for welding only normal strength and higher tensile steels up to and including Grade 36.

3.9.2 Where an electrode is submitted solely for approval for use in contact welding using automatic gravity or similar welding devices, deposited metal tests, butt weld tests and, where appropriate, fillet weld tests similar to those for normal manual electrodes are to be carried out using the process for which the electrode is recommended by the manufacturer.

3.9.3 Where an electrode is submitted for approval for use in contact welding using automatic gravity or similar welding devices in addition to normal manual welding, butt weld and, where appropriate, fillet weld tests, using the gravity or other contact device as recommended by the manufacturer, are to be carried out in addition to the normal approval tests.

3.10 Annual tests

3.10.1 For normal penetration electrodes, the annual tests are to consist of two deposited metal test assemblies. These are to be prepared and tested in accordance with 3.2. If an electrode is available in one diameter only, one test assembly is sufficient.

3.10.2 Where an electrode is approved solely for deep penetration welding, the annual test is to consist of one butt welded test assembly. This is to be prepared and tested in accordance with 3.7.

3.10.3 Where an electrode is approved for both normal and deep penetration welding, annual tests as detailed in 3.10.1 and 3.10.2 are to be carried out.

3.10.4 Where an electrode is approved solely for gravity or contact welding, the annual test is to consist of one deposited metal test assembly using the gravity or other contact device as recommended by the manufacturer.

3.10.5 Where an electrode is approved for both manual and gravity welding, annual tests as detailed in 3.10.1 and 3.10.4 are to be carried out.

■ *Section 4*
Wire-flux combinations for submerged-arc automatic welding

4.1 General

4.1.1 Wire-flux combinations for single and multiple electrode submerged-arc automatic welding, without the use of temporary backing, are divided into the following two categories:

- For use with the multi-run technique.
- For use with the two-run technique.

Where particular wire-flux combinations are intended for welding with both techniques, tests are to be carried out for each technique.

4.1.2 Dependent on the results of mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

4.1.3 The suffixes T or M will be added after the grade mark to indicate approval for the two-run technique or, multi-run technique respectively.

4.1.4 Wire-flux combinations satisfying the requirements for multi-run or two-run techniques will also be approved for fillet welding in the downhand and horizontal-vertical position, subject to agreement by the manufacturer.

4.1.5 If the consumable combination is in compliance with the requirements of the hydrogen test given in 3.4, a suffix H15, H10 or H5 will be added to the grade. Table 11.4.1 shows the mandatory levels of low hydrogen approval for the various approval grades.

4.1.6 For each strength level, wire-flux combinations which have satisfied the requirements for a higher toughness grade are considered as complying with the requirements for a lower grade.

Table 11.4.1 Minimum low hydrogen approval requirements for wire-flux combinations

Approval grade	'H' grade for Multi-run	'H' grade for Two-run
1 (1N), 2 (2N), 3 (3N)	NR	NR
1Y, 2Y, 3Y, 4Y	NR	NR
2Y40 to 5Y40	H15	NR
3Y47	H10	H15
3Y42 to 5Y42	H10	H15
3Y46 to 5Y46	H10	H15
3Y50 to 5Y50	H10	H10
3Y55 to 5Y55	H5	H10
3Y62 to 5Y62	H5	H5
3Y69 to 5Y69	H5	H5
1 1/2 Ni	H15	NR
3 1/2 Ni	H15	NR
5 Ni (*see* Note 2)	NR	NR
9 Ni (*see* Note 2)	NR	NR

NOTES
1. NR – Not required. Approval can be obtained when requested.
2. Assumes use of an austenitic, non-transformable, filler material.

4.1.7 Wire-flux combinations approved with multi-run technique for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

4.1.8 Wire-flux combinations approved with multi-run technique for strength levels Y40 to Y50, but excluding Y47 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

4.1.9 Wire-flux combinations approved with multi-run technique for strength levels Y47, Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

4.1.10 Wire-flux combinations with two-run technique approval are not considered suitable for welding steels of any other strength level with that technique, *see* 4.5.1.

4.1.11 The welding current may be either a.c. or d.c. (electrode positive or negative) according to the recommendation of the manufacturer. If both a.c. and d.c. are recommended, a.c. is to be used for the tests.

4.1.12 Wire-flux combinations for multiple electrode submerged-arc welding will be subject to separate approval tests. These are to be carried out generally in accordance with the requirements of this Section.

4.1.13 Wire-flux combinations are not naturally low hydrogen in character, but for the lower strength grades of steel low hydrogen testing is not normally a requirement for approval. With higher strength steels it is more important and Table 11.4.1 shows the mandatory minimum low hydrogen status required for approval of wire-flux combinations.

4.2 Approval tests for multi-run technique

4.2.1 Where approval for use with the multi-run technique is requested, deposited metal and butt weld tests are to be carried out.

4.3 Deposited metal test assemblies (multi-run technique)

4.3.1 One deposited metal test assembly is to be prepared as shown in Fig. 11.4.1, using any of the grades of steel in Table 11.1.1 up to a strength level which is not more than two levels above that for which approval is sought.

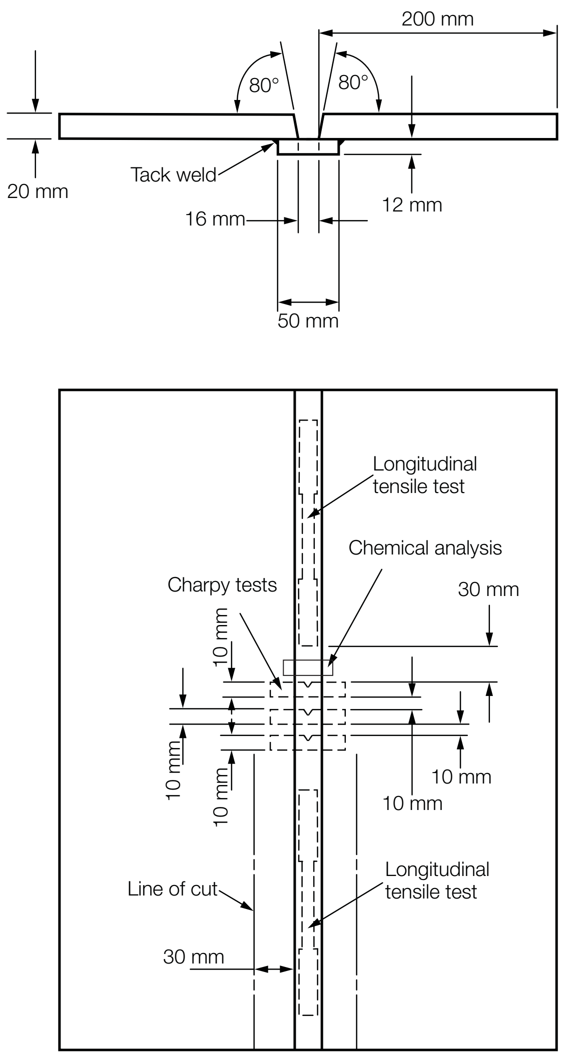


Fig. 11.4.1 Deposited metal test assembly

4.3.2 For Y47 grades, as an alternative to Fig. 11.4.1, the thickness of the plate used for the test assembly may be taken as 50 mm.

4.3.3 The bevelling of the plate edges is to be carried out by machining or mechanised gas cutting. In the latter case any remaining scale is to be removed from the bevelled edges.

4.3.4 Welding is to be in the downhand position, and the direction of deposition of each run is to alternate from each end of the plate. After completion of each run, the flux and welding slag are to be removed. Between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. The thickness of the layer is to be not less than the diameter of the wire nor less than 4 mm, unless it is clearly stated as part of the consumable manufacturer's published recommendations.

4.3.5 The welding conditions (amperage, voltage and rate of travel) are to be in accordance with the recommendations of the manufacturer and are to conform with normal good welding practice for multi-run welding.

4.3.6 The chemical analysis of the deposited weld metal in each test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

4.3.7 Two longitudinal tensile and three impact test specimens are to be taken from each test assembly as shown in Fig. 11.4.1. Care is to be taken that the axes of the tensile test specimens coincide with the centre of the weld and the mid-thickness of the plates. The impact test specimens are to be cut perpendicular to the weld with their axes 10 mm from the upper surface. The notch is to be positioned in the centre of the weld and cut in the face of the test specimen perpendicular to the surface of the plate.

4.3.8 In those cases where two-run technique approval is also sought, only one longitudinal tensile specimen need be prepared and tested from this assembly.

4.3.9 The results of all tests are to comply with the requirements of Table 11.4.2, as appropriate.

4.4 Butt weld test assemblies (multi-run technique)

4.4.1 One butt weld test assembly is to be prepared as shown in Fig. 11.4.2.

Table 11.4.2 Requirements for deposited metal tests (wire-flux combinations)

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 50 mm % minimum	Charpy V-notch impact tests: Test temperature °C	Charpy V-notch impact tests: Average energy (*see* Note) J minimum
1N, 2N, 3N	305	400 – 560	22	+20, 0, –20	34
1Y, 2Y, 3Y, 4Y	375	490 – 660	22	+20, 0, –20, –40	34
2Y40, 3Y40, 4Y40, 5Y40	400	510 – 690	22	0, –20, –40, –60	39
3Y47	460	570 – 720	19	–20	53
3Y40	400	510 – 690	22	–20	39
3Y42	420	530 – 680	20	–20	47
3Y46	460	570 – 720	20	–20	47
3Y50	500	610 – 770	18	–20	50
3Y55	550	670 – 830	18	–20	55
3Y62	620	720 – 890	18	–20	62
3Y69	690	770 – 940	17	–20	69
4Y40	400	510 – 690	22	–40	39
4Y42	420	530 – 680	20	–40	47
4Y46	460	570 – 720	20	–40	47
4Y50	500	610 – 770	18	–40	50
4Y55	550	670 – 830	18	–40	55
4Y62	620	720 – 890	18	–40	62
4Y69	690	770 – 940	17	–40	69
5Y40	400	510 –690	22	–60	39
5Y42	420	530 – 680	20	–60	47
5Y46	460	570 – 720	20	–60	47
5Y50	500	610 – 770	18	–60	50
5Y55	550	670 – 830	18	–60	55
5Y62	620	720 – 890	18	–60	62
5Y69	690	770 – 940	17	–60	69
1½ Ni	375	460	22	–80	34
3½ Ni	375	420	25	–100	34
5 Ni	375	500	25	–120	34
9 Ni	375	600	25	–196	34

NOTE
Energy values from individual impact test specimens are to comply with 1.4.3.

4.4.2 The grade of steel used for the preparation of the test assembly are to be as follows:

Grade 1 wire-flux combination	A
Grade 2 wire-flux combinations	A, B or D
Grade 3 wire-flux combinations	A, B, D or E
Grade 1Y wire-flux combination	AH32 or AH36
Grade 2Y wire-flux combinations	AH32, AH36, DH32 or DH36
Grade 3Y wire-flux combinations	AH32, AH36, DH32, DH36, EH32 or EH36
Grade 4Y wire-flux combinations	AH32, AH36, DH32, DH36, EH32, EH36, FH32 or FH36
Grade 2Y40 wire-flux combination	AH40 or DH40
Grade 3Y40 wire-flux combinations	AH40, DH40 or EH40
Grade 4Y40 wire-flux combinations	AH40, DH40, EH40 or FH40
Grade 5Y40 wire-flux combinations	AH40, DH40 EH40, FH4
Grade 3Y47 wire-flux combinations	EH47

Where Grade 32 higher tensile steel is used, the tensile strength is to be not less than 490 N/mm^2. The chemical composition, including the content of grain refining elements, is to be reported in all cases where higher tensile steel is used.

4.4.3 For all other grades, the steel plates used are to be selected by reference to Table 11.1.1, and are to have at least their chemical composition and tensile properties within the limits specified for that grade in Chapter 3. The strength grade used is to be the same as that for which approval is sought, and the toughness grade is to be no higher than that for which approval is also sought.

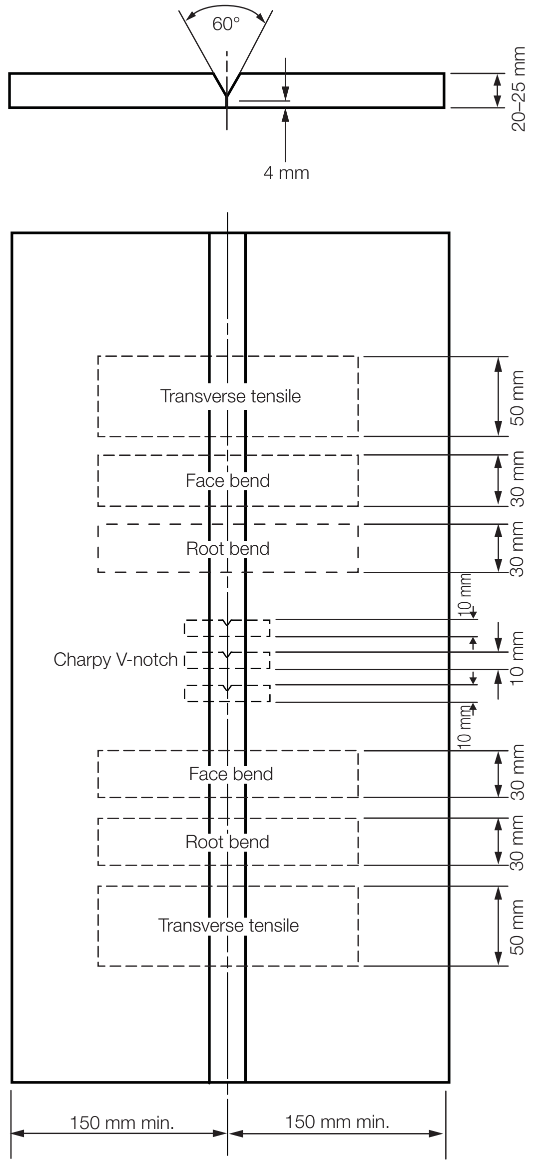


Fig. 11.4.2
Butt weld test assembly (multi-run technique)

4.4.4 The plate edges are to be prepared to form a single V-joint, the included angle between the fusion faces being 60° and the root face being 4 mm. The bevelling of the plate edges is to be carried out by machining or mechanised gas cutting. In the latter case, any remaining scale is to be removed from bevelled edges.

4.4.5 Welding is to be carried out in the downhand position by the multi-run technique, and the welding conditions are to be the same as those adopted for the deposited metal test assembly. The back sealing run is to be applied in the downhand position after cutting out the root run to clean metal.

4.4.6 It is recommended that the welded assembly be subjected to a radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

4.4.7 The test specimens as shown in Fig. 11.3.3 and Fig. 11.4.2 are to be prepared from each test assembly.

4.4.8 The results of all tensile and impact tests are to comply with the requirements of Table 11.4.3, as appropriate. The position of fracture of the transverse tensile test is to be reported.

4.4.9 The bend test specimens can be considered as complying with the requirements if, after bending, no cracks or other open defects exceeding 3 mm in dimension can be seen on the outer surface.

4.5 Approval tests for two-run technique

4.5.1 Where approval for use with the two-run technique is requested, two butt weld test assemblies are to be prepared and tested using plates of the strength level for which approval is required. Each strength level requires separate approval.

4.5.2 Two welded assemblies are to be made from a pair of plates of matching thicknesses. The thickness of the thicker pair of plates will be the maximum for which the approval is valid. The second assembly is to be welded from plates having approximately half of the thickness of the first assembly.

4.6 Butt weld test assemblies (two-run technique)

4.6.1 The grade of steel used for the preparation of the test assemblies is not to be of any higher grade (impact toughness) than that for which approval is required. The chemical composition, including the content of grain refining elements, and the strength properties of the plates used, are to be reported.

4.6.2 The maximum diameter of wire and the edge preparation to be used are to be in accordance with Table 11.4.4. Small deviations in the edge preparation may be allowed if requested by the manufacturer. The bevelling of the plate edges is to be performed by machining or mechanised gas cutting. In the latter case, any remaining scale is to be removed from the bevelled edges. The root gap should not exceed 0,7 mm.

4.6.3 Each butt weld is to be welded in two runs, one from each side, using amperages, voltages and travel speeds in accordance with the recommendations of the manufacturer and normal good welding practice. After completion of the first run, the flux and welding slag are to be removed and the assembly is to be left in still air until it has cooled to less than 100°C, the temperature being taken in the centre of the weld, on the surface of the seam.

4.6.4 It is recommended that the butt weld assemblies be subjected to radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

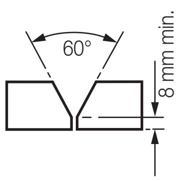
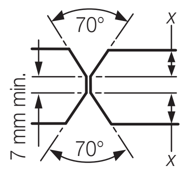
4.6.5 The test specimens, as shown in Fig. 11.4.3 and Fig. 11.4.4, are to be prepared from each test assembly, except as detailed in 4.6.8. The edges of two of the discards are to be polished and etched, and must show complete fusion and inter-run penetration of the welds. At each cut in the test assembly, the edges are also to be examined to ensure that complete fusion has taken place.

Table 11.4.3 Requirements for butt weld tests (wire-flux combinations)

Grade	Tensile strength N/mm^2	Bend test ratio: $\frac{D}{t}$	Charpy V-notch impact tests	
			Test temperature °C	Average energy (*see* Notes 1 and 2) J minimum
1N, 2N, 3N	400	3	+20, 0, –20	34
1Y, 2Y, 3Y, 4Y	490	3	+20, 0, –20, –40	34
2Y40, 3Y40, 4Y40, 5Y40	510	3	0, –20, –40, –60	39
3Y47	570 – 720	4	–20	53
3Y40	510	3	–20	39
3Y42	530 – 680	4	–20	47 (41)
3Y46	570 – 720	4	–20	47
3Y50	610 – 770	4	–20	50
3Y55	670 – 830	5	–20	55
3Y62	720 – 890	5	–20	62
3Y69	770 – 940	5	–20	69
4Y40	510	3	–40	39
4Y42	530 – 680	4	–40	47 (41)
4Y46	570 – 720	4	–40	47
4Y50	610 – 770	4	–40	50
4Y55	670 – 830	5	–40	55
4Y62	720 – 890	5	–40	62
4Y69	770 – 940	5	–40	69
5Y40	510	3	–60	39
5Y42	530 – 680	4	–60	47 (41)
5Y46	570 – 720	4	–60	47
5Y50	610 – 770	4	–60	50
5Y55	670 – 830	5	–60	55
5Y62	720 – 890	5	–60	62
5Y69	770 – 940	5	–60	69
1½ Ni	490	3	–80	27
3½ Ni	450	3	–100	27
5 Ni	540	4	–120	27
9 Ni	640	4	–196	27

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. Values in ( ) apply only to two-run technique impact test specimens.

Table 11.4.4 Butt weld assembly preparation

Plate thickness mm	Recommended diameter	Maximum diameter of wire mm
12,5		5
20–25		6
35–40		7

4.6.6 The results of transverse tensile and impact tests are to comply with the requirements of Table 11.4.3 as appropriate. The position of fracture of the transverse tensile tests is to be reported.

4.6.7 The bend test specimens can be considered as complying with the requirements if, after bending, no crack or other open defects exceeding 3 mm in dimensions can be seen on the outer surface. One of the specimens from each assembly is to be tested with the side first welded in tension, and the second specimen with the other side in tension.

4.6.8 The longitudinal tensile specimen shown in Fig. 11.4.3 is to be prepared from the thicker assembly, even in those cases where multi-run technique approval is also sought. This test specimen is to be machined to the dimensions shown in Ch 11,2.1.1, and the longitudinal axis is to coincide with the centre of the weld about 7 mm below the plate surface on the side from which the second run is made. The test specimen may be given a hydrogen release treatment in accordance with 2.1.1. The results of this test are to comply with the requirements of Table 11.4.2.

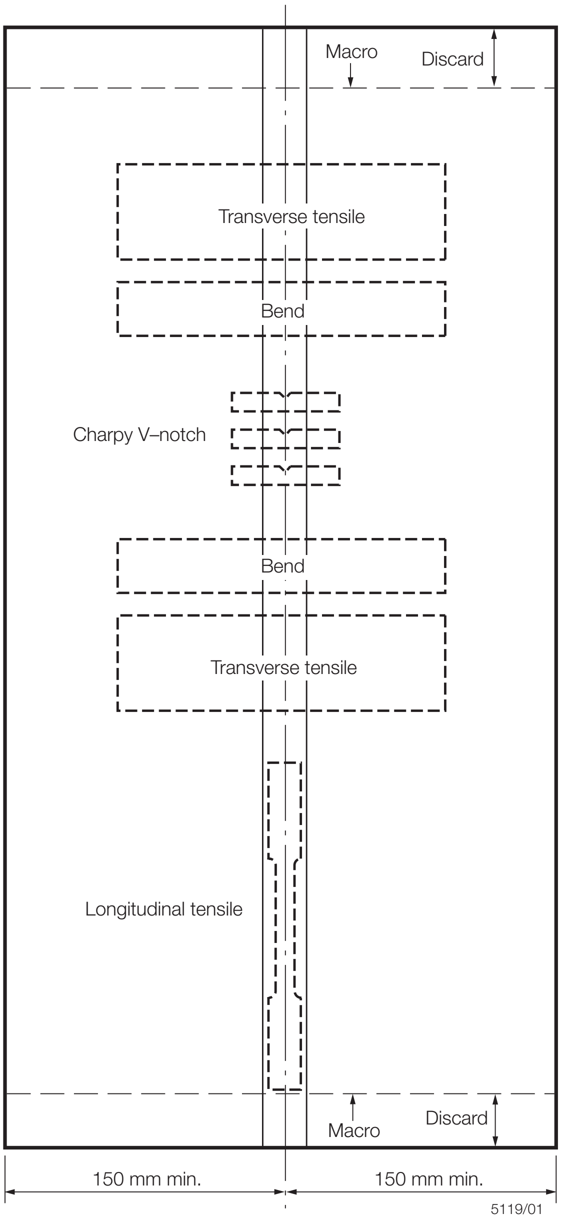


Fig. 11.4.3
Butt weld test assembly (two-run technique)

4.6.9 The chemical analysis of the weld metal of the second run in each assembly is to be determined and reported. This is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

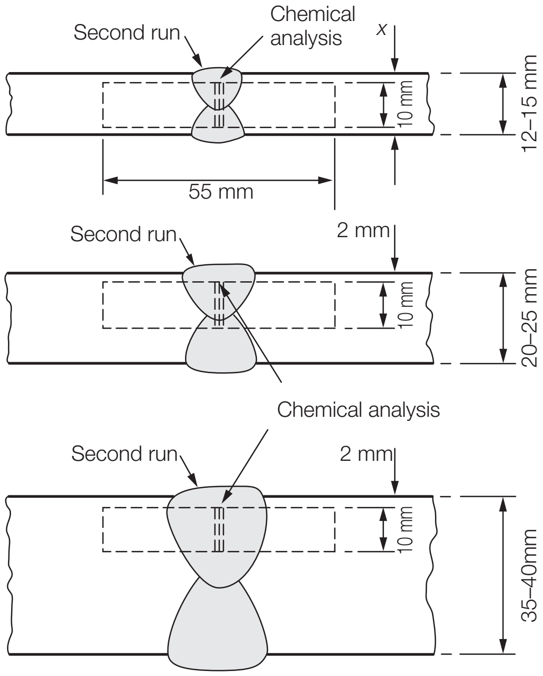


Fig. 11.4.4
Butt weld test assembly (two-run technique): position of impact test specimens

4.7 Annual tests

4.7.1 Annual tests are to consist of at least the following:

(a) For wire-flux combinations approved for the multi-run technique, one deposited metal test assembly.
(b) For wire-flux combinations approved for the two-run technique, one butt weld test assembly using plate material 20 to 25 mm in thickness. For Y47 the thickness of plate material may be taken as 50 mm.

4.7.2 The deposited metal assemblies are to be prepared and tested in accordance with 4.3, except that only one longitudinal tensile, three impact test specimens and a chemical analysis are required.

4.7.3 The butt weld test assemblies are to be prepared and tested in accordance with 4.6, except that only one transverse tensile, two bend, three impact test specimens and a chemical analysis are required. One longitudinal tensile test specimen is also to be prepared where the wire-flux combination is approved solely for the two-run technique.

4.7.4 Where a wire-flux combination is approved for welding a range of steels with different specified minimum strength levels, steel of the highest strength approved is to be used for the preparation of the butt weld assembly required by 4.7.1(b).

Section 5
Wires and wire-gas combinations for manual, semi-automatic and automatic welding

5.1 General

5.1.1 Wire-gas combinations and flux-cored or flux-coated wires (for use with or without a shielding gas) are divided into the following categories for the purposes of approval testing:

(a) For use in manual multi-run welding with the inert gas tungsten arc welding process (GTAW).
(b) For use in semi-automatic multi-run metal arc welding.
(c) For use in single electrode multi-run automatic metal arc and GTAW welding.
(d) For use in single electrode two-run automatic metal arc and GTAW welding.

5.1.2 The term 'manual', is used to describe the technique where the gas-shielded tungsten arc torch is held in one hand and the filler is added separately by the other hand.

5.1.3 The term 'semi-automatic' is used to describe processes in which the weld is made manually by a welder holding a gun through which the wire is continuously fed.

5.1.4 In the GTAW process, 'automatic' refers to the fully mechanised control and application of both torch and separate filler wire.

5.1.5 Dependent on the results of mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

5.1.6 A suffix S will be added after the grade mark to indicate approval for semi-automatic multi-run welding.

5.1.7 For wires intended for automatic welding, the suffixes T or M will be added after the grade mark to indicate approval for two-run or multi-run welding techniques, respectively.

5.1.8 For wires intended for both semi-automatic and automatic welding, the suffices will be added in combination.

5.1.9 Solid wire-gas combinations are considered naturally low hydrogen in character and qualify for 'H15' approval without testing. This is not so for cored wires and continuous coated wires which must be tested if there is a need for low hydrogen approval. For the lower strength grades of steel, low hydrogen testing is not normally a requirement for approval. With higher strength steels, it is more important and Table 11.5.1 shows the mandatory minimum low hydrogen status required for approval of wire-gas combinations.

5.1.10 The testing methods to be used for low hydrogen approval are to be in accordance with 3.4, modified to use the manufacturer's recommended welding conditions and adjusting the deposition rate to give a weld deposit weight per sample similar to that deposited when using manual electrodes.

5.1.11 Where applicable, the approved combination will name either the specific gas composition or its trade name, but in either case the composition of the shielding gas is to be reported. Unless otherwise agreed, additional approval tests are required when a shielding gas is used other than that used for the original approval tests. However a wire and gas combination approved with an argon/carbon dioxide shielding gas where the carbon dioxide is between 15-25 per cent is also approved for other combinations of argon/carbon dioxide, provided the carbon dioxide content is within the range 15-25 per cent. The range of approval is limited to ferritic consumables in solid wire, flux cored and coated wire forms and subject to the agreement of the consumable manufacturer and LR.

Table 11.5.1 Minimum low hydrogen approval requirements for wires and wire-gas combinations

Approval grade	'H' grade for m and S techniques	'H' grade for M technique	'H' grade for T technique
1 (1N), 2 (2N), 3 (3N)	NR	NR	NR
1Y, 2Y, 3Y, 4Y	H15 (see Note 2)	NR	NR
2Y40 to 5Y40	H15	H15	NR
3Y47	H10	H10	H10
3Y42 to 5Y42	H10	H10	H15
3Y46 to 5Y46	H10	H10	H15
3Y50 to 5Y50	H10	H10	H10
3Y55 to 5Y55	H5	H5	H10
3Y62 to 5Y62	H5	H5	H5
3Y69 to 5Y69	H5	H5	H5
$1^1/2$ Ni	H15	H15	NR
$3^1/2$ Ni	H15	H15	NR
5 Ni	NR (see Note 3)	NR	NR
9 Ni	NR (see Note 3)	NR	NR

NOTES
1. NR – Not required. Approval may be obtained when requested.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes use of an austenitic, non-transformable, filler material.

5.1.12 Wires and wire-gas combinations for multiple electrode automatic welding will be subject to separate approval tests. Any proposals are to be submitted for consideration.

5.1.13 Wires and wire-gas combinations approved with multi-run technique for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

5.1.14 Wires and wire-gas combinations approved with multi-run technique for strength levels Y40 to Y50, but excluding Y47 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

5.1.15 Wires and wire-gas combinations approved with multi-run technique for strength levels Y47, Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

5.1.16 Wires and wire-gas combinations with two-run technique approval are not considered suitable for welding steels of any other strength level with that technique, *see* 5.4.1.

5.2 Approval tests for manual and semi-automatic multi-run welding

5.2.1 Approval tests for manual (GTAW) and semi-automatic multi-run welding are to be carried out generally in accordance with the requirements of Section 3, except as required by 5.2, using the respective technique for the preparation of all test assemblies.

5.2.2 Two deposited metal test assemblies are to be prepared in the downhand position as shown in Fig. 11.3.1, one using the smallest diameter, and the other using the largest diameter of wire for which approval is required. Where only one diameter is manufactured, only one deposited metal assembly is to be prepared.

5.2.3 For Y47 grades, as an alternative to Figs. 11.3.1 to 11.3.4, the thickness of the plate used for the test assembly may be taken as 50 mm.

5.2.4 The weld metal is to be deposited according to the practice recommended by the manufacturer, and the thickness of each layer of weld metal is to be between 2 mm and 6 mm, unless it is clearly stated as part of the consumable manufacturer's published recommendations.

5.2.5 The chemical analysis of the deposited weld metal in each test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

5.2.6 Butt weld assemblies as shown in Fig. 11.3.2 are to be prepared for each welding position for which the wire is to be approved. In the case of approvals for normal and higher strength steels (up to 355 N/mm^2 minimum specified yield strength), tests satisfying the requirements in both the downhand and vertical-upward positions will be considered as having also satisfied the requirements for the horizontal-vertical position. In all other cases, approval in the horizontal-vertical position will require a butt weld to be made in that position and be fully tested.

5.2.7 The downhand assembly is to be welded using, for the first run, wire of the smallest diameter to be approved and, for the remaining runs, wire of the largest diameter to be approved.

5.2.8 Where approval is requested only in the downhand position, an additional butt weld assembly is to be prepared in that position using, if possible, wires of different diameter from those required by 5.2.7. If only one wire diameter is to be approved, this second downhand butt weld should be made using either larger or smaller beads than the first assembly.

5.2.9 The butt weld assemblies, in positions other than downhand, are to be welded using, for the first run, wire of the smallest diameter to be approved, and for the remaining runs, the largest diameter of wire recommended by the manufacturer for the position concerned.

5.2.10 Fillet weld test assemblies as detailed in 3.5 are to be prepared, examined and tested.

5.2.11 Low hydrogen approval tests are to be carried out if required by 5.1.9.

5.2.12 Test specimens from each assembly are to be prepared and tested in accordance with the requirements of 3.2 and 3.3.

5.3 Approval tests for multi-run automatic welding

5.3.1 Approval tests for multi-run automatic welding are to be carried out generally in accordance with the requirements of Section 4, except as required by 5.3, using the multi-run automatic welding technique for the preparation of all test assemblies.

5.3.2 One deposited metal test assembly is to be prepared as shown in Fig. 11.4.1. Welding is to be as detailed in 4.3.4, except that the thickness of each layer is to be not less than 3 mm, unless it is clearly stated as part of the consumable manufacturer's published recommendations.

5.3.3 For Y47 grades, as an alternative to Figs. 11.4.1 and 11.4.2, the thickness of the plate used for the test assembly may be taken as 50 mm.

5.3.4 One butt weld test assembly is to be prepared as shown in Fig. 11.4.2 for each welding position to be approved for the automatic multi-run technique.

5.3.5 Test specimens from each test assembly are to be prepared and tested in accordance with the requirements of Section 4 for multi-run submerged-arc automatic welding.

5.3.6 Low hydrogen approval tests are to be made if required by 5.1.9.

5.3.7 At the discretion of LR, wires approved for semi-automatic welding in the downhand position may also be approved without additional tests, for use in multi-run automatic welding.

5.4 Approval tests for two-run automatic welding

5.4.1 Approval tests for two-run automatic welding are to be carried out generally in accordance with the requirements of Section 4, except as required by 5.4, using the two-run automatic welding technique for the preparation of all test assemblies. Two butt weld test assemblies are to be prepared and tested using plates of the strength level for which approval is required. Each strength level requires separate approval.

5.4.2 Two butt weld test assemblies are to be prepared generally as detailed in 4.5 and 4.6 using plates 12 to 15 mm and 20 to 25 mm in thickness.

5.4.3 If approval is requested for welding plate thicker than 25 mm, one assembly is to be prepared using plates approximately 20 mm in thickness and the other using plates of the maximum thickness for which approval is requested.

5.4.4 The edge preparation of the test assemblies is to be as shown in Fig. 11.5.1. Small deviations in edge preparation may be allowed, if these form part of the consumable manufacturer's recommendations. For assemblies using plates over 25 mm in thickness, the edge preparation is to be reported for information.

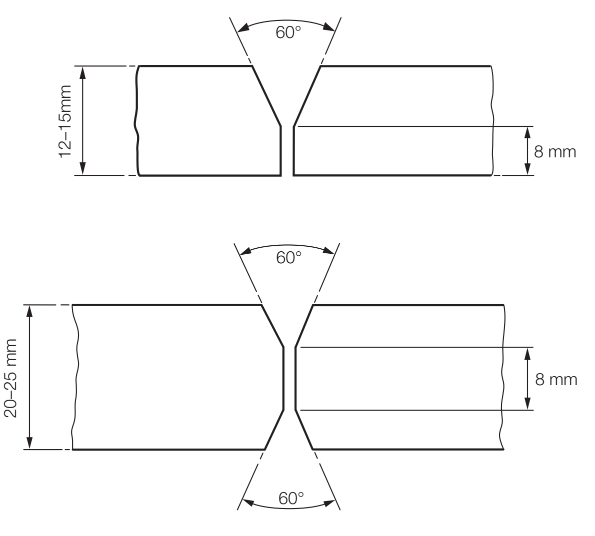


Fig. 11.5.1
Normal edge preparation for two-run butt weld test assemblies

5.4.5 The diameters of wires used are to be in accordance with the recommendations of the manufacturer and are to be reported.

5.4.6 Test specimens from each butt weld assembly are to be prepared and tested in accordance with the requirements of Section 4 for two-run submerged-arc automatic welding.

5.4.7 The weld metal chemical analysis is to be reported as in 4.6.9. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

5.5 Annual tests

5.5.1 Annual tests are to consist of at least the following:

(a) Wires approved for manual welding or semi-automatic welding or either of these combined with approval for automatic multi-run welding:
    one deposited metal test assembly prepared in accordance with 5.2 using a wire of diameter within the approved range.

(b) Wire approved for automatic multi-run welding:
    one deposited metal test assembly prepared in accordance with 5.3 using a wire of diameter as stated in (a).

(c) Wires approved for two-run automatic welding:
    one butt weld test assembly prepared in accordance with 5.4 using plates 20 to 25 mm in thickness or the maximum approved thickness. The diameter of wire used is to be reported.

■ *Section 6*
Consumables for use in electro-slag and electro-gas welding

6.1 General

6.1.1 The requirements for the approval of consumables used for electro-slag or electro-gas welding (including consumable nozzles, where applicable) are generally as detailed in Section 4 for two-run submerged-arc welding consumables, except as otherwise detailed in this Section.

6.1.2 For each grade, approval may be restricted for use with specific compositional types of steel. For Grades 1Y, 2Y, 3Y, 4Y, 2Y40, 3Y40 and 4Y40 this will normally be in respect of the grain refining element content, and tests on niobium grain refined steel will normally qualify for use also on steels treated with aluminium or vanadium or combinations of these elements.

6.1.3 Superscript numbers are applied to the 'Y' of higher strength steel consumables, e.g. $2Y^1$, to indicate the type of parent steel for which approval is applicable as follows:

Y^1 approval Grade for higher strength steel is limited to parent steel which has been treated only with aluminium.

Y^2 approval Grade for higher strength steel is appropriate to niobium-treated steels, whether aluminium treated or not. It also covers steels treated only with aluminium.

6.1.4 Each strength level requires separate approval involving the welding and testing of two butt weld assemblies of different thickness. The greater thickness will determine the maximum approved thickness.

6.2 Butt weld test assemblies

6.2.1 Two butt weld test assemblies are to be prepared, one with plates 20 to 25 mm in thickness and the other with plates 35 to 40 mm in thickness. The steel used is not to be of any higher grade (impact toughness) than that for which approval is required. The limitations of 6.1.2 need to be considered in this Section. The chemical composition of the plate, including the content of grain refining elements, is to be reported.

6.2.2 The welding conditions and the edge preparation adopted are to be in accordance with the recommendations of the manufacturer and are to be reported in detail. The manufacturer's maximum recommended gap between plates is to be used in making the test assemblies.

6.2.3 It is recommended that the assemblies are subjected to radiographic examination to identify any defects before the preparation of any test specimens.

6.2.4 Test specimens as follows, and as shown in Fig. 11.6.1, are to be prepared from each test assembly:

(a) Two longitudinal tensile test specimens.
(b) Two transverse tensile test specimens.
(c) Two bend test specimens.
(d) Two macro-sections.
(e) Two sets of three impact test specimens notched in accordance with Fig. 11.6.2.

6.2.5 The chemical analysis of the weld metal in each assembly is to be determined and reported. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

6.2.6 The results of all transverse tensile and impact tests are to comply with the requirements given in Table 11.4.3 as appropriate. The position of fracture of the transverse tensile test is to be reported. The Charpy V-notch impact test requirements are as for the two-run technique in Table 11.4.3.

6.2.7 The results of all longitudinal tensile tests are to comply with the requirements of Table 11.4.2.

6.2.8 The bend test specimens are to be in accordance with 4.6.7 and Table 11.4.3. Each surface of the weld is to be tested Fension.

6.3 Annual tests

6.3.1 Annual tests are to consist of at least one butt weld test assembly using plate material 20 to 25 mm in thickness.

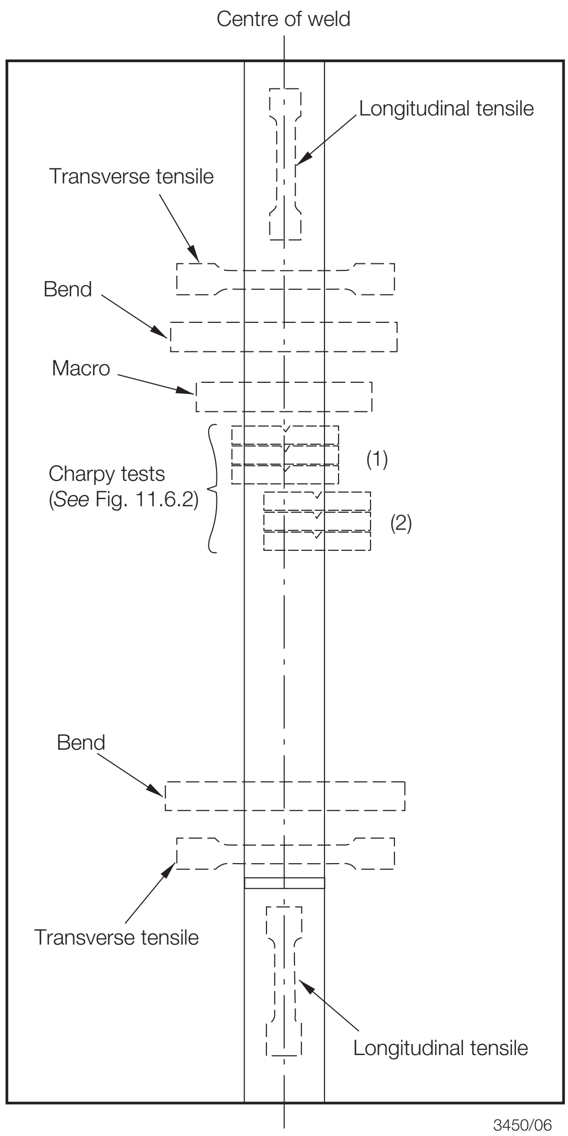
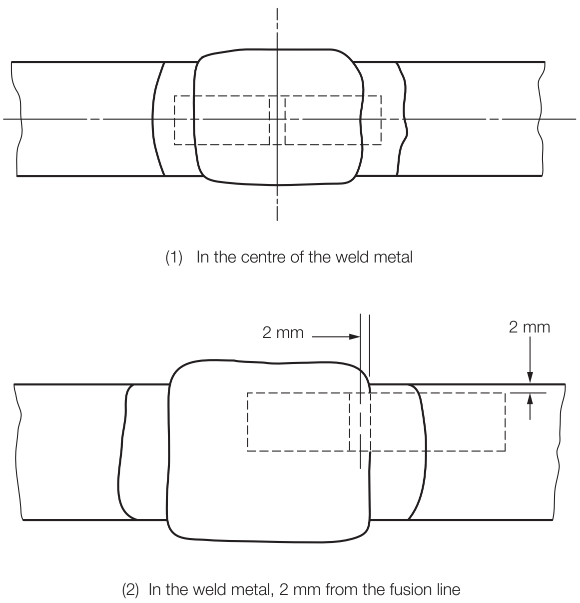


Fig. 11.6.1
Butt weld test assembly for electro-slag or electro-gas welding

6.3.2 The assembly is to be prepared and tested in accordance with 6.2 except that only the following tests are required:

(a) One longitudinal tensile test.
(b) One transverse tensile test.
(c) Two bend tests.
(d) Two sets of three Charpy V-notch impact tests; one set with the notch at the centre of the weld (Position (1) in Fig. 11.6.2), and one set with the notch in the weld metal 2 mm from the fusion line (Position (2) in Fig.11.6.2).
(e) Chemical analysis.
(f) One macro section.

6.3.3 Where a consumable or combination is approved for a range of steels with different specified minimum strength levels, steel of the highest strength level is to be used for the preparation for the assembly required by 6.3.1.



(1) In the centre of the weld metal

(2) In the weld metal, 2 mm from the fusion line

Fig. 11.6.2
Position of Charpy V-notch impact test specimens

■ *Section 7*
Consumables for use in one-side welding with temporary backing materials

7.1 General

7.1.1 The requirements for approval of combinations including temporary backing material, for use in one-side welding techniques, are dependent on the technique used and which basic technique it most closely follows. The following are provided for:

(a) Technique m – for manual electrode/backing combinations.
(b) Technique S – for wire-gas/backing combinations used with semi-automatic multi-run technique.
(c) Technique M – for wire-flux or wire-gas in combination with backing material (and maybe supplementary filler materials) used with an automatic multi-run technique.
(d) Technique A – as for M but using a procedure with a high heat input rate (large bead size relative to thickness welded). This would apply to welds made by four or less runs in 20 mm thickness, or eight or less runs in 35 mm.

7.1.2 For technique m, S or M, a single butt weld is to be made in plate of 20–25 mm thickness. For technique A, two butt welds are to be made, one in plate of the maximum thickness recommended by the manufacturer, the other in plate of approximately half the thickness of the first. Usually this will involve thicknesses in the region of 35–40 mm and 20–25 mm respectively.

7.1.3 A wire and gas combination approved with an argon/carbon dioxide shielding gas where the carbon dioxide content is between 15-25 per cent is also approved for other combinations of argon/carbon dioxide, provided the carbon dioxide content is within the range 15-25 per cent. The range of approval is limited to ferritic consumables in solid wire, flux cored and coated wire forms and subject to the agreement of the consumable manufacturer and LR.

7.1.4 Any unrecognised techniques or unusual combinations will be considered for approval subject to a test programme to be agreed based on the details of the technique and combination which are to be submitted in advance.

7.1.5 Where low hydrogen approval is required either by Table 11.7.1 or by the manufacturer, it should be noted that this will generally be achieved through separate testing of:

(a) the backing material, and
(b) the welding electrode or combination of wire-flux or wire-gas.

7.1.6 The hydrogen potential of the backing material is to be determined using the modified Gayley-Wooding method which expresses the total hydrogen content as water by weight per cent. The qualifying levels are:

To qualify as:	H_20 g/100g sample
H15	0,5
H10	0,3
H5	0,2

7.1.7 The sampling and approval of the combinations without the backing are to follow the general requirements of Sections 3, 4 or 5, as appropriate.

7.1.8 Combinations approved with multi-run technique (m, S and M) for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

7.1.9 Combinations approved with multi-run technique (m, S and M) for strength levels Y40 to Y50, but excluding Y47, are also considered suitable for welding steels in two strength levels below that for which they have been approved.

7.1.10 Combinations approved with multi-run technique (m, S and M) for strength levels Y47, Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

7.1.11 Combinations approved for the 'A' multi-run technique are not considered suitable for welding steels of any other strength level with that technique.

Table 11.7.1 Minimum low hydrogen approval requirements for one-side welding with combinations including temporary backing material

Approval grades	'H' grade for m and S techniques	'H' grade for M technique	'H' grade for A technique
1 (1N), 2 (2N), 3 (3N)	NR	NR	NR
1Y, 2Y, 3Y, 4Y	H15 (*see* Note 2)	NR	NR
2Y40 to 5Y40	H15	H15	NR
3Y47	H10	H10	H15
3Y42 to 5Y42	H10	H10	H15
3Y46 to 5Y46	H10	H10	H15
3Y50 to 5Y50	H10	H10	H10
3Y55 to 5Y55	H5	H5	H10
3Y62 to 5Y62	H5	H5	H5
3Y69 to 5Y69	H5	H5	H5
$1^1/_2$ Ni	H15	H15	NR
$3^1/_2$ Ni	H15	H15	NR
5 Ni (*see* Note 3)	NR	NR	NR
9 Ni (*see* Note 3)	NR	NR	NR

NOTES
1. NR – Not required. Approval may be obtained when requested.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes the use of an austenitic, non-transformable, filler material.

7.2 Approval tests for manual (m), semi-automatic (S) and automatic multi-run (M) techniques

7.2.1 For each position to be approved, one butt weld assembly is to be prepared using plates of 20–25 mm thickness as shown in Fig. 11.7.1. The grade of plate used is to be no higher in toughness than that for which approval is required. The strength is to be appropriate to the grade for which welding approval is requested.

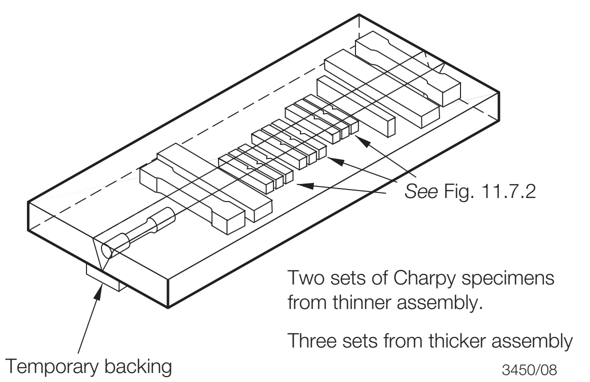


Fig. 11.7.1
Butt weld test assembly and specimens for all techniques

7.2.2 The thickness of test assembly is to be 50 mm for Y47 base material.

7.2.3 The edge preparation and welding conditions are to be in accordance with the recommendations of the manufacturers.

7.2.4 Test specimens are to be prepared as shown in Fig. 11.7.1 and Fig. 11.7.2(a):
(a) One longitudinal tensile test specimen (from the centre of the weld).
(b) Two transverse tensile specimens.
(c) Two bend test specimens, one with the face in tension, the other with the root in tension.
(d) One macrosection.
(e) Two sets of three Charpy impact test specimens positioned and notched in accordance with Fig.11.7.2(a).

7.2.5 The results of all transverse tensile, bend and impact tests are to comply with the requirements in Table 11.3.3 for m and S technique, and Table 11.4.3 for M technique. The position of fracture of the transverse tensile test is to be reported. The appearance of the bend test specimens is to be in accordance with 3.3.13.

7.2.6 The results of all longitudinal tensile tests are to comply with the requirements in Table 11.3.2.

7.2.7 Low hydrogen approval is required in accordance with Table 11.7.1.

7.2.8 Chemical analyses are to be made and reported from positions corresponding to the weld metal in the upper and lower Charpy specimens of the downhand butt weld. These are to be supplied by the manufacturer and are to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

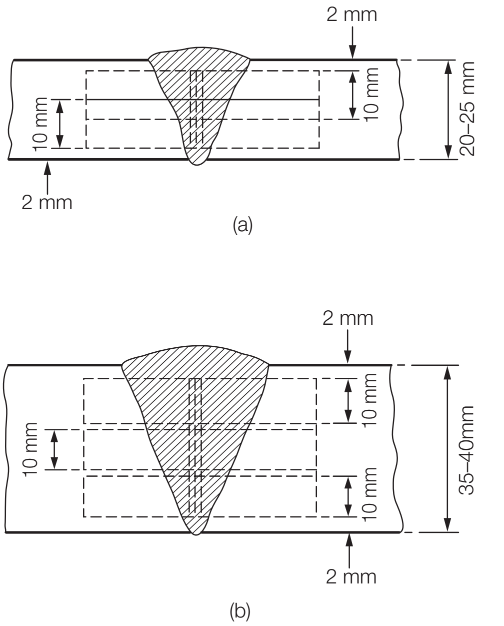


Fig. 11.7.2
Position of Charpy V-notch impact tests for one-side automatic welding

7.3 Approval tests for high heat input automatic (A) techniques

7.3.1 Two butt weld assemblies are to be prepared, usually one of 35–40 mm thickness, the other 20–25 mm, as shown in Fig. 11.7.1, noting that in the thinner assembly only two sets of Charpy specimens are required. The grade of plates used is to be no higher in toughness than that for which approval is required. The strength is to be appropriate to the grade for which welding approval is requested.

7.3.2 For Y47 grade, the thicker assembly is to be prepared from the maximum thickness for which approval is required, and the thinner assembly is to be prepared from 50 mm thickness. Where approval is required for 50 mm thickness, only one assembly from that thickness is required.

7.3.3 The edge preparation and welding conditions are to be in accordance with the manufacturer's recommendations, and are to be reported to LR.

7.3.4 Test specimens as follows are to be prepared as shown in Fig. 11.7.1 and Figs. 11.7.2(a) and (b):
(a) One longitudinal tensile test specimen (from centre of weld).
(b) Two transverse tensile test specimens.
(c) Two bend test specimens.
(d) One macro-section.
(e) From assembly 20 to 25 mm thick, two sets of three impact test specimens positioned and notched in accordance with Fig. 11.7.2(a).
(f) From assembly 35 to 40 mm thick, three sets of three impact test specimens positioned and notched in accordance with Fig. 11.7.2(b).
(g) From assembly of thickness 50 mm or more, three sets of three impact test specimens positioned and notched in accordance with Fig. 11.7.2(b). The second set positioned in the mid-thickness of test assembly.
The bend specimens are to be tested, one with the face in tension, the other with the root in tension.

7.3.5 The results of all transverse tensile, bend and impact tests are to comply with the requirements of Table 11.4.3. The appearance of the bend test specimens is to be in accordance with 3.3.13. The Charpy V-notch impact test requirements are as for the two-run technique in Table 11.4.3.

7.3.6 The results of all longitudinal tensile tests are to comply with the requirements in Table 11.3.2, except that for Grades 1Y, 2Y and 3Y the tensile strength is to be not less than 490 N/mm^2.

7.3.7 Low hydrogen approval is required in accordance with Table 11.7.1.

7.3.8 Chemical analyses are to be made and reported from positions corresponding to the weld metal in the uppermost and lowest Charpy specimens in the thicker plate weld. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

7.4 Annual tests

7.4.1 Annual tests are to consist of, at least, one butt weld test assembly, for each technique approved, using plates of 20 to 25 mm thickness.

7.4.2 The assembly is to be prepared and tested in accordance with 7.2 or 7.3, as appropriate, except that only the following tests are required:
(a) One longitudinal tensile test (from centre of weld).
(b) One transverse tensile test.
(c) Two bend tests.
(d) One set of three impact tests taken from the root of the weld and the specimens notched in accordance with Fig. 11.7.2.
(e) Chemical analysis (one only).

■ *Section 8*
Consumables for welding austenitic and duplex stainless steels

8.1 General

8.1.1 Tests for the approval of consumables intended for welding the austenitic and duplex stainless steels detailed in Ch 3,7 are to be carried out generally in accordance with the Section (3, 4, 5, 6 or 7) relevant to the type of consumable or combination.

8.1.2 Approval will be indicated by the grade or grades of parent stainless steel for which the consumable or combination is approved.

8.1.3 Where a shielding gas is employed, separate approval will be required for each specific shielding gas composition.

8.1.4 Consumables for welding the austenitic stainless steels and the duplex stainless steels to carbon or carbon-manganese steels will be approved in a similar manner. Parent plate used for the butt and fillet weld test assemblies will be carbon or carbon-manganese steel with either austenitic stainless steel or duplex stainless steel, as appropriate. Approval will be indicated by 'SS/CMn' and 'Dup/CMn' respectively, however, no buttering of test assembly plates is allowed for these two approvals.

8.1.5 Separate approval will be given for welding chemical and cryogenic applications. For chemical use, evidence of relevant corrosion resistance will be required. Charpy impact toughness tests will be required for all uses, but for cryogenic use the Charpy impact toughness requirements are more severe.

8.1.6 The welding technique will be indicated in the approval grading by a letter:

m – for manual SMAW or GTAW welding.

S – for wire-gas combinations used with a semi-automatic multi-run technique.

M – for wire-flux or wire-gas combinations used with an automatic multi-run technique.

T – for wire-flux or wire-gas combinations used with an automatic two-run technique.

A – as for M but using a procedure with a high heat input rate (large bead size relative to thickness welded). This would apply to welds made by four or less runs in 20 mm thickness, or eight or less runs in 35 mm.

8.2 Deposited metal test assemblies

8.2.1 Where the relevant Section requires deposited metal assemblies to be made and tested, the plates used must be either of the type for which approval is required or of normal strength carbon, or carbon-manganese steel with the prepared edges built up with stainless steel weld metal and finished with a layer of weld metal from the consumable to be approved.

8.2.2 The chemical analysis of the deposited weld metal is to be reported, including all significant elements. The elements reported will be dependent on the type of stainless steel for which approval of the consumables is requested. Any unusual weld metal compositions will have to be justified in respect of the particular approval requested. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

8.2.3 The results of all tensile and notch impact tests are to comply with the requirements given in Table 11.8.1 as appropriate.

8.2.4 The ferrite content in the last weld run from each deposited metal assembly is to be determined by physical or metallographic means, and reported, indicating the method of determination.

Table 11.8.1 Requirements for deposited metal tests (manual, semi-automatic and automatic multi-run techniques)

Grade	0,2% proof stress N/mm^2 minimum	1% proof stress N/mm^2 minimum	Tensile strength N/mm^2 minimum	Elongation on 50 mm % minimum	Charpy V-notch impact tests		
					Chemical test temperature °C	Cryogenic test temperature °C	Average energy *See* Note 1 J minimum
304L	270	310	500	25	–20	–196	29
304LN	305	345	530	22	–20	–196	29
316L	270	310	500	22	–20	–196	29
316LN	305	345	530	22	–20	–196	29
317L	305	345	530	22	–20	–196	29
317LN	340	380	570	22	–20	–196	29
321	290	330	550	22	–20	–196	29
347	290	330	550	22	–20	–196	29
S 31254	370	410	650	22	–20	–196	29
N 08904	270	310	500	22	–20	–196	29
SS/CMn	270	310	500	22	–20	–60	29
S 31260	485	525	690	20	–20	*see* Note 2	40
S 31803	450	490	620	25	–20		40
S 32550	550	590	760	15	–20		40
S 32750	550	590	800	15	–20		40
S 32760	550	590	750	25	–20		40
Dup/CMn	270	310	500	22	–20	*see* Note 2	40

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. Approval for cryogenic applications is to be obtained at the procedure approval stage.

8.3 Butt weld test assemblies

8.3.1 Where the relevant Section requires butt weld assemblies to be made and tested, the plates used are to be either of the type for which approval is required or of steel having strength and ductility within the range specified for the grade to be approved. In the latter case, provided the consumable is metallurgically compatible with the base material to be used, the prepared edges are to be built up with a layer of weld metal before final machining of the weld preparation.

8.3.2 The results of transverse tensile, notch impact and bend tests are to comply with the requirements of Table 11.8.2 as appropriate. The position of fracture is to be reported to LR.

8.3.3 The ferrite content at the centre of the weld metal in each butt weld assembly is to be determined by physical or metallographic means, and meet the requirements in Table 11.8.2. The method of determination is to be reported.

8.3.4 For austenitic and duplex stainless steel approvals (except for types 304L, 316L, 321 and 347), an appropriate sample from each butt weld assembly is to be submitted to the corrosion testing provided in ASTM G48, Method 'C'. The results are to be reported so as to allow confirmation of the maximum acceptable pitting corrosion resistance temperature. This will be part of the approval grading and will be set at 5°C intervals. The minimum pitting corrosion temperature would not be expected to be less than 20°C.

8.4 Fillet weld test assemblies

8.4.1 Where the relevant Section requires fillet weld assemblies to be made and tested, the plates used must be either of the type for which approval is required or of steel having strength and ductility within the range specified for the grade to be approved. In the latter case, the surfaces on which the fillet weld beads are to be deposited are to be cut back by machining and then built up to original dimensions with weld metal from the consumable to be approved.

8.4.2 The ferrite content at the centre of the weld metal in each fillet weld bead of each assembly is to be determined from the centre macro-section by physical or metallographic means, and reported. The method of determination is also to be reported to LR.

8.4.3 Where approval is sought for fillet welding only, corrosion testing is to be carried out in accordance with 8.3.4 from a sample taken from the deposited metal test assembly.

8.5 Annual tests

8.5.1 Annual tests are to be carried out as required by the relevant Section appropriate to the type of consumable and welding technique. The tests are to include a weld ferrite content in accordance with 8.2.4 or 8.3.3 as appropriate.

8.5.2 The results of all tests are to comply with the requirements given in Table 11.8.1 and Table 11.8.2 as appropriate.

Table 11.8.2 Requirements for butt weld tests (all techniques)

Grade	Tensile strength N/mm^2 minimum	Bend test ratio: $\frac{D}{t}$	Weld ferrite content %	Charpy V-notch impact tests		
				Chemical test temperature °C	Cryogenic test temperature °C	Average energy (*see* Note 1) J minimum
304L	500	3	4–12	–20	–196	27
304LN	530	3	4–12	–20	–196	27
316L	500	3	4–12	–20	–196	27
316LN	530	3	4–12	–20	–196	27
317L	530	3	4–12	–20	–196	27
317LN	570	3	4–12	–20	–196	27
321	550	3	4–12	–20	–196	27
347	550	3	4–12	–20	–196	27
S 31254	650	3	(*see* Note 2)	–20	–196	27
N 08904	500	3	(*see* Note 2)	–20	–196	27
SS/CMn	500	3	4–12	–20	–60	27
S 31260	690	4	35–65	–20	(*see* Note 3)	40
S 31803	620	3	35–65	–20		40
S 32550	760	6	35–65	–20		40
S 32750	800	6	35–65	–20		40
S 32760	750	6	35–65	–20		40
Dup/CMn	500	3	(*see* Note 2)	–20	(*see* Note 3)	40

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. To be reported for special consideration.
3. Approval for cryogenic applications is to be obtained at the procedure approval stage.

Section 9
Consumables for welding aluminium alloys

9.1 General

9.1.1 Tests for the approval of consumables intended for welding the aluminium alloys detailed in Chapter 8 are to be carried out generally in accordance with the requirements of Sections 1, 2 and 5, except as otherwise detailed in this Section.

9.1.2 Approval will be indicated by the grade shown in Table 11.9.1. Plate of the corresponding type of aluminium alloy and of appropriate thickness is to be used for the preparation of the weld test assemblies, and may be of any temper listed in LR Rules.

Table 11.9.1 Requirements for butt weld tests

Consumable Approval Grade (*see* Note 1)	Base material used for the test	Tensile strength N/mm^2 minimum	Bend test ratio $\frac{D}{t}$
LR RA/LR WA	5754	190	3
LR RB/LR WB	5086	240	6
LR RC1/LR WC1	5083	275	6
LR RC2/LR WC2 (*see* Note 2)	5383 or 5456	290	6
LR RC3/LR WC3 (*see* Note 2)	5059	330	6
LR RD/LR WD (*see* Note 4)	6005A 6061 6082	170 170 170	6 6 6

NOTES
1. The prefixes ‘R’ and ‘W’ indicate ‘rod’ form (for Gas Tungsten Arc Welding (GTAW)) or ‘wire’ form (for Gas Metal Arc Welding (GMAW) and GTAW).
2. Approval of grade LR RC2/LR WC2 confers approval of 5383, 5456 and 5083 base material grade.
3. Approval of grade LR RC3/LR WC3 confers approval of 5059, 5383, 5456 and 5083 base material grades.
4. Approval of grade LR RD/LR WD confers approval of 6005A, 6061 and 6082 base material grades.

9.1.3 The welding technique will be indicated in the approval grading by a letter:

m – manual multi-run welding (GTAW),
S – semi-automatic multi-run welding (GMAW),
M – automatic multi-run welding (GTAW or GMAW),
T – automatic two-run welding (GMAW).

9.1.4 The compositions of the shielding gas and the filler/electrode wire are to be reported.

9.1.5 Approval granted using the multi-run technique for a specific filler/electrode wire with a gas in one of the groups listed in Table 11.9.2 will extend to any other gas compositions within that same group, provided that the gas composition is within the range recommended by the consumable manufacturer, subject to agreement with LR.

Table 11.9.2 Shielding gas compositions

Group	Gas composition (Vol. %) (*see* Note)	
	Helium	Argon
I-1	–	100
I-2	100	–
I-3	>0 ≤33	Remainder
I-4	>33 ≤66	Remainder
I-5	>66 ≤95	Remainder
S	Special gas	

NOTE
Gases of other composition (mixed gases) or special purity may be considered as special gases and will require separate approval tests.

9.1.6 Approval granted for the two-run technique will be for a specific shielding gas composition; additional tests may be required if a change in shielding gas composition is sought.

9.1.7 On completion of welding, assemblies are to be allowed to cool naturally to ambient temperature. Welded test assemblies and test specimens are not to be subjected to any heat treatment after welding except for the alloy Grades 6005A, 6061 and 6082. These are to be allowed to naturally age at ambient temperature for a period of 72 hours from the completion of welding, before testing is carried out. A second solution heat treatment is not permitted.

9.1.8 All butt test assemblies are to be subjected to both radiographic and visual examination and imperfections such as lack of fusion, lack of penetration, cavities, inclusions, pores and cracks assessed in accordance with Intermediate Level C of ISO 10042, aided where necessary by dye penetrant and ultrasonic examination.

9.1.9 Fillet weld test assemblies and macro-sections are to be visually examined for imperfections, such as lack of fusion, lack of penetration, cavities, inclusions, pores and cracks, in accordance with Intermediate Level C of ISO 10042, aided where necessary by radiographic and dye penetrant examination.

9.2 Approval tests for manual, semi-automatic and automatic multi-run techniques

9.2.1 Plate of the corresponding type of aluminium alloy and of appropriate thickness is to be used for the preparation of the weld test assemblies.

9.2.2 The welding parameters are to be within the range recommended by the manufacturer and are to be reported.

9.2.3 Welded assemblies are to be prepared and tested in accordance with 9.3, 9.4 and 9.5.

9.3 Deposited metal test assembly

9.3.1 One assembly is to be prepared in the downhand position as shown in Fig. 11.9.1.

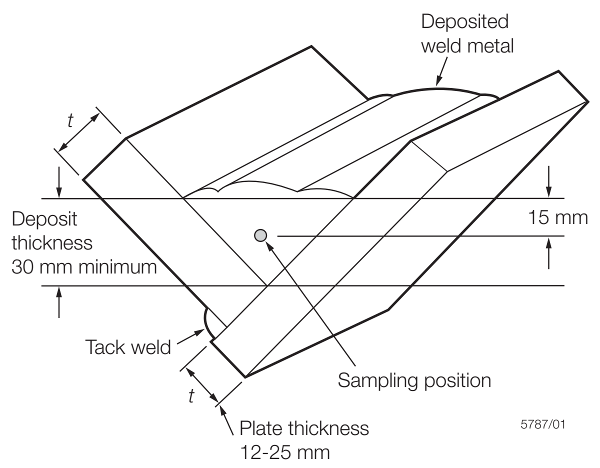


Fig. 11.9.1 Deposited metal test assembly

9.3.2 The chemical composition of the plate used for the assembly is to be compatible with the weld metal.

9.3.3 The thickness of the plate used, and the length of the assembly, are to be appropriate to the welding process. The plate thickness is to be not less than 12 mm.

9.3.4 For the approval of filler wire/gas and electrode wire/gas combinations for manual or semi-automatic welding by GTAW or GMAW, one test assembly is to be welded using any size of wire within the range for which approval is sought.

9.3.5 For automatic multi-run approval, one test assembly is to be welded by the respective process using the recommended diameter of wire.

9.3.6 The weld metal is to be deposited in multi-run layers in accordance with normal practice. The direction of deposition of each layer is to alternate from each end of the plate.

9.3.7 The deposited weld metal in the assembly is to be analysed and reported including the contents of all significant elements. The elements reported will be dependent on the type of aluminium alloy for which approval of the consumables is requested. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

9.4 Butt weld test assemblies

9.4.1 Plate of the corresponding type of aluminium alloy and of an appropriate thickness is to be used for the preparation of the test assemblies.

9.4.2 In order to ensure sound and representative welds, it is essential that test assemblies are cleaned and degreased prior to welding. Assemblies as shown in Fig. 11.9.2 are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward, vertical-downward, and overhead) for which the consumable is recommended by the manufacturer; except that consumables satisfying the requirements for downhand and vertical-upward positions will be considered as also complying with the requirements for the horizontal-vertical position. Any wire diameter(s) to be approved may be used.

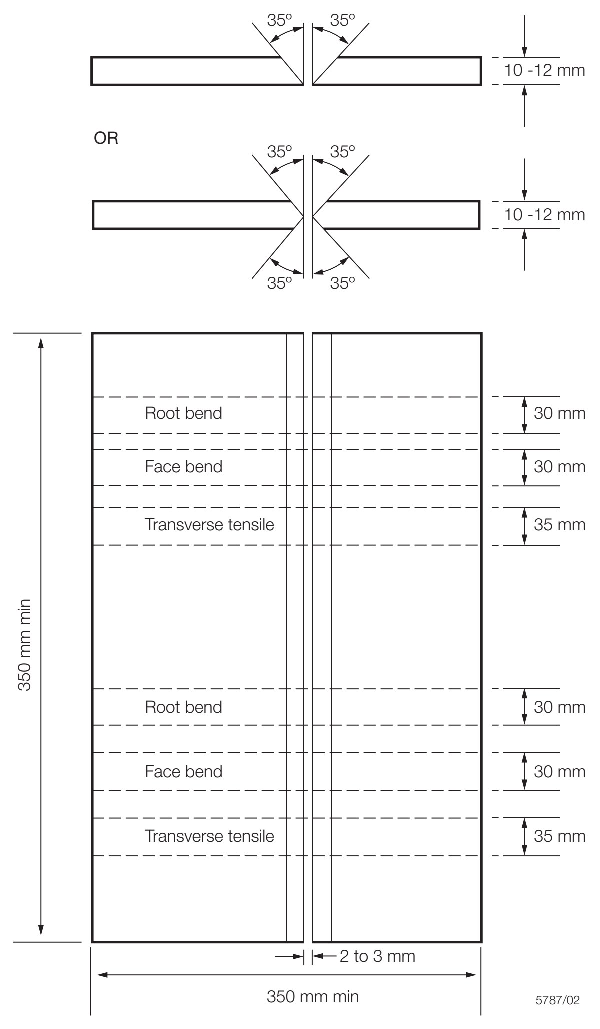


Fig. 11.9.2
Butt weld test assembly
(positional, multi-run technique)

9.4.3 One assembly, as shown in Fig. 11.9.3, is to be prepared for welding in the downhand position. The assembly is to be welded using, for the first run, wire of the smallest diameter recommended by the manufacturer and, for the remaining runs, wire of the largest diameter to be approved.

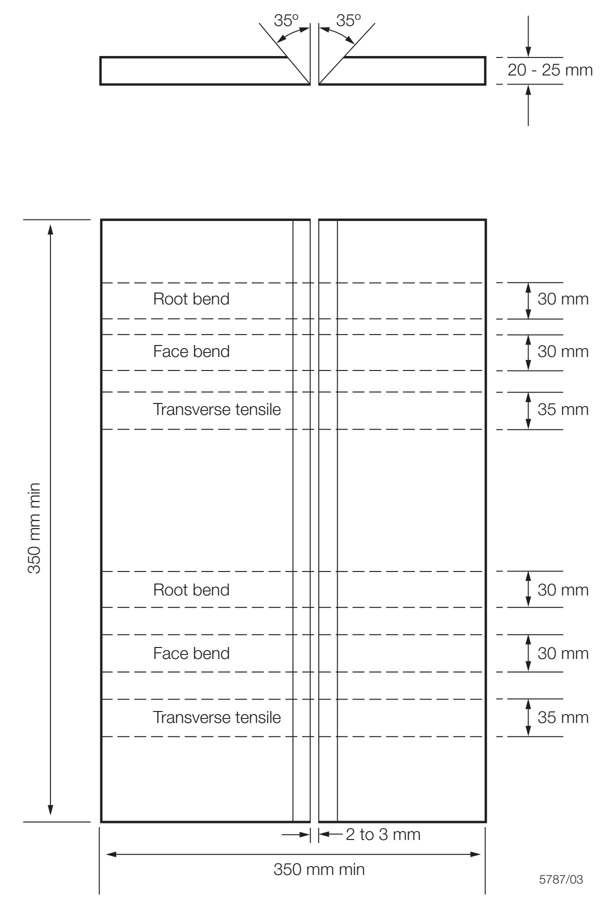


Fig. 11.9.3
Butt weld test assembly
(downhand, multi-run technique)

9.4.4 The welding conditions are to be in accordance with the recommendations of the manufacturer and are to be reported in detail.

9.4.5 The welded assemblies are to be subjected to NDE. Imperfections are to be assessed in accordance with 9.1.8.

9.4.6 The test specimens are to be taken from the welded assemblies as shown in Fig. 11.9.2 and Fig. 11.9.3. For each assembly they are to comprise:

- 2 transverse tensile specimens;
- 2 face bend specimens; and
- 2 root bend specimens.

9.4.7 All tensile test specimens are to have a tensile strength not less than the respective value shown in Table 11.9.1. The position of each fracture is to be reported.

9.4.8 The bend test specimens are to be bent around a former having a diameter not more than the number of times the thickness of the test specimen, as shown in Table 11.9.1, and can be considered as complying with the requirements if, after bending to an angle of not less than 180°, no crack or other open defect exceeding 3 mm in length can be seen on the outer surface. Flaws appearing at the corners of a test specimen may be ignored.

9.4.9 In order to obtain uniform bending of the bend test specimens, it is recommended that the wrap-around or guided bend test using a roller method is employed.

9.5 Fillet weld test assembly

9.5.1 When approval is being sought for both butt and fillet welding, one assembly is to be prepared and welded in the horizontal-vertical position and tested in accordance with the appropriate requirements of 3.5, except that the plates are to be of an aluminium alloy compatible with the weld metal, that no hardness tests are required and that for automatic multi-run approval only one fillet weld bead is to be made using the recommended wire diameter. In this case, the bead size is to be as large as the maximum single bead size recommended by the manufacturer for fillet welding.

9.5.2 When approval is being sought for fillet welding only, one assembly is to be prepared and welded in each position for which approval is sought, and tested as detailed in 9.5.1.

9.5.3 The results of examination of the macro-specimens and the fractured fillet welds are to be reported in accordance with 3.5.4 and 3.5.6. Imperfections are to be assessed in accordance with 9.1.9.

9.6 Approval tests for two-run technique

9.6.1 Two butt weld test assemblies are to be prepared using the following plate thicknesses:
(a) one with the maximum thickness for which approval is requested; and
(b) one with a thickness approximately one half to two thirds that of the maximum thickness.

9.7 Butt weld test assemblies (two-run technique)

9.7.1 The plates used are to be of the aluminium alloy appropriate to the approval required as shown in Table 11.9.1. The composition of the plate material is to be within the range specified for that alloy in Table 8.1.2 in Chapter 8 and is to be reported including all significant elements.

9.7.2 The wire diameter, edge preparation, welding current, arc voltage and travel speed are to be in accordance with the manufacturer's recommendations and are to be reported.

9.7.3 Each butt weld is to be made in two runs, one from each side. After completion of the first run, the assembly is to be left in still air until it has cooled to less than 50°C.

9.7.4 The welded assemblies are to be subjected to NDE. Imperfections are to be assessed in accordance with 9.1.8.

9.7.5 The test specimens as shown in Fig. 11.9.4 are to be prepared from each test assembly. The edges of the discards are to be polished and etched, and must show complete fusion and inter-run penetration of the welds. Each cut in the assembly is also to be examined to confirm that complete fusion and penetration have been achieved.

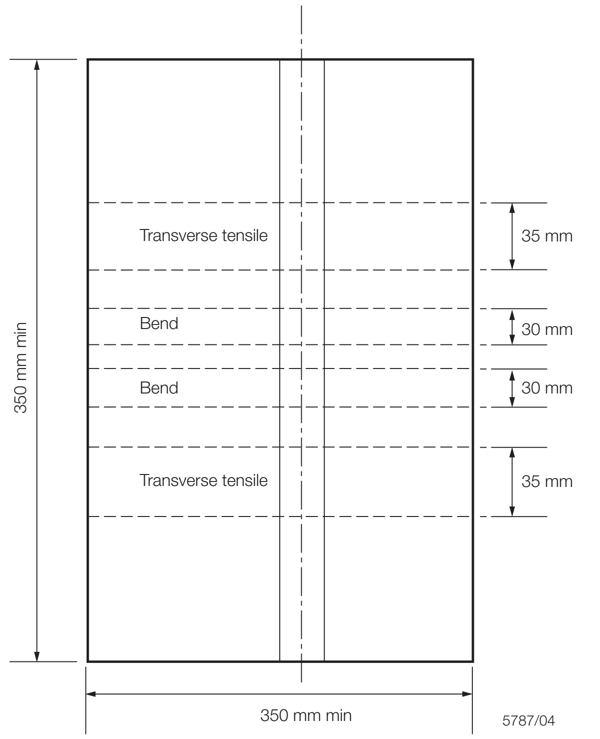


Fig. 11.9.4
Butt weld test assembly (two-run technique)

9.7.6 The results of the transverse tensile tests are to be as in 9.4.7 and of the bend tests as in 9.4.8. The position of the fracture in each transverse tensile specimen is to be reported.

9.8 Annual tests

9.8.1 Annual tests are to consist of the following:
(a) for combinations approved for the multi-run technique, one deposited metal assembly in 9.3 and one downhand butt assembly in 9.4;
(b) for combinations approved for the two-run technique, one butt weld assembly in plate material of thickness equal to one half to two thirds that of the maximum thickness approved.

9.8.2 For the automatic two-run technique, one butt weld assembly is to be prepared and tested in accordance with 9.7.

Section

■ *Section 1* General qualification requirements

1.1 General

1.1.1 This Section applies to all welding qualifications and tests required to be performed in the course of new construction, conversions, modifications or repairs made on ships, other marine structures and their associated pressure vessels, machinery and equipment.

1.1.2 These Rules also apply to all welding work related to other applications for which Lloyd's Register (hereinafter referred to as LR) have issued Rules or have an interest.

1.1.3 It is the responsibility of the manufacturer to ensure compliance with all aspects of these Rules. All deviations are to be recorded as non-compliances and brought to the attention of the Surveyor along with the corrective actions taken. Failure to do this is considered to render the welding tests as not complying with the Rules.

1.1.4 Welding tests are to be performed under survey at the manufacturer's works. Welding procedure qualification tests and welder qualifications tests are to be performed and approved prior to commencement of fabrication or construction.

1.1.5 Weld procedure tests made in accordance with EN, ISO, JIS, ASME or AWS may be considered for acceptance provided that, as a minimum, they are equivalent to and meet the technical intent of these Rules to the satisfaction of the Surveyor.

1.1.6 Welding tests that have previously been carried out may be considered for acceptance, provided that they have been supervised by an independent body acceptable to LR and the Surveyor is satisfied with the authenticity of such tests.

1.1.7 The responsibility for the performance of the weld tests rests with the manufacturer. Aspects of the welding tests, such as mechanical testing, non-destructive testing and heat treatment, may be subcontracted by the manufacturer provided that the subcontractor performs the work under the technical control and direction of the manufacturer, and this is agreed with the Surveyor prior to commencing the work.

1.1.8 In these Rules, the term 'manufacturer' is considered to include any firm or organisation that performs welding and is considered to be the shipbuilder, or construction firm, or fabricator, or material manufacturer.

1.2 Design

1.2.1 Welding procedure qualification tests are required to give assurance that construction welds made in accordance with the approved plans or the approved design have acceptable properties. It is the manufacturer's responsibility to establish and document whether a procedure is suitable for a particular application.

1.2.2 The requirements relate to mechanical properties of the weld and heat affected zone, however, other tests may be required on certain materials, for example, corrosion or fatigue tests, in order to ensure suitability for the proposed application.

1.3 Materials

1.3.1 Materials used for testing are to be of the same grade, type and from the same manufacturing process as those to be used for construction, unless prior agreement is obtained from the Surveyor. Such agreements will only apply on a case-by-case basis.

1.3.2 All materials used for testing are to be suitably marked and identifiable to the original manufacturer's material certificate.

1.4 Performance of welding tests

1.4.1 All welding and subsequent testing is to be performed in accordance with the requirements of this Chapter.

1.4.2 The manufacturer is responsible for monitoring the tests and for recording all the welding variables as specified in 2.2 and for compiling all the non-destructive examination (NDE) reports and mechanical test records for submission to the Surveyor.

1.4.3 The laboratory or testing establishment used to perform the tests is to have the necessary equipment, maintained in good order and suitably calibrated. The Surveyor is to be satisfied that the laboratory personnel have the appropriate skills and are appropriately qualified in accordance with Ch 2,1.2.1.

■ *Section 2*
Welding procedure qualification tests for steels

2.1 General

2.1.1 The requirements of this Section relate to welding procedure test requirements of carbon, carbon-manganese steels and low alloys steels. Additional requirements for austenitic and austenitic/ferritic duplex stainless steels, aluminium and copper alloys are specified in Sections 3 and 4 respectively.

2.1.2 Prior to performing the welding procedure qualification test, the manufacturer is to present to the Surveyor a preliminary Welding Procedure Specification (pWPS) detailing the welding processes, positions, joint types, materials and heat treatments to be performed during the test. The pWPS is to be presented for information prior to commencing the test.

2.1.3 The type and extent of testing to be applied to each welding procedure test is to be in accordance with subsequent Sections of this Chapter.

2.1.4 For the welding procedure approval, the welding procedure qualification tests given in this Section are to be carried out with satisfactory results. Welding procedure specifications are to refer to the test results achieved during welding procedure qualification testing.

2.2 Welding variables

2.2.1 In order that the conditions of the qualification test may be applied to production welding operations, the appropriate variables are to be recorded by the manufacturer during welding and testing from the following list:
(a) The unique qualification reference number and the date of welding;
(b) The material type, grade, product form, dimensions and identification;
(c) Welding process(es), including tack welds;
(d) Joint type, dimensions and surface condition;
(e) Welding position(s);
(f) Welding technique(s), weaving, multiple electrodes, etc;
(g) Welding consumables including fluxes, shielding gases, etc;
(h) Control of consumables, baking or drying conditions, etc;
(j) Welding parameters, current, voltages, travel speeds, etc;
(k) Number and sequence of weld runs;
(l) Backing materials including any backing gas;
(m) Preheats and interpass temperatures;
(n) Methods used for cleaning and inspection of root deposits;
(o) Post-weld heat treatment, temperature and cycle times;
(p) Special weld profiling requirements.

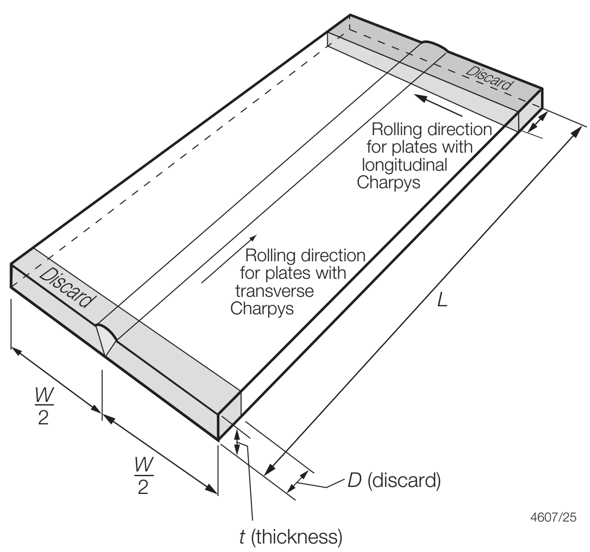
2.2.2 Other variables may need to be recorded depending on the particular welding process or application and are to be agreed with the Surveyor, for example the peak and base current and cycle times for pulse welding, electrode type and nozzle size for GTAW welding, etc.

2.3 Steel test assemblies

2.3.1 Tests are to be performed using the welding process and positions anticipated for actual construction. The weld test assemblies are to be representative of construction conditions and are to be welded in the same manner as intended for the actual production welds. Where pre-fabrication primers are used in the shipyard, these are to be included in the test assemblies.

2.3.2 For plate tests, the direction of plate rolling relative to the weld direction is to be considered. Where the material used for the test requires longitudinal impact tests, the plate rolling direction is to be perpendicular to the weld direction and for material which requires impact testing in the transverse direction, the rolling direction is to be parallel to the weld direction. For weld tests intended for liquefied gas storage or cargo tanks and associated process pressure vessels, the direction of plate rolling is to be parallel to the weld direction in all cases.

2.3.3 Typical test assemblies are shown in Fig. 12.2.1(a) to (c). These are a minimum requirement to permit the removal of all the necessary mechanical test specimens. Where impact tests or other toughness tests are required, the total width is not to be less than 8 times the material thickness of the thicker material being joined.



Welding Processes	*L* (min) mm	*W* (min) mm	*D* (min) mm
Manual/Semi-automatic	350	300	50
Automatic	1000	400	75

Fig. 12.2.1(a) Butt weld test assembly in plate

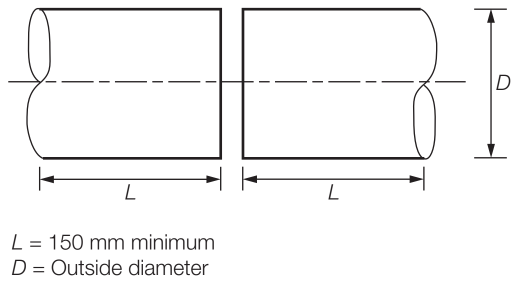
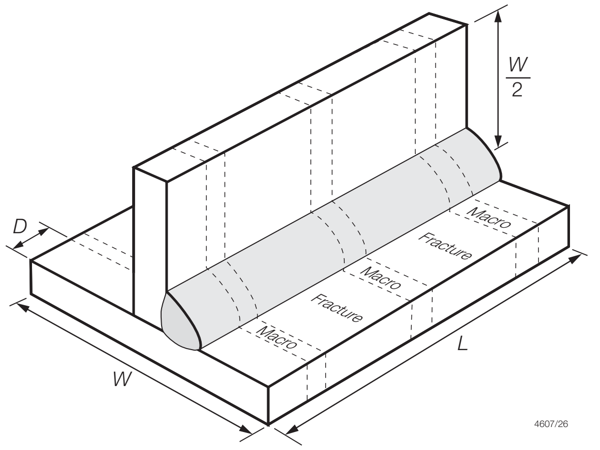


Fig. 12.2.1(b) Butt weld test assembly in pipe



Welding Processes	*L* (min) mm	*W* (min) mm	*D* (min) mm
Manual/Semi-automatic	350	300	50
Automatic	1000	300	75

Fig. 12.2.1(c) Fillet weld test assembly in plate

2.3.4 Welding procedure test assemblies are to be welded separately from production welds and are to be marked with the unique test identification number. The individual pieces of the test assembly may be held together to maintain their relative joint conditions by means of suitable tack welds, clamps or strongbacks.

2.3.5 Welding of the test assemblies and testing of test specimens is to be monitored by the Surveyor.

2.3.6 The test assembly is to be placed in one of the welding positions shown in Fig. 12.2.2(a) to (d), as specified in the test Welding Procedure Specification (pWPS) and the specified level of preheat applied prior to the start of welding.

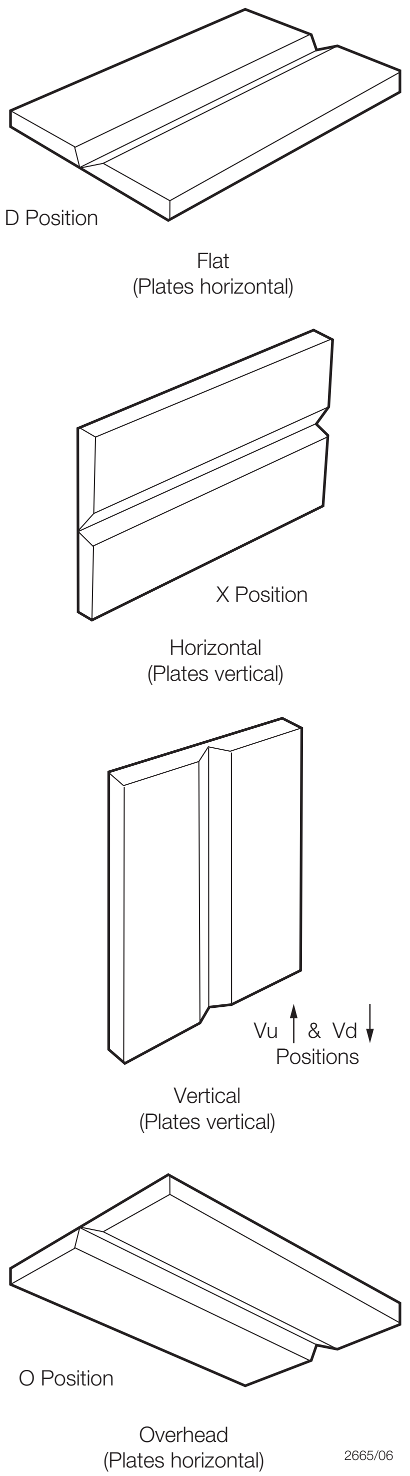
2.3.7 Designations for equivalent welding positions shown by different standards are shown in Table 12.2.1.

Table 12.2.1 Equivalent designations of welding positions

Weld position		Standard ISO 6947	Standard AWS
Plate butt welds			
Flat	D	PA	1G
Horizontal	X	PC	2G
Vertical, weld up	Vu	PF	3G
Vertical, weld down	Vd	PG	3G
Overhead	O	PE	4G
Pipe butt welds			
Pipe horizontal, rotated, weld horizontal	D	PA	1G
Pipe vertical, not rotated, weld horizontal	X	PC	2G
Pipe horizontal, not rotated, weld flat, vertical and overhead	D+Vu+O D+Vd+O	PF PG	5G
Pipe inclination fixed, not rotated	45°	H-L045 J-L045	6G
Plate fillet welds			
Flat	D	PA	1F
Horizontal	X	PB	2F
Vertical up	Vu	PF	3F
Vertical down	Vd	PG	3F
Overhead	O	PD	4F
Pipe fillet welds			
Flat, pipe rotated	D	PA	1FR
Horizontal, pipe fixed	X	PB	2F
Horizontal, pipe rotated	D	PB	2FR
Overhead, pipe fixed	O	PD	4F
Multiple, pipe fixed	D+Vu+O D+Vd+O	PF PG	5F

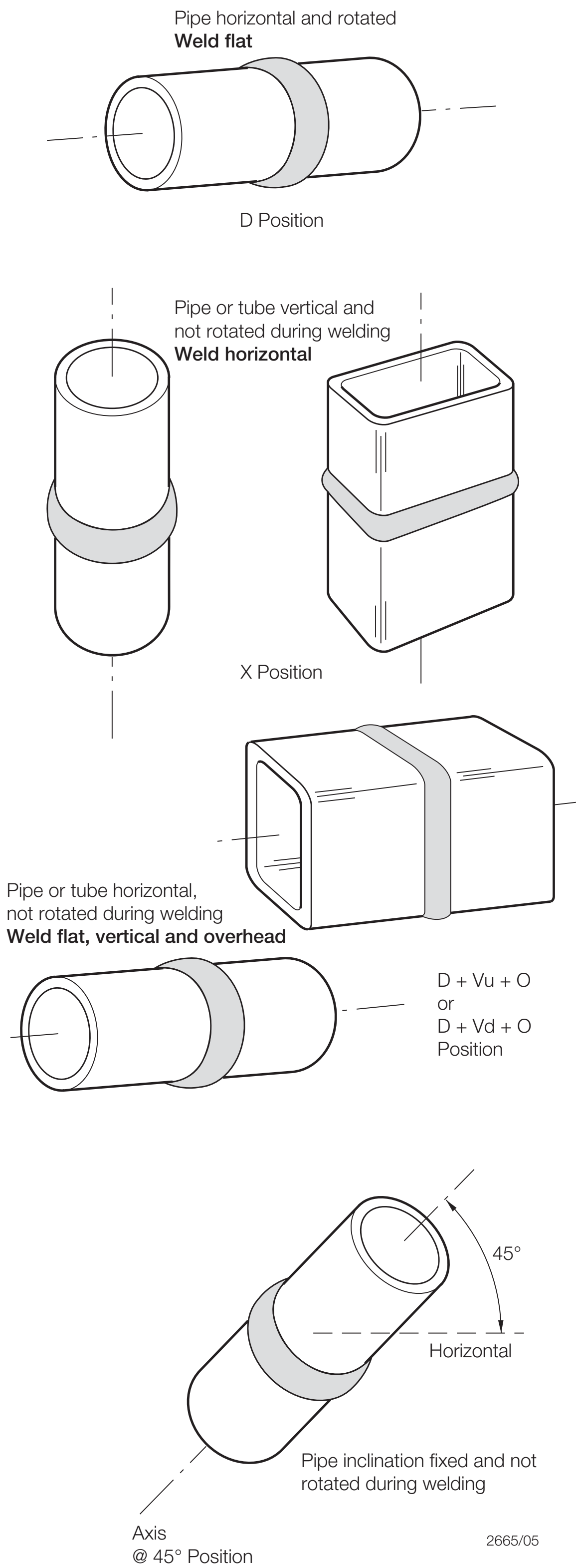
2.4 Welding of steel test assemblies

2.4.1 Welding of the test assembly is to be carried out in accordance with the agreed pWPS. Where, during the progress of the test, it is found necessary to change the conditions specified on the pWPS, this is to be brought to the attention of the Surveyor. If agreed, the test may be permitted to continue with the new conditions and these are to be recorded.



Position of test plates for plate assemblies

Fig. 12.2.2(a) Plate butt weld test positions



Position of pipes and welds for qualification weld test assemblies

Fig. 12.2.2(b) Pipe butt weld test positions

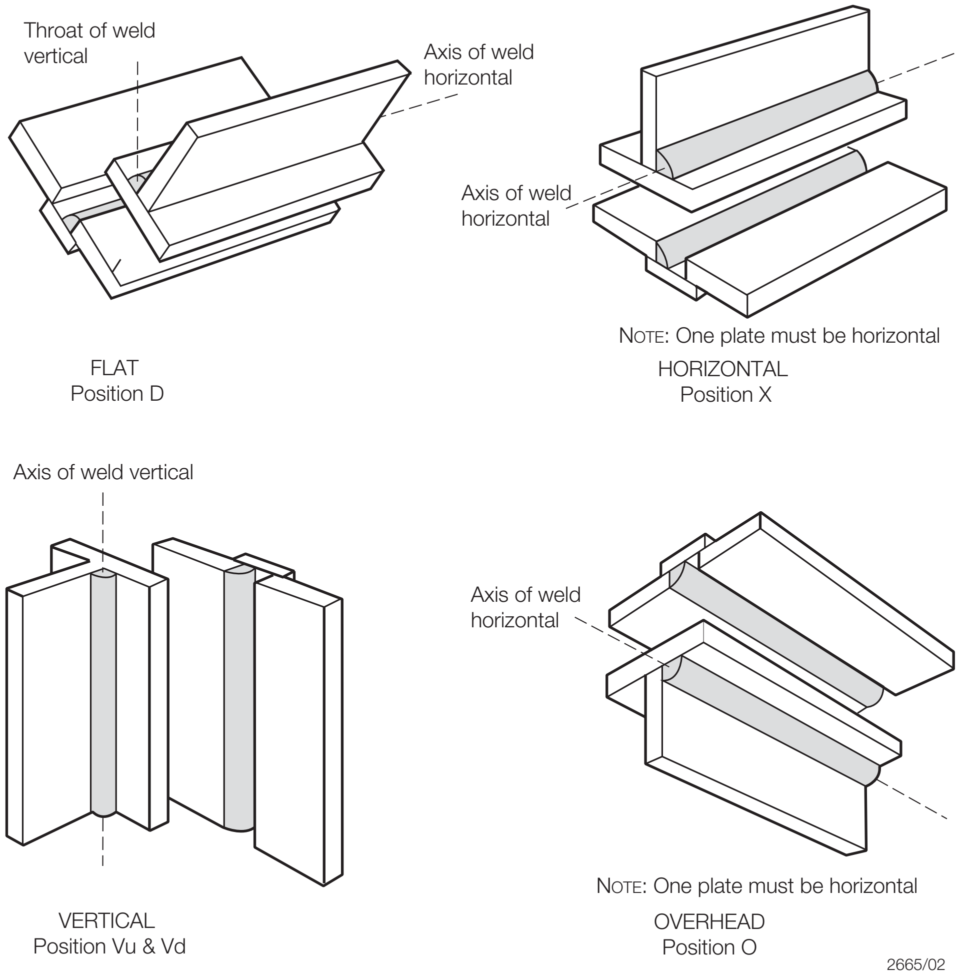


Fig. 12.2.2(c) Plate fillet weld test positions

2.4.2 Where the production work requires welding over tack welds, the test is to simulate this condition and the tack welds are to be included in the inspection length of the test weld and their position recorded.

2.4.3 For manual and semi-automatic welding processes, weld stops and re-starts are to be included in the inspection length of the test weld.

2.4.4 Fillet weld test assemblies are welded on one side only.

2.4.5 Where the construction welding is predominately fillet welding, in addition to the butt weld qualification test, a fillet weld qualification test is to be performed to confirm that acceptable weld quality is achieved.

2.5 Non-destructive examination (NDE)

2.5.1 On completion of welding, prior to sectioning for mechanical tests, the inspection length of the test assembly is to be subjected to both visual examination and surface crack detection.

2.5.2 Butt weld assemblies are also to be subjected to radiographic or ultrasonic examination over the whole inspection length of the weld.

2.5.3 For welds in steels with specified yield strength up to 400 N/mm^2, and with carbon equivalent less than or equal to 0,41 per cent, NDE may be performed as soon as the test assembly has cooled to ambient temperature. For other steels, NDE is to be delayed for a period of at least 48 hours after the test assembly has cooled to ambient temperature.

2.5.4 Where post-weld heat treatment is required, NDE is to be performed after the heat treatment is complete.

2.5.5 All NDEs are to be carried out in accordance with the requirements of Ch 1,5. Assessment of results is to be in accordance with ISO 5817 Level B except for excess convexity and excess throat thickness where Level C will apply. Linear porosity is not permitted.

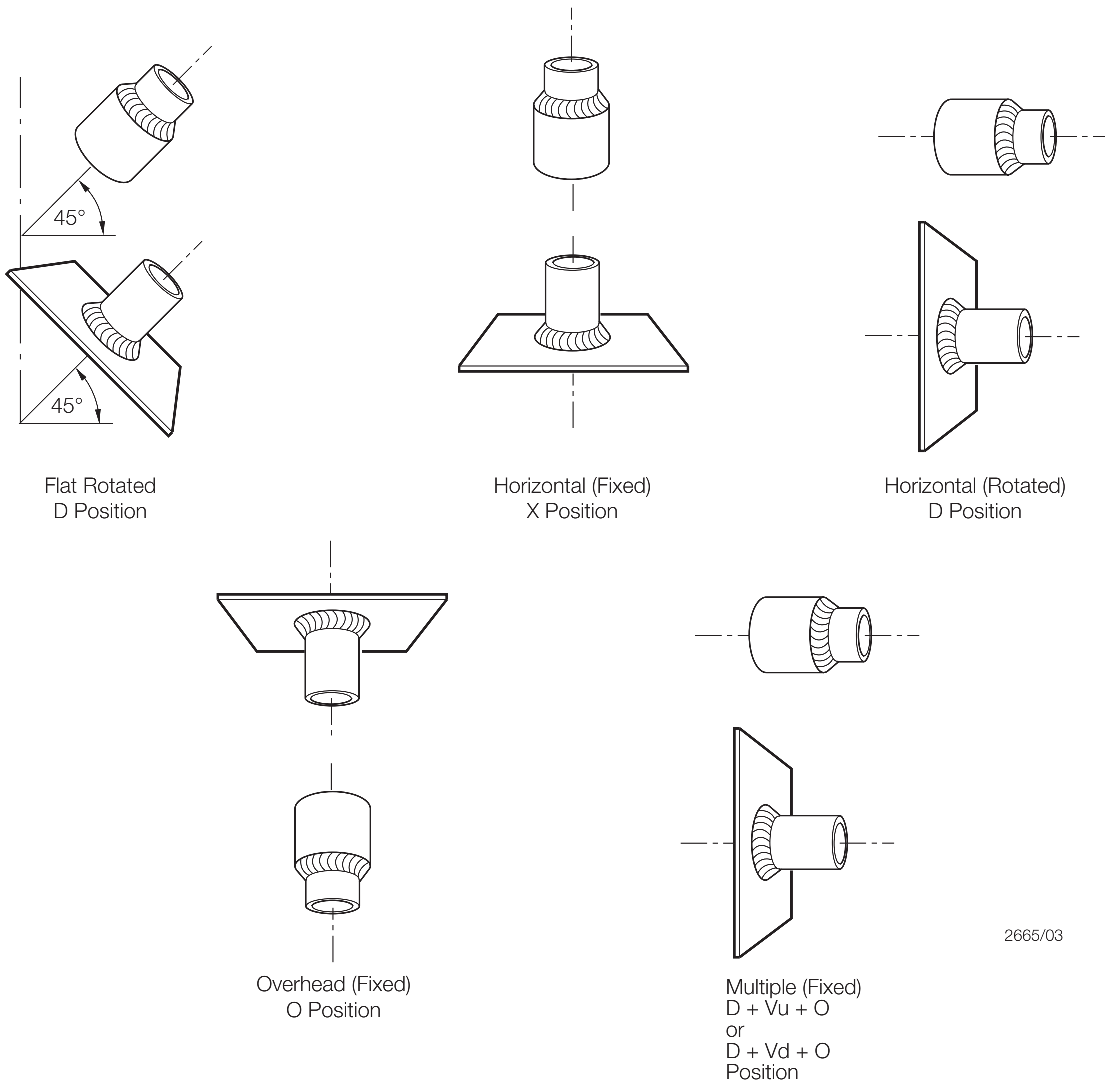


Fig. 12.2.2(d) Pipe fillet weld test positions

2.5.6 As an alternative to radiography, ultrasonic examination may be carried out and acceptance criteria that are considered to result in equivalent weld quality (in accordance with 2.5.5) are to be agreed, with the Surveyor, prior to the tests being carried out. Ultrasonic testing will be subject to the thickness limitation specified in Ch 13,2.12.5.

2.5.7 Where the test assembly does not satisfy the non-destructive examination acceptance criteria, the test is to be rejected. A duplicate test assembly may be welded using the original welding conditions. If this fails NDE, the welding procedure is to be considered as incapable of achieving the requirements without modification.

2.5.8 Subject to prior agreement with the Surveyor, where unacceptable imperfections are of a volumetric nature and are localised in one small area of the test assembly, the test may be permitted to continue and specimens for destructive testing may be removed, avoiding this area.

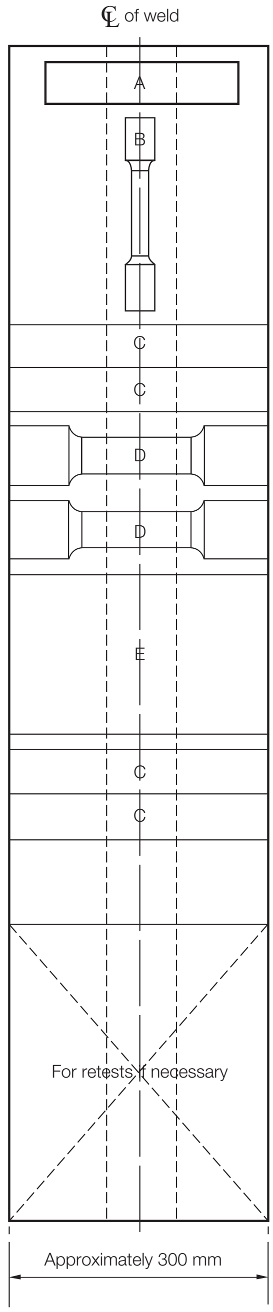
2.6 Destructive tests – General requirements

2.6.1 The weld test assembly may only be sectioned for destructive testing after any heat treatment and the required non-destructive examinations have been completed successfully.

2.6.2 The dimensions of the test specimens and testing conditions are to be in accordance with the requirements specified in Chapter 2.

2.6.3 The results of destructive tests are to be assessed in accordance with the acceptance criteria specified in 2.12, unless other, more stringent requirements are specified for the application.

2.6.4 Where a weld test is made between materials of different grades, the acceptance criteria that are to be applied are those applicable to the lower grade material.



Test requirements
A One macro including hardness survey
B All weld metal tensile test
C Four bend tests.
Two root bends and two face bends for thickness up to 12 mm.
For thickness above 12 mm four side bends
D Two transverse tensiles
E Five sets of Charpy V-notch impact tests, notched at the following positions:
1 set at weld centre
1 set at fusion line (FL)
1 set at FL + 2 mm
1 set at FL + 5 mm (if required by Figs. 12.2.6 and 12.2.7)
1 set at FL + 10 mm (if required)

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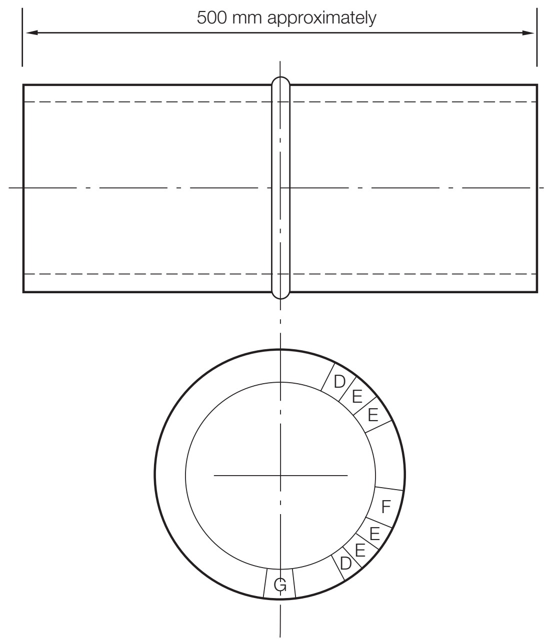
Fig. 12.2.3
Butt welds in plate and pipe over 750 mm diameter



The diameter of the test piece is to be a minimum of *D*/2
where
D is the maximum diameter of the pipe to be welded in construction

Test requirements
A Visual examination
B Surface crack detection
C 100% radiographic examination
D Two transverse tensile tests
E Four bend tests.
Four side bends for thickness greater than 12 mm.
In other cases, two face and two root bends
F Four sets Charpy V-notch impact tests
1 set notched at centre of weld
1 set notched at fusion line (FL)
1 set notched at FL + 2 mm
1 set notched at FL + 5 mm (if required by Figs. 12.2.6 and 12.2.7)
G One macro specimen including hardness survey

Fig. 12.2.4
Butt welds in pipe less than 750 mm diameter

2.7 Destructive tests for steel butt welds

2.7.1 The test assembly is to be sectioned for mechanical testing in accordance with Figs. 12.2.3 or 12.2.4.

2.7.2 The longitudinal all weld metal tensile test specimen is to be of circular cross-section as detailed in Ch 11,2.1.1. Where more than one welding process or type of consumable has been used to make the weld, test specimens are to be removed from each respective area of the weld. This does not apply to the process or consumables used to make the root or first weld run. During the test, the yield or proof stress, ultimate tensile strength, and elongation to failure are to be recorded.

2.7.3 Where approved welding consumables have been used, the longitudinal all weld metal tensile test may be omitted. For Type C independent tanks intended for liquefied gases, the all weld tensile test is mandatory for all welding procedure tests.

2.7.4 The transverse tensile test specimen is to be of full thickness with the dimensions shown in Ch 11,2.1.1. The tensile strength and fracture locations are to be reported.

2.7.5 Where the maximum load required to fracture the transverse tensile specimen is likely to exceed the capacity of the tensile testing equipment, several tensile specimens may be removed through the thickness and tested. Specimens are to be prepared such that they overlap in the thickness direction so that the full plate thickness is tested.

2.7.6 Transverse bend specimens of rectangular section are to be prepared with the weld centred in the middle of the specimen as shown in Fig. 12.2.5. For material of thickness 12 mm or greater, the face and root bends may be substituted by side bend tests. Where there is a significant difference between the strength of the weld and base material, longitudinal bend specimens may be used.The weld reinforcement may be removed by grinding or machining prior to testing and the edges rounded to a radius not exceeding 10 per cent of the specimen thickness. Each specimen is to be bent through an angle of at least 180°. The bend test ratio is to be the lesser of the following:

(a) $D_f = (D/t) + 1$

or

(b) $D_f = 100/E_m$ (rounded up to the next whole number)

where

D_f = is the bend test ratio

(D/t) = is the value from Tables 11.3.3, 11.4.3 or 11.8.2 in Chapter 11, as appropriate

E_m = is the minimum specified percentage elongation for the test material (based on a proportional gauge length of $5{,}65\sqrt{S_o}$)

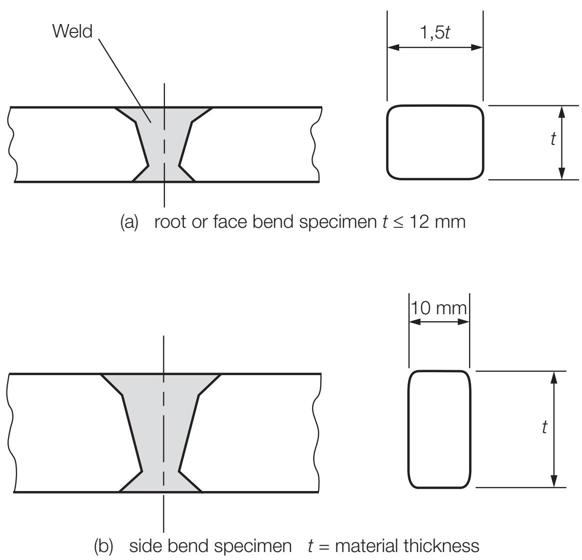


Fig. 12.2.5 Transverse bend test specimens

2.7.7 Where the weld test is made between different material types, the requirements of 2.7.8 are to be applied to the material with the lower toughness specification.

2.7.8 For hull structural steels, impact test specimens are to be prepared from the locations shown in Figs. 12.2.6 or 12.2.7, with the notch perpendicular to the plate surface and have the dimensions and proportions in accordance with Ch 2,3. Where more than one welding process or type of consumable has been used to make the weld, test specimens are also to be removed from these respective parts of the weld. Note that this does not apply to the welding process or consumables used solely to make the root or first weld run. Where the weld thickness exceeds 50 mm, an additional set of impact tests is required from the root area of the weld irrespective or whether different welding process or welding consumables are used as shown in Figs. 12.2.6 and 12.2.7.

2.7.9 For offshore structures and pressure vessels, impact test specimens are not required to be notched at the FL + 10 mm location. Where more than one welding process or type of consumable has been used to make the weld, test specimens are to be removed from the respective areas of the weld. This does not apply to the process or consumables used solely to make the root or first weld run.

2.7.10 For pressure vessels and tanks employed in transportation of liquefied gases, Charpy impact test locations from the weld and heat affected zone are to be in accordance with Fig. 12.2.8.

2.7.11 At least one macro examination specimen is to be removed from the test plate, near the end where welding started. The specimen is to include the complete cross-section of the weld and the heat affected zone and be prepared and etched to clearly reveal the weld runs and the heat affected zone. Examination is to be performed under a magnification of between x5 and x10.

2.7.12 A chemical analysis of the weld metal is to be performed on the macro specimen where approved welding consumables have not been used. The results are to comply with the limits given in the welding consumable specification.

2.7.13 A Vickers hardness survey is to be performed on the macro specimen taken from the weld start end of the test assembly in accordance with that shown in Fig. 12.2.9, using a test load not in excess of 10 kg. For each row of indents, there are to be a minimum of 3 individual indentations in the weld metal, the heat affected zones (both sides) and the base metal (both sides). The recommended distance between indents is 1,0 mm, but the distance between indents should not be less than the minimum specified in ISO 6507/1.

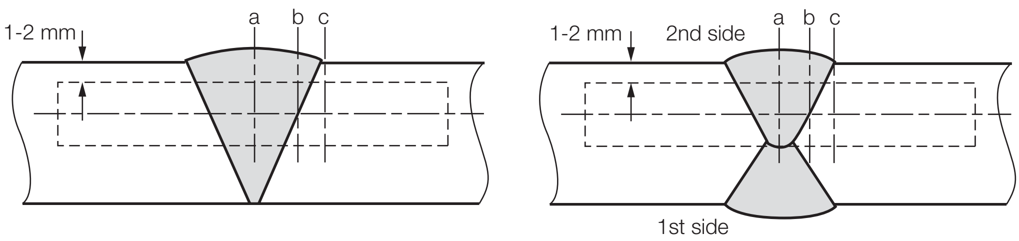
2.8 Destructive tests for steel fillet welds

2.8.1 Fillet weld test assemblies are to be sectioned for destructive testing in accordance with Fig. 12.2.1(c) and as follows:

(a) two fracture tests;
(b) three macro-sections;
(c) one hardness survey.

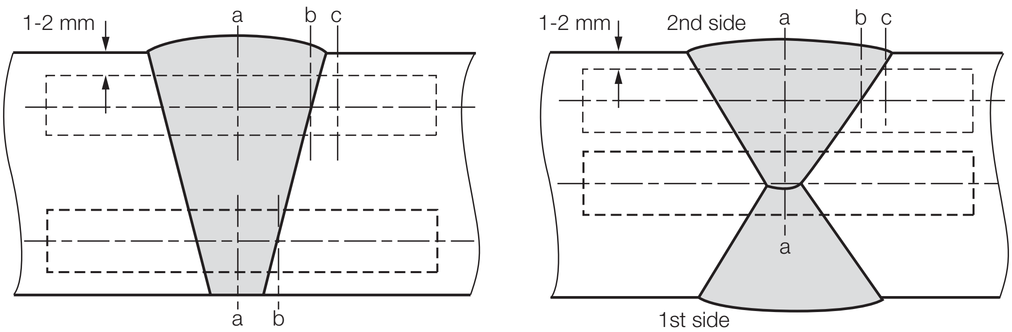
2.8.2 Two fracture test specimens are to be removed from the test weld and are to be subjected to testing by bending the upright plate onto the through plate to produce fracture, as shown in Fig. 12.2.1(c).

(a) $t \leq$ 50 mm, *see* Note



NOTE
For one side single run welding over 20 mm notch location ‘a’ is to be added on root side

(a) $t >$ 50 mm



Notch locations:
a : centre of weld ‘WM’
b : on fusion line ‘FL’
c : in HAZ, 2mm from fusion line

Fig. 12.2.6 Locations of V-notch for butt weld of normal heat input (heat input ≤ 50 kJ/cm)

2.8.3 At least three macro examination specimens are to be removed from the test plate. The specimens are to include the complete cross-section of the weld and the heat affected zone and is to be prepared to clearly reveal the weld runs and the heat affected zone. One of the specimens is to include a weld stop/start position. Examination is to be performed under a magnification of between x5 and x10.

2.8.4 A Vickers hardness survey is to be performed on the macro specimen taken from the weld start end of the test assembly in accordance with that shown in Fig. 12.2.10, using a test load not exceeding 10 kg.

2.9 Destructive tests for T, K, Y steel nozzle welds

2.9.1 Full penetration ‘T’, ‘K’ and ‘Y’ joints for structural applications and nozzle welds for pressure vessels are to be sectioned for testing in accordance with Fig. 12.2.11 and tested as detailed below:
(a) three macro specimens;
(b) impact tests from the weld, fusion line and fusion line + 2 (where the material thickness permits);
(c) one hardness survey.

In addition, butt weld tests are to be performed in accordance with 2.7, using the same welding conditions, in order to verify acceptable weld and heat affected zone properties.

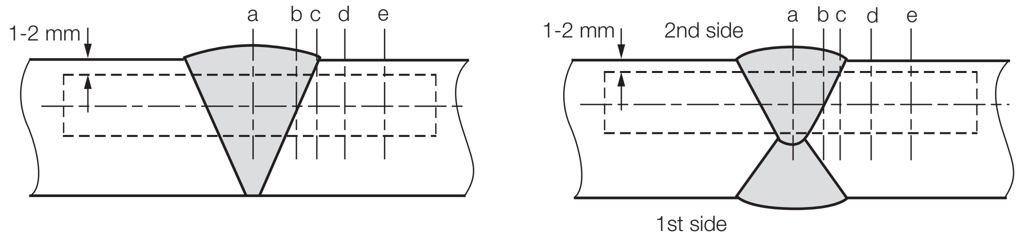
2.9.2 The impact tests are to be removed from the vertical (up) position ‘B’ in Fig. 12.2.11 and tested in accordance with 2.7.8.

2.9.3 A Vickers hardness survey is to be performed on the macro-section removed from position ‘A’ or ‘C’ in accordance with that shown in Fig. 12.2.12 using a test load not exceeding 10 kg.

2.10 Destructive tests for steel pipe branch welds

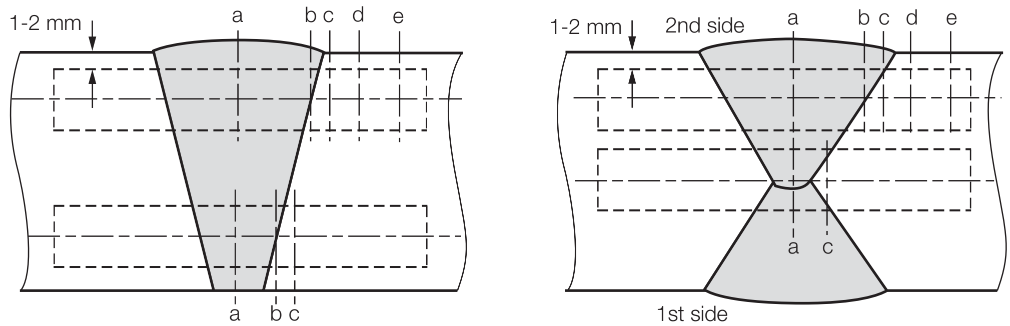
2.10.1 Pipe branch welds may be by either full penetration, partial penetration or fillet welded, depending on the application and the approved plans. Where these types of welded joints are used, tests are to be performed which simulate the construction conditions.

(a) $t \leq 50$ mm, *see* Note



NOTE
For one side welding with thickness over 20 mm notch location 'a', 'b' and 'c' are to be added on root side

(a) $t > 50$ mm



Notch locations:
a : centre of weld 'WM'
b : on fusion line 'FL'
c : in HAZ, 2 mm from fusion line
d : in HAZ, 5 mm from fusion line
e : in HAZ, 10 mm from fusion line in case of heat input > 200 kJ/cm

Fig. 12.2.7 Locations of V-notch for butt weld of high heat input (heat input > 50 kJ/cm)

2.10.2 The test weld assembly is to simulate the smallest angle between the branch and main pipe and is to be subjected to macro-examination and hardness testing, as follows:

(a) For a branch weld that is full penetration, testing is to be performed in accordance with the requirements for 'T', 'K' and 'Y' joints in 2.9.
(b) For a branch weld that is either a partial penetration or fillet weld, testing is to be in accordance with the requirements for fillet welds in 2.8.

2.11 Destructive tests for weld cladding of steel

2.11.1 Where weld cladding or overlay is allowed by Chapter 13, and is considered as providing strength to the component to which it is welded, the type and location of test specimens are to be in accordance with Fig. 12.2.13, except that micro-sections are not required. Impact tests may be omitted where the base material does not have specified impact properties. The longitudinal tensile and bend tests are to be tested in a similar manner to transverse specimens specified in 2.7.2 and 2.7.6, respectively.

2.11.2 Where the weld cladding is not considered as contributing to the strength of the component, but is required for corrosion or wear resistance, the type and location of test specimens are to be in accordance with Fig. 12.2.13, except that tensile and impact tests are not required.

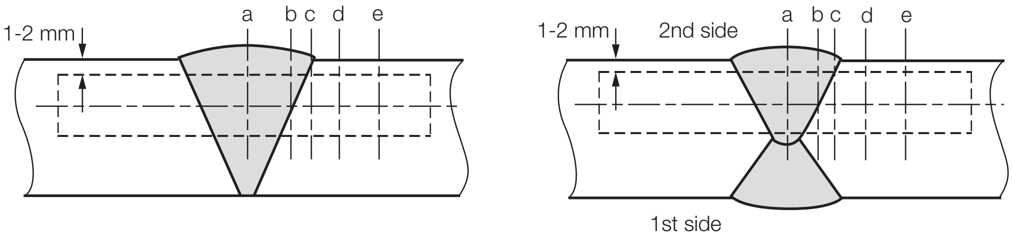
2.11.3 Where the weld cladding is applied for corrosion resistance, in addition to the above, weld metal analysis is to be performed on one of the micro-sections, on the final weld surface but 2 mm deep. The analysis is to be within the limits specified for the corrosion resistance required.

2.12 Mechanical test acceptance criteria for steels

2.12.1 **Longitudinal all weld metal tensile test**:

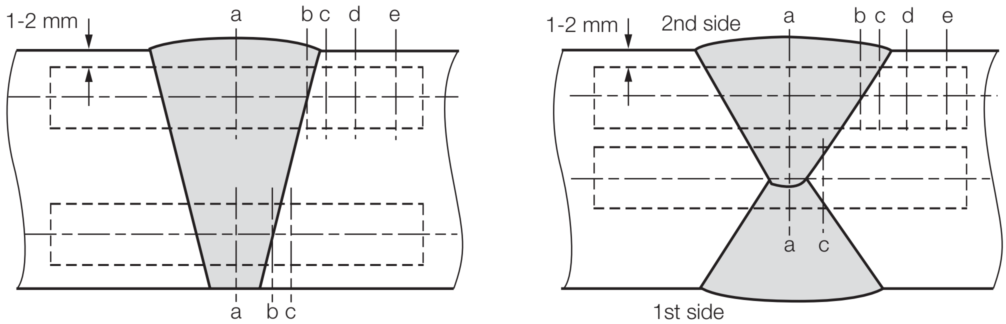
(a) In general, the longitudinal all weld tensile test is to meet the minimum properties specified in Tables 11.3.2 or 11.4.2 in Chapter 11, as appropriate to the grade of steel and welding process used in the test.
(b) Where the application is such that no consumable approvals are specified in Chapter 11, the longitudinal all weld tensile test tensile is to meet the minimum properties specified for the base materials used in the test.

(a) *t* ≤ 50 mm, *see* Note



NOTE
For one side welding with thickness over 20 mm notch locations ‘a’, ‘b’ and ‘c’ are to be added on root side

(a) *t* > 50 mm



Notch locations:
a : centre of weld ‘WM’
b : on fusion line ‘FL’
c : in HAZ 1 mm from fusion line
d : in HAZ 3 mm from fusion line
e : in HAZ 5 mm from fusion line
f : in base metal remote from weld (Type C independent tanks only)

Fig. 12.2.8 Locations of V-notch tests for butt welds intended for liquefied gas containment systems

(c) For pressure vessels manufactured from carbon or carbon/manganese steels, the tensile strength from the longitudinal all weld tensile test is not to be less than the minimum specified for the plate material and is not to be more than 145 N/mm^2 above this value, *see* Ch 13,4.8.3.

(d) For tanks intended for liquefied gases, the weld metal strength may be lower than the minimum specified for the base metal provided that the application has design approval. In such cases the strength is not to be less than that specified in the approved design.

2.12.2 **Transverse tensile test**: The tensile strength measured from the transverse tensile test is not to be less than the minimum specified for the base material used in the test. For tanks intended for liquefied gases, a lower ultimate tensile may be accepted subject to design approval as in 2.12.1(d).

2.12.3 **Bend tests**:

(a) In general, bend tests are to exhibit no defects exceeding 3,0 mm measured in any direction across the tension face of the specimen after being bent over the required diameter of former to the appropriate angle.

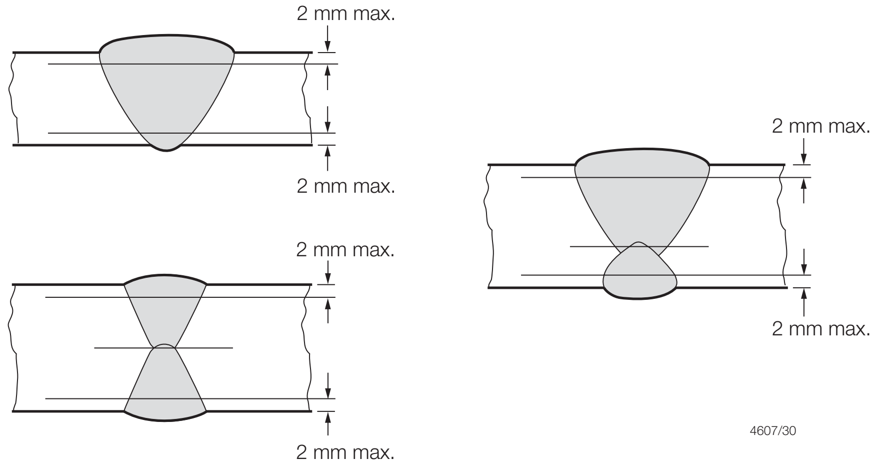
(b) Bend tests for pressure vessel applications are to exhibit no defects exceeding 3,0 mm measured along the specimen or 1,5 mm measured transverse to the specimen axis, after bending.

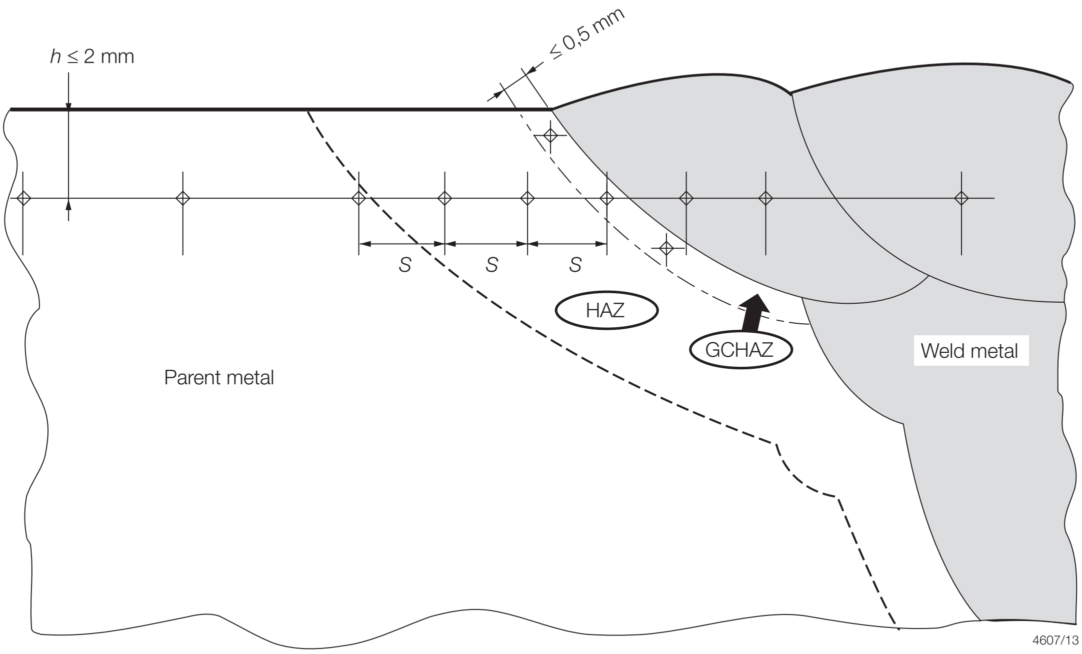
(c) In all cases, premature failure of the bend tests at the edges of the specimen is to not be cause for rejection unless these are associated with a weld defect.

2.12.4 **Impact toughness tests**:

(a) Impact test specimens for hull construction are to be tested at the temperature, and are to achieve the minimum impact energy, as specified in Tables 12.2.2 and 12.2.3.

(b) Impact test specimens for applications other than hull construction are to be tested at the same temperature and achieve the same minimum energy values, as specified for the base materials used in the test.





HAZ Heat affected zone
GCHAZ Grain coarsened heat affected zone
S Indentation spacing

Fig. 12.2.9 Hardness testing locations for butt welds

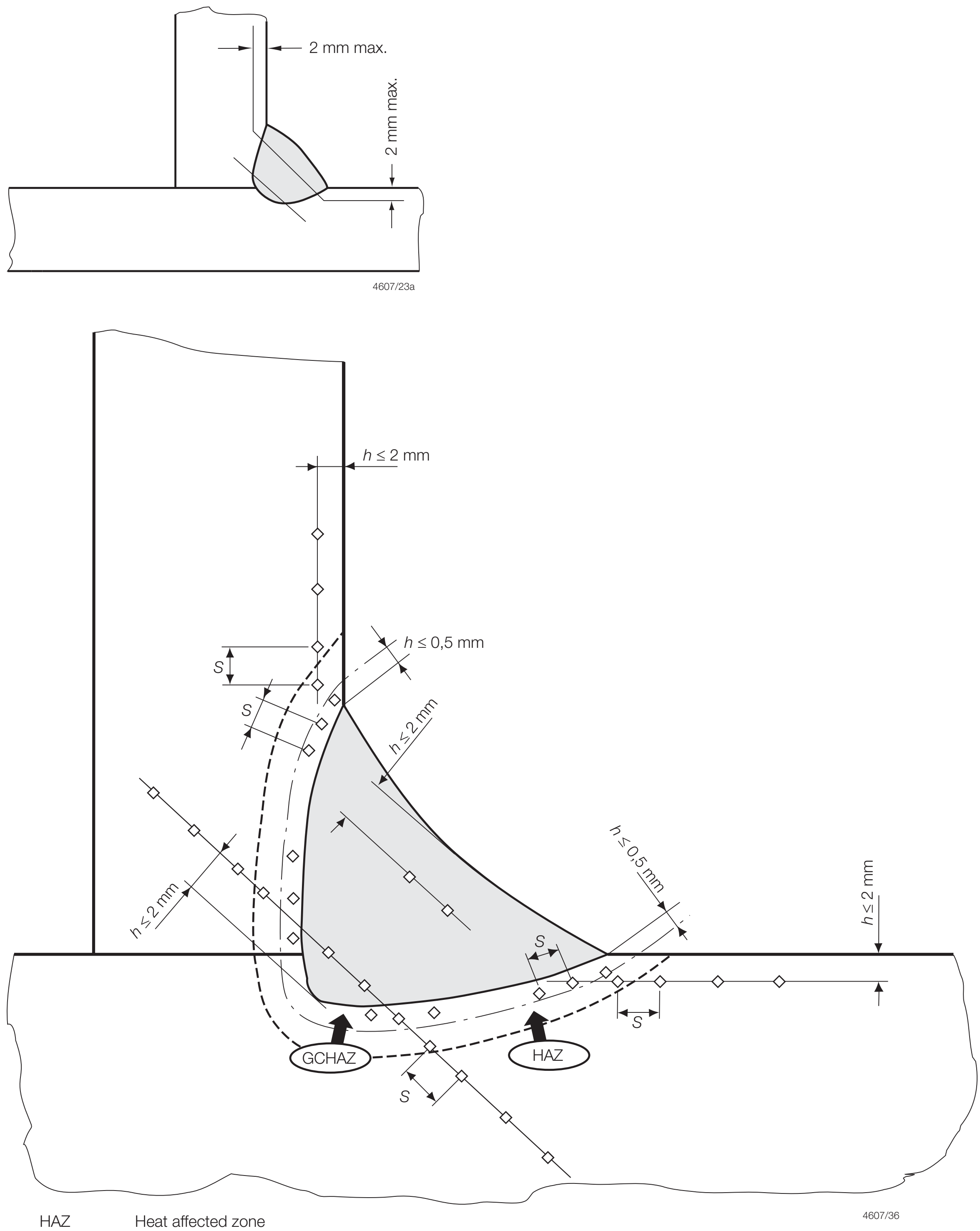
(c) Impact test acceptance criteria are to be in accordance with the above unless the Rules applicable to the particular construction specify more stringent requirements.

(d) For quench and tempered steels, the required test temperature and absorbed energy are to be in accordance with that specified for the parent materials.

2.12.5 **Macro-examination**: The macro-section is to reveal an even weld profile blending smoothly with the base material. The weld dimensions are to be in accordance with the requirements of the pWPS and any defects present are to be assessed against the non-destructive examination acceptance criteria given in 2.5.5.

2.12.6 **Hardness surveys**: The maximum hardness value reported, is not to exceed 350 Hv for steels with a specified minimum yield strength up to ≤420 N/mm^2, nor exceed 420 Hv for steels with a specified minimum yield strength in the range 420 N/mm^2 to 690 N/mm^2.

2.12.7 **Weld fracture or break tests (for pressure vessel test welds)**: The faces of the broken fillet weld fracture or weld break test are to be examined for defects and assessed in accordance with the non-destructive acceptance criteria given in ISO 5817 Level B, except for excess convexity and excess throat thickness where Level C will apply.



HAZ Heat affected zone
GCHAZ Grain coarsened heat affected zone
S Indentation spacing

Fig. 12.2.10 Hardness test locations for fillet welds

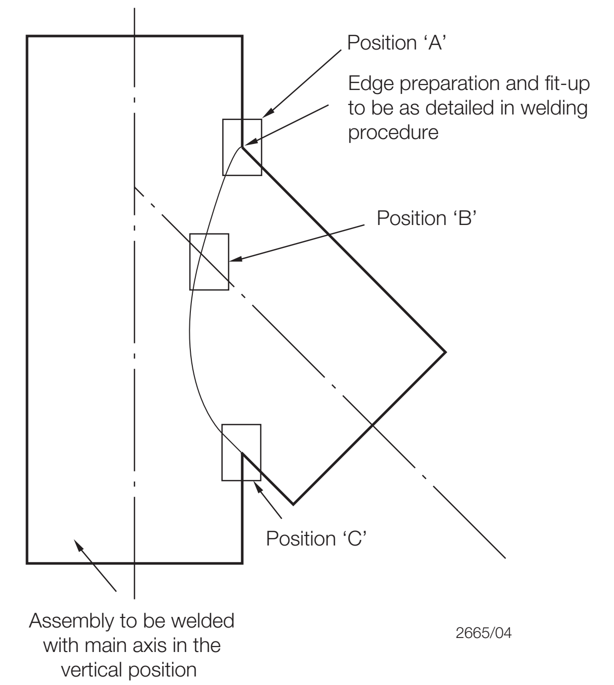


Fig. 12.2.11
Location of macro-examination test specimens for T, K and Y joints

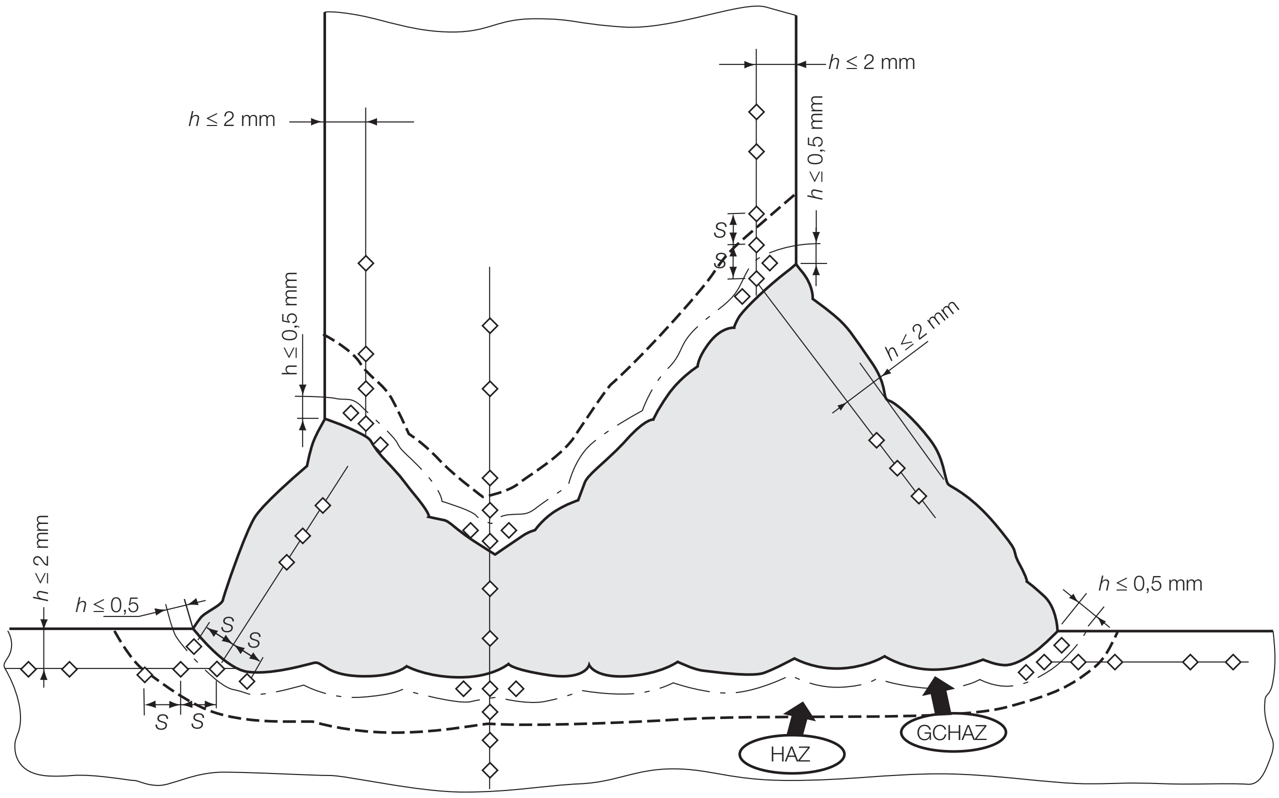
2.13 Failure to meet requirements (Retests)

2.13.1 Where a tensile, bend or hardness specimen fails to meet requirements, further test specimens may be removed and tested in accordance with the requirements of Ch 2,1.4.1.

2.13.2 Where an impact specimen fails to meet requirements, a further set of three specimens may be removed and tested in accordance with the requirements of Ch 2,1.4.4.

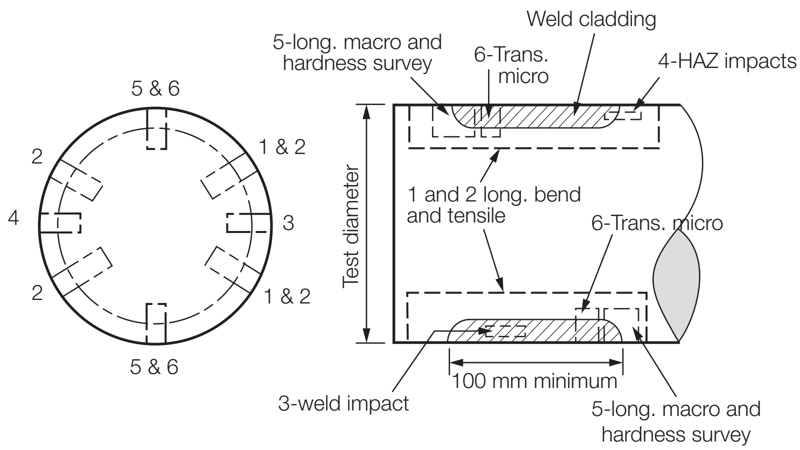
2.13.3 Where a macro specimen reveals a defect that is planar in nature, the welding procedure test is to be considered as not satisfying the requirements and a new test assembly is required.

2.13.4 Where a macro specimen does not meet requirements as a result of a volumetric imperfection exceeding the permitted size, two additional specimens may be removed from the same test weld and examined. If either of these macro-sections also fails to satisfy the requirements, the welding procedure is to be considered as not having met the requirements.



HAZ Heat affected zone
GCHAZ Grain coarsened heat affected zone
S Indentation spacing

Fig. 12.2.12 Hardness test locations for T, K and Y joints



Test specimens
1 Longitudinal tensile test to include the weld metal, heat affected zone (HAZ) and base metal.
2 Longitudinal side bend test to include the weld metal, heat affected zone (HAZ) and base metal.
3 Weld metal Charpy V notch impact test.
4 HAZ Charpy impact test from Fusion Line and Fusion Line + 2 mm.
5 Longitudinal macro-section and hardness survey.
6 Transverse micro-section.

NOTE
In the case of shafts and pipes of circular section, the longitudinal direction is parallel to the centreline of the shaft or pipe axis.

Fig. 12.2.13 Type and location of test specimens for weld cladding

Table 12.2.2 Impact test requirements for butt joints (*t* ≤ 50 mm) *see* Notes 1 and 2

Grade of steel	Test temperature (°C) *see* Note 4	Value of minimum energy absorbed (J), *see* Note 4		
		Manual or semi-automatic welded joints		Automatically welded joints
		Downhand, Horizontal, Overhead	Vertical upward, Vertical downward	
A, *see* Note 3 B, *see* Note 3, D E A32, A36 D32, D36 E32, E36 F32, F36	20 0 –20 20 0 –20 –40	47	34	34
A40 D40 E40 F40	20 0 –20 –40		39	39

NOTES
1. Steel with yield strength greater than 390 N/mm^2 is not permitted in thickness less than 50 mm, *see* Table 3.3.1 in Chapter 3.
2. These requirements are to apply to test piece of which butt weld is perpendicular to the rolling direction of the plates.
3. For grade A and B steels average absorbed energy on fusion line and in heat affected zone is to be a minimum of 27 J.
4. For Naval ships both the test temperature and value of minimum energy absorbed are to be those specified for the parent material.

2.13.5 If there is a single hardness value above the maximum values specified, additional hardness tests are to be carried out, either on the reverse of the specimen, or after sufficient grinding of the tested surface. None of the additional hardness values is to exceed the maximum hardness values specified, otherwise the welding procedure is to be considered as not having met the requirements.

2.13.6 Where there is insufficient material available in the welded test assembly to provide re-test specimens, subject to prior agreement with the Surveyor, a second assembly may be welded using the same conditions as the original test weld.

Table 12.2.3 Impact test requirements for butt joints (*t* > 50 mm) *see* Note 1

Grade of steel	Test temperature (ºC) *See* Note 2	Value of absorbed energy (J, min), *see* Note 2		
		Manual or semi-automatic welded joints		Automatically welded joints
		Downhand, Horizontal, Overhead	Vertical upward, Vertical downward	
A B D E	20 0 0 –20	34 34 47 47	34 34 38 38	34 34 38 38
AH32, AH36 DH32, DH36 EH32, EH36 FH32, FH36	20 0 –20 –40	47 47 47 47	41 41 41 41	41 41 41 41
AH40 DH40 EH40 FH40	20 0 –20 –40	50 50 50 50	46 46 46 46	46 46 46 46
EH47	–20	64	64	64

NOTES
1. These requirements are to apply to test piece of which butt weld is perpendicular to the rolling direction of the plates.
2. For the Naval ships both the test temperature and value of minimum absorbed energy are to be those specified for the parent material.

2.14 Test records

2.14.1 The procedure qualification record (PQR) is to be prepared by the manufacturer and is to include details of the welding conditions used in the test specified in 2.2 and the results of all the non-destructive examinations and destructive tests, including re-tests.

2.14.2 Provided that the PQR lists all the relevant variables and there are no inconsistent features and the results satisfy the requirements, the PQR may be endorsed by the Surveyor as satisfying the requirement of the Rules, *see also* 1.1.4.

2.15 Range of approval

2.15.1 A welding procedure qualification test that has successfully met the requirements may be used for a wider range of applications than those used during the test.

2.15.2 Changes outside of the ranges specified are to require a new welding procedure test.

2.15.3 Other ranges of approval from those specified in this Section may be agreed with the Surveyor, provided that they are in accordance with recognised National or International Standards.

2.15.4 **Manufacturer**. A welding procedure qualified by a manufacturer is valid for welding in workshops under the same technical and quality management.

2.15.5 **Welding process and technique**. The welding process and welding techniques approved are to be those employed during the welding procedure qualification test. Where multiple welding processes are used, these are to be employed in the same order as that used in the welding procedure qualification test. However, it may be acceptable to delete or add a welding process where it has been used solely to make the first weld run in the root of the joint, provided back gouging or grinding of the root weld is specified on the WPS. For multi-process procedures, the welding procedure approval may be carried out with separate welding procedure tests for each welding process.

2.15.6 **Welding positions**. Approval for a test made in any position is restricted to that position. To qualify a range of positions, test assemblies are to be welded for the highest heat input position, and the lowest heat input position, and all applicable tests are to be made on those assemblies. The above excludes welding in the vertical position with travel in the downward direction which will always require separate qualification testing and only be acceptable for that position.

2.15.7 **Joint types**. A qualification test performed on a butt weld may be considered acceptable for fillet and partial penetration welds, provided the same welding conditions are used. The range of approval depending on the type of joint for butt welds is given in Table 12.2.4.

Table 12.2.4 Range of approval for different types of butt joints

Type of welded joint for test assembly				Range of approval
Butt welding	One side	With backing Without backing	A B	A,C A,B,C,D
	Both sides	With gouging Without gouging	C D	C C,D

2.15.8 **Range of material types**:

(a) A qualification test performed on one strength level of steel may be used to weld all similar materials with the same or lower specified minimum yield stress with the exception of the two-run (T) or high welding heat input (A) techniques where acceptance is limited to the strength level used in the test. Similarly, a qualification test performed on a steel with one toughness level may be considered acceptable for welding all similar materials with the same or three toughness grades lower specified minimum toughness level.

(b) A qualification test performed on H47 strength grade steels may be used to weld the steel of the same strength level or grade H40 and all lower toughness grades to that tested.

(c) For high strength quenched and tempered steels, for each strength level, welding procedures are considered applicable to the same and lower toughness grades as that tested. For each toughness grade, welding procedures are considered applicable to the same and one lower strength level as that tested. The approval of quenched and tempered steels does not qualify thermo-mechanically rolled steels (TMCP steels) and vice versa.

(d) For weldable C and C-Mn steel forgings, welding procedures are applicable to the same and lower strength level as that tested. The approval of quenched and tempered steel forgings does not qualify other delivery conditions and vice versa.

(e) For weldable C and C-Mn steel castings, welding procedures are applicable to the same and lower strength level as that tested. The approval of quenched and tempered steel castings does not qualify other delivery conditions and vice versa.

Dissimilar materials. Where a qualification test has been performed using dissimilar materials, acceptance is to be limited to the materials used in the test.

2.15.9 **Thickness and diameter range**:

(a) For straight butt welds, the material thickness range to be approved is to be based on the thickness of the test piece and the type of weld as shown in Table 12.2.5.

(b) For butt welds between plates of unequal thickness, the lesser thickness is the ruling dimension.

(c) For fillet welds and 'T' butt welds, Table 12.2.5 is to be applicable to both the abutting and through member thicknesses. In addition to the requirements of Table 12.2.5, the range of approval of throat thickness '*a*' for fillet welds is to be as follows:

- single run: 0,75*a* to 1,5*a*
- multi-run: as for butt welds with multi-run (i.e. $a = t$)

Table 12.2.5 Welding procedure thickness approval range – Butt welds

Test thickness, *see* Note 1 (t in mm)	Range approved	
	All multi-run butt welds and all fillet welds *see* Notes 3 and 4	All single-run or two-run two-run (T technique) butt welds
$t \leq 3$	t to $2t$	$0{,}7t$ to $1{,}1t$
$3 < t \leq 12$	3 to $2t$	$0{,}7t$ to $1{,}1t$
$12 < t \leq 100$	$0{,}5t$ to $2t$, *see* Note 2	$0{,}7t$ to $1{,}1t$ *see* Note 5
$t > 100$	$0{,}5t$ to $1{,}5t$	$0{,}7t$ to $1{,}1t$ *see* Note 5

NOTES
1. Where the test plates have dissimilar thickness, the thickness, t, is to be based on the minimum thickness for butt welds and the maximum thickness for fillet welds.
2. Subject to a maximum limit of 150 mm.
3. For multi process procedures, the recorded thickness contribution of each process is to be used as a basis for the range of approval of the individual welding process.
4. For vertical down welding, the test piece thickness, t, is the upper limit of the range of application.
5. For processes with heat input over 5,0 kJ/mm, the upper limit of the range of approval is to be 1,0 t.

(d) Notwithstanding any of the above, the approval of maximum thickness of base metal for any technique is to be restricted to the thickness of the test assembly if three of the hardness values in the heat affected zone are found to be within 25 Hv of the maximum permitted.

(e) The material diameter range to be approved is to be based on the diameter of the test piece and type of weld as shown in Table 12.2.6.

Table 12.2.6 Diameter range approved

Diameter used for test, *see* Note 1	Range of diameters approved
$D \leq 25$ mm	$0{,}5D$ to $2D$
$D > 25$ mm	$> 0{,}5D$, *see* Note 2

NOTES
1. D is the outside diameter of the pipe or the smallest side dimension of rectangular hollow section.
2. Lower diameter range limited to 25 mm minimum.

2.15.10 **Welding consumables**:

(a) For manual and semi-automatic welding used for the fill and capping weld runs, it may be acceptable to change the brand or trade name of the welding electrode or wire from that used in the test, provided the proposed alternative has the same or higher approval grading and the same flux type (e.g. basic low hydrogen, rutile, etc.) as used in that test.

(b) For the consumable used to make the root weld of full penetration butt welds made from one side only, no change in the type or trade name of the consumable or backing material is permitted. Alternative backing materials may be used provided they are equivalent to those used for approval. Where the approved backing material is a low hydrogen grade and the steel being welded requires a low hydrogen backing material, testing of the alternative backing material is to confirm compliance with the requirements of Ch 11,7

(c) For processes with heat input over 5 kJ/mm, no change in the type or trade name of the consumable is permitted.

2.15.11 **Shielding gas**. For gas shielded welding processes, a change in shielding gas composition from that used in the test will require a new qualification test.

2.15.12 **Heat Input**. The upper limit of heat input approved is 25 per cent greater than that used in the test, or 5,5 kJ/mm, whichever is the smaller. With heat input over 5,0 KJ/mm, the upper limit is 10 per cent above that used in the test. In all cases, the lower limit of heat input approved is 25 per cent lower than that used in the test.

2.15.13 **Current type**. The current type used during the qualification test is to be the only type approved. Additionally, changes from or to pulsed current require new qualification tests.

2.15.14 **Preheat temperature**. The temperature used during the test is to be the minimum approved. Higher temperatures may be specified for production welds up to the maximum interpass temperature. Where hardness tests have been performed that exhibit results near the maximum permitted, an increase in preheat temperature is required when welding material of greater thickness than that used in the test.

2.15.15 **Interpass temperature**. The maximum interpass temperature recorded during qualification testing is to be the maximum approved. Lower temperatures may be specified for production welding, but no lower than the minimum preheat temperature.

2.15.16 **Post-weld heat treatment**. A qualification test performed with no post weld heat treatment is only acceptable for production welding where no heat treatment is applied. Where the qualification test has included a post weld heat treatment, this is to be applied to all welds made with the welding procedure. The average specified soak temperature may vary by up to 25°C from that tested.

2.15.17 **Shop primers.** Welding procedure qualification with shop primers qualifies welds without primer, but not vice versa.

2.16 Welding procedure specification (WPS)

2.16.1 A welding procedure specification (WPS) is to be prepared by the manufacturer detailing the welding conditions and techniques to be employed for production welding. The WPS is to be based on the conditions and variables used during the qualification test, and is to include all the ranges of the essential variables specified in 2.2.1 and 2.15.

2.16.2 The WPS should reference the procedure qualification record upon which it is based and is to be approved by the Surveyor prior to commencing production welding.

■ *Section 3* Specific requirements for stainless steels

3.1 Scope

3.1.1 The requirements of this Section relate to the group of steel materials classed as stainless steels and include austenitic and duplex grades and martensitic grades.

3.1.2 In all cases, welding procedure tests are to be performed generally in accordance with Section 2 with the specific requirements specified below.

3.2 Austenitic stainless steels

3.2.1 The requirements of this Section relate to the group of stainless steel materials that are austenitic at ambient and sub-zero temperatures, (e.g., 304L, 316L types), *see* Table 3.7.1 in Chapter 3.

3.2.2 Impact tests are to be performed from specimens removed from the weld metal. Tests in the heat affected zone are not required.

3.2.3 Hardness tests are generally not required.

3.2.4 For cryogenic or corrosion resistant applications, the ferrite content in the weld cap region is to be measured and is to be in the range 2 to 10 per cent, with the exception of grades S 31245 and N 08904 where the content is to be nominally zero.

3.2.5 A qualification test performed on an austenitic grade may be considered acceptable for welding other austenitic steels with the same or lower level of alloying elements and the same or lower tensile strength.

3.2.6 A qualification test performed for cryogenic applications may be considered acceptable for chemical applications, but not vice versa.

3.3 Duplex stainless steels

3.3.1 The requirements of this Section relate to the group of stainless steel materials that have a ferritic-austenitic structure and are usually referred to as duplex or super duplex stainless steels (e.g.,S 31803, S 32760).

3.3.2 Impact test specimens are to be removed from the weld and heat affected zone in accordance with Section 2 with the exception that impact test specimens notched at the FL + 10 mm location are not required. The specimens are to be tested at a temperature of –20°C or the minimum design temperature whichever is the lower and exhibit a minimum average energy of 40 J.

3.3.3 The corrosion resistance is to be maintained in the welded condition and the following tests are to be performed to demonstrate acceptable resistance, unless agreed otherwise.

(a) A sample is to be removed from the weld and heat affected zone for micro-structural examination and is to be suitably prepared and etched so that the micro-structures of the weld and heat affected zones can be examined at a magnification of x200 or higher. The micro-structure of the weld and heat affected zone is to be examined, the percentage grain boundary carbides and intermetallic precipitates is to be reported.

(b) The ferrite content in the un-reheated weld cap and cap HAZ along with the weld root and root HAZ are to be measured and reported. The ferrite content is to be in accordance with Table 12.3.1. Where the intended construction is such that the corrosion medium is only in contact with one surface of the weld (i.e., the weld root), the ferrite determination need only be reported in that surface area.

(c) Corrosion testing is to be performed on samples removed from the weld such that both the weld and HAZ are included in the test. The critical pitting temperature is to be determined in accordance with ASTM G48 Method C and meet the requirements specified in Table 12.3.1. The cap and root surfaces are to be inspected for evidence of pitting and may require probing the surface with a needle. Pitting found on the ends of the specimen in the weld cross-section may be ignored. The use of the weight loss method for corrosion testing may be accepted subject to special consideration.

Table 12.3.1 Requirements for ferrite content and corrosion tests for duplex stainless steel test welds

Duplex Stainless Steel Material Grade	Weld and HAZ Ferrite content	Minimum Critical Pitting Temperature (CPT)
S 31260	30 to 70%	20°C
S 31803	30 to 70%	20°C
S 32550	35 to 65%	25°C
S 32750	35 to 65%	25°C
S 32760	35 to 65%	25°C

3.3.4 Where the test weld is between a grade of carbon steel and duplex stainless steel, the test requirements of 3.3.3(a) and (c) are not required and the ferrite content of the weld and the duplex heat affected zone are to be reported for information.

3.3.5 A qualification test performed on a duplex stainless steel grade may be considered acceptable for welding other duplex grades which have the same or less stringent mechanical or corrosion properties.

3.3.6 The range of heat input is not to vary by more than +10 per cent or –25 per cent from that used during testing.

3.4 Martensitic stainless steels

3.4.1 The requirements of this Section relate to the group of stainless steel materials that have a martensitic structure at ambient temperatures, *see* Table 4.5.1 in Chapter 4.

3.4.2 The results of the hardness survey results are to be reported for information purposes only.

3.4.3 A qualification test is considered acceptable only for the grade of material used in the test.

■ *Section 4*
Welding procedure tests for non-ferrous alloys

4.1 Requirements for aluminium alloys

4.1.1 The requirements for welding procedure qualification tests for aluminium alloys are to be in accordance with the general requirements of Section 2 with the following exceptions and specific requirements.

4.1.2 Non-destructive examination is to be performed in accordance with 2.5 and the assessment of results is to be in accordance with Table 12.4.1 and Table 12.4.2.

4.1.3 Acceptance of the mechanical tests is to be in accordance with Ch 11,9. Welding of the strain hardened and heat treatable aluminium alloys will generally result in a loss of tensile strength in the heat affected zone below that specified for the base materials and the tensile strength acceptance criteria to be applied is that specified for the material in the annealed or ‘as fabricated’ condition. Minimum values of tensile strength measured on the transverse tensile samples are given in Table 12.4.3.

4.1.4 Impact tests and hardness surveys are not required for aluminium alloys.

Table 12.4.1 Acceptance criteria for surface imperfections of aluminium alloys

Surface discontinuity	Classification according to ISO 6520-1	Acceptance criteria
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete root penetration in butt joints welded from one side	4021	Not permitted
Surface pore	2017	$d \leq 0{,}1s$ or $0{,}1a$ max. 1,0 mm
Uniformly distributed porosity (*see* Note 1)	2012	≤ 0,5% of area
Clustered porosity	2013	Not permitted
Continuous undercut	5011	Not permitted
Intermittent undercut	5012	$h \leq 0{,}1t$ or 0,5 mm (whichever is the lesser)
Excess weld metal (*see* Note 2)	502	$h \leq$ 1,5 mm + $0{,}1b$ or 6 mm (whichever is the lesser)
Excess penetration	504	$h \leq$ 4 mm
Root concavity (*see* Note 2)	515	$h \leq 0{,}05t$ or 0,5 mm (whichever is the lesser)
Linear misalignment (*see* Notes 3 and 4)	507	$h \leq 0{,}2t$ or 2,0 mm (whichever is the lesser)

Symbols

a = nominal throat thickness of a fillet weld
b = width of weld reinforcement
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size)

NOTES
1. To be in accordance with EN ISO 10042.
2. A smooth transition is required.
3. The limits for linear misalignment relate to deviations from the correct position. Unless otherwise specified, the correct position is to be taken when the centrelines coincide.
4. Dimensional tolerances not specified in these Rules are to be mutually agreed between the manufacturer and the Surveyor.

4.1.5 Four side bend tests may be used in place of root and face bends where the test thickness exceeds 12 mm, and longitudinal bend tests may be used instead of transverse tests where the test weld is between different grades of alloy. Bend specimens are to be bent round a former in accordance with Table 11.9.1 in Chapter 11, with the exception that the 6000 series alloys may be bent round a former with $D/t = 7$.

4.1.6 The ranges of approval to be applied to the WPS are to be as specified for steel in 2.15 with the following exceptions:

(a) The welding positions approved are as detailed in Table 12.4.4.
(b) The aluminium alloys are grouped into three groups as follows:
- Group A: aluminium-magnesium alloys, with Mg content ≤3,5 per cent (alloy 5754).
- Group B: aluminium-magnesium alloys with 4 per cent ≤ Mg ≤5,6 per cent (alloys 5059, 5083, 5086, 5383 and 5456).
- Group C: aluminium-magnesium-silicon alloys (alloys 6005A, 6061 and 6082). For each group, the qualification made on one alloy qualifies the procedure also for the other alloys in the group, with equal or lower tensile strength after welding. The qualification made on group B alloys qualifies the procedure for Group A alloys also. Approval for the range of material grades is summarised in Table 12.4.5.

(c) The qualification of a procedure carried out on a test assembly of thickness t is valid for the thickness range given in Table 12.4.6. In the case of butt joints between dissimilar thicknesses, t is the thickness of the thinner material. In the case of fillet joints between dissimilar thicknesses, t is the thickness of the thicker material. In addition to the requirements of Table 12.4.6, the range of the qualification of throat thickness of fillet welds, a, is given in Table 12.4.7. Where a fillet weld is qualified by a butt weld test, the throat thickness range qualified is to be based on the thickness of the deposited weld metal.
(d) The range of shielding gas compositions approved is to be in accordance with Table 11.9.2 in Chapter 11.
(e) A change in the brand or trade name of the filler metal from that used in the test is acceptable, provided that the proposed consumable has the same or higher strength grading.
(f) A change in post-weld heat treatment or ageing is not permitted, except that for the heat treatable alloys, artificial ageing may give approval for prolonged natural ageing.

Table 12.4.2 Acceptance criteria for internal imperfections of aluminium alloys

Internal discontinuity	Classification according to ISO 6520-1	Acceptance criteria
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete penetration	402	Not permitted
Single gas pore	2011	$d \leq 0{,}2s$ or $0{,}2a$ or 4 mm (whichever is the lesser)
Linear porosity (*see* Note 2)	2014	Not permitted
Uniformly distributed porosity (*see* Note 2)	2012	$0{,}5t$ to $3t$ ≤ 1% of area $> 3t$ to $12t$ ≤ 2% of area $> 12t$ to $30t$ ≤ 3% of area $> 30t$ ≤ 4% of area
Clustered porosity (*see* Note 1)	2013	$dA \leq 15$ mm or wp (whichever is the lesser)
Elongated cavity Wormhole	2015 2016	$l \leq 0{,}2s$ or $0{,}2a$ or 3 mm (whichever is the lesser)
Oxide inclusion (*see* Note 2)	303	$l \leq 0{,}2s$ or $0{,}2a$ or 3 mm (whichever is the lesser)
Tungsten inclusion	3041	$l \leq 0{,}2s$ or $0{,}2a$ or 3 mm (whichever is the lesser)
Copper inclusion	3042	Not permitted
Multiple imperfections in any cross-section	—	The sum of the acceptable individual imperfections in any cross-section is not to exceed $0{,}2t$ or $0{,}2a$ (whichever is the lesser)

Symbols

a = nominal throat thickness of a fillet weld
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size), in mm
wp = width of weld or width or height of cross-sectional area
dA = diameter of area surrounding gas pores
l = length of imperfection in longitudinal direction of weld

NOTES
1. For this acceptance criterion, linear porosity is to be considered as three aligned gas pores in a length of 25 mm.
2. Porosity is to be determined in accordance with ISO 10042. The requirements for a single gas pore are to be met by all the gas pores within this circle. Systematic clustered porosity is not permitted.

Table 12.4.3 Tensile strength requirements by grade for aluminium alloys

Parent material Grade (alloy designation)	Minimum tensile strength (N/mm^2)
5754	190
5086	240
5083	275
5383	290
5059	330
5456	290
6005A	170
6061	170
6082	170

Table 12.4.4 Welding procedure approval, welding positions for aluminium alloys

Test position		Positions approved
Downhand	D	D
Horizontal-vertical	X	D, X
Vertical up	Vu	D, X, Vu
Overhead	O	D, X, Vu and O

NOTE
Welding in vertical down (Vd) position is not recommended.

Table 12.4.5 Welding procedure approval, aluminium material grades approved

Material used in qualification test	Material Grades approved				
5754	5754				
5086	5086	5754			
5083	5083	5086	5754		
5383	5383	5083	5086	5754	
5059	5059	5383	5083	5086	5754
5456	5456	5383	5083	5086	5754
6005A	6005A	6082	6061		
6082	6005A	6082	6061		
6061	6005A	6082	6061		

NOTE
Approval includes all the different strained and tempered conditions in each case.

Table 12.4.6 Range of qualification for parent material thickness

Thickness of test assembly, *t* (mm)	Range of qualification Multi pass welds	Range of qualification All single-run or two-run (T technique) butt welds
$t \leq 3$	0,5 to 2t	0,5t to 1,1t
$3 < t \leq 20$	3 to 2t	0,5t to 1,1t
$t > 20$	$\geq 0{,}8t$	0,5t to 1,1t

Table 12.4.7 Range of qualification of throat thickness for fillet welds

Throat thickness of test piece, *a* (mm)	Range of qualification
$a < 10$	0,75 a to 1,5 a
$a \geq 10$	$\geq 7{,}5$

4.2 Requirements for copper alloys

4.2.1 The requirements for welding procedure qualification tests for copper alloys are to be in accordance with the requirements for steel as given in Section 2 with the following exceptions and additions.

4.2.2 Impact tests on copper alloys are not required.

4.2.3 Hardness tests are not required for seawater service.

4.2.4 For the welding of cast copper alloys for propellers, the minimum tensile strength from the transverse tensile test is to be in accordance with Table 12.4.8.

4.2.5 Bend tests are to be performed over a diameter of former as detailed in Table 12.4.9.

Table 12.4.8 Minimum transverse tensile strengths for welded copper alloy propellers

Alloy designation	Minimum tensile strength (N/mm^2)
CU 1	370
CU 2	410
CU 3	500
CU 4	550

4.2.6 The range of approval to be applied to the WPS is to be as specified in 2.15 with the exception of the material grades which are detailed in Table 12.4.10.

Table 12.4.9 Former diameters for bend testing of copper alloy welds

Alloy designation (*see* Chapter 9)	Former diameter (D/t)
Cast propellers:	
CU1	4
CU2	4
CU3	6, *see* Note
CU4	6, *see* Note
Other short freezing range castings:	
Copper-Nickel 90/10	4
Copper-Nickel 70/30	4
Aluminium bronze	6
Wrought alloys (tubes and pipes):	
Copper-phosphorus	3
Aluminium-brass	3
90/10 Copper-nickel-iron	3
70/30 Copper-nickel-iron	3

NOTE
Where the qualification tests for these alloys are subjected to post-weld heat treatment the former diameter may be increased to D/t = 10.

Table 12.4.10 Range of approval for copper alloy material grades

Category	Alloy grade used in the qualification test	Alloy grades approved
Propellers	CU1 CU2 CU3 CU4	CU1 CU1 and CU2 CU1, CU2 and CU3 CU4 *see* Note 1
Tubes/pipes	90/10 Copper-Nickel-Iron 70/30 Copper-Nickel-Iron	90/10 Copper-Nickel-Iron 70/30 Copper-Nickel-Iron and 90/10 Copper-Nickel-Iron
Tubes/pipes *see* Note 2	Copper-Phosphorus deoxidised – arsenical Copper-Phosphorus deoxisised – non arsenical Aluminium-brass	Copper-Phosphorus deoxidised – arsenical Copper-Phosphorus deoxisised – non arsenical Aluminium-brass

NOTES
1. Where a CU3 type welding consumable has been used for the qualification test, the range of approval may also include welding of CU3.
2. These grades have limited weldability and approval to weld is subject to the materials satisfying the requirements of Table 9.3.1 in Chapter 9.

■ *Section 5* Welder qualification tests

5.1 Scope

5.1.1 The requirements of this Section relate to qualification of welders involved in welded construction associated with ships, or other marine structures, and products or components intended for use on or in these structures.

5.1.2 The requirements relate to fusion welding processes that are designated as manual, semi-automatic or partly mechanised. Special consideration will be given to other welding processes adapted from these requirements.

5.1.3 Prior to commencing production welding, the welder is to have performed a qualification test that satisfies these requirements. It is the responsibility of the manufacturer to ensure that the welder possesses the required level of skill for the work to be undertaken.

5.1.4 The qualification of welders is to be documented by the manufacturer and the records are to be available for review by the Surveyor.

5.1.5 Welder qualification tests made in accordance with EN, ISO, JIS, ASME or AWS may be considered for acceptance provided that, as a minimum, they are equivalent to, and meet the technical intent of these Rules to the satisfaction of the Surveyor.

5.2 Welder qualification test assemblies

5.2.1 The welding of the welder qualification test assembly is to simulate, as far as practicable, the conditions to be experienced in production and be witnessed by the Surveyor. The test is to be carried out on a test assembly piece and not by way of production welding.

5.2.2 The test is to simulate, as far as practicable, the welding techniques and practices to be encountered during production welding. The test assembly is to be designed to test the skill of the welder and have the shape and dimensions appropriate to the range of approval required.

5.2.3 The inspection length of the test weld is to be such as to permit the removal of all the necessary test specimens and for plate tests, but in no case is to be less than 250 mm. The test assembly is to be set in one of the positions as shown in Fig. 12.2.2 appropriate to the welding positions to be approved.

5.2.4 A welding procedure specification (WPS) is required for the execution of the qualification test and is to include the information specified in 2.2.1, as a minimum.

5.2.5 The test assembly is to be marked with a unique identification and the inspection length is to be identified prior to commencing welding. For pipe welds, the whole circumference is to be considered as the inspection length.

5.2.6 During welding of the test assembly, the welding time is to be similar to that expected under production conditions. For manual or semi-automatic processes, at least one stop and re-start in the root and in the top surface layer is to be included in the inspection length and marked for future inspection.

5.2.7 During welding of the test assembly, minor imperfections may be removed by the welder by any method that is used in production, except on the surface layer.

5.2.8 The Surveyor may stop the test if the welding conditions are not correct or if there is any doubt about the competence of the welder to achieve the required standard.

5.3 Examination and testing

5.3.1 Each completed test weld is to be examined and tested in accordance with the requirements of Table 12.5.1.

5.3.2 Visual examination is to be performed in the as welded state prior to any other assessment.

5.3.3 For plate butt welds, fracture testing may be used in place of radiography.

5.3.4 Where a backing strip has been used, it is to be retained for non-destructive examinations, but is to be removed prior to performing any bend or fracture tests.

5.3.5 Where fracture tests are required, they are to sample as much of the inspection length as practicable and the test assembly may be cut into several test specimens to achieve this. Testing is to be performed as shown in Figs. 12.5.1(a) or 12.5.1(b).

5.3.6 For butt weld tests in aluminium alloys both radiography and bend tests are required.

5.3.7 When bend tests are required, 2 root and 2 face bends are to be tested and where the test thickness exceeds 12 mm, these may be substituted by 4 side bends specimens. The diameter of former to be used is to be in accordance with that specified for welding procedure qualification testing given in 2.7.6(a).

5.3.8 Where macro examination is required, the specimen is to be polished and etched to reveal the weld runs and heat affected zones, and be examined at a magnification between x5 and x10.

Table 12.5.1 Welder qualification test requirements

Examination type	Butt welds	Fillet welds	Pipe branch welds
Visual	100%	100%	100%
Surface crack detection	*See* Note 1	100%	100%
Radiography	100% *See* Notes 2 and 6	Not required	Not required
Bend tests	4 required *See* Notes 3 and 6	Not required	Not required
Fracture tests	Not required	1 required *See* Note 4	Not required
Macro	Not required	1 required *See* Note 4	4 required *See* Note 5

NOTES
1. Surface crack detection examination may be required by the Surveyor in order to clarify the acceptability of any weld feature.
2. Radiography may be replaced by ultrasonic examination for carbon and low alloy steels where the thickness exceeds 8 mm.
3. Bend tests are required for gas metal arc welding with solid wire (GMAW) and oxy-acetylene welding.
4. The fracture test may be replaced with 4 macro sections equally spaced along the inspection length.
5. Macro-sections are to be separated by 90° measured around the abutting pipe member.
6. Radiography and bend tests are required for tests in aluminium alloys.

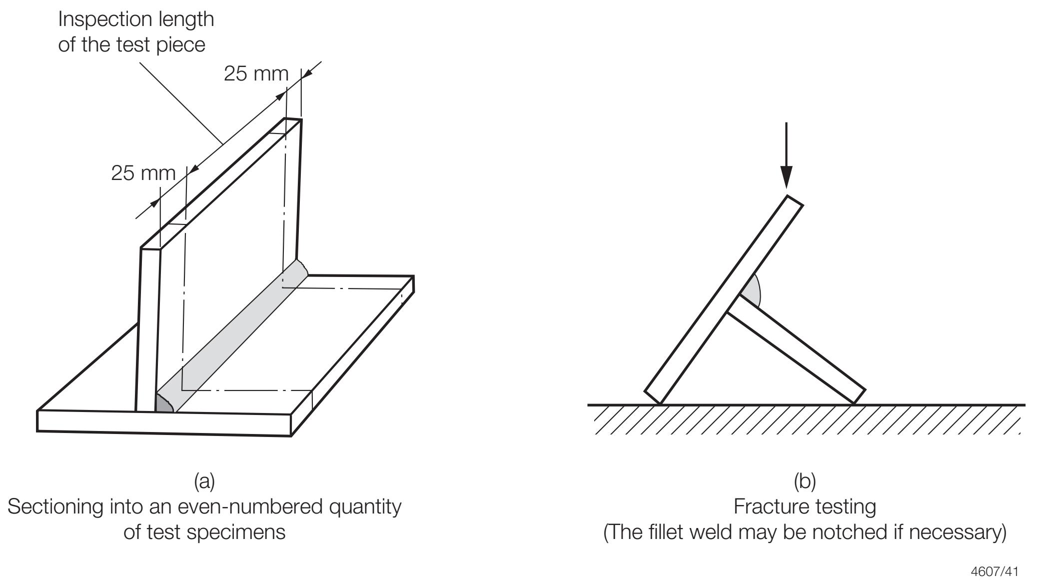


Fig. 12.5.1(a) Preparation and fracture testing of test specimens for a fillet weld in plate

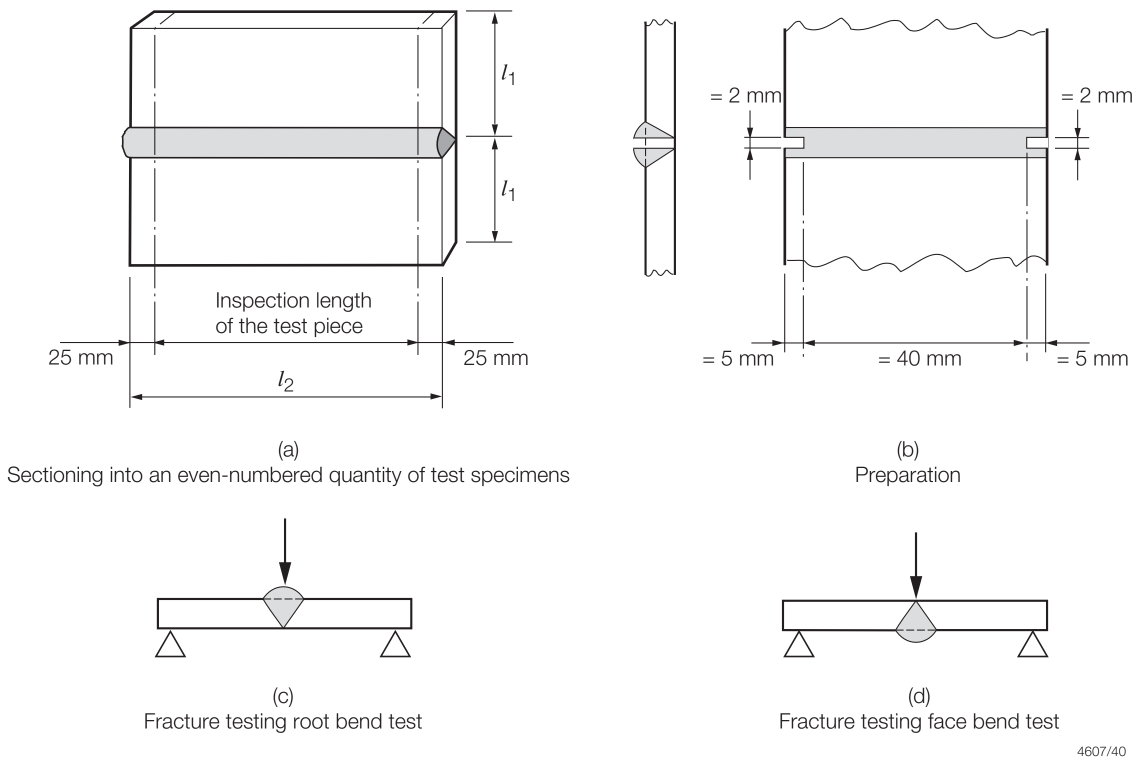


Fig. 12.5.1(b) Preparation and fracture testing of test specimens for a butt weld in plate

5.4 Acceptance criteria

5.4.1 The acceptance criteria are to be in accordance with 2.5.5.

5.4.2 Fracture tests and macro-sections are to be assessed in accordance with the non-destructive examination acceptance criteria.

5.4.3 Bend tests are considered acceptable if after bending through an angle of at least 180°, there are no defects on the tension side of the specimen greater than 3 mm in any direction.

5.5 Failure to meet requirements

5.5.1 Where a macro-section fails to meet requirements, one additional specimen may be removed from the test assembly and examined.

5.5.2 Where a bend or fracture test specimen fails to meet requirements, two additional specimens may be prepared from the same test assembly. If there is insufficient material, the welder may be permitted to weld an additional assembly to the same WPS, at the discretion of the Surveyor.

5.5.3 Where any of the additional test specimens fails to satisfy the requirements, the test will be considered as not meeting the requirements.

5.5.4 Where a test fails to comply with the acceptance criteria, the welder may be permitted to weld a second test piece. If this does not meet requirements, the welder is to be considered as not being capable of achieving the requirements.

5.6 Range of approval

5.6.1 Upon successful completion of all the necessary examinations and tests, the welder is to be considered qualified. The essential variables and the range of welding conditions for which the welder is considered approved are specified in the following paragraphs.

5.6.2 Welding variables such as preheat, interpass temperature, heat input and current type are not considered welder qualification variables. However, if the WPS used for testing specify these, they are to be included in the test and the welder is expected to follow the specific instructions.

5.6.3 Where the WPS used for the welder qualification test specifies post weld heat treatment, this need not be applied to the test weld unless bend tests are required and the material exhibits low ductility in the as welded condition.

5.6.4 The qualification test performed by a manufacturer is only applicable to workshops under the same technical control and quality system as that used for the test.

5.6.5 The welding process used in the qualification test is the process approved. However, it is possible for the welder to use more than one process in the test and the range of approval that may be applied to each will be within the limits of the essential variables appropriate to the part of the test where each welding process was used.

5.6.6 Material types are to be grouped as shown in Table 12.5.2 for welder qualifications. A qualification test performed on one material from a group will permit welding of all other materials within the same group. In addition, qualification on one group of materials may confer approval to weld other groups as shown in Table 12.5.3.

5.6.7 A qualification test performed on one thickness will confer approval to weld other thicknesses as specified in Table 12.5.4. Where welding is required between materials of different thickness, the reference thickness for approval purposes is to be the lesser thickness.

5.6.8 A qualification test performed on plate confers approval to weld on pipes having an outside diameter greater than 500 mm in a fixed position (*see* Table 12.5.5 and Table 12.5.6).

5.6.9 A qualification test performed using a specific diameter of pipe will give approval to weld other diameters as shown in Table 12.5.5. For branch welds, the diameter upon which approval is based is to be the branch member.

5.6.10 A qualification test performed on a butt weld may be considered as giving approval for fillet welds.

5.6.11 A butt qualification test welded from one side, with the root unsupported (i.e., no backing), will give approval for welds made from both sides with or without back gouging or grinding, but not vice versa.

5.6.12 A qualification test performed in one position will give approval to weld in other positions as shown in Table 12.5.6.

5.6.13 For manual metal arc welding with covered electrodes, a qualification test performed using an electrode with one type of coating will only be approved for welding with that type of coating. However, a qualification test performed using a basic low hydrogen type coating will confer approval to use electrodes with rutile coatings.

5.6.14 For gas shielded welding processes that use a single component shielding gas, no change to the gas composition is permitted from that tested. Where the test has used a two component shielding gas, a change in the ratio of component gases is permitted, provided that one of the components is not reduced to zero. Where the test has used a three component shielding gas, changes are permitted in the ratio of component gases and the gas with the smallest ratio may be reduced to zero, provided this does not change the shielding gas from an active one to an inert one or vice versa. In addition, where a change in shielding gas composition requires a different welding method or technique to be employed, a new qualification test will be required.

5.6.15 A change of welding flux from that used for the test is permitted.

Table 12.5.2 Welder qualification materials groupings

Material group	Material description	Typical LR Grades	Rules for Material references
WQ 01	Low carbon unalloyed, C/Mn, or Low alloyed steels (Re ≤ 360 N/mm^2)	A, B, D and E AH to FH32 and 36 Boiler 510FG and lower LT-AH to FH32 and 36 U1 and U2 Steel castings Steel pipes	Ch 3,2 Ch 3,3 Ch 3,4 Ch 3,6 Ch 3,9 and Ch 10 Ch 4,2, 3, 6 and 7 Ch 6,2, 3, 4 and 6
WQ 02	Cr-Mo, or Cr-Mo-V creep resisting steels	13CrMo45 and 11CrMo910 1Cr½Mo and 2¼Cr1Mo ½Cr½Mo¼V	Ch 3,4 Ch 4,6 and Ch 6,2, 3 and 6 Ch 4,6 and Ch 6,2
WQ 03	High strength fine grained, Normalised or quenched, or Tempered structural steels (2,0 – 5% Ni, with Re > 360 N/mm^2)	AH to FH40 to 69 LT-AH to LT-FH40 1½ , 3½ Ni steels and castings U3, R3, R3S and R4	Ch 3,3 and 10 Ch 3,6 Ch 3,6, Ch 4,7 and Ch 6,4 Ch 3,9 and Ch 10
WQ 04	Ferritic, or martensitic stainless steels (12 to 20% Cr)	13% Cr (martensitic)	Ch 4,5 (martensitic)
WQ 05	Ferritic low temperature steels	5Ni and 9Ni	Ch 3,6
WQ 011	Ferritic-austenitic stainless steels, Austenitic stainless steels, or Cr-Ni steels	304, 316, 317, 321 and 347 S31260, S31803, S32550 and S32750	Ch 3,7 and 8 Ch 4,8 and Ch 6,5
WQ 22a	Aluminium alloy – Non-heat treatable Mg < 3,5%	5754	Chapter 8
WQ 22b	Aluminium alloy – Non-heat treatable 3,5% < Mg < 5,6%	5083 and 5086	Chapter 8
WQ 23	Aluminium alloy – Heat treatable	6005-A, 6061 and 6082	Chapter 8
WQ 30	Copper alloys for propellers – Manganese bronze	Cu1	Ch 9,1
WQ 31	Copper alloys for propellers – Nickel-manganese bronze	Cu2	Ch 9,1
WQ 32	Copper alloys for propellers – Nickel-aluminium bronze	Cu3	Ch 9,1
WQ 33	Copper alloys for propellers – Manganese-aluminium bronze	Cu4	Ch 9,1
WQ 34	Copper alloys for tubes – Copper phosphorus	Deoxidised – non-arsenical and arsenical	Ch 9,3
WQ 35	Copper alloys for tubes – Aluminium brass	Aluminium brass	Ch 9,3
WQ 36	Copper alloys for tubes – Copper-nickel-iron	70/30 Cu/Ni and 90/10 Cu/Ni	Ch 9,3

5.7 Welders qualification certification

5.7.1 All the relevant conditions used during the test are to be entered on the welder's qualification certificate along with the permitted range of approval.

5.7.2 If the Surveyor is satisfied that the welder has demonstrated the appropriate level of skill and all tests are satisfactory, the Surveyor will endorse the certificate verifying that the details contained on it are correct and that the test welds were prepared, welded and tested in accordance with the specified Rules, Codes or Standards.

5.7.3 The welder is considered to be approved for an initial validity period of 2 years. The welder is considered to have retained the qualification subject to the manufacturer confirming every 6 months that the welder has used the welding process with acceptable performance in the preceding 6 months.

5.7.4 After 2 years, the Surveyor may extend the validity of the approval for another period of two years provided that records or documented evidence is made available confirming acceptable welding performance, within the original range of approval, without a break exceeding 6 months. The Surveyor will signify acceptance of the extension to the validity by endorsing the certificate.

Table 12.5.3 Welder qualification, range of approval for material groups

Material group used for testing	Material groups approved to weld			
WQ 01	WQ 01			
WQ 02	WQ 01	WQ 02		
WQ 03	WQ 01	WQ 02	WQ 03	
WQ 04	WQ 01	WQ 02	WQ 04	
WQ 05	WQ 05			
WQ 11	WQ 11	WQ 05, *see* Note	WQ 04, *see* Note	
WQ 22a	WQ 22a	WQ 22b		
WQ 22b	WQ 22a	WQ 22b		
WQ 23	WQ 22a	WQ 22b	WQ 23	
WQ 30	WQ 30	WQ 31	WQ 32	WQ 33
WQ 31	WQ 30	WQ 31	WQ 32	WQ 33
WQ 32	WQ 30	WQ 31	WQ 32	WQ 33
WQ 33	WQ 30	WQ 31	WQ 32	WQ 33
WQ 34	WQ 34	WQ 35		
WQ 35	WQ 34	WQ 35		
WQ 36	WQ 36			

NOTE
Provided an austenitic welding consumable compatible with material group WQ 11 is used.

Table 12.5.4 Welder qualification, range of approval for material thickness

Material type	Test piece thickness (mm)	Range approved, *see* Note (mm)
Steel and copper alloys	$t \leq 3$ $3 < t \leq 12$ $t > 12$	t to $2t$ 3,0 to $2t$ ≥ 5,0
Aluminium alloys	$t \leq 6$ $6 < t \leq 15$ $t > 40$ mm	0,7 to $2{,}5t$ $6{,}0 < t \leq 40{,}0$ 41 to $2t$

NOTE
For oxy-acetylene welding the maximum thickness is limited to 1,5 t.

Table 12.5.5 Welder qualification, diameter range of approval for pipes and hollow sections

Material type	Test piece diameter (mm)	Range approved (mm)
Steel and copper alloys	$D \leq 25$ $25 < D \leq 150$ $D > 150$ Plate, *see* Note 2	D to $2D$ $0{,}5D$ to $2D$, *see* Note 1 $\geq 0{,}5D$ ≥ 500
Aluminium alloys	$D \leq 125$ $D > 125$ Plate, *see* Note 2	$0{,}25D$ to $2D$ $\geq 0{,}5D$ ≥ 500

NOTES
1. Subject to 25 mm minimum diameter.
2. Plate qualification will approve welding on pipes greater than 150 mm diameter when the pipe is rotated.

Table 12.5.6 Welding position ranges for welder qualification

Test weld conditions		Positions qualified			
Type of weld	Test position	Plate		Pipe, *see* Note 1	
		Butt weld	Fillet weld	Butt weld	Fillet weld
Plate butt, *see* Note 5	D	D	D	D	D
	X	D,X	D, X	D	D, X
	Vu	D, Vu	D, X, Vu	D	D, Vu
	Vd	Vd	Vd	–	–
	O	D, X, Vu, O	D, X, Vu, O	D	D, X, Vu, O
Plate Fillet, *see* Note 5	D	–	D	–	D
	X	–	D, X	–	D, X
	Vu	–	D, X, Vu	–	D, X, Vu
	Vd	–	Vd	–	–
	O	–	D, X, Vu, O	–	D, X, Vu, O
Pipe butt	D	D	D, X	D	D, X
	X	D, X	D, X	D, X	D, X
	D+Vu+O, *see* Note 3	D, Vu, O	D, X, Vu, O	D, Vu, O	D, X, Vu, O
	D+Vd+O, *see* Notes 2 and 3	Vd	Vd	Vd	Vd
	Axis at 45°, *see* Note 4, Travel Vu	D, X, Vu, O	D, X, Vu, O	D, X, Vu, O	D, X, Vu, O
	Axis at 45°, *see* Notes 2, 3 and 4, Travel Vd	Vd	Vd	Vd	Vd
Pipe fillet	D	–	D	–	D
	X	–	D, X	–	D, X
	D+Vu+O *see* Note 3	–	D, X, Vu, O	–	D, X, Vu, O
	D+Vd+O *see* Note 3	–	Vd	–	Vd

NOTES
1. Pipe D position means pipe in horizontal position and rotated, *see* Fig. 12.2.2(b) and Fig. 12.2.2(d).
2. Vd position not usually recommended for pipe welds less than 500 mm diameter.
3. Pipe fixed with axis in the horizontal position (e.g. ASME 5G).
4. Pipe fixed with axis at 45° to the horizontal (e.g. ASME 6G).
5. Plate qualification tests confers approval to weld pipes with diameter greater than 500 mm.

5.7.5 Where there is any reason to question the welder's ability, or there is a lack of continuity in the use of the welding process, or insufficient recorded evidence of acceptable weld performance, the welder is to perform a new qualification test.

5.7.6 Where the manufacturer has existing welders that have previously performed qualification tests, these may be considered for acceptance provided they satisfy the above requirements and the tests have been performed in the presence of an independent examiner that is acceptable to the Society.

5.7.7 Not withstanding the above, the Surveyor may at any time request a review of a welder's qualification records. If there is any reason for doubt concerning the skill of the welder, the Surveyor may withdraw the qualification and require a re-qualification test to be performed.

Section 6
Qualification of friction stir welding of aluminium alloys

6.1 Scope

6.1.1 The requirements of this Section relate to the Friction Stir Welding (FSW) of aluminium alloys. These requirements include requirements for verification of welding equipment, welding procedures, qualification of welding procedures and qualification of welding operators.

6.2 Welding equipment

6.2.1 Welding equipment (e.g., welding machines and FSW tools) is to be capable of producing welds that meet the specified acceptance levels.

6.2.2 Welding equipment is to be maintained in a good condition and is to be repaired or adjusted when necessary.

6.2.3 After installation of new or refurbished equipment, appropriate tests are to be performed to verify that the equipment functions correctly.

6.3 Weld procedures

6.3.1 This Section defines the requirements for welding procedures to be applied for FSW of aluminium alloys.

6.3.2 Manufacturers are to prepare a preliminary welding procedure specification (pWPS) defining procedures for how FSW is to be conducted.

6.3.3 A pWPS is to comply with the requirements of ISO 25239-4.

6.3.4 Qualification of a pWPS is achieved by conducting weld procedure qualification tests in accordance with ISO 25239-4. Minimum acceptance criteria for destructive tests are to be in accordance with these Rules. Reporting of the qualification tests are to be in accordance with ISO 25239-4.

6.3.5 Provided that the procedure qualification record lists all the relevant variables and there are no inconsistent features and the results satisfy the requirements, the procedure qualification record may be endorsed by the Surveyor as satisfying the requirement of the Rules.

6.3.6 A welding procedure specification (WPS) is to be prepared after the procedure qualification test report has been endorsed by the Surveyor.

6.3.7 For welding procedure specifications, the range of approval is to be limited as follows:

(a) **Manufacturer**. A welding procedure qualified by a manufacturer is valid for welding in workshops under the same technical and quality management.

(b) **Range of material type**. Approval is restricted to the specific aluminium grade and supply condition used in the qualification test.

(c) **Thickness**. Approval is restricted to the thickness of the test piece in the qualification test.

(d) **Joint types**. The joint types approved are to be those from the welding procedure qualification test only.

(e) **Welding tool**. Approval is restricted to the specific design of welding tool employed during the qualification test.

(f) **Other**. A range of approval for any other variables will be subject to special consideration.

6.4 Qualification of welding operators

6.4.1 Welding operators are to be qualified in accordance with ISO 25239-3.

6.4.2 Welding operators are to be suitably trained and will be required to demonstrate a knowledge of FSW and have a working knowledge of the welding installation. Knowledge of the FSW process may be demonstrated by exams passed during the training period. Demonstration of a working knowledge of the welding installation will be subject to the Surveyor's satisfaction.

6.4.3 Qualification of welding operators is to be by welding tests as specified in ISO 25239-3 or by conducting weld procedure qualification tests.

6.4.4 Upon successful completion of all necessary examination and tests, the welding operator is to be considered qualified. The range of qualification is to be as specified in ISO 25239-3.

6.4.5 A certificate of qualification is to be issued in accordance with ISO 25239-3.

Section

■ *Section 1* General welding requirements

1.1 Scope

1.1.1 This Chapter specifies requirements for fabrication and welding during construction and repair of ships or other marine structures, and their associated pressure vessels, machinery, equipment, components and products intended for use in these structures.

1.1.2 The requirements for fabrication and welding during construction and repair of tanks intended for transport or storage of liquefied gases are located in the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk* or the *Rules and Regulations for the Classification of a Floating Offshore Installation at a Fixed Location*, as appropriate.

1.1.3 The requirements relate to fusion welding. Special consideration will be given to the use of other welding processes based on these requirements.

1.1.4 It is the responsibility of the manufacturer to ensure compliance with all aspects of these Rules and inform the Surveyor of any deviations that have occurred. All deviations are to be recorded as non-compliances along with the corrective actions taken and failure to do this is considered to render the fabrication to be in non-compliance with the Rules.

1.1.5 Welded constructions that comply with National or International specifications may be accepted to the satisfaction of the surveyor, provided that these specifications give reasonable equivalence to the requirements of this Chapter.

1.1.6 All welded construction is to be to the satisfaction of the Surveyor.

1.2 Design

1.2.1 Prior to commencing any work, the component to be manufactured is to be subjected to design review and approval in accordance with the Rule requirements.

1.2.2 The material characteristics that are affected by welding, particularly the loss of strength (e.g., in precipitation or strain hardened aluminium alloys) are to be considered in the design. The weld joints in such materials are to be arranged such that they are in areas of lower stress.

1.3 Materials

1.3.1 Materials used in welded construction are to be manufactured at works approved by LR. The use of materials from alternative sources will be subject to agreement of the Surveyor and satisfactory verification testing.

1.3.2 Materials are to be supplied and certified in accordance with the requirements of Chapters 1 to 10 of these Rules.

1.3.3 Materials used in welded construction are to be readily weldable and are to have proven weldability, unless requirements are agreed with LR in advance.

1.3.4 Where the construction details are such that materials are subject to through-thickness strains, consideration is to be given to using material with specified through-thickness properties as specified in Ch 3,8.

1.3.5 When ordering materials for construction, consideration is to be taken of the possible degradation of properties during fabrication or post-weld heat treatment. Where these materials are used, consideration is to be given to additional test requirements being specified to the supplier.

1.3.6 The identity of materials is to be established by way of markings etc, during fabrication, so that traceability to the original manufacturer's certificate is maintained.

1.3.7 Pre-fabrication shop primers may be applied prior to welding, provided that they are of an approved type and have been tested to demonstrate that they have no deleterious effects on the completed weld.

1.3.8 Where it is proposed to weld forgings and/or castings, full details of the joint details, welding procedures and post-weld heat treatments are to be submitted for consideration.

1.4 Requirements for manufacture and workmanship

1.4.1 The welding workshops are to be assessed by the Surveyor for their capability to produce work of the required quality in accordance with the requirements specified for the type of construction, *see* Sections 2 to 5.

1.4.2 Where structural components are to be assembled and welded in works sub-contracted by the builder, the Surveyor is to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter is achieved.

1.4.3 The manufacturer is to provide a system of regular supervision of all welding, by suitably qualified and experienced personnel.

1.4.4 Welding is to be performed in covered workshops as far as practicable. Where this is not possible, provision is to be made in the welding area to give adequate protection from wind, rain and cold, etc.

1.4.5 Where required, arrangements are to be such as to permit adequate ventilation and access for preheating, and for the satisfactory completion of all welding operations.

1.4.6 The location of welding connections and sequences of welding are to be arranged to minimise distortion and the build up of residual stresses. Welded joints are to be so arranged as to facilitate the use of downhand welding wherever possible.

1.4.7 In the case of repairs to existing structures or components, care is to be exercised when attaching fit-up aids by welding to ensure that the base materials in way of the attachments are of weldable quality.

1.4.8 In order to prevent cross-contamination of different material types, the welding of carbon steel materials is to be in areas segregated from that used for either austenitic or non-ferrous materials, *see* Section 7.

1.5 Cutting of materials

1.5.1 Materials may be cut to the required dimensions by thermal means, shearing or machining in accordance with the manufacturing drawings or specifications.

1.5.2 Cold shearing is not to be used on materials in excess of 25 mm thick. Where used, the cut edges that are to remain un-welded are to be cut back by machining or grinding for a minimum distance of 3 mm.

1.5.3 Material, which has been thermally cut, is to be free from excessive oxides, scale and notches.

1.5.4 All cut edges are to be examined to ensure freedom from material and/or cutting defects. Visual examination may be supplemented by other techniques.

1.5.5 Thermal cutting of alloy and high carbon steels may require the application of preheat, and special examination of these cut edges will be required to ensure no cracking. In these cases, the cut edge is to be machined or ground back a distance of at least 2 mm, unless it has been demonstrated that the cutting process has not damaged the material.

1.5.6 Any material damaged in the process of cutting is to be removed by machining, grinding or chipping back to sound metal. Weld repair may only be performed with the agreement of the Surveyor.

1.6 Forming and bending

1.6.1 Plates, pipes, etc., may be formed to the required shape by any process which does not impair the quality of the material.

1.6.2 Where hot forming is employed or during cold forming where the material is subjected to a permanent strain exceeding 10 per cent or formed to a diameter to thickness ratio less than 10, tests are required to be performed to demonstrate that the material properties remain acceptable.

1.6.3 As far as practicable, forming is to be performed by the application of steady continuous loading using a machine designed for that purpose. The use of hammering, in either the hot or cold condition is not to be employed.

1.6.4 Material may be welded prior to forming or bending, provided that it can be demonstrated that the weld mechanical properties are not impaired by the forming operation. All welds subjected to bending are to be inspected on completion to ensure freedom from surface breaking defects.

1.7 Assembly and preparation for welding

1.7.1 Excessive force is not to be used in fairing and closing the work. Where excessive root gaps exist between surfaces or edges to be joined, corrective measures are to be adopted.

1.7.2 Provision is to be made for retaining correct alignment during welding operations in accordance with the approved manufacturing specifications and welding procedures.

1.7.3 Tack welds are to be avoided as far as practicable. When used, tack welds are to be of the same quality as the finished welds, made in accordance with approved welding procedures, and where they are to be retained as part of the finished weld, they are to be clean and free from defects.

1.7.4 Generally, tack welds are not to be applied in lengths of less than 30 mm for mild steel grades and aluminium alloys, and 50 mm for higher tensile steel grades. Smaller tack welds may be accepted for steels, provided that the carbon equivalent of the materials being welded is not greater than 0,36 per cent.

1.7.5 Where deep penetration welding is used (*see* 2.4.6), welding procedure tests are to demonstrate that the specified degree of penetration is achieved in way of tack welds left in place.

1.7.6 Where temporary bridge pieces or strong-backs are used, they are to be of similar materials to the base materials and welded in accordance with approved welding procedures.

1.7.7 Any fit-up aids and tack welds, where welded to clad materials, are to be attached to the base material and not to the cladding.

1.7.8 Surfaces of all parts to be welded, are to be clean, dry and free from rust, grease, debris and other forms of contamination.

1.7.9 When misalignment of structural members either side of bulkheads, decks etc., exceeds the agreed tolerance, the misaligned item is to be released, realigned and re-welded in accordance with an approved procedure.

1.8 Welding equipment and welding consumables

1.8.1 Welding plant and equipment is to be suitable for the purpose intended and properly maintained, taking into account relevant safety precautions.

1.8.2 Suitable means of measuring the welding parameters (i.e. current, voltage and travel speed) are to be available. Electrical meters are to be properly maintained and have current calibrations.

1.8.3 Welding consumables are to be suitable for the type of joint and grade of material to be welded, and in general, are to be LR Approved in accordance with Chapter 11.

1.8.4 Special care is to be taken in the distribution, storage and handling of all welding consumables. They are to be kept in heated dry storage areas with a relatively uniform temperature in accordance with the consumable manufacturer's recommendations. Condensation on the metal surface (e.g., wire electrodes and studs) during storage and use is to be avoided.

1.8.5 Prior to use, welding consumables are to be dried and/or baked in accordance with the consumable manufacturer's recommendations.

1.8.6 Satisfactory storage and handling facilities for consumables are to be provided close to working areas and the condition of welding consumables are to be subject to regular inspections.

1.9 Welding procedure and welder qualifications

1.9.1 Welding procedures are to be developed by the manufacturer for all welding, include weld repairs, and are to be capable of achieving the mechanical property requirements and non-destructive examination quality appropriate to the work being undertaken.

1.9.2 Welding procedures are to be established for the welding of all joints and are to be qualified by testing in accordance with Chapter 12. The welding procedures are to give details of the welding process, type of consumable, joint preparation, welding position and filler metals to be used.

1.9.3 The proposed welding procedures are to be approved by the Surveyor prior to construction.

1.9.4 All welders and welding operators are to be qualified in accordance with the requirements of Chapter 12. Qualification records to demonstrate that welding personnel have the skills to achieve the required standard of workmanship are to be available to the Surveyor.

1.10 Welding during construction

1.10.1 Materials to be assembled for welding are to be retained in position by suitable means such that the root gaps and alignment are in accordance with the approved manufacturing specifications and welding procedures.

1.10.2 Surfaces of all parts to be welded, are to be clean, dry and reasonably free from rust, scale and grease.

1.10.3 Pre-heat is to be applied, as specified in the approved welding procedure, for a distance of at least 75 mm from the joint preparation edges. The method of application and temperature control are to be such as to maintain the required level throughout the welding operation.

1.10.4 When the ambient temperature is 0°C or less, or where moisture resides on the surfaces to be welded, due care is to be taken to pre-heat the joint to a minimum of 20°C, unless a higher pre-heat temperature is specified.

1.10.5 Where tack welds are to be removed from the root of the weld joint, this is to be carried out such that the surrounding material and joint preparation is not damaged.

1.10.6 The welding arc is to be struck on the parent metal which forms part of the weld joint or on previously deposited weld metal.

1.10.7 Where the welding process used is slag forming (e.g., manual metal arc, submerged arc, etc.) each run of deposit is to be cleaned and free from slag before the next run is applied.

1.10.8 Full penetration welds are to be made from both sides of the joint as far as practicable. Prior to welding the second side, the weld root is to be cleaned, in accordance with the requirements of the approved welding procedure, to ensure freedom from defects. When air-arc gouging is used, care is to be taken to ensure that the ensuing groove is slag and oxide free and has a profile suitable for welding.

1.10.9 Where welding from one side only, care is to be exercised to ensure the root gap is in accordance with the approved welding procedure and the root is properly fused.

1.10.10 Particular care is to be exercised in welding in the vertical position with direction of travel downward (Vd) to avoid welding defects. The use of solid wire gas metal arc (GMAW) process in the vertical down position is to be avoided.

1.10.11 Welding is to proceed systematically with each welded joint being completed in correct sequence without undue interruption.

1.10.12 After welding has been stopped for any reason, care is to be taken in restarting to ensure that the previously deposited weld metal is thoroughly cleaned of slag and debris, and preheat has been re-established.

1.10.13 Care is to be taken to avoid stress concentrations such as sharp corners or abrupt changes of section, and completed welds are to have an even contour, blending smoothly with the base materials. The weld shape and size is to be in accordance with that specified in the approved drawings or specifications.

1.10.14 Welded temporary attachments used to aid construction are to be removed carefully by grinding, cutting or chipping. The surface of the material is to be finished smooth by grinding followed by crack detection.

1.10.15 Where fabricated and welded components require to be machined, all major welding operations are to be completed prior to final machining.

1.10.16 Welding to parts which are subjected to rotating fatigue (e.g., shafts) is not generally permitted.

1.10.17 Welding onto parts that have been hardened for wear resistance or strength (e.g., gear teeth) is not permitted.

1.10.18 Where welding of clad ferritic steel plates is to be undertaken, the clad materials are to be ground back from the prepared edge by at least 10 mm. In general, the ferritic materials are to be welded prior to welding of the cladding material.

1.11 Non-destructive examination of welds

1.11.1 Non-destructive examinations are to be made in accordance with a definitive written procedure prepared and endorsed by a person qualified according to a Nationally Recognised Scheme with a grade equivalent to Level III qualification of ISO 9712, SNT-TC-1A, or ASNT Central Certification Program (ACCP). As a minimum, the procedure will identify personnel qualification levels, NDE datum and identification system, extent of testing, methods to be applied with technique sheets, acceptance criteria and reporting requirements. These procedures are to be reviewed by the Surveyor. *See* Ch 1,5.

1.11.2 Non-destructive examinations are to be undertaken by personnel qualified according to a Nationally Recognised Scheme with a grade equivalent to Level II qualification of ISO 9712, SNT-TC-1A or ASNT Central Certification Program (ACCP). Operators qualified to Level I of the above schemes (or equivalent recognised by LR) may be engaged in testing under the supervision of personnel qualified to Level II or III (or equivalent recognised by LR). Personnel qualifications are to be verified by certification.

1.11.3 Effective arrangements are to be provided by the manufacturer for the inspection of finished welds to ensure that all welding, and where necessary, all post-weld heat treatment, has been satisfactorily completed.

1.11.4 Welds are to be clean and free from paint at the time of visual inspection unless specified otherwise in the following Sections.

1.11.5 The weld surface finish is to ensure accurate and reliable detection of defects. Where the weld surface is irregular or has other features likely to interfere with the interpretation of non-destructive examination, the weld is to be ground or machined.

1.11.6 Prior to inspection, welded temporary attachments and lifting eyes used to aid construction are to be removed carefully by grinding, cutting or chipping or other approved means. The surface of the material is to be finished smooth by grinding followed by crack detection. Any defects caused in the removal process are to be repaired and re-inspected.

1.11.7 For welds in steels with specified yield strength up to 400 N/mm^2, and with carbon equivalent less than or equal to 0,41 per cent, NDE may be performed as soon as the test assembly has cooled to ambient temperature. For other steels, NDE is to be delayed for a period of at least 48 hours after the test assembly has cooled to ambient temperature.

1.11.8 Non-destructive examinations are to be performed in accordance with the requirements of the Rules. Examinations are to be in accordance with agreed written procedures prepared by the manufacturer or ship builder.

1.11.9 The Surveyor may request additional inspections where there is reason to question the quality of workmanship, or where the weld is part of a complicated fabrication where there is high restraint or high residual stresses.

1.11.10 Welds are to be examined after completion of any post-weld heat treatment.

1.11.11 Where weld defects are discovered, the full extent is to be ascertained by applying additional non-destructive examinations where required. Unacceptable defects are to be completely removed and, where necessary, weld repaired in accordance with the relevant Sections of this Chapter. The repairs are to be re-inspected using the same technique as the original inspection.

1.11.12 Results of non-destructive examinations are to be recorded and evaluated by the constructor on a continual basis in order that the quality of welding can be monitored. These records are to be available to the Surveyor.

1.11.13 The constructor is to be responsible for the review, interpretation, evaluation and acceptance of the results of NDE. Reports stating compliance or otherwise with the criteria established in the inspection procedure are to be issued. Reports are to comply, as a minimum, with the requirements of Ch 1,5.

1.11.14 The extent of applied non-destructive examination is to be increased when warranted by the analysis of previous results.

1.12 Routine weld tests

1.12.1 Routine or production weld tests may be specified as a means of monitoring the quality of the welded joints. This type of quality control test is generally specified for pressure vessel and LNG construction but may be used for other types of welded fabrication.

1.12.2 Routine weld tests may be requested by the Surveyor where there is reason to doubt the quality of workmanship.

1.12.3 Where routine test welds have been agreed, they are to be performed in accordance with the general requirements for the type of construction, *see* Sections 3 and 4.

1.13 Rectification of material defects

1.13.1 Repair of defects found in base materials is not to be carried out without the prior approval of the Surveyor.

1.13.2 In general, surface defects in the material may be removed by grinding, chipping, etc., provided the remaining material thickness is not reduced below the minimum thickness tolerance, and the area is ground to blend in smoothly with the surrounding material.

1.13.3 Confirmation that the defect has been removed is required by performing visual examination, augmented by either magnetic particle or dye penetrant examination techniques.

1.13.4 Surface defects, which cannot be repaired by the above method, may be repaired by welding where permitted by Chapters 3 to 9. Such repairs are to be performed in accordance with the requirements of this Section and those specified in Chapters 3 to 9.

1.13.5 Any defects in the structure resulting from the removal of temporary attachments are to be prepared, efficiently welded and ground smooth so as to achieve a defect free repair.

1.14 Rectification of distortion

1.14.1 Fairing, by linear or spot heating, to correct distortions due to welding, may be carried out. In order to ensure that the properties of the material are not adversely affected, approved procedures are to be utilised. On completion of such processes, visual examination of all heat affected areas in the vicinity is to be carried out to ensure freedom from cracking.

1.14.2 When misalignment of members exceeds the agreed tolerance, the misaligned item is to be cut apart, realigned and re-welded in accordance with an approved procedure.

1.15 Rectification of welds defects

1.15.1 Where repairs are extensive the manufacturer is to investigate the reason for the defects and take the necessary actions to prevent recurrence. In addition, consideration is to be given to the sequence of repairs and to providing temporary supports to prevent misalignment or collapse.

1.15.2 Cracks are to be reported to the Surveyor and the cause established prior to undertaking weld repairs.

1.15.3 Defects may be removed by grinding, chipping or thermal gouging. Where thermal gouging is used, the repair groove is to be subsequently ground clean to remove oxides and debris. The groove is to have a profile suitable for welding.

1.15.4 Prior to commencing repair welding, it is to be confirmed that no defect exists on the prepared surface by performing visual examination, augmented by either magnetic particle or dye penetrant examination techniques.

1.15.5 Repair welding is to be performed using approved welding procedures.

1.15.6 Completed repairs are to be re-examined by the non-destructive examination method(s) that detected the original defect and are to confirm that the original defect has been removed.

1.15.7 Where the component or structure has been subjected to post-weld heat treatment prior to weld repair, this is to be repeated after completion of all repair welding.

1.15.8 Where non-destructive examination reveals that the original defect has not been successfully removed, one more repair attempt may be performed.

1.15.9 The manufacturer is to monitor the quality of welding and maintain records of welding repairs and take the necessary corrective actions where repair rates are outside normal limits.

1.16 Post-weld heat treatment

1.16.1 On completion of welding, post-weld heat treatment may be required depending on the type of welded construction, the material type and thickness as specified by the relevant Parts or Sections of the Rules.

1.16.2 In general, heat treatment after welding is to be a stress relief treatment in order to reduce residual stresses introduced by welding and is generally applicable to ferritic steels. Where other types of heat treatment (e.g., normalising, solution annealing) are proposed, demonstration of acceptable mechanical properties of the weldment are to be confirmed by a welding procedure test which includes a simulated heat treatment.

1.16.3 Parts are to be properly prepared for heat treatment. Machined surfaces (e.g., flange faces, screw threads, etc.) are to be protected against scaling and sufficient temporary supports provided to prevent distortion or collapse of the structure.

1.16.4 Details of the heat treatment to be applied, soaking time and temperature, heating and cooling rates, etc., are to be submitted for review prior to commencing.

1.16.5 Post-weld heat treatment is to be carried out in a purpose built furnace which is efficiently maintained. In special cases, where the configuration of the component is such that thermal stresses during heating and cooling can be minimised, local post-weld heat treatment may be used. This would not normally apply to the complex geometry of cast materials during manufacture within the foundry environment.

1.16.6 In all cases, the heat treatment facilities and arrangements are to be capable of controlling the temperature throughout the heat treatment cycle and adequate means of measuring and recording the component temperature are to be provided. Thermocouples are to be attached so they are in contact with the component.

1.16.7 Unless specified otherwise, stress relief heat treatment is to be carried out by means of controlled heating from 300°C, to the soak temperature, holding within the prescribed soaking temperature range for the time specified (usually 1 hour per 25 mm of weld thickness) followed by controlled cooling to below 300°C.

1.16.8 Where post-weld stress relief is specified for welded constructions that contain joints between different materials (e.g. ferritic to austenitic steels), the details of the materials, welding procedures and heat treatment cycle to be applied are to be submitted for special consideration and approval.

1.16.9 Non-destructive examination of welds is to be performed after completion of any heat treatment.

1.17 Certification

1.17.1 Products or components are not to be considered complete until all the requirements of the construction specification have been met and all activities have been completed.

1.17.2 Upon completion of the works, the manufacturer is to provide documentation which indicates that:

(a) All welds are complete and there are no outstanding repairs.
(b) The appropriate post-weld heat treatments have been performed.
(c) Appropriate destructive tests have been performed.
(d) Proof testing of welds has been performed.

1.17.3 Before the test certificates or shipping statements are signed by the Surveyor, the manufacturer is required to provide a written declaration stating that the product is in accordance with the requirements of 1.17.2.

■ *Section 2* Specific requirements for ship hull structure and machinery

2.1 Scope

2.1.1 The requirements of this Section apply to the construction of ships, including hull structure, superstructure and deckhouses, components forming part of the ship structure and its machinery (excluding pressure equipment and piping, *see* Section 4). These requirements are in addition to the general welding requirements specified in Section 1.

2.1.2 The shipyard and manufacturer's works are to be assessed to give assurance that they have the facilities, equipment, personnel and quality control procedures to produce work of the required quality.

2.2 Welding consumables

2.2.1 Welding consumables used for hull construction are to be approved in accordance with Chapter 11 and are to be suitable for the type of joint and grade of material to be welded.

2.2.2 Steel welding consumable approvals, up to and including Grade Y40 and Y47, are considered acceptable for hull construction in line with Table 11.1.1 in Chapter 11, Ch 12,2.2.2 and the following:

(a) Consumables up to Grade Y are acceptable for welding steels up to 3 strength levels below that for which the approval applies, e.g., a consumable with approval grading 3Y is acceptable for welding EH36, EH32 and EH27S higher tensile ship steels and grade E normal strength ship steel.
(b) Consumables for Grade Y40 are acceptable for welding steels up to two strength levels below that for which the approval applies. Consumables for Grade Y47 are acceptable for welding steels up to one strength level below that for which the approval applies.
(c) Consumables with an approved impact toughness grading are acceptable for welding steels with lower specified impact properties subject to (a) above, e.g. a consumable with approval grading 3Y is acceptable for welding EH, DH and AH materials.
(d) For welding steels of different grades or different strength levels, the welding consumables may be of a type suitable for the lesser grade or strength being connected. The use of a higher grade of welding consumable may be required at discontinuities or other points of stress concentration.

2.2.3 In general, the use of preheating and hydrogen controlled welding consumables for welding of ship steels up to strength grade H40 is to be in accordance with Table 13.2.1. The carbon equivalent is to be calculated from the ladle analysis using the formula given below:

$$\text{Carbon equivalent} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{NI + Cu}{15}$$

Preheat and the use of low hydrogen controlled consumables will be required for welding of steel grades higher than Grade H40.

Table 13.2.1 Preheat and consumable requirements for welding of carbon and carbon manganese steels up to strength grade H40

Carbon equivalent C_{eq}	Pre-heat	Hydrogen controlled consumables
C_{eq} equal to or less than 0,41%	Not required	Not required, *see* Note 3
C_{eq} above 0,41 but not exceeding 0,45%	Not required, *see* Notes 1 and 2	Required
C_{eq} greater than 0,45%	Required	Required

NOTES
1. Preheat may need to be applied in order to meet the maximum hardness values specified in Ch 12,2.12.6.
2. Under conditions of high restraint or low ambient temperature preheat may need to be applied.
3. Hydrogen controlled consumables may need to be considered for welding of
   (a) Thicker materials (i.e., > 35 mm).
   (b) Higher strength materials.
   (c) Welds subject to high restraint.

2.2.4 All aluminium alloy welding consumables are to be approved in accordance with Chapter 11 and are suitable for welding the grades of material as shown in Table 13.2.2.

Table 13.2.2 Welding of aluminium alloys – Consumable requirements

Consumable approval grade	Base material alloy grade
RA or WA	5754
RB or WB	5086, 5754
RC or WC	5083, 5086, 5754
RD or WD	6005A, 6061, 6082

2.2.5 All austenitic stainless steel and duplex stainless steel welding consumables are to be approved in accordance with the Chapter 11 and are suitable for welding the grades of material as shown in Table 13.2.3.

2.3 Welding procedure and welder qualifications

2.3.1 Welding procedures and welder qualifications are to be tested and approved in accordance with the requirements of Chapter 12.

2.4 Construction and workmanship

2.4.1 Weld preparations and openings may be formed by thermal cutting, machining or chipping. Chipped surfaces that will not be subsequently covered by weld metal are to be ground smooth.

Table 13.2.3 Welding of austenitic stainless and duplex stainless steels – Consumable requirements

Consumable approval grade	Suitable for welding material alloy grades
Austenitic stainless steels	
321	321
347	347 and 321
Austenitic stainless steel – Low carbon	
304L (*see* Note 3)	304L
304LN (*see* Note 3)	304LN and 304L
316L	316L and 304L
316LN	316LN, 316L, 304LN and 304L
317L	317L, 316LN, 316L, 304LN and 304L
317LN	317LN, 317L, 316LN, 316L, 304LN and 304L
Super austenitic stainless steels, *see* Note 2	
S31254	S31254 and N08904
N08904	N08904
Duplex stainless steels, *see* Note 1	
S31260	S31260 and S31803
S31803	S31803
S32550	S32550
S32750	S32750 and S32550
S32760	S32760, S32550, S31260 and S31803
Stainless steels welded to carbon steels	
SS/CMn	Carbon steel to all steels in Sections 1, 2 and 3
Duplex/CMn	Carbon steel to all duplex stainless steel in Section 4

NOTES
1. The use of a different welding consumable grade from that of the base material may require demonstration of acceptable corrosion properties.
2. May be used for welding low carbon austenitic grades provided measures are taken to prevent solidification cracking from occurring.
3. These are LR Grades and do not correspond to any National or International Standards/Grades.

2.4.2 Prior to welding, the alignment of plates and stiffeners forming part of the hull structure is to be in accordance with the tolerances specified in the relevant part of the Rules.

2.4.3 When welding from one side only, care is to be exercised to ensure the root gap and fit up are in accordance with the approved welding procedure and the root is properly fused.

2.4.4 Where it is proposed to use permanent backing strips, the intended locations and welding procedures are to be submitted for consideration.

2.4.5 Temporary backing strips may be used provided they are in accordance with approved welding procedures and are subsequently removed on completion of welding.

2.4.6 The outer surfaces of completed welds are to blend smoothly with the base materials and provide a smooth transition and gradual change of section.

2.4.7 Weld joints in parts of oil engine structures that are stressed by the main gas or inertia loads are to be designed as continuous full penetration welds. They are to be arranged so that welds do not intersect, and that welding can be effected without difficulty.

2.4.8 When modifications or repairs have been made which result in openings having to be closed by welded inserts, particular care is to be given to the fit of the insert and the welding sequence. The welding is also to be subject to non-destructive examination.

2.4.9 Where welding of aluminium alloy is employed, the following additional requirements are to be complied with so far as they are applicable:

(a) Welding is to be performed by fusion welding using inert gas or tungsten inert gas process or by the friction stir welding process. Where it is proposed to use other welding processes, details are to be submitted for approval.

(b) The weld joint surfaces should be scratch brushed, preferably immediately before welding, in order to remove oxide or adhering films of dirt, filings, etc.

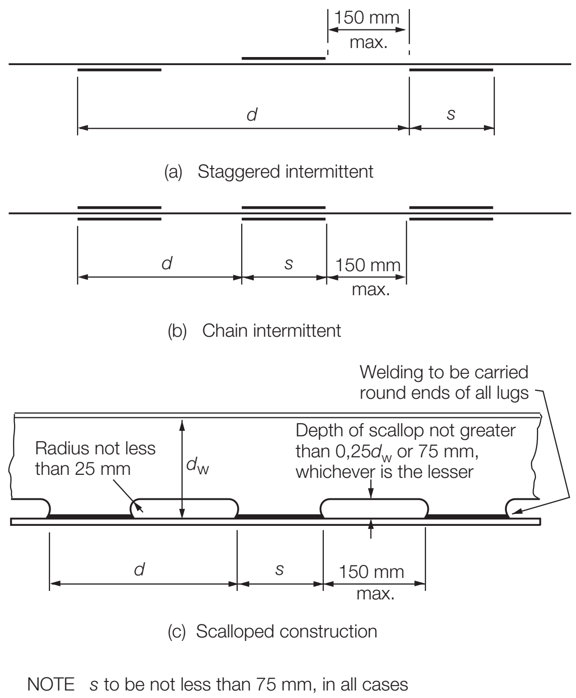


Fig. 13.2.1 Weld types

2.5 Butt welds

2.5.1 Where the ship hull is constructed of plates of different thicknesses, the thicker plates are to be chamfered in accordance with the approved plans. In all cases the chamfer is not to exceed a slope of 1 in 3 so that the plates are of equal thickness at the weld seam. Alternatively, if so desired, the width of the weld may be included as part of the smooth taper to the thicker plate provided the difference in thickness is not greater than 3 mm.

2.5.2 Where stiffening members are attached by continuous fillet welds and cross completely finished butt or seam welds, these are to be made flush in way of the fillet weld. Similarly for butt welds in webs of stiffening members, the butt weld is to be complete and generally made flush with the stiffening member before the fillet weld is made. Where these conditions cannot be complied with, a scallop is to be arranged in the web of the stiffening member, *see* Fig. 13.2.1. Scallops are to be of such a size and in such a position that a satisfactory weld can be made.

2.6 Lap connections

2.6.1 Overlaps are generally not to be used to connect plates which may be subjected to high tensile or compressive loading and alternative arrangements are to be considered. However, where plate overlaps are adopted, the width of the overlap is not to exceed four times, nor be less than three times the thickness of the thinner plate and the joints are to be positioned to allow adequate access for completion of sound welds. The faying surfaces of lap joints are to be in close contact and both edges of the overlap are to have continuous fillet welds.

2.7 Closing plates

2.7.1 For the connection of plating to internal webs, where access for welding is not practicable, the closing plating is to be attached by continuous full penetration welds or by slot fillet welds to face plates fitted to the webs. Slots are to have a minimum length of 90 mm and a minimum width of twice the plating thickness, with well rounded ends. Slots cut in plating are to be smooth and clean and are to be spaced not more than 230 mm apart, centre to centre. Slots are not to be filled with welding.

2.7.2 For the attachment of rudder shell plating to the internal stiffening of the rudder, slots are to have a minimum length of 75 mm and, in general, a minimum width of twice the side plating thickness. The ends of the slots are to be rounded and the space between them is not to exceed 150 mm.

2.8 Stud welding

2.8.1 Where permanent or temporary studs are to be attached by welding to main structural parts in areas subject to high stress, the proposed location of the studs and the welding procedures adopted are to be approved.

2.9 Fillet welds

2.9.1 T-connections are generally to be made by fillet welds on both sides of the abutting plate, the dimensions and spacing of which are shown in Fig. 13.2.1. Where the connection is highly stressed, deep penetration or full penetration welding may be required. Where full penetration welding is required, the abutting plate may be required to be bevelled.

2.9.2 Where an approved deep penetration procedure is used, the fillet leg length calculated may be reduced by 15 per cent provided that the manufacturer is able to meet the following requirements:

(a) Use of a welding consumable approved for deep penetration welding in accordance with Chapter 11 for either the ‘p’ or ‘T’ techniques.
(b) Demonstrations by way of production weld testing that the minimum required penetration depths (i.e., throat thicknesses) are maintained. This is to be documented on a monthly basis by the manufacturer and be available to the Surveyor.

2.9.3 The calculated fillet leg length may be reduced by 20 per cent, provided that in addition to the requirements of 2.9.2(a) and (b), the manufacturer is able to consistently meet the following additional requirements:

(a) The documentation required in 2.9.2(b) is to be completed and made available to the Surveyor upon request on a weekly basis.
(b) Suitable process selection confirmed by satisfactory welding procedure tests covering both minimum and maximum root gaps.

2.9.4 Where intermittent welding is used, the welding is to be made continuous in way of brackets, lugs and scallops and at orthogonal connections with other members.

2.10 Post-weld heat treatment

2.10.1 Post-weld stress relief heat treatment is applied to improve the fatigue performance or to improve resistance to brittle fracture and is generally required for carbon and carbon-manganese and low alloy steels under any of the following conditions:

(a) Where the material thickness exceeds 65 mm.
(b) For complicated weld joints where there are high stress concentrations.
(c) Where fatigue loads are considered high.

2.10.2 Post-weld heat treatment is to be applied to the following types of welded construction:

(a) Welding of steel castings where the thickness of the casting at the weld exceeds 30 mm, except where castings are directly welded to the hull structure.
(b) Oil engine bedplates except engine types where the bedplate as a whole is not subjected to direct loading from the cylinder pressure. For these types, only the transverse girder assemblies need to be stress relieved.
(c) Welding of gear wheels.
(d) Welding of gear cases associated with main or auxiliary engines, *see* Part 5 of the Rules for Ships.

2.10.3 Where required, heat treatment is to be performed in accordance with the requirements specified in 4.6 for pressure vessel construction.

2.10.4 Special consideration may be given to omit the required post-weld heat treatment. Evaluation is to be based on critical engineering assessment involving fracture mechanics testing and proposals are to be submitted which include full details of the application, materials, welding procedures, inspection procedures, design stresses, fatigue loads and cycles. Evidence will be required to demonstrate that the inspection techniques and procedures to be employed are able to detect flaws down to the sizes determined from the fracture mechanics (and or fatigue) calculations. Alternative procedures for omission of post-weld heat treatment will be subject to special consideration.

2.11 Tolerances

2.11.1 Tolerances after welding are to be in accordance with the relevant Part of the Rules.

2.11.2 Distortion which has resulted from welding may be corrected by spot heating in accordance with 1.14.

2.12 Non-destructive examination of welds

2.12.1 All finished welds are to be sound and free from cracks and substantially free from lack of fusion, incomplete penetration, porosity and slag. The surfaces of welds are to be reasonably smooth and substantially free from undercut and overlap. Care is to be taken to ensure that the specified dimensions of welds have been achieved and that both excessive reinforcement and under-fill of welds is avoided.

2.12.2 Welds forming part of the hull and superstructure may be coated with a thin layer of protective primer prior to inspection provided it does not interfere with inspection and is removed, if required by the Surveyor, for closer interpretation of possible defective areas.

2.12.3 All welds are to be visually inspected by personnel designated by the builder. Visual inspection of all welds may be supplemented by other non-destructive examination techniques in cases of unclear interpretation, as considered necessary. The acceptance criteria for visual testing are given in Table 13.2.4.

2.12.4 In addition to visual inspection, welded joints are to be examined using any one or a combination of ultrasonic, radiographic, magnetic particle, eddy current, dye penetrant or other acceptable methods appropriate to the configuration of the weld.

Table 13.2.4 Acceptance criteria for visual testing, magnetic particle and liquid penetrant testing

Surface discontinuity	Classification according to ISO 6520-1	Acceptance criteria for visual testing
Crack	100	Not accepted
Lack of fusion	401	Not accepted
Incomplete root penetration in butt joints welded from one side	4021	Not accepted
Surface pore	2017	Single pore diameter $d \leq 0{,}25t$, for butt welds, with maximum diameter 3 mm, *see* Note 1 $d \leq 0{,}25a$, for fillet welds, with maximum diameter 3 mm, *see* Note 1 2,5d as minimum distance to adjacent pore
Undercut in butt welds	501	Depth ≤ 0,5 mm, whatever the length Depth ≤ 0,8 mm, with a maximum continuous length of 90 mm, *see* Note 2
Undercut in fillet welds	501	Depth ≤ 0,8 mm, whatever the length

NOTES
1. t is the plate thickness of the thinnest plate, and a is the throat of the fillet weld.
2. Adjacent undercuts separated by a distance shorter than the shortest undercut are to be regarded as a single continuous undercut.

2.12.5 The method to be used for the volumetric examinations of welds is the responsibility of the builder. Radiography is generally preferred for the examination of butt welds of 8 mm thickness or less. Ultrasonic testing is acceptable for welds of 8 mm thickness or greater and is to be used for the examination of full penetration tee butt or cruciform welds or joints of similar configuration. Advanced ultrasonic techniques, such as Phased Array Ultrasonic Testing (PAUT), may be used as a volumetric testing method in lieu of radiography or manual ultrasonic testing. If these methods are used, the thickness limitations for manual ultrasonic testing apply.

2.12.6 The acceptance criteria for radiographic testing are given in Table 13.2.5, and those for ultrasonic testing in Table 13.2.6.

2.12.7 Checkpoints examined at the pre-assembly stage are to include ultrasonic testing on examples of the stop/start points of automatic welding and magnetic particle inspection of weld ends.

2.12.8 Checkpoints examined at the assembly stage are generally to be selected from those welds intended to be examined as part of the agreed quality control programme to be applied by the builder. The locations and number of checkpoints are to be approved by the Surveyor.

2.12.9 Where components of the structure are subcontracted for fabrication, the same inspection regime is to be applied as if the item had been constructed within the main contractor's works. In these cases, particular attention is to be given to highly loaded fabrications (such as stabiliser fin boxes) forming an integral part of the hull envelope.

2.12.10 Particular attention is to be paid to highly stressed items. Magnetic particle inspection is to be used at ends of fillet welds, T-joints, joints or crossings in main structural members and at stern frame connections.

2.12.11 Special attention is to be given to the examination of plating in way of lifting eye plate positions to ensure freedom from cracks. This examination is not restricted to the positions where eye plates have been removed, but includes the positions where lifting eye plates are permanent fixtures.

2.12.12 Checkpoints for volumetric examination are to be selected so that a representative sample of welding is examined.

2.12.13 Typical locations for volumetric examination and number of checkpoints to be taken are given in the relevant Sections of the Rules. A list of the proposed items to be examined is to be submitted for approval.

2.12.14 For the hull structure of refrigerated spaces, and of ships designed to operate in low air temperatures, the extent of non-destructive examination will be specially considered. For non-destructive examination of gas ships *see* the *Rules for the carriage for Liquefied Gases*.

2.12.15 For all ship types, the builder is to carry out random non-destructive examination at the request of the Surveyor.

2.12.16 Results of non-destructive examinations made during construction are to be recorded and evaluated by the builder on a continual basis in order that the quality of welding can be monitored. These records are to be available to the Surveyor.

2.12.17 The extent of applied non-destructive examinations is to be increased when warranted by the analysis of previous results.

Table 13.2.5 Acceptance criteria for radiographic testing

Discontinuity	Classification according to ISO 6520-1	Acceptance criteria for radiographic testing, *see* Note 1
Crack	100	Not accepted
Lack of fusion	401	Continuous maximum length t/2 or 25 mm, whichever is the less, *see* Note 2 Intermittent cumulative length maximum t or 50 mm, whichever is less, *see* Note 3
Lack of root fusion	4013	Not accepted in butt joints welded from one side
Incomplete root penetration	4021	Not accepted in butt joints welded from one side
		Continuous maximum length t/2 or 25 mm, whichever is lesser, *see* Note 2 Intermittent cumulative maximum length t or 50 mm, whichever is less, *see* Note 3
Slag inclusion	301	Continuous maximum length t or 50 mm, whichever is less, *see* Note 2 Intermittent cumulative length maximum 2t or 100 mm, whichever is less, *see* Notes 3 and 4
Gas pore	2011	Maximum dimension for a single pore: $d \leq 0{,}2t$, max. 4,0 mm *see* Note 5
Uniformly distributed porosity	2012	Maximum dimension of the area of imperfections: For single run welds: ≤ 1,5% For multi-run welds: ≤ 3% *See* Notes 6 and 7
Clustered (localised) porosity	2013	Maximum dimension of the summation of the projected area of the imperfection: ≤ 8% *See* Notes 6 and 7
Elongated cavity	2015	$h \leq 0{,}3t$, max. 3,0 mm $l \leq t$, max. 50 mm *See* Notes 8 and 9
Wormholes	2016	$h \leq 0{,}3t$, max. 3,0 mm $l \leq t$, max. 50 mm *See* Notes 8 and 9
Metallic inclusions other than copper	304	$h \leq 0{,}3t$, max. 3,0 mm *See* Note 8
Copper inclusions	3042	Not permitted

NOTES
1. t is the thickness of the thinnest plate.
2. Two adjacent individual discontinuities of length l_d1 and l_d2 situated on a line and where the distance l_d between them is shorter than the shortest discontinuity are to be regarded as a continuous discontinuity of length $l_d1 + l_d + l_d2$.
3. Sum of the length of individual continuous discontinuities.
4. Parallel inclusions not separated by more than 3 times the width of the largest inclusion are to be regarded as one continuous discontinuity.
5. d is the diameter of the gas pore.
6. The limits for the maximum single gas pore within this group still apply.
7. Further reference to porosity limits may be obtained in ISO 5817:2007.
8. h is the width of the imperfection.
9. l is the length of the imperfection.

2.13 Weld repairs

2.13.1 The full extent of any weld defect is to be ascertained by applying additional non-destructive examination where required. Unacceptable defects are to be completely removed and, where necessary, re-welded and re-examined in accordance with the requirements of 1.15.

2.13.2 During the assembly of large components, root gaps in excess of those specified in the approved welding procedure may be rectified by welding.

Table 13.2.6 Acceptance criteria for ultrasonic testing

Echo height	Acceptance criteria for ultrasonic testing, *see* Note
Greater than 100% of DAC curve	Maximum length *t*/2 or 25 mm, whichever is less
Greater than 50% of DAC curve, but less than 100% of DAC curve	Maximum length *t* or 50 mm, whichever is less
Indications evaluated to be cracks are unacceptable regardless of echo height; Indications evaluated to be lack of penetration or lack of root fusion in joints welded from one side are unacceptable regardless of echo height.	
NOTE Two adjacent individual discontinuities of length L1 and L2 situated on a line and where the distance L between them is shorter than the shortest discontinuity are to be regarded as a continuous discontinuity of length L1 + L + L2.	

2.13.3 Rectification of wide root gaps in butt welds, up to a maximum gap of 16 mm, may be performed provided that the length of these areas is small in relation to the whole weld length. Repairs may be executed by applying weld buttering layers to one edge of the weld joint, followed by machining or grinding to return the root opening to the required dimensions. The weld buttering and filling of the joint are to be in accordance with welding procedures qualified in accordance with Chapter 12.

2.13.4 For sub-assemblies, rectification of wide root gaps may be performed using a backing strip, provided that it is removed on completion of the welding.

2.13.5 Rectification of wide root gaps in fillet welds may be carried out as follows:

(a) where the root gap, *g*, is in excess of 3 mm, but not greater than 5 mm, the fillet leg length, *z*, may be increased by g – 2,0 mm;

(b) where the root gap is in excess of 5 mm, the joint detail may be changed into a full penetration weld.

2.13.6 Where repair welds are made using small weld beads, suitable precautions (including preheat) are to be taken to avoid high hardness and possible cold cracking.

2.14 Welding afloat with water backing

2.14.1 Welding afloat with water backing is not recommended due to the additional precautions required during survey and therefore, is generally not permitted. However consideration may be given to welding afloat with water backing after specific LR approval has been obtained by the yard or fabricator prior to such welding being carried out. Such approval will only be given once all of the following conditions are satisfied:

(a) The welding procedure qualification tests are carried out on steel plates with water backing and the water is maintained at the flow rate and minimum water temperature anticipated during fabrication.

(b) The carbon equivalent of the steel plates used in the welding procedure qualification tests are to be greater than 0,41 per cent based on the IIW formula. Where it can be shown that all hull steel plates and new sections will have a carbon equivalent value below this figure, steel plates with the maximum carbon equivalent value may be used for the welding procedure qualification tests.

(c) Welding procedure qualification tests are carried out without preheat.

(d) The thickness of steel plate used in the welding procedure qualification test is the minimum hull plate thickness to be used during fabrication.

(e) The maximum measured hardness on the completed welding procedure qualification assembly is less than or equal to 350 HV10. Following fabrication welding, 10 per cent of welds are to be hardness tested in way of heat-affected zones at weld starts to confirm compliance with the 350 HV10 limit.

(f) The heat input used in the welding qualification test is the minimum permitted heat input during fabrication.

(g) Only low hydrogen welding consumables (H5) are used.

(h) In addition to normal non-destructive testing for welds, 10 per cent of the welds are additionally subject to magnetic particle inspection 48 hours after welding is complete.

(j) The welding procedure qualification tests for the repair of welds carried out afloat with water backing are to be carried out on test pieces that have previously been welded afloat and also meet the requirements above.

2.14.2 For new construction, conversion or permanent repairs, wet underwater welding is not permitted.

■ *Section 3* Specific requirements for fabricated steel sections

3.1 Scope

3.1.1 Fabricated steel sections are items used in place of rolled sections and as such will not be regarded as sub-assemblies. Products regarded as sub-assemblies are subject to requirements of welded construction specified in Section 2.

3.1.2 The requirements for structural steel sections are based on these being manufactured from flat products by automatic welding and intended for use in the construction of ships and other marine structures.

3.1.3 Fabricated steel sections are to be manufactured in accordance with the requirements of this Section and the general requirements of Section 1.

3.1.4 In all cases, sections are to be manufactured at works, which have been assessed and approved in accordance with *Materials and Qualification Procedures for Ships, Book J, MQPS Procedure 12-1*.

3.2 Dimensions and tolerances

3.2.1 Products are to conform dimensionally to the provisions of an acceptable National or International Standard.

3.2.2 The minimum throat thickness of fillet welds is to be determined from:

Throat thickness = 0,34t but not to be taken as less than 3 mm

where

t = plate thickness of the thinner member to be joined (generally the web).

3.2.3 Where a welding procedure using deep penetration welding is used (*see* Chapter 11, 'p' and 'T' welding techniques) the minimum leg length required will be specially considered provided the requirements of 2.9.2 are complied with.

3.2.4 Unless agreed otherwise, the leg length of the weld is to be not less than 1,4 times the specified throat thickness.

3.3 Identification of products

3.3.1 Every finished item is to be clearly marked by the manufacturer in at least one place with the following particulars:

(a) The manufacturer's name or trade mark.
(b) Identification mark for the grade of steel.
(c) Identification number and/or initials which will enable the full history of the item to be traced.
(d) Where required by the purchaser, the order number or other identification mark.
(e) The letters 'LR'.
(f) The Surveyor's personal stamp.

The above particulars, but excluding the manufacturer's name or trade mark where this is embossed on finished products, are to be encircled with paint or otherwise marked so as to be easily recognisable.

3.3.2 In the event of any material bearing LR's brand failing to comply with the test requirements, the brand is to be removed or unmistakably defaced, *see also* Ch 1,4.7.

3.4 Manufacture and workmanship

3.4.1 For cut edges that are to remain unwelded, it is to be demonstrated that the plate preparation procedures used are able to achieve edges that are free from cracks or other deleterious imperfections.

3.4.2 Where assembly jigs and devices are used to bring the web into contact with the flanges and hold these in place during welding, means are to be provided to ensure that the degree of contact is maintained until welding is complete.

3.4.3 Welding procedures are to be established for the welding of all joints including weld repairs and are to be approved in accordance with Chapter 12. Welders are to be approved in accordance with Chapter 12, and qualification records are to be available to the Surveyor.

3.4.4 The welding consumables used are to be approved in accordance with Chapter 11 and are to be suitable for the type of joint and grade of steel as described in 2.2. For joining steel of different tensile strengths, the consumables are to be suitable for the tensile strength of the component considered in the determination of weld size.

3.4.5 The application of pre-heat and the use of low hydrogen welding consumables are to be in accordance with the requirements of 2.2.

3.4.6 Welding is to be double continuous fillet welding or full penetration welding as specified in the approved plans.

3.4.7 Where deep penetration welding is used, the requirements of 2.9.2 are to be complied with.

3.5 Non-destructive examination

3.5.1 Surface inspection and verification of dimensions are the responsibility of the manufacturer and are to be carried out on all materials prior to despatch. Acceptance by the Surveyor of material later found to be defective does not absolve the manufacturer from this responsibility.

3.5.2 The Surveyor will carry out checks to ensure that the weld size and profile are in accordance with the manufacturing specification and the manufacturer's Quality Control Procedures.

3.5.3 The manufacturer is to examine the welds by magnetic particle or dye penetrant methods. The length examined is to be 200 mm at each end, for each length cut for delivery.

3.5.4 If cracks are revealed, these are to be reported to the Surveyor and the whole of the length is to be examined by magnetic particle or dye penetrant methods. Corrective action in respect of the manufacturing process, and repairs are to be as indicated in the manufacturers' Quality Control Manual.

3.5.5 The weld defect is not to exceed the acceptance levels given in Table 13.2.4.

3.6 Routine weld tests

3.6.1 One production batch test is required for every 500 m of fabricated section manufactured, or fraction thereof. From each batch test, two samples are to be removed, one from near the beginning of the production run and one from near the end. From each of these test samples one macro specimen and one fracture test specimen are to be taken.

3.6.2 The macro specimens are to be prepared and etched to demonstrate freedom from unacceptable defects and that the weld penetration is in accordance with the manufacturing specification. The fracture specimens are to be broken, one for each side of the fillet weld, and the fractured surfaces examined for compliance with the requirements of Table 13.2.5.

3.6.3 Where the welding procedure used has employed the deep penetration technique, the amount of root penetration is to be measured on the macro specimen and is not to be less than that demonstrated during welding procedure approval testing.

3.6.4 For the purposes of this Section, a batch is to consist of products of only one size and grade of material.

3.7 Certification and records

3.7.1 Each test certificate is to include the following particulars:

(a) Purchaser's name and order number.
(b) Where known, the contract number for which the material is intended.
(c) Address to which material is despatched.
(d) Description and dimensions of the product.
(e) Specification or grade of the steel.
(f) Identification number and/or initials.
(g) Cast number and chemical composition of ladle samples of constituent plates.
(h) Mechanical test results of constituent plates.
(j) Condition of supply when other than as-rolled.
(k) Make and brand of welding consumables.

3.7.2 Test certificates or shipping statements may be signed by the Surveyor, provided the documentation requirements of 1.17 are satisfied. The following form of declaration will be accepted if stamped or printed on each test certificate or shipping statement with the name of the works and signed by an authorised representative of the manufacturer:

'We hereby certify that the material has been made by an approved procedure in accordance with the Lloyd's Register's Rules for Materials'.

3.7.3 The manufacturer is to maintain records by which sources of material can be identified together with the results of all inspections and tests.

■ *Section 4*
Specific requirements for fusion welded pressure vessels

4.1 Scope

4.1.1 The requirements of this Section apply to fusion welded pressure vessels and process equipment, heating and steam raising boilers, and steam or gas turbine rotors and cylinders and are in addition to those requirements referred to in Section 1.

4.1.2 The allocation of pressure vessel Class is determined from the design criteria in Pt 5, Ch 10 and 11 of the Rules for Ships. Prior to commencing construction, the design of the vessel is to be approved. Construction requirements for turbine rotors and cylinders are to be in accordance with Class 2/1, unless a higher Class is specified in the approved plans.

4.1.3 Pressure vessels will be accepted only if manufactured by firms equipped and competent to undertake the quality of welding work required for the Class of vessel proposed. The manufacturer's works are to be approved in accordance with the requirements specified in *Materials and Qualification Procedures for Ships, Book A, Procedure MQPS 0-4*.

4.1.4 The term 'fusion weld', for the purpose of these requirements, is applicable to welded joints made by manual, semi-automatic, or automatic electric arc welding processes. Special consideration will be given to the proposed use of other fusion welding processes.

4.2 Cutting and forming of shells and heads

4.2.1 Cut or chipped surfaces which will not be subsequently covered by weld metal are to be ground smooth.

4.2.2 Shell plates and heads are to be formed to the correct contour up to the extreme edge of the plate.

4.2.3 Vessels manufactured from carbon or carbon manganese steel plates (*see* Table 3.4.1 in Chapter 3, grades 360AR to 510FG), which have been hot formed or locally heated for forming, are to be re-heat treated in accordance with the original supplied condition on completion of this operation. Vessels formed from plates supplied in the as-rolled condition are to be heat treated in accordance with the material manufacturer's recommendations.

4.2.4 Subsequent heat treatment will not be required where steels are supplied in the as-rolled, normalised or normalised and controlled rolled condition, or hot forming is carried out entirely at a temperature within the normalising range.

4.2.5 For alloy steel vessels where hot forming is employed (*see* Table 3.4.1 in Chapter 3, 13Cr Mo 45, etc.), the plates are to be heat treated on completion in accordance with the material manufacturer's recommendations.

4.2.6 Where plates are cold formed, subsequent heat treatment is to be performed where the internal radius is less than 10 times the plate thickness. For carbon and carbon-manganese steels this heat treatment may be a stress relief heat treatment.

4.2.7 In all cases where hot forming is employed, and for cold forming to a radius less than 10 times the thickness, the manufacturer is required to demonstrate that the forming process and subsequent heat treatments result in acceptable properties.

4.3 Fitting of shell plates and attachments

4.3.1 The location of welded joints is to be such as to avoid intersecting butt welds in the vessel shell plates. The attachment of nozzles and openings in the vessels are to be arranged to avoid main shell weld seams.

4.3.2 The surfaces of the plates at the longitudinal or circumferential seams are not to be out of alignment with each other, at any point, by more than 10 per cent of the plate thickness. In no case is the misalignment to exceed 3 mm for longitudinal seams, or 4 mm for circumferential seams.

4.3.3 Where a vessel is constructed of plates of different thicknesses (tube plate and wrapper plate), the plates are to be so arranged that their centrelines form a continuous circle.

4.3.4 For longitudinal seams, the thicker plate is to be equally chamfered inside and outside by machining over a circumferential distance not less than twice the difference in thickness, so that the plates are of equal thickness at the longitudinal weld seam. For the circumferential seam, the thickest plate is to be similarly prepared over the same distance longitudinally.

4.3.5 For the circumferential seam, where the difference in the thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the weld joint. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper to the thicker plate.

4.3.6 All attachments (lugs, brackets, reinforcing plates, etc.) are to conform to the shape of the surface to which they are attached.

4.4 Welding

4.4.1 Welding procedures are to be established for all welds joining pressure containing parts and for welds made directly onto pressure containing parts. Welding procedures are to be based on qualification tests performed in accordance with Chapter 12.

4.4.2 In all cases where tack welds, in the root of the weld seam, are used to retain plates or parts in position prior to welding, they are to be removed in the process of welding the seam.

4.4.3 Steel backing strips may be used for the circumferential seams of Class 2/1, Class 2/2 and Class 3 pressure vessels and are to be the same nominal composition as the plates to be welded.

4.4.4 Fillet welds are to be made to ensure proper fusion and penetration at the root of the fillet. At least two layers of weld metal are to be deposited at each weld affixing branch pipes, flanges and seatings.

4.4.5 The outer surface of completed welds is to be at least flush with the surface of the plates joined, and any weld reinforcement is to provide a smooth transition and gradual change of section with the plate surface.

4.4.6 Where attachment of lugs, brackets, branches, manhole frames, reinforcement plates and other members are to be made to the main pressure shell by welding, this is to be to the same standard as required for the main vessel shell construction.

4.4.7 The main weld seams and all welded attachments made to pressure containing parts are to be completed prior to post-weld heat treatment.

4.4.8 The finish of welds attaching pressure parts and non-pressure parts to the main pressure shell is to be such as to allow satisfactory examination of the welds. In the case of Class 1 and Class 2/1 pressure vessels, these welds are to be ground smooth, if necessary, to provide a suitable finish for examination.

4.5 General requirements for routine weld production tests

4.5.1 Routine weld production tests are specified as a means of monitoring the quality of the welded joints and are required for pressure vessel Classes 1, 2/1 and 2/2.

4.5.2 Routine production test plates are required during the manufacture of vessels and as part of the initial approval test programme for Class 1 vessel manufacturers, refer to MQPS 0-4.

4.5.3 Routine production weld tests are not required for Class 3 pressure vessels unless there are doubts about the weld quality where check tests may be requested by the Surveyor.

4.5.4 Routine production test plates are not required for circumferential seams of cylindrical pressure vessels. Spherical vessels are to have one test plate prepared having a welded joint which is a simulation of the circumferential seams.

4.5.5 Routine production weld tests may be requested by the Surveyor where there is reason to doubt the quality of workmanship.

4.6 Production test plate assembly requirements

4.6.1 Two test plates and one complete test assembly, of sufficient dimensions to provide all the required mechanical test specimens is to be prepared for each vessel and is to be welded as a continuation and simulation of the longitudinal weld joint.

4.6.2 For Class 2/2 vessels, where a large number are made concurrently at the same works using the same welding procedure and the plate thicknesses do not vary by more than 5 mm, one test may be performed for each 37 m of longitudinal plus circumferential weld seam. In these cases the thickness of the test plate is to be equal to the thickest shell plate used in the construction.

4.6.3 Where the vessel size or design results in a small number of longitudinal weld seams, one test assembly may be prepared for testing provided that the welding details are the same for each seam.

4.6.4 Test plate materials are to be the same grade, thickness and supply condition and from the same cast as that of the vessel shell. The test assembly is to be welded at the same time as the vessel weld to which it relates and is to be supported so that distortion during welding is minimised.

4.6.5 As far as practicable, welding is to be performed by different welders where there is a requirement for several routine tests to be welded.

4.6.6 The test assembly may be detached from the vessel weld only after the Surveyor has performed a visual examination and has added his mark or stamp. Straightening of test welds prior to mechanical testing is not permitted.

4.6.7 Where the pressure vessel is required to be subjected to post-weld heat treatment, the test weld is to be heat treated, after welding, in accordance with the same requirements. This may be performed separately from the vessel.

4.7 Inspection and testing

4.7.1 The test weld is to be subjected to the same type of non-destructive examination and acceptance criteria as specified for the weld seam to which the test relates. Non-destructive examination is to be performed prior to removing specimens for mechanical testing, but after any post-weld heat treatment.

4.7.2 The test weld is to be sectioned to remove the number and type of test specimens for mechanical testing as given in 4.8.

4.8 Mechanical requirements

4.8.1 The routine production test assembly is to be machined to provide the following test specimens:

(a) Tensile.
(b) Bend.
(c) Hardness.
(d) Impact (*see* Table 13.4.1).
(e) Macrograph and hardness survey of full weld section.

4.8.2 One set of specimens for mechanical testing are to be removed, as shown in Figs. 13.4.1 or 13.4.2 as appropriate for the Class of approval. Impact tests are to be removed and tested where required by Table 13.4.1.

4.8.3 **Longitudinal tensile test for weld metal**. An all-weld metal longitudinal tensile test is required. For thicknesses in excess of 20 mm, where more than one welding process or type of consumable has been used to complete the joint, additional longitudinal tests are required from the respective area of the weld. This does not apply to the welding process or consumables used solely to deposit the root weld. Specimens are to be tested in accordance with the following requirements:

(a) The diameter and gauge length of the test specimen is to be in accordance with Ch 11,2.1.1.
(b) For carbon and carbon-manganese steels the tensile strength of the weld metal is to be not less than the minimum specified for the plate material and not more than 145 N/mm^2 above this value. The percentage elongation, A, is to be not less than that given by:

A = $(980-R)/21{,}6$ but not less than 80 per cent of the minimum elongation specified for the plate

where

R is the tensile strength, in N/mm^2, obtained from the all weld metal tensile tests.

(c) For other materials the tensile strength and percentage elongation is not to be less than that specified for the base materials welded.

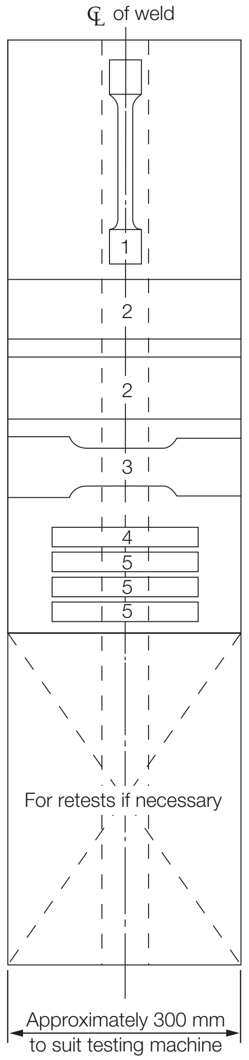
4.8.4 **Transverse tensile test for joint**. Transverse tensile test specimens are to be removed and tested in accordance with the following requirements:

(a) One reduced section tensile test specimen is to be cut transversely to the weld to the dimensions shown in Ch 11,2.1.1 and the weld reinforcement is to be removed.

Table 13.4.1 Impact test requirements

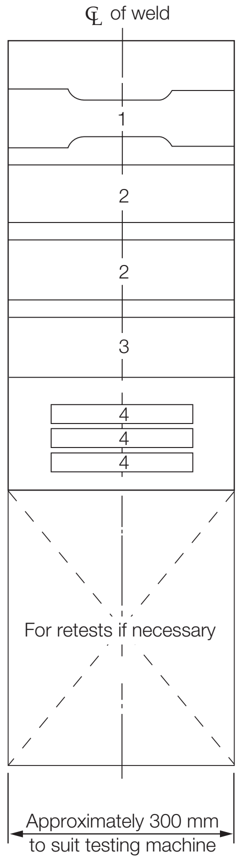
Pressure vessel Class	Minimum design temperature	Plate material thickness t	Impact test temperature
Class 1 *see* Note	–10°C or above	All	5°C below the minimum design temperature or 20°C, whichever is the lower
All Classes	Below –10°C	$t \leq 20$ mm	5°C below the minimum design temperature
		$20 \text{ mm} < t \leq 40$ mm	10°C below the minimum design temperature
		Over 40 mm	Subject to special consideration

NOTE
Impact testing is not required for Classes 2/1, 2/2 and 3.



1. All weld metal tensile test specimen.
2. Bend test specimens.
3. Tensile test for joints.
4. Macro-test specimen.
5. Charpy V-notch impact.
(For all Class 1 pressure vessels and other Classes of pressure vessels where the minimum design temperature is below –10°C).

Fig. 13.4.1
Routine weld test – Test specimens for Class 1 and Class 2/1



1. Tensile test for joints.
2. Bend test specimens.
3. Nicked bend test specimen.
4. Charpy V-notch impact test specimens (if required by Table 13.4.1).

Fig. 13.4.2
Routine weld tests – Test specimens for Class 2/2 and Class 3

(b) In general, where the plate thickness exceeds 30 mm, or where the capacity of the tensile test machine prevents full thickness tests, each tensile test may be made up of several reduced section specimens, provided that the whole thickness of the weld is subjected to testing.
(c) The tensile strength obtained is to be not less than the minimum specified tensile strength for the plate material, and the location of the fracture is to be reported.

4.8.5 **Transverse bend test**. The bend test specimens are to be removed and tested in accordance with the following requirements:
(a) Two bend test specimens of rectangular section are to be cut transversely to the weld, one bent with the outer surface of the weld in tension (face bend), and the other with the inner surface in tension (root bend).
(b) The specimen dimensions are to be in accordance with Chapter 2.
(c) Each specimen is to be mounted on roller supports with the centre of the weld midway between the supports. The former is to have a diameter specified in Ch 12,2.7.6 depending on the material being welded.
(d) After bending through an angle of at least 180° there is to be no crack or defect exceeding 1,5 mm measured across the specimen or 3 mm measured along the specimen. Premature failure at the edges of the specimen is not to be cause for rejection, unless this is associated with a weld defect.

4.8.6 **Macro-specimen and hardness survey**. A macro examination specimen is to be removed from the test assembly near the end where welding started. The specimen is to include the complete cross-section of the weld and the heat affected zone. The specimen is to be prepared and examined in accordance with the following requirements:

(a) The cross-section of the specimen is to be ground, polished and etched to clearly reveal the weld runs, and the heat affected zones.
(b) The specimen is to show an even weld profile that blends smoothly with the base material and have satisfactory penetration and fusion, and an absence of significant inclusions or other defects.
(c) Where there is doubt in the condition of the weld as shown by macro-etching, the area concerned is to be microscopically examined.
(d) For carbon, carbon manganese and low alloy steels, a Vickers hardness survey is to be performed on the macro-specimen using either a 5 kg or 10 kg load. Testing is to include the base material, the weld and the heat affected zone. Hardness scans on the cross-section are to be performed as specified in Fig. 12.2.9 in Chapter 12. The maximum recorded hardness is to not exceed 350 Hv.

4.8.7 **Charpy V-notch impact test**. Charpy V notch impact test specimens are to be prepared and tested as required by Table 13.4.1 and in accordance with the following requirements:

(a) The dimensions and tolerances of the specimens are to be in accordance with Chapter 2.
(b) Charpy V-notch impact specimens and are to be removed with the notch perpendicular to the plate surface.
(c) Specimens are to be removed for testing from the weld centreline and the heat affected zone (fusion line and fusion line + 2 mm locations) detailed in Fig. 12.2.6 or Fig. 12.2.7 in Chapter 12, as appropriate. Heat affected zone impact tests may be omitted where the minimum design temperature is above +20°C.
(d) For thicknesses in excess of 20 mm, where more than one welding process or type of consumable has been used to complete the joint, impact tests are required from the respective areas of the weld. This does not apply to the welding process or consumables used solely to deposit the root weld.
(e) The average energy of a set of three specimens is not to be less than 27 J or the minimum specified for the base material, whichever is the higher. The minimum energy for each individual specimen is to meet the requirements of Ch 1,4.5.2.

4.8.8 **Nick break bend tests**. A nick bend or fracture test specimen is to be a minimum of 100 mm long measured along the weld direction and is to be tested in accordance with and meet the requirements of the following:

(a) The specimen is to have a slot cut into each side along the centreline of the weld and perpendicular to the plate surface.
(b) The specimen is to be bent along the weld centreline until fracture occurs and the fracture faces are to be examined for defects. The weld is to be sound, with no evidence of cracking or lack of fusion or penetration and be substantially free from slag inclusions and porosity.

4.9 Failure to meet requirements

4.9.1 Where any test specimen fails to meet the requirements, additional specimens may be removed and re-tested in accordance with Ch 2,1.4.

4.9.2 Where a routine weld test fails to meet requirements, the welds to which it relates will be considered as not having met the requirements. The reason for the failure is to be established, and the manufacturer is to take such steps as necessary to either

(a) Remove the affected welds and have them re-welded, or
(b) Demonstrate that the affected production welds have acceptable properties.

4.10 Post-weld heat treatment

4.10.1 Fusion welded pressure vessels, where indicated in Table 13.4.2, are to be heat treated on completion of the welding of the seams and of all attachments to the shell and ends, and before the hydraulic test is carried out.

4.10.2 Tubes which have been expanded into headers or drums may be seal welded without further post-weld heat treatment.

4.10.3 Steam and gas turbine cylinders and rotors are to be subjected to post-weld heat treatment irrespective of thickness.

4.10.4 Where the weld attaches parts of different thicknesses, the thickness to be used when applying the requirements for post-weld heat treatment is to be either the thinner of the two plates for butt welded connections, or the thickness of the shell for welds to flanges, tubeplates and similar connections.

4.10.5 Care is to be exercised to provide drilled holes in double reinforcing plates and other closed spaces prior to heat treatment.

4.11 Basic requirements for post-weld heat treatment of fusion welded pressure vessels

4.11.1 Recommended soaking temperatures and soak durations for post-weld heat treatment are given in Table 13.4.3 for different materials. Where other materials are used for pressure vessel construction, full details of the proposed heat treatment are to be submitted for consideration.

4.11.2 Where pressure vessels are of dimensions that the whole length cannot be accommodated in the furnace at one time, the pressure vessels may be heated in sections, provided that sufficient overlap is allowed to ensure the heat treatment of the entire length of the longitudinal seam.

4.11.3 Where materials other than those detailed in Table 13.4.3 are used or where it is proposed to adopt special methods of heat treatment, full particulars are to be submitted for consideration. In such cases, it may be necessary to carry out tests to show the effect of the proposed heat treatment.

Table 13.4.2 Post-weld heat treatment requirements

Type of steel	Plate thickness above which post-weld heat treatment (PWHT) is required	
	Steam raising plant	Other pressure vessels
Carbon and carbon/manganese steels without low temperature impact values	20 mm	30 mm
Carbon and carbon/manganese steels with low temperature impact values	20 mm	40 mm
1Cr ½Mo	All thicknesses	All thicknesses
2¼Cr 1Mo	All thicknesses	All thicknesses
½Cr ½Mo ¼V	All thicknesses	All thicknesses
Other alloy steels	Subject to special consideration	

Table 13.4.3 Post-weld soak temperatures and times

Material type	Soak temperature (°C)	Soak period
Carbon and carbon/manganese grades	580–620°	1 hour per 25 mm of thickness, minimum of 1 hour
1Cr ½Mo	620–660°	1 hour per 25 mm of thickness, minimum of 1 hour
2¼Cr 1Mo	650–690°	1 hour per 25 mm of thickness, minimum of 1 hour
½Cr ½Mo ¼V	670–720°	1 hour per 25 mm of thickness, minimum of 1 hour
NOTE For materials supplied in the tempered condition, the post-weld heat treatment temperature is to be lower than the material tempering temperature.		

4.12 Non-Destructive Examination of welds

4.12.1 Non-Destructive Examinations (NDE) of pressure vessel welds are to be carried out in accordance with a nationally recognised code or standard.

4.12.2 NDE is not to be applied until an interval of at least 48 hours has elapsed since the completion of welding.

4.12.3 NDE Personnel are to be qualified to an appropriate level of a nationally recognised certification scheme.

4.12.4 Qualification schemes are to include assessments of practical ability for Levels I and II individuals. These examinations are to be made on representative test pieces containing relevant defects.

4.13 Extent of NDE for Class 1 pressure vessels

4.13.1 All butt welded seams in drums, shells, headers and test plates, together with tubes or nozzles with outside diameter greater than 170 mm, are subject to 100 per cent volumetric and surface crack detection inspections.

4.13.2 For circumferential butt welds in extruded connections, tubes, headers and other tubular parts with an outside diameter of 170 mm or less, at least 10 per cent of the total number of welds is to be subjected to volumetric examination and surface crack detection inspections.

4.13.3 Full penetration tube sheet to shell welds are to be subjected to 10 per cent volumetric examination and 10 per cent surface inspection, prior to the installation of the tubes.

4.13.4 In addition to the acceptance limits stated in Tables 13.2.4 to 13.2.6, no cracks, lack of fusion, or lack of penetration is permitted.

4.13.5 When an unacceptable indication is detected, the full length of the weld is to be subjected to 100 per cent examination by the same method, testing conditions and acceptance criteria.

4.14 Extent of NDE for Class 2/1 pressure vessels

4.14.1 For Class 2/1 pressure vessels, volumetric and surface crack detection inspections are to be applied at selected regions of each main seam. At least 10 per cent of each main seam is to be examined together with the full length of each welded test plate. When an unacceptable indication is detected, at least two additional check points in the seam are to be selected by the surveyor for examination using the same inspection method. Where further unacceptable defects are found either:

(a) the whole length of weld represented is to be cut out and re-welded and re-examined as if it was a new weld with the test plates being similarly treated, or
(b) the whole length of the weld represented is to be re-examined using the same inspection methods.

4.14.2 Butt welds in furnaces, combustion chambers and other pressure parts for fired pressure vessels under external pressure, are to be subject to spot volumetric examination. The minimum length for each check point is to be 300 mm.

4.14.3 The extent of NDE for turbine cylinders and rotors is to be agreed with the Surveyor.

4.14.4 The requirements of 4.13.3, 4.13.4 and 4.13.5 apply to Class 2/1 pressure vessels.

4.15 NDE Method

4.15.1 Volumetric examinations may be made by radiography. For welds of nominal thickness greater than or equal to 8 mm, the examinations may be by ultrasonic testing. The preferred method for surface crack detection in ferrous metals is magnetic particle inspection. The preferred method for non-magnetic materials is liquid penetrant inspection.

4.16 Evaluation and reports

4.16.1 The manufacturer is to be responsible for the review, interpretation, evaluation and acceptance of the results of NDE. Reports stating compliance, or non-compliance, with the criteria established in the inspection procedure are to be issued. Reports are to comply, as a minimum, with the requirements of Ch 1,5.

4.17 Repair to welds

4.17.1 Where non-destructive examinations reveal unacceptable defects in the welded seams, they are to be repaired in accordance with 1.15 and are to be shown by further non-destructive examinations to have been eliminated.

4.17.2 In the case where spot radiography has revealed unacceptable defects, the requirements of 4.14.1 apply.

4.17.3 Where post-weld heat treatment is required in accordance with 4.10, weld repairs to the vessel or cylindrical shell or parts attaching to the shell are to be subjected to a subsequent heat treatment in accordance with 4.10.

4.17.4 In the event of unsuccessful weld repair of a defect, only one more repair attempt may be made of the same defect. Any subsequent repairs may require the re-repair excavation to be enlarged to remove the original repair heat affected zone.

■ *Section 5*
Specific requirements for pressure pipework

5.1 Scope

5.1.1 Fabrication of pipework is to be carried out in accordance with the requirements of this Section and the general requirements given in Section 1, unless more stringent requirements have been specified.

5.1.2 Piping systems are to be constructed in accordance with the approved plans and specifications.

5.1.3 Fabricated pipework will be accepted only if manufactured by firms that have demonstrated that they have the facilities and equipment and are competent to undertake the quality of welding required for the Class of pipework proposed.

5.2 Manufacture and workmanship

5.2.1 Pipe welding may be performed using manual, semi-automatic or fully automatic electric arc processes. The use of oxy-acetylene welding will be limited to Class 3 pipework in carbon steel or carbon/manganese material that is not for carrying flammable fluids and limited to butt joints in pipes not exceeding 100 mm diameter or 9,5 mm thickness.

5.2.2 Welding of pipework, including attachment welds directly to pressure retaining parts is to be performed in accordance with approved welding procedures that have been qualified in accordance with Chapter 12.

5.2.3 Where the work involves a significant number of branch connections, tests will be required to demonstrate that the type of joint(s) and welding techniques employed are capable of achieving the required quality.

5.2.4 Where pressure pipework is assembled and butt welded insitu, the piping is to be arranged well clear of adjacent structures to allow sufficient access for preheating, welding, heat-treatment and non-destructive examination of the joints.

5.2.5 Alignment of pipe butt welds is to be in accordance with Table 13.5.1 unless more stringent requirements have been agreed. Where fusible inserts are used, the alignment is to be within 0,5 mm in all cases.

5.2.6 The number of welds is to be kept to a minimum. The minimum separation between welds, measured toe-to-toe, is to be not be less than 75 mm. Where it is not possible to achieve this, adjacent welds are to be subjected to surface crack detection NDE.

5.2.7 Welding consumables and fusible root inserts, where used, are to be suitable for the materials being joined.

Table 13.5.1 Pipe butt weld alignment tolerances

Pipe size	Maximum permitted misalignment
D < 150 mm and t ≤ 6 mm	1,0 mm or 25% of t, whichever is the lesser
D < 300 mm and t ≤ 9,5 mm	1,5 mm or 25% of t, whichever is the lesser
D ≥ 300 and t > 9,5 mm	2,0 mm or 25% of t, whichever is the lesser
where D = pipe internal diameter t = pipe wall thickness	

5.2.8 Acceptable methods of flange attachment are to be used, *see* Fig. 12.2.2 in Pt 5, Ch 12 of the Rules for Ships. Where backing rings are used with flange type (a) they are to fit closely to the bore of the pipe and be removed after welding. The rings are to be made of the same material as the pipes. The use of flange types (b) and (c) with alloy steel pipes is limited to pipes up to and including 168,3 mm outside diameter.

5.2.9 Where socket welded fittings are employed, the diametrical clearance between the outside diameter of the pipe and the base of the fitting is not to exceed 0,8 mm, and a gap of approximately 1,5 mm is to be provided between the end of the pipe and the internal step at the bottom of the socket.

5.2.10 For welding of carbon, carbon/manganese and low alloy steels, the preheat to be applied will be dependent on the material grade, thickness and hydrogen grading of the welding consumable in accordance with Table 13.5.2, unless welding procedure testing indicates that a higher level is required.

5.2.11 Welding without filler metal is generally not permitted for welding of duplex stainless steel materials.

5.2.12 All welds in high pressure, high temperature pipelines are to have a smooth surface finish and even contour; and where necessary, made smooth by grinding.

5.2.13 Check tests of the quality of the welding are to be carried out periodically.

5.3 Heat treatment after bending of pipes

5.3.1 After forming or bending of pipes, the heat treatments specified in this Section are to be applied unless the pipe material manufacturer specifies or recommends other requirements.

5.3.2 Generally, hot forming is to be carried out within the normalising temperature range. When carried out within this temperature range, no subsequent heat treatment is required for carbon and carbon/manganese steels. For alloy steels, 1Cr 1/2Mo, 2 1/4Cr 1Mo and 1/2Cr 1/2Mo 1/4V, a subsequent tempering heat treatment in accordance with the temperatures and times specified in Table 13.5.3 is required, irrespective of material thickness.

5.3.3 When hot forming is performed outside the normalising temperature range, a subsequent heat treatment in accordance with Table 13.5.3 is required.

5.3.4 After cold forming to a radius (measured at the centreline of the pipe) of less than four times the outside diameter, heat treatment in accordance with Table 13.5.3 is required.

5.3.5 Heat treatment should be carried out in accordance with 1.16.

Table 13.5.2 Welding preheat levels for pipework

Material Grade	Thickness, t (mm) *see* Note 4	Minimum preheat temperature (°C) *See* Note 1	
		Non-low H_2	Low H_2 *see* Note 2
Carbon and carbon/manganese grades: 320 and 360	t ≤ 15 t ≥ 15	50 100	10 50
Carbon and carbon/manganese grades: 410, 460 and 490	t ≤ 15 t ≥ 15	75 150	20 100
1Cr ½Mo	t < 13 t ≥ 13	*See* Note 3	100 150
2¼Cr 1Mo	t < 13 t ≥ 13	*See* Note 3	150 200
½Cr ½Mo ¼V	t < 13 t ≥ 13	*See* Note 3	150 200

NOTES
1. Where the ambient temperature is 0°C or below, pre-warming of the weld joint is required in all cases.
2. Low hydrogen process or consumables are those that have been tested and have achieved a grading of H15 or better (*see* Chapter 11).
3. Low hydrogen welding process is required for these materials.
4. t = the thickness of the thinner member for butt welds, and the thicker member for fillet and branch welds.

Table 13.5.3 Heat treatment after bending of pipes

Type of steel	Heat treatment required
Carbon and carbon/manganese: Grades 320, 360, 410, 460 and 490	Normalise at 880 to 940°C
1Cr ½Mo	Normalise at 900 to 940°C, followed by tempering at 640 to 720°C
2¼Cr 1Mo	Normalise at 900 to 960°C, followed by tempering at 650 to 780°C
½Cr ½Mo ¼V	Normalise at 930 to 980°C, followed by tempering at 670 to 720°C
Other alloy steels	Subject to special consideration

5.3.6 Bending procedures and subsequent heat treatment for other alloy steels will be subject to special consideration.

5.4 Post-weld heat treatment

5.4.1 Post-weld heat treatment is to be carried out in accordance with the general requirements specified in 1.16 and 4.10.

5.4.2 The thickness limits, the recommended soaking temperatures and periods, for application of post-weld heat treatment are given in Table 13.5.4.

5.4.3 Where the use of oxy-acetylene welding is proposed, due consideration is to be given to the need for normalising and tempering after such welding.

5.5 Non-destructive examination

5.5.1 Non-destructive examination of pipe welds is to be carried out in accordance with the general requirements of 1.11 and the following.

5.5.2 Butt welds in Class 1 pipes with an outside diameter greater or equal to 75 mm are to be subject to 100 per cent volumetric and visual inspections. Consideration is to be given to the extent and method of testing applied to butt welds in Class 1 pipes with an outside diameter less than 75 mm.

5.5.3 Butt welds in Class II pipes are to be subjected to at least 10 per cent random volumetric inspections when the outside diameter is greater than 100 mm.

5.5.4 NDE for Class II pipes with a diameter less than 100 mm is to be at the discretion of the Surveyor.

5.5.5 Non-destructive examination procedures, methods and the evaluation of reports are to be in accordance with 4.15 and 4.16.

5.5.6 Fillet welds on flange pipe connections of Class I pipes are to be examined by surface crack detection methods.

5.6 Repairs to pipe welds

5.6.1 Where non-destructive examinations reveal unacceptable defects in a weld, the defects are to be removed and repaired in accordance with 1.15. Completed repairs are to be shown by further non-destructive examination to have eliminated the defects.

5.6.2 For pipes with diameter less than 88 mm and where unacceptable defects have been found during non-destructive examination, consideration is to be given to cutting the weld out completely, re-making the weld preparation and re-welding as a new joint (because of the difficulty of making small repairs).

Table 13.5.4 Post-weld heat treatment requirements for pipework

Material Grade	Thickness for which post-weld heat treatment is required	Soak temperature (°C) *see* Note 2	Soak period
Carbon and carbon/manganese grades: 320, 360, 410, 460, 490	Over 30 mm	580–620°C	1 hour per 25 mm of thickness, minimum of 1 hour
1Cr ½Mo	Over 8 mm	620–660°C	1 hour per 25 mm of thickness, minimum of 1 hour
2¼Cr 1Mo	All	650–690°C	1 hour per 25 mm of thickness, minimum of 1 hour
½Cr ½Mo ¼V	All, *see* Note 1	670–720°C	1 hour per 25 mm of thickness, minimum of 1 hour

NOTES
1. Heat treatment may be omitted for thicknesses up to 8 mm and diameters not exceeding 100 mm provided welding procedure tests have demonstrated acceptable properties in the as welded condition.
2. For materials supplied in the tempered condition, the post-weld heat treatment temperature is to be at least 20°C less than the material tempering temperature.

5.6.3 Where repeated weld repairs have to be made to a weld, only two such attempts are to be permitted, thereafter the weld is to be cut apart and removed, and re-welded as a new joint.

5.6.4 Where pipework requires post-weld heat treatment weld, repairs to the pressure retaining parts are to be subjected to a subsequent heat treatment. Similarly, where welding is conducted after pressure testing, a further pressure test is to be required unless specific exemption has been agreed.

■ *Section 6*
Repair of existing ships by welding

6.1 Scope

6.1.1 This Section specifies requirements for repairs made by welding after introduction into service. This Section includes defects to hull structures, machinery, equipment and components. It also includes replacement of structure due to damage or corrosion. These requirements are in addition to those specified in the preceding Sections of this Chapter.

6.1.2 These requirements apply unless the original builder or manufacturer has specified alternative requirements.

6.2 Materials used for repairs

6.2.1 Permanent materials used in the repair are to be in accordance with 1.3.

6.2.2 Prior to commencing any welding, the material grades present in the original structure in way of the repair are to be determined. Where the materials cannot be identified from the ship records, test samples may be removed for chemical analysis and mechanical testing in order to determine the material grades.

6.2.3 Temporary materials that are to be welded to the main structure to assist in executing the repairs, but removed on completion, are to be of weldable quality.

6.3 Workmanship

6.3.1 A repair method is to be established by the shipyard or repair yard and is to be agreed by the Surveyor prior to commencing any repair work.

6.3.2 The removal of crack-like defects is to be confirmed by visual examination and surface crack detection NDE. This may be augmented by ultrasonic examination where several defects are reported at different depths at the same location.

6.3.3 The weld joint or groove shape used for the repair is to have a profile suitable for welding.

6.3.4 The weld area is to be carefully cleaned, in particular, where the material surface has been painted or has been subjected to an oily or greasy environment.

6.4 Non-destructive examination

6.4.1 On completion of welding and any post-weld heat treatment, repair welds are to be subjected to the type and extent of NDE and assessed in accordance with the acceptance criteria specified for the original construction.

6.4.2 Where the original construction specification did not specify NDE, the completed welds are to be, as a minimum, subject to visual examination. Consideration of other NDE techniques is to take due cognisance of the location or the repair within the vessel.

6.4.3 Where spot NDE is applied and defects are found, the extent of NDE is to be increased to include an equal amount of weld length. Where this reveals unacceptable defects, either the whole weld will be rejected or the extent of inspection increased to 100 per cent examination.

6.4.4 The acceptance criteria to be applied are to generally be in accordance with the original build specification. Where conflict of requirements exist, the NDE acceptance limits for welding procedure tests specified in Ch 12,2.5.5 may be used as a minimum requirement.

6.5 Repairs to welds defects

6.5.1 Where NDE reveals unacceptable defects, these are to be repaired in accordance with 1.15.

■ *Section 7*
Austenitic and duplex stainless steel – Specific requirements

7.1 Scope

7.1.1 This Section specifies requirements for the fabrication and welding of austenitic and duplex stainless steels, and is in addition to those detailed above.

7.1.2 Fabrication and welding of these materials is to be in designated areas which are separated from those used for other materials, such as carbon steels and copper alloys. Where work is performed in the same workshop as other materials, adequate barriers or screening are to be provided to prevent cross-contamination of different material types.

7.1.3 All tools and equipment used are to be suitable for use on stainless steel materials. The use of tools or equipment made of carbon steel materials is to be avoided. It is permissible to use carbon steel tools provided that the surfaces that come into contact with the austenitic and duplex stainless materials are protected with an austenitic or nickel base alloy.

7.2 Design

7.2.1 Care is to be exercised in the weld design to prevent crevice corrosion from occurring, particularly where austenitic materials are used. In this respect fillet welds and partial penetration welds are to be continuous and welded on both sides of the joint.

7.3 Forming and bending

7.3.1 Materials that are cold formed, such that the total strain exceeds 15 per cent (i.e., where the formed diameter to thickness ratio is less than 6:1) are to be subjected to a subsequent softening heat treatment in accordance with the material manufacturers recommendations, unless it is demonstrated by testing that the material properties are acceptable in the 'as formed' condition.

7.3.2 Materials may be hot formed provided that a subsequent softening heat treatment is carried out. The forming process and the subsequent heat treatment are to be in accordance with the material manufacturer's recommendations.

7.4 Fabrication and welding

7.4.1 Welding may be performed using shielded manual arc welding (SMAW), gas tungsten arc welding (GTAW), MIG/MAG welding (GMAW), flux cored arc welding (FCAW), plasma arc welding (PAW) and submerged arc welding (SAW). The use of other welding processes will be subject to special consideration and will require submission of the process details, consumables and the weld properties achieved.

7.4.2 Misalignment may be corrected by the application of steady even force (e.g., using hydraulic or screw-type clamps). Hammering or heating is not permitted.

7.4.3 For full penetration welds, a backing or shielding gas is to be provided to prevent oxidation of the root weld. The backing gas is to be maintained until completion of, at least, the root and first fill layer. The backing gas may be omitted where the weld is back gouged or ground to remove the root weld.

7.4.4 Shielding and backing gases are to be an inert type of high purity and oxygen free.

7.4.5 For welding of Duplex stainless, the use of backing gases that contain up to 2 per cent nitrogen is permitted.

7.4.6 Welding of duplex stainless steels without filler metal is generally not permitted.

7.4.7 Degreasing agents, acid solutions, washing water etc. used for cleaning and any marking crayons and paints used are to be free of chlorides.

7.5 Repairs

7.5.1 Correction of distortion by the application of heat is not permitted.

■ *Section 8* Specific requirements for welded aluminium

8.1 Scope

8.1.1 This Section specifies requirements for the fabrication and welding of aluminium alloys, and is in addition to those detailed in this Chapter.

8.1.2 Fabrication and welding of these materials is to be in designated areas which are separated from those used for other materials, such as carbon steels, stainless steels and copper alloys. Where work is performed in the same workshop as other materials, adequate barriers or screening are to be provided to prevent cross-contamination of different material types.

8.1.3 All tools and equipment used are to be suitable for use on aluminium alloy materials. The use of tools made of carbon steel materials is to be avoided where possible.

8.2 Forming and bending

8.2.1 Aluminium alloys are to be subject to cold forming and cold bending only.

8.3 Fabrication and welding

8.3.1 Welding may be performed using gas tungsten arc welding (GTAW) or metal inert gas welding (GMAW), MIG/MAG welding (GMAW), or variants thereof. The use of other welding processes such as friction stir welding (FSW) will be subject to special consideration and will require submission of the process details, consumables and the weld properties achieved.

8.3.2 A comparison of the mechanical properties for selected welded and unwelded alloys is given in Table 13.8.1.

8.3.3 Misalignment may be corrected by the application of steady even force (e.g., using hydraulic or screw-type clamps). Hammering or heating is not permitted.

8.3.4 Correction of distortion by the application of heat is not permitted.

Table 13.8.1 Minimum mechanical properties for aluminium alloys

Alloy	Condition		0,2% proof stress, N/mm^2		Ultimate tensile strength, N/mm^2	
			Unwelded	Welded (*see* Note 4)	Unwelded	Welded (*see* Note 4)
5083	O/H111		125	125	275	275
5083	H112		125	125	275	275
5083	H116/H321		215	125	305	275
5383	O/H111		145	145	290	290
5383	H116/H321		220	145	305	290
5086	O/H111		100	95	240	240
5086	H112		125 (*see* Note 2)	95	250 (*see* Note 2)	240
5086	H116/H321		195	95	275	240
5059	O/H111		160	160	330	330
5059	H116/H321		260	160	360	300
5456	O		125	125	285	285
5456	H116		200 (*see* Note 5)	125	290 (*see* Note 5)	285
5456	H321		215 (*see* Note 5)	125	305 (*see* Note 5)	285
5754	O/H111		80	80	190	190
6005A (see Note 1)	T5/T6	Extruded: Open Profile Extruded: Closed Profile	215 215	100 100	260 250	160 160
6061 (see Note 1)	T5/T6	Rolled Extruded: Open Profile Extruded: Closed Profile	240 240 205	125 125 125	290 260 245	160 160 160
6082	T5/T6	Rolled Extruded: Open Profile Extruded: Closed Profile	240 260 240	125 125 125	280 310 290	190 190 190

NOTES
1. These alloys are not normally acceptable for application in direct contact with sea-water.
2. See also Table 8.1.3 or Table 8.1.4 in Chapter 8.
3. The mechanical properties to be used to determine scantlings in other types and grades of aluminium alloy manufactured to National or proprietary standards and specifications are to be individually agreed with LR, *see also* Ch 8,1.1.5.
4. Where detail structural analysis is carried out, 'unwelded' stress values may be used away from heat affected zones and weld lines, *see also* Pt 3, Ch 2, 1.1.3 of the Rules for Ships.
5. For thickness less than 12,5 mm, the minimum unwelded 0,2% proof stress is to be taken as 230 N/mm^2 and the minimum tensile strength is to be taken as 315 N/mm^2.

8.4 Non-destructive examination

8.4.1 The requirements of Ch 13,1.11 and Ch 13,2.12 apply; however, acceptance criteria applicable to aluminium are to be in accordance with Table 13.8.2 and Table 13.8.3.

8.4.2 Alternative NDE acceptance criteria will be subject to special consideration provided that they are equivalent to these requirements.

Table 13.8.2 Acceptance criteria for surface imperfections of aluminium

Surface discontinuity	Classification according to ISO 6520-1	Acceptance criteria
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete root penetration in butt joints welded from one side	4021	Not permitted
Surface pore	2017	$d \leq 0{,}3s$ or $0{,}3a$ or 1,5 mm (whichever is the lesser)
Linear porosity (*see* Note 1)	2014	Not permitted
Uniformly distributed porosity (*see* Note 2)	2012	≤ 1% of area
Clustered porosity	2013	Not permitted
Continuous undercut	5011	$h \leq 0{,}1t$ or 0,5 mm (whichever is the lesser)
Intermittent undercut	5012	$h \leq 0{,}1t$ or 1,0 mm (whichever is the lesser)
Excess weld metal (*see* Note 3)	502	$h \leq 1{,}5$ mm + $0{,}15b$ or 8 mm (whichever is the lesser)
Excess penetration	504	$h \leq 4$ mm
Root concavity (*see* Note 3)	515	$h \leq 0{,}1t$ or 1 mm (whichever is the lesser)
Linear misalignment (*see* Notes 4 and 5)	507	$h \leq 0{,}1t$ or 1,0 mm (whichever is the lesser)
Angular misalignment	508	(*see* Note 6)

Symbols

a = nominal throat thickness of a fillet weld
b = width of weld reinforcement
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size)

NOTES
1. For these acceptance criteria, linear porosity is to be considered as three aligned gas pores in a length of 25 mm.
2. To be in accordance with EN ISO 10042.
3. A smooth transition is required.
4. Linear misalignment is to be a maximum of 0,5 mm in highly stressed areas. For other areas, the linear misalignment is to be a maximum of 1,0 mm locally, where the sum of the length of imperfection is not more than 10% of the weld length.
5. The limits for linear misalignment relate to deviations from the correct position. Unless otherwise specified, the correct position is that when the centrelines coincide.
6. Angular misalignment shall be mutually agreed between the designer and the fabricator.

Table 13.8.3 Acceptance criteria for internal imperfections of aluminium

Internal discontinuity	Classification according to ISO 6520-1	Acceptance criteria (*see* Note 1)
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete penetration	402	Not permitted
Single gas pore	2017	$d \le 0{,}3s$ or $0{,}3a$ or 5 mm (whichever is the lesser)
Linear porosity	2014	Assess as lack of fusion
Uniformly distributed porosity (*see* Note 1)	2012	$0{,}5 < t < 3$ mm ≤ 2% of area $3 < t < 12$ mm ≤ 4% of area $12 < t < 30$ mm ≤ 6% of area $t > 30$ mm ≤ 8% of area
Clustered porosity (*see* Note 1)	2013	$dA \le 20$ mm or wp (whichever is the lesser)
Elongated cavity Wormhole	2015 2016	$l \le 0{,}3s$ or $0{,}3a$ or 4 mm (whichever is the lesser)
Oxide inclusion (*see* Note 2)	303	$l \le 0{,}5s$ or $0{,}5a$ or 5 mm (whichever is the lesser)
Tungsten inclusion	3041	$l \le 0{,}3s$ or $0{,}3a$ or 4 mm (whichever is the lesser)
Copper inclusion	3042	Not permitted
Multiple imperfections in any cross-section	—	The sum of the acceptable individual imperfections in any cross-section is not to exceed $0{,}3t$ or $0{,}3a$ (whichever is the lesser)

Symbols

- a = nominal throat thickness of a fillet weld
- b = width of weld reinforcement
- d = diameter of a gas pore
- h = height or width of an imperfection
- s = nominal butt weld thickness
- t = wall or plate thickness (nominal size)
- wp = width of weld or width or height of cross-sectional area
- dA = diameter of area surrounding gas pores
- l = length of imperfection in longitudinal direction of weld

NOTES
1. Porosity is to be determined in accordance with ISO 10042. The requirements for a single gas pore are to be met by all the gas pores within this circle. Systematic clustered porosity is not permitted.
2. If several oxide inclusions l_1, l_2, l_3, ... exist in one cross-section, then they are summed: $l = l_1 + l_2 + l_3 + ... + l_n$.

■ *Section 9* Friction stir welding requirements for aluminium alloys

9.1 Scope

9.1.1 The requirements of this Section apply to the application of FSW during construction.

9.1.2 Prior to welding, the friction stir welding equipment is to have been demonstrated as being suitable for use.

9.1.3 Qualified welding procedures that have been approved by LR are required. Procedures to ISO 25239-4 that are endorsed by another Classification Society may be accepted if they are to the satisfaction of the attending Surveyor.

9.1.4 Welding operators are to be qualified to ISO 35239-3 standard. Where qualifications have been certified by another Classification Society, acceptance of the qualifications will be subject to document review and demonstration of knowledge of the FSW process and function of the FSW installation.

9.2 Production quality control

9.2.1 The general requirements for quality control are specified in ISO 35239-5.

9.2.2 Unless otherwise specified in relevant parts of the Rules, the following production tests will be required.

9.2.3 A production test is required when there is a change in procedure, a change in tooling, after equipment repairs or modifications, after deviation from optimum parameters are detected, when defects are identified by non-destructive testing, after continuous welding of every 100 m length during a single shift and with a maximum interval between procedure tests of 8 hours. For butt welds the production tests are to consist of 100 per cent visual examination, two face bend tests, two root bend tests and one macro section. For thicknesses exceeding 12 mm, sets of face and bend tests may be replaced by side bend tests. For test assembly, *see* Fig. 13.9.1. The production tests for other joint geometry are to be agreed between the Surveyor and the fabricator.

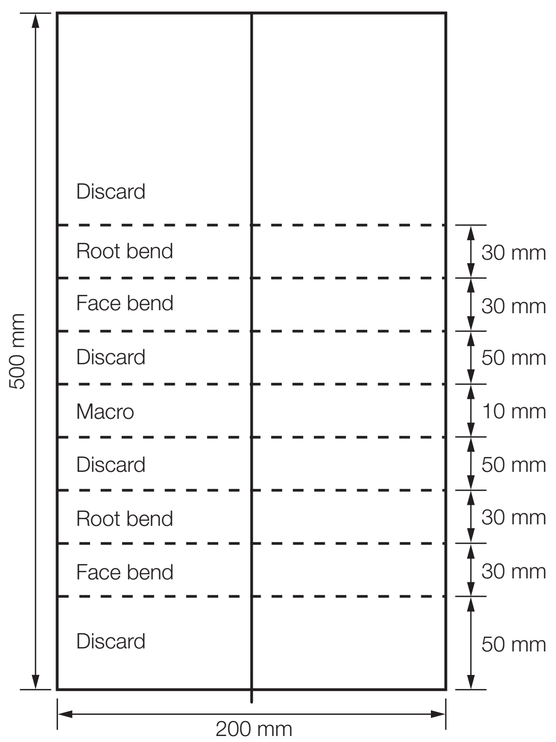


Fig. 13.9.1 Production test assembly for Friction Stir Welds

9.2.4 As an automated process, all essential variables are to be recorded by the FSW system. The welding operator is responsible for ensuring that the system continues to produce welds that are in compliance with the qualified procedure. Surveyors are to be informed when the system exceeds the operating parameters. Surveyors are periodically to review the welding records.

9.2.5 Production welds are to be subject to 100 per cent visual examination by the fabricator and be subject to random checking by the Surveyor.

9.2.6 Surface and volumetric NDE testing is to be conducted on production welds at a frequency of two per welded panel or one every 100 m of weld, whichever is the greater.

9.2.7 Assessment of imperfections is to be in accordance with ISO 35239-5 Annex A and the requirements of Table 13.8.3.

9.3 Repair

9.3.1 All defective welds are to be reported to the Surveyor.

9.3.2 The manufacturer is to have an approved procedure for the repair of defective welds.

9.3.3 Weld repairs are to be conducted by qualified welders or welding operators in accordance with qualified weld procedures. Welding procedures and welders/operators are to be qualified in accordance with the requirements of Chapter 12 as appropriate to the welding process used for the weld repair.

9.3.4 All repairs are to be subject to 100 per cent visual, surface and volumetric NDE.

Section

■ *Section 1* General requirements

1.1 Scope

1.1.1 Provision is made in this Chapter for the manufacture and testing of plastics pipes, together with approval requirements for base materials used in the construction or repair of composite vessels, other marine structures, piping and any associated machinery components and fittings which are to be certified or are intended for classification.

1.1.2 These materials and products are to be manufactured and surveyed in accordance with the general requirements of Sections 1, 2 and 3 of this Chapter; and LR's *Materials and Qualification Procedures for Ships (MQPS) Book K*, *see* Ch 1,2.2.2, which, in addition to the test programme, also details the procedures for application for approval of manufacturers and products and details of the information to be supplied by the manufacturer.

1.1.3 For base materials, the manufacturer's works do not require approval by Lloyd's Register (hereinafter referred to as 'LR'), however the Quality Control procedures must be acceptable in accordance with the appropriate Section of this Chapter.

1.1.4 Where a requirement exists for the material to be approved, the test requirements and information to be submitted for approval of polymers, resins, reinforcements and associated materials are defined in Sections 2 and 3.

1.1.5 Specific material requirements relating to the design and manufacture of plastics pipes and fittings are indicated in Section 4, with the material requirements for hull structures contained in Section 5.

1.1.6 For Builders constructing composite vessels, Section 5 provides the minimum material control requirements for acceptance of the works by LR.

1.1.7 For the purposes of these Rules a 'plastics material' is regarded as an organic substance which may be thermosetting or thermoplastic and which, in its finished state, may contain reinforcements or additives.

1.1.8 Materials not listed in 2.1.1 may be considered for approval on a case-by-case basis. The approved test results will be listed on the issued certificate. Subject to satisfactory service experience and validation of approval, the material may be entered in 2.1.1 of the Rules.

1.2 Information on material quality and application

1.2.1 Where plastics products are to be classed or certified, the manufacturer is to provide the material producer with such information as is essential to ensure that the base materials to be used are in accordance with the approval requirements and the product specification. This information is to include any survey requirements for the materials.

1.3 Manufacture

1.3.1 Plastics products are to be made at works which have been approved (or accepted) for the type of product being supplied using base materials that have been approved.

1.3.2 Base materials are to be approved in accordance with the requirements of Sections 2 and 3.

1.3.3 In order that a works can be approved (or accepted), the manufacturer is required to demonstrate to the satisfaction of LR that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel. A specified programme of tests is to be carried out under the supervision of the Surveyors, and the results are to be to the satisfaction of LR. When a manufacturer has more than one works, the approval (or acceptance) is only valid for the individual works which carried out the test programme.

1.3.4 In order to maintain approval, the manufacturer is required to confirm in writing that there have been no changes in the formulation or production process for the material in question and that the site of manufacture remains unchanged.

1.4 Survey procedure

1.4.1 The Surveyors are to be allowed access to all relevant parts of the works and are to be provided with the necessary facilities and information to enable them to verify that manufacture is being carried out in accordance with the approved procedure. Facilities are also to be provided for the selection of test material, the witnessing of specified tests and the examination of materials, as required by the Rules.

1.4.2 Prior to the provision of test material for acceptance, manufacturers are to provide the Surveyors with details of the order, specification and any special conditions additional to the Rule requirements.

1.4.3 Before final acceptance, all test materials are to be confirmed as typical of the manufactured product and be submitted to the specified tests and examinations under conditions acceptable to the Surveyors. The results are to comply with the specification and any Rule requirements and are to be to the satisfaction of the Surveyors.

1.4.4 These specified tests and examinations are to be carried out prior to the despatch of finished products from the manufacturer's works.

1.4.5 In the event of any material proving unsatisfactory, during subsequent working, machining or fabrication, it is to be rejected, notwithstanding any previous certification.

1.5 Alternative survey procedure

1.5.1 Where materials are manufactured in quantity by semi-continuous or continuous processes under closely controlled conditions, an alternative system for testing and inspection may be adopted, subject to the agreement of the Surveyors.

1.5.2 In order to be considered for approval, manufacturers are to comply with the requirements of Ch 1,2.

1.6 Post-cure heating

1.6.1 Post-cure heating is to be carried out in properly constructed ovens which are efficiently maintained and have adequate means for control and recording of temperature. The oven is to be such as to allow the whole item to be uniformly heated to the necessary temperature. In the case of very large components which require post-cure heating, alternative methods will be specially considered.

1.7 Test material

1.7.1 Sufficient material is to be provided for the preparation of the test specimens detailed in the specific requirements. It is, however, in the interests of manufacturers to provide additional material for any re-tests which may be necessary, as insufficient or unacceptable test material may be a cause for rejection.

1.7.2 Where test materials, (either base materials or product sample materials) are selected by the Surveyor or a person nominated by LR, these are to be suitably identified by markings which are to be maintained during the preparation of the test specimens.

1.7.3 All base material samples for testing are to be prepared under conditions that are as close as possible to those under which the product is to be manufactured. Where this is not possible, a suitable procedure is to be agreed with the Surveyor.

1.7.4 During production, check test samples are to be provided as requested by the Surveyor.

1.7.5 Should the taking of these samples prove impossible, model samples are to be prepared concurrently with production. The procedure for the preparation of these samples is to be agreed with the Surveyor.

1.7.6 The dimensions, number and orientation of test specimens are to be in accordance with the requirements of a National or International Standard acceptable to LR.

1.8 Re-test procedure

1.8.1 Where test material fails to meet the specified requirement, two additional tests of the same type may be made at the discretion of the Surveyor.

1.8.2 Where an individual test result in a group, (minimum five) deviates from the mean by more than two standard deviations in either the higher or lower direction, the result is to be excluded and a re-test made. Excluded results of tests are to be reported with confirmation that they have been excluded. Only one exclusion is acceptable in any group of tests.

1.9 Visual and non-destructive examination

1.9.1 Prior to the final acceptance, surface inspection, verification of dimensions and non-destructive examination are to be carried out in accordance with the requirements detailed in Sections 3, 4 and 5 of this Chapter.

1.9.2 When there is visible evidence to doubt the soundness of any material or component, such as flaws or suspicious surface marks, it is to be the responsibility of the manufacturer to prove the quality of the material by any suitable method.

1.10 Rectification of defective material

1.10.1 Small surface blemishes may be removed by mechanical means provided that, after such treatment, the dimensions are acceptable, the area is proved free from structural defects and the rectification has been completed to the satisfaction of the Surveyor.

1.10.2 Repair procedures for larger defects are to be agreed with LR prior to implementation.

1.11 Identification of products and base materials

1.11.1 The manufacturer of approved materials is to identify each batch with a unique number.

1.11.2 The manufacturer of plastics products is to adopt a system of identification which will enable all finished products to be traced to the original batches of base materials. Surveyors are to be given full facilities for tracing any component or material when required.

1.11.3 When any item has been identified by the personal mark of a Surveyor, or deputy, this is not to be removed until an acceptable new identification mark has been made by a Surveyor. Failure to comply with this condition will render the item liable to rejection.

1.11.4 Before any pipe or fitting is finally accepted it is to be clearly marked by the manufacturer in at least one place with the particulars detailed in the appropriate specific requirements as given in Section 4.

1.11.5 Where a number of identical items are securely fastened together in bundles, the manufacturer need only brand the top item of each bundle. Alternatively, a durable label giving the required particulars may be attached to each bundle.

1.12 Certification

1.12.1 Certification of the finished product is to be in accordance with the requirements of the appropriate Sections.

■ *Section 2* Tests on polymers, resins, reinforcements and associated materials

2.1 Scope

2.1.1 This Section gives the tests and data required by LR for materials approval and/or inspection purposes on the following:
(a) Thermoplastic polymers.
(b) Thermosetting resins.
(c) Reinforcements.
(d) Reinforced thermoplastic polymers.
(e) Reinforced thermosetting resins.
(f) Core materials.
 (i) End-grain balsa.
 (ii) Rigid foams.
 (iii) Synthetic felt type materials.
(g) Machinery chocking compounds.
(h) Rudder and pintle bearings.
(j) Stern tube bearings.
(k) Plywoods.
(l) Adhesive and sealant materials.
(m) Repair compounds.

2.2 Thermoplastic polymers

2.2.1 The following data is to be provided by the manufacturer for each thermoplastic polymer:
(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Bulk density.
(e) Filler content, where applicable.
(f) Pigment content, where applicable.
(g) Colour.

2.2.2 Samples for testing are to be prepared by moulding or extrusion under the polymer manufacturer's recommended conditions.

2.2.3 The following tests are to be carried out on these samples:
(a) Tensile stress at yield and break.
(b) Modulus of elasticity in tension.
(c) Tensile strain at yield and break.
(d) Compressive stress at yield and break.
(e) Compressive modulus.
(f) Temperature of deflection under load.
(g) Determination of water absorption.

2.3 Thermosetting resins

2.3.1 The data listed in Table 14.2.1 is to be provided by the manufacturer for each thermosetting resin.

Table 14.2.1 Data requirements for thermosetting resins

Data	Type of resin		
	Polyester (*see* Note 3 for vinylester)	Epoxide	Phenolic
Specific gravity of liquid resin	required	required	required
Viscosity	required	required	required
Gel time	required	required	not applicable
Appearance	required	required	required
Mineral content (*see* Note 1)	required	required	not applicable (*see* Note 2)
Volatile content	required	not applicable	not applicable
Acid value	required	not applicable	not applicable
Epoxide content	not applicable	required	not applicable
Free phenol	not applicable	not applicable	required
Free formaldehyde	not applicable	not applicable	required

NOTES
1. This is to be the total filler in the system, including thixotrope, filler, pigments, etc., and is to be expressed in parts by weight per hundred parts of pure resin.
2. If the resin is pre-filled, the mineral content is required.
3. Vinylesters are to be treated as equivalent to polyesters.

2.3.2 Cast samples are to be prepared in accordance with the manufacturer's recommendations and are to be cured and post-cured in a manner consistent with the intended use. The curing system used and the ratio of curing agent (or catalyst) to resin are to be recorded. Where post-cure conditions equivalent to ambient-cure conditions apply, *see* 3.2.2 and 3.2.3.

2.3.3 The following are to be determined using these samples:

(a) Tensile strength (stress at maximum load) and stress at break.
(b) Tensile strain at maximum load.
(c) Tensile secant modulus at 0,5 per cent and 0,25 per cent strain respectively.
(d) Temperature of deflection under load.
(e) Barcol hardness.
(f) Determination of water absorption.
(g) Volume shrinkage after cure.
(h) Specific gravity of cast resin.

2.3.4 In addition, for gel coat resins the stress at break and modulus of elasticity in flexure are to be determined.

2.3.5 Where resins which have been modified by the addition of waxes or polymers, for example 'low styrene emission or air inhibited' materials, it is to be confirmed that the use of such resins will not result in poor interlaminar adhesion when interruptions to the laminating process occur. The test procedure is to be as follows:

(a) A conventional room temperature curing catalyst/ accelerator system is to be used with the resin for laminate preparation.
(b) A laminate of 25 to 35 per cent glass content in mass is to be prepared using two plies of 450 g/m^2 chopped strand mat. The laminate is to be prepared at ambient temperature (18° to 21°C). The laminate is to be allowed to stand for a minimum of four days but no longer than 6 days at ambient temperature.
(c) A further two plies of 450 g/m^2 chopped strand mat are to be laminated onto the exposed surface and cured at ambient temperature for 24 hours. The finished laminate is then to be post-cured at 40°C for 16 hours. The finished laminate is to have a glass content of 25 to 35 per cent.
(d) After cooling, the apparent interlaminar shear strength of the laminate is to be determined in accordance with ISO 14130; the minimum value is given in Table 14.5.5. Before testing the samples shall be conditioned at 23°C and relative humidity of 50 per cent for a period of 88 hours before testing.
(e) If the tests are undertaken at the resin manufacturer's own laboratory, the individual test values are to be reported and the broken test specimens retained for examination by LR.

Alternative test procedures will be considered with prior agreement.

2.4 Reinforcements

2.4.1 The following data is to be provided, where applicable, for each type of reinforcement:

(a) Reinforcement type.
(b) Fibre type for each direction.
(c) Fibre tex value.
(d) Fibre finish and/or treatment.
(e) Yarn count in each direction.
(f) Width of manufactured reinforcement.
(g) Weight per unit area of manufactured reinforcement.
(h) Weight per linear metre of manufactured reinforcement.
(j) Compatibility (e.g. suitable for polyesters, epoxides, etc.).
(k) Constructional stitching – details of yarn, specific gravity, type, frequency and direction.
(l) Weave type.
(m) Binder type and content.
(n) Density of the fibre material.

2.4.2 Tests of the mechanical properties are to be made on laminate samples containing the reinforcement and prepared as follows:

(a) an approved resin of suitable type is to be used;
(b) a minimum of three layers of the reinforcement is to be laid with parallel ply to give a laminate not less than 4 mm thick;
(c) the weights of resin and reinforcement used are to be recorded together with the measured thickness of the laminate, including the measured weight per unit area of the reinforcement used;
(d) for glass reinforcements, the glass/resin ratios, by weight, as shown in Table 14.2.2 are to be used;
(e) for reinforcement type other than glass, a fibre volume fraction, as shown in Table 14.2.3, is to be used.

Table 14.2.2 Glass fraction by weight for different reinforcement types

Reinforcement type	Glass fraction nominal values
Unidirectional	0,60
Chopped strand mat	0,30
Woven roving	0,50
Woven cloth	0,50
Composite roving (*see* Note)	0,45
Gun rovings	0,33
±45° stitched parallel plied roving	0,50
Triaxial parallel plied roving	0,50
Quadriaxial parallel plied roving	0,50
NOTE Continuous fibre reinforcement with attached chopped strand mat.	

2.4.3 Rovings intended for filament winding are to be tested as unidirectional rovings.

2.4.4 The following tests as defined in Section 3 are to be made on the samples:

(a) Tensile strength (stress at maximum load).
(b) Tensile strain at break.
(c) Tensile secant modulus at 0,5 per cent and 0,25 per cent strain respectively.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus.
(f) Flexural strength (stress at maximum load).
(g) Modulus of elasticity in flexure.
(h) Apparent interlaminar shear.

Table 14.2.3 Content by volume for different reinforcement types

Reinforcement type	Content by volume nominal values
Unidirectional	0,41
Chopped strand mat	0,17
Woven roving	0,32
Woven cloth	0,32
Composite roving (*see* Note)	0,28
Gun rovings	0,19
±45° stitched parallel plied roving	0,32
Triaxial parallel plied roving	0,32
Quadriaxial parallel plied roving	0,32

NOTE
The volume content may be converted to weight fractions by use of the formula:

$W_F = V_F D_F / (D_F V_F + D_R V_R)$

where

W_F = fibre fraction by weight
D_F = density of fibre
D_R = density of cured resin
V_F = fibre fraction by volume
V_R = resin fraction by volume

(j) Fibre content.
(k) Determination of water absorption.

2.4.5 The laminate is to be tested in air in the directions indicated by Table 14.2.4.

Table 14.2.4 Fibre orientations in reinforced test specimens

Type of reinforcement	Test orientations
Unidirectional	0°
Chopped strand mat Gun roving	any direction
Woven roving Woven cloth Composite roving	0° and 90°
± 45° parallel plied roving Triaxial plied roving Quadriaxial plied roving	0°, 45°, 90° and –45°

2.4.6 Additionally, tests in 2.4.4(c) and (f) are to be repeated, in one direction only, after immersion in fresh water at 35°C for 28 days with the exception of 2.4.4(k).

2.5 Reinforced thermoplastic polymers

2.5.1 Thermoplastic polymers intended for use with reinforcements are to be tested in accordance with 2.2.1 to 2.2.3.

2.5.2 A laminate is to be prepared using the polymer and an approved reinforcement in accordance with a manufacturing specification. The laminate is to be tested in accordance with the appropriate requirements of 2.4.4. Testing may be confined to one direction only.

2.6 Reinforced thermosetting resins

2.6.1 Thermosetting resins intended for use with reinforcements are to be tested in accordance with 2.3.1 to 2.3.4.

2.6.2 No further tests are required for gel coat resins.

2.6.3 For laminating resins, a laminate is to be prepared using the resin and an approved reinforcement as follows:
(a) For polyester resins, chopped strand mat.
(b) For epoxide resins, a balanced woven roving.
(c) For phenolic resins, a balanced woven material.

2.6.4 The laminate is to be tested in accordance with procedures outlined in MQPS Book K procedure 14-1 and 2.4.4 in one fibre direction only.

2.7 Core materials

2.7.1 **General requirements**. The following data is to be provided for each type of core material:
(a) Type of material.
(b) Density.
(c) Description (block, scrim mounted, grooved).
(d) Thickness and tolerance.
(e) Sheet/block dimensions.
(f) Surface treatment.

2.7.2 Manufacturers are required to provide a full application procedure for use of the product.

2.8 Specific requirements for end-grain balsa

2.8.1 The supplier is to provide a signed statement that the balsa (ochroma lozopus) is cut to end-grain, is of good quality, being free from unsound or loose knots, holes, splits, rot, pith and corcho, and that it has been treated against fungal and insect attack, shortly after felling, followed by homogenisation, sterilisation and kiln drying to an average moisture content of no more than 12 per cent.

2.8.2 The following tests are to be carried out on the virgin material, both parallel to and perpendicular to the grain:
(a) Compressive strength (stress at maximum load).
(b) Compressive modulus of elasticity.
(c) Tensile strength (stress at maximum load).
The density of the virgin material is also to be tested.

2.8.3 Where the balsa is mounted on a carrier material (e.g. scrim), any adhesive used is to be of a type compatible with the proposed resin system.

2.8.4 Core shear properties are to be determined according to the requirements of 3.8.1.

2.9 Specific requirements for rigid foams (PVC, Polyurethane and other types)

2.9.1 The foam is to be of the closed cell type and compatible with the proposed resin system (e.g., polyester, epoxide, etc.).

2.9.2 Foams are to be of uniform cell structure.

2.9.3 Data is to be provided on the dimensional stability of the foam by measurement of the shrinkage.

2.9.4 The following test data is to be submitted for each type of foam:
(a) Density.
(b) Tensile strength (stress at maximum load).
(c) Tensile modulus of elasticity.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus of elasticity.

2.9.5 Core shear properties are to be determined according to the requirements of 3.8.1.

2.9.6 Additionally, the compressive properties (*see* 2.9.4(d) and (e)) are to be determined at a minimum of five points over the temperature range ambient to maximum recommended service or 70°C, whichever is the greater.

2.10 Synthetic felt type materials with or without microspheres

2.10.1 For materials of this type, the following data is required in addition to the requirements of 2.7.1:
(a) Fibre type.
(b) Width.
(c) Width of finished material.
(d) Weight per unit area of the manufactured material.
(e) Weight per linear metre of the manufactured material.
(f) Compatibility.
(g) Details of the method of combining.

2.10.2 A laminate of the material is to be prepared using a suitable approved resin under conditions recommended by the manufacturer.

2.10.3 The following properties are to be determined:
(a) Tensile strength (stress at maximum load).
(b) Tensile strain at break.
(c) Modulus of elasticity in tension or secant modulus at 0,25 per cent and 0,5 per cent strain.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus.
(f) Flexural strength (stress at maximum load).
(g) Modulus of elasticity in flexure.
(h) Fibre content.
(j) Water absorption.

2.10.4 In the case of anisotropic materials (e.g., where combined with other reinforcements) the tests listed in 2.10.3 are to be conducted in the 0°, 90° directions and in any other reinforcement direction.

2.10.5 Additionally, the tests listed in 2.10.3 are to be repeated after immersion in fresh water at 35°C for 28 days. For anisotropic materials, the requirement is for this test to be carried out in one direction only.

2.10.6 The shear properties (of the resin filled system) are to be determined according to 3.8.1.

2.11 Machinery chocking compounds (resin chocks)

2.11.1 Thermosetting materials for filling the space between the base of machinery and its foundation where the maintenance of accurate alignment is necessary are to be approved by LR before use.

2.11.2 Approval will be considered by LR for use under the following service conditions:
- Loading of 3,5 N/mm^2 (max) for a temperature not exceeding 60°C.
- Loading of 2,5 N/mm^2 (max) for a temperature not exceeding 80°C.
- Other loading conditions.

2.11.3 The exotherm temperature, defined as the maximum temperature achieved by the reacting resin under conditions equivalent to those of intended use, is to be determined according to a procedure approved by LR.

2.11.4 The following properties are to be determined on chock material cured at the measured exotherm temperature:
(a) The impact resistance (Izod).
(b) Hardness.
(c) Compressive strength (stress at maximum load) and modulus of elasticity.
(d) Water absorption.
(e) Oil absorption.
(f) Heat deflection temperature.
(g) Compressive creep is to be measured according to 3.9.4.
(h) Curing linear shrinkage.
(j) Flammability.

2.11.5 The chocking compound approval is contingent on the material achieving the minimum exotherm value as specified when used on an installation under practical conditions.

2.11.6 Where the resin chock is to be used for installation of sterntubes and sternbushes in addition to the requirements of 2.11.4, the tensile strength and modulus of elasticity in tension are to be measured.

2.11.7 The manufacturer's installation procedure is required to be documented and is to be to the satisfaction of LR.

2.12 Rudder and pintle bearings

2.12.1 Materials used for rudder and pintle bearings are to be approved by LR before use.

2.12.2 Initial approval is to be based on a review of the following physical properties of the material:

(a) Compressive strength (stress at maximum load) and modulus of elasticity.
(b) Tensile strength (stress at maximum load) and modulus of elasticity.
(c) Shear strength (stress at maximum load).
(d) Impact strength.
(e) Swelling in oil and in water.
(f) Hardness.

2.12.3 Additionally, friction data is to be provided under both wet and dry conditions.

2.12.4 Furthermore, the installation instructions (especially recommended clearances) are to be reviewed by LR prior to provisional approval being given.

2.12.5 If the above data is satisfactory, the material will be provisionally approved until sufficient service experience has been gained.

2.13 Sterntube bearings

2.13.1 Materials used for sterntube bearings are to be approved by LR before use.

2.13.2 Approval is to be based on a review of the physical properties as given by 2.12.2.

2.13.3 Friction data is to be provided under the lubrication system(s) proposed for the material(s).

2.14 Plywoods

2.14.1 All plywoods are to be approved to BS 1088 or equivalent National or International Standard in accordance with LR's Type Approval Procedure.

2.14.2 For structural applications in the marine environment, a minimum timber rating of moderate durability according to BS 1088-1 and BS 1088-2 is required.

2.14.3 Enhancement of durability by use of preservatives is permitted, subject to each veneer layer being treated with a recognised preservative.

2.14.4 Where Okoume, as specified by BS 1088 is involved, (i.e. non-durable timber classification) this may only be used for marine structures subject to the specific application being acceptable to LR.

2.15 Adhesive and sealant materials

2.15.1 Materials of these types are to be accepted by LR before use.

2.15.2 The requirements for acceptance are dependent on the nature of the application.

2.15.3 In the first instance, the manufacturer is to submit full details of the product, procedure for method of use (including surface preparation) and the intended application. After review of these details, LR will provide a specific test schedule for confirmation of the material's properties.

2.15.4 Any acceptance granted will be limited to specific applications and will be contingent on the instructions for use being adhered to.

2.16 Repair compounds

2.16.1 Materials used for repairs are to be accepted by LR before use.

2.16.2 For acceptance purposes, the manufacturer is to submit full product details, and user instructions, listing the types of repair for which the system is to be used together with details of any installer accreditation schemes.

2.16.3 Dependent on the proposed uses, LR may require testing in accordance with a specified test programme.

2.16.4 Materials will not be accepted for the following uses unless specific evidence of their suitability is provided:

(a) Any component in rubbing contact.
(b) Any component subject to dynamic cyclic loading.
(c) Any pressure part in contact with gas or vapour.
(d) Any pressure part in contact with liquid above 3,5 bar.
(e) Any component where operating temperature exceeds 90°C.

All uses of materials of these types are subject to the discretion of the Surveyor.

■ *Section 3*
Testing procedures

3.1 General

3.1.1 This Section gives details of the test methods to be used for base materials and on finished plastics products such as fibre reinforced plastics (FRP) piping and any testing required in the construction of composite vessels.

3.1.2 In general, testing is to be carried out by a competent independent test house which, at the discretion of LR, may or may not require witnessing by the Surveyor.

3.1.3 Alternatively, testing may be carried out by the manufacturer subject to these tests being witnessed by the Surveyor.

3.1.4 All testing is to be carried out by competent personnel.

3.1.5 Unless specified otherwise, testing is to be carried out in accordance with a recognised ISO Standard, where one exists, and all test programmes are to have written procedures.

3.1.6 Alternatively, testing may be carried out in accordance with a National Standard provided that it conforms closely to an appropriate ISO standard and subject to prior agreement with the Surveyor.

3.1.7 Mechanical properties are to be established using suitable testing machines of approved types. The machines and other test equipment are to be maintained in a satisfactory and accurate condition and are to be recalibrated at approximately annual intervals. Calibration is to be undertaken by a nationally recognised authority or other organisation of standing and is to be to the satisfaction of the Surveyor. A record of all calibrations is to be kept available in the test house. The accuracy of test machines is to be within ±one per cent.

3.2 Preparation of test samples

3.2.1 Thermoplastic samples are to be prepared in accordance with the manufacturer's recommendations for moulding. For finished products, samples are to be taken from the product during production in accordance with the manufacturer's quality plan, but where this is impractical, separate test samples are to be prepared in a manner identical with that of the product.

3.2.2 Samples of thermosetting resins are to be prepared using the curing system recommended by the manufacturer and identical with that used for the finished product.

3.2.3 The post curing conditions for samples of thermosetting resins are to be as recommended by the manufacturer and identical with those used for the finished product. Where the samples are made for the general approval of a resin, the post curing conditions are to be those in which the resin is intended to be used.

3.2.4 Where curing of the product is intended to take place at room temperature, the sample is to be allowed to cure at room temperature (18 to 21°C) for 24 hours followed by a post-cure at 40°C for 16 hours.

3.2.5 Where a reinforcement is to be used, the ratio of reinforcement to resin or polymer is to be nominally the same as that of the finished product or in accordance with Table 14.2.2 or 14.2.3.

3.2.6 Where laminates are prepared specifically for approval test purposes, the reinforcement is to be laid parallel plied.

3.3 Preparation of test specimens

3.3.1 The test specimen is to be prepared in accordance with the appropriate ISO standard and the requirements of this Section.

3.3.2 Precautions are to be taken during machining to ensure that the temperature rise in the specimen is kept to a minimum.

3.4 Testing

3.4.1 Strain measurement is to be made by the use of a suitable extensometer or strain gauge.

3.4.2 The rate of strain is to be in accordance with the appropriate ISO standard.

3.4.3 The number of test specimens from each sample to be tested is to be in accordance with the ISO standard. For mechanical testing this is five.

3.5 Discarding of test specimens

3.5.1 If a test specimen fails because of faulty preparation or incorrect operation of the testing machine, it is to be discarded and replaced by a new specimen.

3.5.2 In addition, if the deviation of one result in a group of five exceeds the mean by more than two standard deviations, that result is to be discarded and one further specimen tested, *see* 1.8.1 and 1.8.2.

3.6 Reporting of results

3.6.1 All load/displacement graphs and tabulated results are to be reported, including mean values and the calculated standard deviation.

3.6.2 Additionally, full details of the sample and specimen preparation are to be provided including (where applicable):
(a) Catalyst/accelerator or curing agent types and mix ratio.
(b) Weights of resins, and/or reinforcements used.
(c) Casting/laminate dimensions.
(d) Number of layers of reinforcement used.
(e) Curing/post-curing conditions.

3.7 Tests for specific materials

3.7.1 The data requirements in 2.2 and 2.3 for thermoplastic or thermosetting resins or polymers are to be determined in accordance with suitable National or International Standards.

3.7.2 Recognised Standards to which specimens of unreinforced thermoplastic resins are to be tested are listed in Table 14.3.1.

3.7.3 Test standards for unreinforced cast thermosetting resins are given in Table 14.3.2.

3.7.4 The Standards to which laminate specimens of any type are to be tested are listed in Table 14.3.3.

Table 14.3.1 Tests for unreinforced thermoplastic resins

Test	Standard	
Tensile properties	ISO 527-2:1993	Test speed = 5 mm/min Specimen 1A or 1B
Flexural properties	ISO 178:2001	Test speed = $\frac{\text{Thickness}}{2}$ mm/min
Water absorption	ISO 62:2008	Method 1
Temperature of deflection under load	ISO 75-2:2004	Method A
Compressive properties	ISO 604:2002	Test speed – as for ductile materials

NOTES
1. Water absorption – result to be expressed as milligrams.
2. Tensile modulus values are to be determined using an extensometer which may be removed for strain to failure.

Table 14.3.2 Tests on unreinforced cast thermoset resin specimens

Test	Standard	
Tensile properties	ISO 527-2:1993	Test speed = 5 mm/min Specimen 1A or 1B
Flexural properties	ISO 178:2001	Test speed = $\frac{\text{Thickness}}{2}$ mm/min
Water absorption	ISO 62:2008	Method 1
Temperature of deflection under load	ISO 75-2:2004	Method A
Compressive properties	ISO 604:2002	Test speed = 1 mm/min

NOTES
1. ISO 62:2008 – where resins are intended for use under ambient conditions to avoid additional post-curing, the requirement in ISO 62:2008 for pre-drying the test specimen at 50°C is to be omitted. The test result is to be expressed as mg of water.
2. ISO 527-2:1993 – tensile properties are to be measured using extensometry.

3.8 Structural core materials

3.8.1 Initially, the core shear strength and modulus are to be determined by ISO 1922:2001 or ASTM C273/C273M. Test sandwich panels are then to be prepared and subjected to four-point flexural tests to determine the apparent shear properties according to ASTM C393/C393M:06 (short beam) at two representative thicknesses (i.e., 15 mm and 30 mm). Testing is to be carried out at ambient temperature and at 70°C. The following requirements are to be observed:

Table 14.3.3 Tests on laminate specimens

Test	Standard	
Tensile properties	ISO 527-4:1997	Test speed = 2 mm/min Specimens Types II or III
Flexural properties	ISO 14125:1998	Test speed = $\frac{\text{Thickness}}{2}$ mm/min Method A
Compressive properties	ISO 604:2002	Test speed = 1 mm/min
Interlaminar shear	ISO 14130:1997	
Water absorption	ISO 62:2008	Method 1
Glass content	ISO 1172:1996	

NOTES
1. ISO 62:2008 – where resins are intended for use under ambient conditions to avoid additional post-curing, the requirement in ISO 62:2008 for pre-drying the test specimen at 50°C is to be omitted. The test result is to be expressed as mg of water.
2. ISO 527-4:1997 – tensile properties are to be measured using extensometry.
3. Tensile modulus values are to be determined using an extensometer which may be removed for strain to failure.

(a) Each skin is to be identical and have a thickness not greater than 21 per cent of the nominal core thickness. For hand laid constructions, each skin is to comprise a lightweight chopped strand mat reinforcement (300 g/m^2) consolidated at a glass content, by weight, of 0,3 against the core, plus the required number of woven reinforcements consolidated, using an isophthalic polyester resin, to give a minimum glass content, by weight, of 0,5.
(b) The method of construction of the sandwich laminate is to reflect the core material manufacturer's instructions for use, i.e., application of bonding paste, surface primer or any other recommended system.
(c) Where vacuum bagging techniques or equivalent systems are used, these will be subject to individual consideration.
(d) All resins and reinforcements are to hold current LR approval.
(e) Curing conditions are to be in accordance with 3.2.3 and 3.2.4.
(f) The dimensions of the test samples should be based on the requirements of ASTM C393 Paragraph 5.1, and the ratio parameters as indicated in ASTM C393 Paragraph 5.2, using a proportional limit stress (F) for the woven roving skins of 130 N/mm^2 and a span (a_2) of not less than 400 mm.

3.8.2 For each type of test sample, the following data are to be reported, together with the submission of a representative test sample showing the mode of failure for each density of core material:
(a) Skin and core thickness, and core type and density.
(b) Resin/catalyst/accelerator ratio.
(c) Skin construction, including types and weight of reinforcements, resin(s), etc.
(d) Details of production method and curing conditions (temperature and times).
(e) Where additional preparation of the foam is involved, for example the use of primers or bonding pastes, full details are to be provided.
(f) Actual span between base supports for each type of test sample.

3.8.3 The following requirements apply to end-grain balsa:
(a) The data requirements of 2.7.1 are to be provided, where applicable, according to suitable National or International Standards.
(b) The balsa is to be tested according to the requirements of 3.8.1.
(c) The test methods for balsa are given in Table 14.3.4.

Table 14.3.4 Tests on end-grain balsa

Test	Standard
Density	ISO 845:2006
Tensile properties	ASTM C297/C297M:04 Test speed = $\frac{\text{Thickness}}{10}$ mm/min
Compressive properties	ISO 844:2007 Test speed = $\frac{\text{Thickness}}{10}$ mm/min
Shear properties	ISO 1922:2001 Test speed = 1mm/min

3.8.4 The following requirements apply to rigid foams:
(a) The data requirements of 2.7.1 are to be provided in accordance with a suitable National or International Standard.
(b) The foam is to be tested according to the requirements of 3.8.1.
(c) The test methods for rigid foams are to be in accordance with Table 14.3.4.

3.8.5 The following requirements apply to synthetic felt type materials:
(a) The data requirements of 2.10.1 are to be provided according to suitable National or International Standards.
(b) The material is to be tested according to the requirements of 3.8.1, with the following modifications:
 (i) The core of the laminate test sandwich panel is to be prepared with a fibre content as recommended by the manufacturer.
 (ii) The felt fibre/resin ratio is to be stated.
 (iii) The required test thicknesses of the cores are to be changed from 30 mm and 15 mm to 12 mm and 6 mm respectively.
(c) The prepared laminate of the base material is to be of minimum thickness 3,5 mm with a minimum of three layers.
(d) The specified tests on the laminate (*see* 2.10.3) are to be conducted according to the requirements of Table 14.3.3.

3.9 Machinery chocking compounds

3.9.1 Test samples of the cured chock resin are to be prepared under ambient conditions and then post-cured at the exotherm temperature as determined in 2.11.3.

3.9.2 The specified properties are to be determined as required by Table 14.3.5.

Table 14.3.5 Tests for machinery chocking compounds

Test	Standard
Izod Impact Resistance	ISO 180-2000 Unnotched
Barcol hardness	ASTM D2583-07 or BS 2782 part 10 Method 1001
Compressive strength	ISO 604:2002 Test speed = 1 mm/min
Water absorption	ISO 62:2008 Method 1 25 mm x 20 mm cylinder (to constant weight)
Oil absorption (light machine)	ISO 175:1999 25 mm x 20 mm cylinder (to constant weight)
Temperature of deflection under load	ISO 75-2 Method A

3.9.3 The percentage linear shrinkage of cured material is to be measured.

3.9.4 Creep is to be measured according to the following method:
(a) A 25 mm x 20 mm diameter parallel faced cylinder is to be pre-loaded against a steel base at 2,5 N/mm^2 or 3,5 N/mm^2, or at the specified higher loading condition, at ambient temperature for 16 hours.
(b) The temperature is to be increased at the rate of 8°C per hour until the service temperature (60°C or 80°C) is reached.
(c) During this time, the creep of the cylinder is to be measured at 15 minute intervals.
(d) The temperature and loading are to be maintained for a minimum of 100 days measuring the creep at intervals of 24 hours.
(e) A plot of creep in mm (linear scale) against time (log scale), together with full experimental details, is to be provided for review by LR.

3.10 Rudder and pintle bearings

3.10.1 All mechanical properties as required by 2.12 are to be measured according to suitable National or International Standards.

3.10.2 Frictional properties are to be determined according to a method agreed with LR.

3.11 Sterntube bearings

3.11.1 The requirements for sterntube bearings are as defined in 2.13.

■ *Section 4*
Plastics pipes and fittings

4.1 Scope

4.1.1 This Section gives the general requirements for plastics pipes and fittings, with or without reinforcement, intended for use in the services listed in the relevant Rules dealing with design and construction. Hoses and mechanical couplings are not covered by these requirements.

4.1.2 Pipes and fittings intended for application in Class I, Class II and Class III systems for which there are Rule requirements, are to be manufactured in accordance with the requirements of Section 1 and this Section.

4.1.3 As an alternative to 4.1.2, plastics pipes and fittings which comply with National or proprietary specifications may be accepted, provided that the specifications give reasonable equivalence to the requirements of this Section or, alternatively, are approved for a specific application. The survey and certification are however to be carried out in accordance with the requirements of this Section.

4.2 Design requirements

4.2.1 The requirements for design approval are detailed in the relevant Rules.

4.2.2 The design submission is to include a materials list with confirmation that the materials listed have properties and characteristics conforming with those values used in the design submission. As a minimum, the details given should include the following:
(a) Resin.
(b) Accelerator (type and concentration).
(c) Catalyst or curing agent (type and concentration).
(d) Reinforcement.
(e) Cure/post-cure conditions.
(f) Resin/reinforcement ratio.
(g) Wind angle (or lay-up sequence) and orientation.
(h) Dimensions and tolerances.
This submission is to include similar details for the fittings together with a description of the method of attachment of the fittings to the pipes.

4.2.3 Any alteration of the component materials or manufacturing operations from those used in the design submission will necessitate a completely new submission.

4.2.4 If the piping manufacturer anticipates the possible use of alternative materials, these should be listed in the design submission. Proof that the modified product will meet the specified requirements will be needed prior to its use.

4.3 Manufacture

4.3.1 Plastics pipes and fittings intended for use in Class I, Class II and Class III systems are to be manufactured at facilities approved by LR, using materials approved by LR.

4.3.2 A Manufacturing Specification is to be submitted. This is to contain details of the following:
(a) All constituent materials.
(b) Manufacturing procedures such as lay-up sequence or wind angle, the ratios of curing agent to resin and reinforcement to resin, the laminate thickness, the mandrel dwell time (initial cure) and the cure and post-cure conditions.
(c) Quality control procedures including details and frequency of tests on the incoming materials, tests made during production and on the finished piping.
(d) Acceptance standards and tolerances, including all dimensions.
(e) Procedures for cosmetic repair.
(f) System for traceability of the finished piping to the batches of raw materials.
(g) Method of bonding pipes and fittings.

4.3.3 Details of all raw materials are to be submitted for approval and are to be in accordance with the Manufacturing Specification and the design submission.

4.3.4 All batches of raw materials are to be provided with unique identifications by their manufacturers.

4.3.5 No batch of material is to be used later than its date of expiry.

4.3.6 The piping manufacturer is to ensure that all batches of materials are used sequentially.

4.3.7 The piping manufacturer is to maintain records of the amounts of resin and reinforcement used, in order to ensure that the proportions remain within the limits set in the Manufacturing Specification.

4.3.8 Records are to be kept of the wind angle and/or the orientation of the reinforcement.

4.3.9 The piping manufacturer is to ensure that each item of piping is traceable to the batch or batches of material used in its manufacture. The unique identifications referred to in 4.3.4 are to be included on all documents.

4.3.10 The curing oven is to be suitable for the intended purpose and all pyrometric equipment is to be calibrated at least annually and adequate records maintained.

4.3.11 The temperature of the pipe or fitting is to be controlled and recorded by the attachment of suitably placed thermocouples.

4.4 Quality assurance

4.4.1 The piping manufacturer is to have a quality assurance system approved to ISO 9001 or equivalent. This system should ensure that the pipes and fittings are produced with uniform and consistent mechanical and physical properties in accordance with acceptable standards.

4.5 Dimensional tolerances

4.5.1 Dimensions and tolerances are to conform to the Manufacturing Specification.

4.5.2 The wall thicknesses of the pipes are to be measured at intervals around the circumference and along the length in accordance with an appropriate National Standard. The thicknesses are to accord with the Manufacturing Specification.

4.5.3 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer. Occasional checking by the Surveyor does not absolve the manufacturer from this responsibility.

4.6 Composition

4.6.1 The composition of the pipes and fittings is to be in accordance with the Manufacturing Specification.

4.6.2 Where alternative materials are used (*see* 4.2.4), the manufacturer is to demonstrate to the Surveyor's satisfaction, and prior to their introduction, their suitability with respect to the performance of the piping. Otherwise, full testing as specified in 4.7 will be required.

4.7 Testing

4.7.1 For thermoplastic pipes, the polymer manufacturer is to make the following measurements on samples taken from each batch:
(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Filler/pigment content, where applicable.
(e) Tensile stress at yield and break.
(f) Tensile strain at yield and break.

4.7.2 The values obtained are to be certified by the polymer manufacturer.

4.7.3 For reinforced thermoset pipes,the resin manufacturer is to determine, on samples taken from each batch, at least the following:
(a) All resins:
  (i) Viscosity.
  (ii) Gel time.
  (iii) Filler content, where applicable.
(b) Polyester resins:
  (i) Type (orthophthalic, isophthalic, etc.).
  (ii) Volatiles content.
  (iii) Acid value.
(c) Epoxide resins:
  (i) Free epoxide content.
(d) Phenolic resins:
  (i) Free phenol content.
  (ii) Free formaldehyde content.

4.7.4 The values obtained are to comply with the requirements of the Manufacturing Specification.

4.7.5 Where the resin manufacturer mixes batches, both the original batches and the mixed batch are to be tested in accordance with 4.7.1 to 4.7.3 as appropriate. The mixed batch is then to be given a unique batch number.

4.7.6 The polymer or resin manufacturer is to demonstrate that each batch of polymer or resin satisfies the requirement for temperature of deflection under load and this is not to be less than 80°C.

4.7.7 These measurements should be repeated on each batch by the piping manufacturer. Where this is not done, LR may require that the tests be made on a random basis by an independent laboratory.

4.7.8 The piping manufacturer is to confirm, by means of tests on at least one batch in twenty, that the temperature of deflection under load exceeds the specified minimum under manufacturing conditions.

4.7.9 Where reinforcements are used, at least the following are to be recorded, where applicable:
(a) Tex of yarn(s) or roving(s).
(b) Ends per 100 mm in all reinforcement orientations.
(c) Weight per square metre.
(d) Binder/size content.
(e) Stitch type and count.
(f) Type of fibre used.
(g) Surface treatment and/or finish.

4.7.10 All items in 4.7.9 are to comply with the Manufacturing Specification.

4.7.11 The piping manufacturer is to maintain accurate records of resin and glass usage and is to calculate the resin/glass ratio on an ongoing basis.

4.7.12 During manufacture of the piping, apart from the requirements of 4.7.5, 4.7.6 and 4.7.8, tests are to be carried out on the constituents and final product in accordance with Table 14.4.1.

4.7.13 The standards of acceptance are those listed in the Manufacturing Specification approved by LR.

Table 14.4.1 Testing during manufacture of pipes

Component/ operation	Characteristic	Rate of testing
Resin/curing agent/catalyst	Gel time Rate of consumption	Two per shift Continuous
Reinforcement	Quality Wind angle Rate of consumption	Continuous Continuous Continuous
Resin/ reinforcement	Ratio	Continuous
Pipe	Post-cure: temperature of the pipe in oven	Continuous
	Cure level	At least eight per length
	Dimensions	Each length
	Hydraulic pressure test	Each length
	Electrical resistance	Each length (*see* Note)
	Hydraulic bursting test	At Surveyor's discretion
	Axial strength	At Surveyor's discretion

NOTE
Measurements of electrical resistance are only required on piping where the operating conditions given in Pt 5, Ch 12,5.2.4 of the *Rules and Regulations of the Classification of Ships* apply.

4.7.14 At the Surveyor's discretion, sections of pipe are to be subjected to hydraulic bursting tests and/or measurements of axial strength.

4.7.15 If the batch of resin or polymer, or the curing agent, or their ratio is changed during manufacture of a batch of pipes, at least two additional measurements of the gel time are to be carried out during each shift.

4.8 Visual examination

4.8.1 All pipes and fittings are to be visually examined and are to be free from surface defects and blemishes.

4.8.2 The pipes are to be reasonably straight and the cut ends are to be square to the axis of the pipe.

4.9 Hydraulic test

4.9.1 Each length of pipe is to be tested at a hydrostatic pressure not less than 1,5 times the rated pressure of the pipe.

4.9.2 The test pressure is to be maintained for sufficient time to permit proof and inspection. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test, endorsed by the Surveyor, will be accepted.

4.10 Repair procedure

4.10.1 Repairs are not allowed, with the exception of minor cosmetic blemishes as detailed in 1.10.1.

4.10.2 A repair procedure for these minor blemishes is to be included in the Manufacturing Specification.

4.11 Identification

4.11.1 All piping is to be identified in such a manner that traceability to all the component materials used in its manufacture is ensured. The Surveyor is to be given full facilities for tracing the material when required.

4.11.2 Pipes and fittings are to be permanently marked by the manufacturer by moulding, hot stamping or by any other suitable method, such as printing, in accordance with 1.11. The markings are to include:
(a) Identification number, *see* 4.11.1.
(b) LR or Lloyd's Register, and the abbreviated name of LR's local office.
(c) Manufacturer's name or trademark.
(d) Pressure rating.
(e) Design standard.
(f) Material system with which the piping is made.
(g) Maximum service temperature.

4.12 Certification

4.12.1 The manufacturer is to provide the Surveyor with copies of the test certificates or shipping statements for all material which has been accepted.

4.12.2 Each test certificate is to contain the following particulars:
(a) Purchaser's name and order number.
(b) If known, the contract number for which the piping is intended.
(c) Address to which piping is despatched.
(d) Type and specification of material.
(e) Description and dimensions.
(f) Identification number, *see* 4.11.1.
(g) Test results.

■ *Section 5* Control of material quality for composite construction

5.1 Scope

5.1.1 This Section gives the general requirements for control of material quality when used in the construction of composite craft.

5.1.2 For composite craft built under the Rules, the survey of materials is to be conducted in accordance with the requirements of Sections 1 to 3 and this Section.

5.2 Design submission

5.2.1 The requirements for design submission are detailed in the appropriate Part of the Rules which includes full information on composite materials.

5.3 Construction

5.3.1 All constructions are to be carried out using materials approved or accepted by LR.

5.3.2 All materials are to be in accordance with the approved construction documentation.

5.3.3 All batches of materials are to be provided with unique identifications by their manufacturers. Components are to be similarly identified.

5.3.4 No batch of material is to be used later than its date of expiry.

5.3.5 The Builder is to ensure that all batches of materials are used systematically and sequentially.

5.3.6 The Builder is to maintain, on a continuous basis, records of the amounts of resin and reinforcement used, in order to ensure that the proportions remain within the limits set in the construction documentation.

5.3.7 Records are to be kept of the sequence and orientation of the reinforcements.

5.3.8 The Builder is to ensure that each section of the construction is traceable to the batch or batches of material used. The unique identifications required under 1.11.1 are to be included on all relevant quality control documentation.

5.3.9 Any curing system used is to be demonstrated as suitable for the intended purpose and all pyrometric equipment is to be calibrated at least annually and adequate records maintained.

5.3.10 The post-curing temperature is to be controlled and recorded by the attachment of suitably placed thermocouples.

5.4 Quality assurance

5.4.1 Where the Builder has a quality assurance system, this is to include the requirements of this Section.

5.5 Dimensional tolerances

5.5.1 Dimensions and tolerances are to conform to the approved construction documentation.

5.5.2 The thicknesses of the laminates are, in general, to be measured at not less than ten points, evenly distributed across the surface. In the case of large sections, at least ten evenly distributed measurements are to be taken in bands across the width at maximum spacing of two metres along the length.

5.5.3 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the Builder. Monitoring and random checking by the Surveyor does not absolve the Builder from this responsibility.

5.5.4 Where ultrasonic thickness gauges are used, these are to be calibrated against an identical laminate (of measured thickness) to that on which the thickness measurement is to be carried out. If suitable pieces are not available from the construction, then a small sample of identical lay-up is to be prepared.

5.6 Material composition

5.6.1 The materials, prefabricated sections or components used are to be in accordance with the approved construction documentation.

5.6.2 Where alternative materials are used, these are to be of approved or accepted types and the manufacturer is to demonstrate to the Surveyor's satisfaction, prior to their introduction, their suitability with respect to performance, otherwise full testing as appropriate will be required.

5.7 Material testing

5.7.1 Where so required, the material manufacturer is to provide the purchaser with certificates of conformity for each batch of material supplied, indicating the relevant values specified in 5.7.4 to 5.7.8. These values are to comply with those specified by the approved construction documentation.

5.7.2 Where the Builders do not conduct verification testing of the information indicated in 5.7.4 to 5.7.8, they are to ensure that copies of all certificates of conformity (which must indicate the actual tested values) are obtained for all batches of materials received, and maintain accurate records. The Surveyor may at any time select a sample of a material for testing by an independent, where applicable, source and should such tests result in the material failing to meet the specification, then that batch will be rejected.

5.7.3 The following tests are to be carried out, where applicable, on receipt of any material:

(a) The consignment is to be divided into its respective batches and each batch is to be labelled accordingly.
(b) Each batch is to be visually examined for conformity with the batch number, visual quality and date of expiry.
(c) Each batch is to be separately labelled and stored separately.
(d) Each unit, within the batch, is to be labelled with the batch number.
(e) Records are to be maintained of the above and these are to be cross-referenced with the certificate of conformity for the material and/or the Builder's own test results.

5.7.4 For thermosetting resins, reinforced or otherwise, the resin manufacturer is to have determined, on samples taken from each batch, at least the following:

(a) All resins:
 (i) Viscosity.
 (ii) Gel time.
 (iii) Filler content, where applicable.
(b) Polyester and vinylester resins:
 (i) Type (orthophthalic, isophthalic, etc.).
 (ii) Volatiles content.
 (iii) Acid value.
(c) Epoxide resins:
 (i) Free epoxide content.
(d) Phenolic resins:
 (i) Free phenol content.
 (ii) Free formaldehyde content.

5.7.5 For thermoplastics, the polymer manufacturer is to have made the following measurements on samples taken from each batch:

(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Filler/pigment content, where applicable.
(e) Tensile stress at yield and break.
(f) Tensile strain at yield and break.

5.7.6 Where the resin or polymer manufacturer mixes batches, both the original batches and the mixed batch are to be tested in accordance with 5.7.4 or 5.7.5 as appropriate. The mixed batch is then to be given a unique batch number.

5.7.7 For reinforcements, the material manufacturer is to have recorded, where applicable, the following for each batch of material:

(a) Tex of yarn(s) or roving(s).
(b) Ends per 100 mm in all reinforcement orientations.
(c) Weight per square metre.
(d) Binder/size content.
(e) Stitch type and count.
(f) Type of fibre used.
(g) Surface treatment and/or finish.

5.7.8 For core materials, the following properties are to be recorded by the manufacturer for each batch:

(a) Type of material.
(b) Density.
(c) Description (block, scrim mounted, grooved).
(d) Thickness and tolerance.
(e) Sheet/block dimensions.
(f) Surface treatment.

Together with the following mechanical properties:
In the case of rigid foams:

(g) Compressive strength (stress at maximum load) and modulus of elasticity.
(h) Core shear strength.In the case of end-grain balsa:
(j) Tensile strength (stress at maximum load).
(k) Compressive strength (stress at maximum load) and modulus of elasticity.

5.7.9 During construction, tests are to be carried out on the constituents and final product in accordance with Table 14.5.1.

5.7.10 The standards of acceptance for testing are those listed in the material manufacturer's specification, approved construction documentation or agreed quality control procedures as applicable.

5.7.11 Laminate fibre content is to be determined at the request of the Surveyor, in particular where the thickness measured does not correlate with the specified fibre content, by weight. This will, in general, result in additional reinforcement being required.

5.7.12 If the batch of resin or polymer, or the curing agent, or their ratio is changed, at least two additional measurements of the gel time are to be carried out during each shift.

Table 14.5.1 Testing during construction

Component/operation	Characteristic	Rate of testing
Resin/curing agent/catalyst	Gel time Rate of consumption	Two per shift Continuous
Reinforcement	Quality Orientation Rate of consumption	Continuous Continuous Continuous
Resin/reinforcement	Ratio	Continuous
Construction	Temperature during cure/post cure Dimensions Cure level (Barcol) against resin manufacturer's specification Laminate thickness Laminate fibre content	Continuous Continuous against approved construction documentation At least one per square metre Continuous against material usage and approved construction documentation (*see also* 5.5.2 to 5.5.4) At the Surveyor's request (*see* 5.7.11)

5.8 Visual examination

5.8.1 All constructional mouldings and any components are to be visually examined and are to be free from surface defects and blemishes.

5.9 Repair procedure

5.9.1 Repairs of minor cosmetic blemishes are permitted providing that these are brought to the attention of the Surveyor.

5.9.2 A repair procedure for these minor blemishes is to be included in the agreed quality control procedures.

5.9.3 Structural repairs are subject to individual consideration and full written details must be approved by the plan approval office prior to introduction.

5.10 Material identification

5.10.1 Records of the construction are to be kept in such a manner that traceability of all the component materials used is ensured. The Surveyor is to be given full facilities for tracing the material's origin when required.

5.10.2 Small representative samples of each batch of material are to be retained, these being suitably labelled to ensure traceability.

5.10.3 When so requested by the Surveyor, the Builder is to provide copies of all test data and/or manufacturers' certificates of conformity appertaining to any material used.

5.11 Minimum tested requirements for material approval

5.11.1 This Section provides the minimum property values required of a material for approval or acceptance by LR and are applicable to materials cured under ambient conditions.

5.11.2 **Gel coat resins**. When the cast resin is tested according to the requirements of 2.3, Table 14.5.2 gives the minimum values for the respective properties.

5.11.3 **Laminating resins**. When tested according to the requirements of 2.3 and 2.4, Tables 14.5.3 and 14.5.4 give the minimum properties for the cast resin and chopped strand mat laminate respectively.

5.11.4 When tested to the requirements of 2.4 for reinforcements, Table 14.5.5 gives the minimum properties for laminates.

5.11.5 Alternatively, materials may be approved by use of the actual tested values whereby the approval value shall equal the mean of the tested values minus twice the standard deviation of a minimum of five tested values.

Table 14.5.2 Gel coat resins, minimum property values

Properties	Minimum value
Tensile strength (stress at maximum load)	40 N/mm^2
Tensile stress at break	40 N/mm^2
Tensile strain at maximum load	2,5%
Modulus of elasticity in tension	As measured
Flexural strength (stress at maximum load)	80 N/mm^2
Modulus of elasticity in flexure	As measured
Barcol hardness	As measured at full cure
Water absorption	70 mg (max)

Table 14.5.3 Laminating resins, minimum property values

Properties	Minimum value
Tensile strength (stress at maximum load)	40 N/mm^2
Tensile stress at break	40 N/mm^2
Tensile strain at maximum load	2,0%
Modulus of elasticity in tension	As measured
Barcol hardness	As measured at full cure
Temperature of deflection under load	55°C
NOTE These minimum values are for the recommended glass content by weight of 0,3.	

5.12 Closed cell foams for core construction based on PVC or polyurethane

5.12.1 Table 14.5.6 gives minimum values for closed cell forms for core construction based on PVC or polyurethane.

5.12.2 Other types of foam will be subjected to individual consideration. A minimum core shear strength of 0,5 N/mm^2 is to be achieved.

5.13 End-grain balsa

5.13.1 Table 14.5.7 gives the minimum property requirement for end-grain balsa.

5.14 Synthetic chocking compounds

5.14.1 After 1000 hours the chocking resin must be stabilised and maximum creep is to be less than or equal to 0,2 per cent.

Table 14.5.4 Laminating resins, minimum values for properties for CSM laminate at 0,3 glass fraction by weight

Properties	Minimum value
Tensile strength (stress at maximum load)	90 N/mm^2
Secant modulus at 0,25% and 0,5% strain respectively	6,9 kN/mm^2
Compressive strength (stress at maximum load)	125 N/mm^2
Compressive modulus	6,4 kN/mm^2
Flexural strength (stress at maximum load)	160 N/mm^2
Modulus of elasticity in flexure	5,7 kN/mm^2
Apparent interlaminar shear strength (*see* Note)	18 N/mm^2
Fibre content	As measured (0,3)
Water absorption	70 mg (max)

NOTE
Applicable only to the special test for environmental control resins.

5.14.2 Compliance with 5.14.1 is to be demonstrated at the time of chocking compound approval for a specified cure/post-cure schedule. The Izod, barcol, compression, and water and oil absorption are additionally to be determined for the creep tested cure/post cure schedule.

5.14.3 Confirmation of creep, barcol and compression will be required for cure/post-cure conditions which differ from those shown on the product approval certificate.

5.15 Other materials

5.15.1 All other materials will be subject to special consideration.

Table 14.5.5 Laminates, minimum property requirements

Material type	Property	Value
Chopped strand mat	Tensile strength (stress at maximum load) (N/mm^2)	$200G_c + 30$
	Modulus of elasticity in tension (kN/mm^2)	$15G_c + 2,4$
Bi-directional reinforcement	Tensile strength (stress at maximum load) (N/mm^2)	$400G_c – 10$
	Modulus of elasticity in tension (kN/mm^2)	$30G_c – 0,5$
Uni-directional reinforcement	Tensile strength (stress at maximum load) (N/mm^2)	$1800G_c^2 – 1400G_c + 510$
	Modulus of elasticity in tension (kN/mm^2)	$130G_c^2 – 114G_c + 39$
Chopped strand mat	Flexural (stress at maximum load) (N/mm^2)	$502G_c^2 + 114,6$
	Modulus of elasticity in flexure (kN/mm^2)	$33,4G_c^2 + 2,7$
All	Flexural strength (stress at maximum load) (N/mm^2)	$502G_c^2 + 106,8$
	Modulus of elasticity in flexure (kN/mm^2)	$33,4G_c^2 + 2,2$
	Compressive strength (stress at maximum load) (N/mm^2)	$150G_c + 72$
	Compressive modulus (kN/mm^2)	$40G_c – 6$
	Interlaminar shear strength (N/mm^2)	$22 – 13,5G_c$ (min 15)
	Water absorption (mg)	70 (maximum)
	Glass content (% by weight)	As measured

NOTES
1. After water immersion, the values shall be a minimum of 75% of the above.
2. Where materials have reinforcement in more than two directions, the requirement will be subject to individual consideration dependent on the construction.
3. G_c = glass fraction by weight.

Table 14.5.6 Minimum characteristics and mechanical properties of rigid expanded foams at 20°C

Material	Apparent density kg/m^3	Strength (stress at maximum load) (N/mm^2)			Modulus of elasticity (N/mm^2)	
		Tensile	Compressive	Shear	Compressive	Shear
Polyurethane	96	0,85	0,60	0,50	17,20	8,50
Polyvinylchloride	60					

Table 14.5.7 Minimum characteristics and mechanical properties of end-grain balsa

Apparent density (kg/m^3)	Strength (stress at maximum load) (N/mm^2)					Compressive modulus of elasticity (N/mm^2)		Shear modulus of elasticity (N/mm^2)
	Compressive		Tensile		Shear	Direction of stress		
	Direction of stress							
	Parallel to grain	Perpendicular to grain	Parallel to grain	Perpendicular to grain		Parallel to grain	Perpendicular to grain	
96	5,0	0,35	9,00	0,44	1,10	2300	35,2	105
144	10,6	0,57	14,6	0,70	1,64	3900	67,8	129
176	12,8	0,68	20,5	0,80	2,00	5300	89,6	145

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Section

■ *Section 1* Rule application

1.1 General

1.1.1 The Rules apply in general to single hull ships of normal form, proportions and speed. Relevant parameters to define what is regarded as normal are given by limitations specified at the beginning of individual ship type Chapters. Although the Rules are, in general, for steel ships of all welded construction, other materials for use in hull construction will be considered.

1.2 Exceptions

1.2.1 Ships of unusual form, proportions or speed, intended for the carriage of special cargoes, or for special or restricted service, not covered by Parts 3 and 4, will receive individual consideration based on the general standards of the Rules.

1.2.2 The requirements of 7.1 are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation, *see* Pt 1, Ch 2,2.3.

1.3 Loading

1.3.1 The Rules are framed on the understanding that ships will be properly loaded and handled; they do not, unless it is stated or implied in the class notation, provide for special distributions or concentrations of loading other than those included in the approved Loading Manual. The Committee may require additional strengthening to be fitted in any ship which, in their opinion, would otherwise be subjected to severe stresses due to particular features of the design, or where it is desired to make provision for exceptional load or ballast conditions.

1.4 Advisory services

1.4.1 The Rules do not cover certain technical characteristics, such as stability, trim, vibration, docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

1.5 Intact stability

1.5.1 New ships to which the Load Lines Conventions are applicable will be assigned Class only after it has been demonstrated that the level of intact stability is adequate, *see* Pt 1, Ch 2,1.1.9.

■ *Section 2* Direct calculations

2.1 General

2.1.1 Direct calculations may be specifically required by the Rules or may be required for ships having novel design features, as defined in 1.2 or may be submitted in support of alternative arrangements and scantlings. Lloyd's Register (hereinafter referred to as 'LR') may, when requested, undertake calculations on behalf of designers and make recommendations in regard to suitability of any required model tests.

2.1.2 Where model testing is undertaken to complement direct calculations the following details would normally be required to be submitted:
- Schedule of tests;
- details of test equipment;
- input data;
- analysis; and
- calibration procedure together with tabulated and plotted output.

2.2 Submission of direct calculations

2.2.1 LR's direct calculation procedures and facilities are summarised in the document entitled *ShipRight Procedures Overview*.

2.2.2 In cases where direct calculations have been carried out using ShipRight procedures, the following supporting information should be submitted as applicable:
(a) Reference to the ShipRight direct calculation procedure and technical program used.
(b) A description of the structural modelling.
(c) A summary of analysis parameters including properties and boundary conditions.
(d) Details of the loading conditions and the means of applying loads.
(e) A comprehensive summary of calculation results. Sample calculations should be submitted where appropriate.

2.2.3 In general, submission of large volumes of input and output data associated with such programs as finite element analysis will not be necessary.

2.2.4 The responsibility for error free specification and input of program data and the subsequent correct transposal of output rests with the Builder.

■ *Section 3* Equivalents

3.1 Alternative arrangements and scantlings

3.1.1 In addition to cases where direct calculations are specifically required by the Rules, LR will consider alternative arrangements and scantlings which have been derived by direct calculations in lieu of specific Rule requirements. All direct calculations are to be submitted for examination.

3.1.2 Where calculation procedures other than those available within ShipRight are employed, supporting documentation is to be submitted for appraisal and this is to include details of the following:

- calculation methods, assumptions and references;
- loading;
- structural modelling;
- design criteria and their derivation, e.g., permissible stresses, factors of safety against plate panel instability, etc.

3.1.3 LR will be ready to consider the use of Builders' programs for direct calculations in the following cases:

(a) Where it can be established that the program has previously been satisfactorily used to perform a direct calculation similar to that now submitted.

(b) Where sufficient information and evidence of satisfactory performance is submitted to substantiate the validity of the computation performed by the program.

■ *Section 4* National and International Regulations

4.1 International Conventions

4.1.1 The Committee, when authorised, will act on behalf of Governments and, if requested, LR will certify compliance in respect of National and International statutory safety and other requirements for passenger and cargo ships.

4.1.2 In satisfying the Load Line Conventions, the general structural strength of the ship is required to be sufficient for the draught corresponding to the freeboards to be assigned. Ships built and maintained in accordance with LR's Rules and Regulations possess adequate strength to satisfy the Load Line Conventions. However, some National Authorities may, in addition, require to be supplied with calculations of bending moments and shear forces for certain conditions of loading.

4.2 International Association of Classification Societies (IACS)

4.2.1 Where applicable, the Rules take into account unified requirements and interpretations established by IACS.

4.3 International Maritime Organization (IMO)

4.3.1 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside classification as defined in these Rules and Regulations.

■ *Section 5* Information required

5.1 General

5.1.1 The categories and lists of information required are given in 5.2.

5.1.2 Plans are generally to be submitted in triplicate, but one copy only is necessary for supporting documents and calculations.

5.1.3 Plans are to contain all necessary information to fully define the structure, including construction details, equipment and systems as appropriate.

5.1.4 Additional requirements for individual ship types are given in subsequent Chapters.

5.2 Plans and supporting calculations

5.2.1 Plans covering the following items are to be submitted:

- Midship sections showing longitudinal and transverse material.
- Profile and decks.
- Shell expansion.
- Oiltight and watertight bulkheads.
- Propeller brackets.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Hatch coamings.
- Hatch cover construction.
- Deckhouses and superstructures.
- Sternframe.
- Rudder, stock and tiller.
- Equipment.
- Loading Manuals, preliminary and final.
- Ice strengthening.
- Welding.
- Hull penetration plans.
- Support structure for masts, derrick posts or cranes.
- Bilge keels showing material grades, welded connections and detail design.

- Supporting structure of deck fittings used for towing and mooring.

5.2.2 The following supporting documents are to be submitted:

- General arrangement.
- Capacity plan.
- Lines plan or equivalent.
- Dry-docking plan.
- Freeboard plan or equivalent showing freeboards and items relative to the conditions of assignment.
- Towing and mooring arrangements plan as defined in 5.3.10.
- When the ship is required to comply with statutory damage stability criteria:
  Watertight Integrity plan or equivalent showing watertight boundaries and associated design head necessary to satisfy damage stability criteria.

5.2.3 The following supporting calculations are to be submitted:

- Calculation of Equipment Number.
- Calculation of hull girder still water bending moment and shear force as applicable.
- Calculation of midship section modulus.
- Calculations for structural items in the aft end, midship and fore end regions of the ship.
- Preliminary freeboard calculation.

5.2.4 Where an ***IWS** (In-water Survey) notation is to be assigned (*see* Pt 1, Ch 2,2.3.11), plans and information covering the following items are to be submitted:

- Details showing how rudder pintle and bush clearances are to be measured and how the security of the pintles in their sockets are to be verified with the vessel afloat.
- Details showing how stern bush clearances are to be measured with the vessel afloat.
- Details of high resistant paint, for information only.

5.2.5 Where it is intended to exchange ballast water at sea resulting in the partial filling of the ballast spaces, the scantlings and structural arrangements of the tank boundaries are to be capable of withstanding the loads imposed by the movement of the ballast water in those spaces. The magnitude of the predicted loadings, together with the scantling calculations, may require to be submitted.

5.2.6 Ships that are required to comply with SOLAS Regulation 3-6 in chapter II-1 for 'Access to and within spaces in the cargo area of oil tankers and bulk carriers' are to supply information showing attachment of the access arrangements to the ship structure. This is to include necessary strength calculations, local detail and any reinforcements.

5.2.7 Ships that are required to comply with the *Performance Standards for Protective Coatings* of SOLAS Regulation II-1/3-2 and IACS *Common Structural Rules* are to submit information on the coating specification agreed by the shipyard, the ship owner and the manufacturer, including the coating system selection, surface preparation and coating application and inspection procedure.

5.3 Plans to be supplied to the ship

5.3.1 To facilitate the ordering of materials for repairs, plans are to be carried in the ship indicating the disposition and grades (other than Grade A) of hull structural steel, the extent and location of higher tensile steel together with details of specification and mechanical properties, and any recommendations for welding, working and treatment of these steels.

5.3.2 Similar information is to be provided when aluminium alloy or other materials are used in the hull construction.

5.3.3 A copy of the final Loading Manual, when approved, and details of the loadings applicable to approved decks, hatch covers and inner bottom are to be placed on board the ship.

5.3.4 Details of any corrosion prevention systems applied or fitted, are to be placed onboard the ship.

5.3.5 For ships that are required to comply with IMO *Performance Standard for Protective Coatings*, a copy of the Coating Technical File (CTF) is to be kept onboard.

5.3.6 Details of any corrosion control system fitted are to be placed on board the ship.

5.3.7 Copies of main scantling plans are to be placed on board.

5.3.8 Where an ***IWS** (In-water Survey) notation is to be assigned, approved plans and information covering the items detailed in 5.2.4 are to be placed on board.

5.3.9 Where a ShipRight **CM** (Construction Monitoring) notation or descriptive note is to be assigned, the approved Construction Monitoring Plan (CMP), as detailed in the *ShipRight Construction Monitoring Procedures*, is to be maintained on board the ship.

5.3.10 The towing and mooring arrangements plan is to be provided on board for the guidance of the Master. The information provided on the plan is to include the following in respect of each shipboard fitting:

- Location on the ship.
- Fitting type.
- Safe working load (SWL).
- Purpose of fitting (mooring/harbour towing/escort towing).
- Manner of applying towing or mooring line load, including limiting fleet angles.
- Strength of each mooring line.
- The number of mooring lines supplied on board the ship.

This information is to be incorporated into the pilot card in order to provide the pilot with the necessary information on harbour/escorting operations.

5.4 Fire protection, detection and extinction

5.4.1 For information and plans required, *see* Pt 6, Ch 4.

Section 6
Definitions

6.1 Principal particulars

6.1.1 Rule length, L, is the distance, in metres, on the waterline at draught T, from the forward side of the stem to the after side of the rudder post or to the centre of the rudder stock if there is no rudder post. L is to be not less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on the waterline. For ships without rudders, the Rule length is to be taken as 97 per cent of the extreme length on the waterline. In ships with unusual stem or stern arrangements the Rule length, L, will be specially considered.

6.1.2 Amidships is to be taken as the middle of the Rule length, L, measuring from the forward side of the stem.

6.1.3 Breadth, B, is the greatest moulded breadth, in metres.

6.1.4 Depth, D, is measured, in metres, at the middle of the length, L, from top of keel to top of the deck beam at side on the uppermost continuous deck, or as defined in appropriate Chapters. When a rounded gunwale is arranged, the depth, D, is to be measured to the continuation of the moulded deck line.

6.1.5 Draught, T, is the summer draught, in metres, measured from top of keel, or a greater value if such a value has been specified as 'scantling draught'. Both of the draughts are to be indicated on the midship plan, irrespective of whether or not they are of the same value.

6.1.6 The block coefficient, C_b, is the moulded block coefficient at draught, T, based on Rule length, L, and moulded breadth, B, as follows:

$$C_b = \frac{\text{moulded displacement (m}^3\text{) at draught } T}{LBT}$$

6.1.7 Length between perpendiculars, L_{pp}, is the distance, in metres, on the waterline at draught T, from the fore side of the stem to the after side of the rudder post, or to the centre of the rudder stock if there is no rudder post. In ships with unusual stern arrangements the length, L_{pp}, will be specially considered. The forward perpendicular, F.P., is the perpendicular at the intersection of the waterline with the fore side of the stem. The after perpendicular, A.P., is the perpendicular at the intersection of the waterline with the after side of the rudder post. For ships without a rudder post, the A.P. is the perpendicular at the intersection of the waterline with the centreline of the rudder stock.

6.1.8 Load line length, L_L, is to be taken as 96 per cent of the total length on a waterline at 85 per cent of the least moulded depth measured from the top of the keel, or as the length from the fore side of the stem to the axis of the rudder stock on that waterline, if that is greater. In ships designed with a rake of keel, the waterline on which this length is measured is to be parallel to the designed waterline. The length L_L is to be measured in metres.

6.1.9 Load line block coefficient, C_{bL}, is defined as:

$$C_{bL} = \frac{\nabla}{L_L B T_L}$$

where

∇ = volume of the moulded displacement, in m^3, excluding appendages, taken at draught T_L

T_L = moulded draught, in metres, measured to the waterline at 85 per cent of the least moulded depth.

6.1.10 Maximum service speed, V, means the maximum ahead service speed, in knots, which the ship is designed to maintain, at the summer load waterline at maximum propeller RPM and corresponding MCR.

6.1.11 Bow reference height, H_b, is defined as:
For ships less than 250 m in length:

$$H_b = 0{,}056 L_L \left(1 - \frac{L_L}{500}\right)\left(\frac{1{,}36}{C_{bL} + 0{,}68}\right) \text{ m}$$

For ships 250 m or greater in length:

$$H_b = 7\left(\frac{1{,}36}{C_{bL} + 0{,}68}\right) \text{ m}$$

where

L_L is defined in 6.1.8
C_{bL} is defined in 6.1.9.

6.2 Freeboard deck

6.2.1 The freeboard deck is normally the uppermost complete deck exposed to weather and sea, which has permanent means of closing all openings in the weather part, and below which all openings in the sides of the ship are fitted with permanent means of watertight closing.

6.2.2 For the purposes of the Load Lines Conventions, as applicable, where the assigned summer freeboard is increased such that the resulting draught is not more than that corresponding to a minimum summer freeboard for the same ship, but with an assumed freeboard deck located a distance below the actual freeboard deck at least equal to the standard superstructure height, the related items for the conditions of assignment to the actual freeboard deck may be as required for a superstructure deck.

6.3 Weathertight

6.3.1 A closing appliance is considered weathertight if it is designed to prevent the passage of water into the ship in any sea conditions.

6.3.2 Generally, all openings in the freeboard deck and in enclosed superstructures are to be provided with weathertight closing appliances.

6.4 Watertight

6.4.1 A closing appliance is considered watertight if it is designed to prevent the passage of water in either direction under a head of water for which the surrounding structure is designed.

6.4.2 Generally, all openings below the freeboard deck in the outer shell/envelope (and in main bulkheads) are to be fitted with permanent means of watertight closing.

6.5 Position 1 and Position 2

6.5.1 For the purpose of Load Line conditions of assignment, there are two basic positions of hatchways, doorways and ventilators defined as follows:

Position 1 – Upon exposed freeboard and raised quarterdecks, and exposed superstructure decks within the forward 0,25 of the load line length.

Position 2 – Upon exposed superstructure decks abaft the forward 0,25 of the load line length and located at least one standard height of superstructure above the freeboard deck. Upon exposed superstructure decks situated within the forward 0,25 of the Load Line length and located at least two standard heights of superstructure above the freeboard deck.

6.6 Passenger ship

6.6.1 A passenger ship is a ship which carries more than 12 passengers.

6.7 Reference system

6.7.1 For hull reference purposes, the ship is divided into 21 equally spaced stations where Station 0 is the after perpendicular, Station 20 is the forward perpendicular, and Station 10 is mid–L_{pp}.

6.8 Co-ordinate system

6.8.1 Unless otherwise stated, the co-ordinate system is as shown in Fig. 1.6.1, that is, a right-hand co-ordinate system with the X axis positive forward, the Y axis positive to port and the Z axis positive upwards. Angular motions are considered positive in a clockwise direction about the X, Y or Z axes.

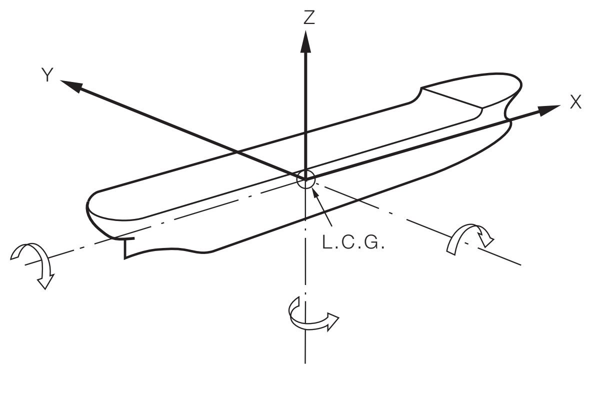


Fig. 1.6.1 Co-ordinate system

Section 7 Equipment Number

7.1 Calculation of Equipment Number

7.1.1 The equipment of anchors and chain cables specified in Ch 13,7 is based on an 'Equipment Number' which is to be calculated as follows:

$$\text{Equipment Number} = \Delta^{2/3} + 2BH + \frac{A}{10}$$

where

A = area, in m^2, in profile view of the hull, within the Rule length of the vessel, and of superstructures and houses above the summer load waterline, which are within the Rule length of the vessel, and also having a breadth greater than $\frac{B}{4}$

See also 7.1.3 and 7.1.4

B = greatest moulded breadth, in metres

H = freeboard amidships, in metres, from the summer load waterline to the upper deck, plus the sum of the heights at the centreline, in metres, of each tier of houses having a breadth greater than $\frac{B}{4}$

See also 7.1.2, 7.1.3 and 7.1.4

Δ = moulded displacement, in tonnes, to the summer load waterline.

7.1.2 In the calculation of H and A, sheer and trim are to be ignored. Where there is a local discontinuity in the upper deck, H is to be measured from a notional deckline.

7.1.3 If a house having a breadth greater than $\frac{B}{4}$ is above a house with a breadth of $\frac{B}{4}$ or less, then the wide house is to be included, but the narrow house ignored.

7.1.4 Screens and bulwarks more than 1,5 m in height are to be regarded as parts of houses when determining H and A. Where a screen or bulwark is of varying height, the portion to be included is to be that length, the height of which exceeds 1,5 m.

7.1.5 The Equipment Number for tugs is to be calculated as follows:

$$\text{Equipment Number} = \Delta^{2/3} + 2(Bf + \Sigma bh) + \frac{A}{10}$$

where

Δ, B and A are defined in 7.1.1

b = breadth, in metres, of the widest superstructure or deckhouse on each tier

f = freeboard amidships, in metres, from the summer load waterline

h = the height, in metres, of each tier of superstructure or deckhouse at side having a breadth of $\frac{B}{4}$ or greater. In the calculation of h, sheer and trim are to be ignored.

Section 8
Inspection and workmanship

8.1 Inspection

8.1.1 Adequate facilities are to be provided to enable the Surveyor to carry out a satisfactory inspection of all components during each stage of prefabrication and construction.

8.2 Workmanship

8.2.1 All workmanship is to be of good quality and in accordance with good shipbuilding practice. Any defect is to be rectified to the satisfaction of the Surveyor before the material is covered with paint, cement or other composition. The materials and welding are to be in accordance with the requirements of the Rules for Materials. The assembly sequence and welding sequence are to be agreed prior to construction and are to be to the satisfaction of the Surveyor. Plates which have been subjected to excessive heating while being worked are to be satisfactorily heat treated before being erected in the hull.

8.2.2 **Wood sheathing on decks**. Where plated decks are sheathed with wood, the sheathing is to be efficiently attached to the deck, caulked and sealed, to the satisfaction of the Surveyor.

8.2.3 **Rudder and sternframe**. The final boring out of the propeller boss and sternframe skeg or solepiece, and the fit-up and alignment of the rudder, pintles and axles, are to be carried out after completing the major part of the welding of the after part of the ship. The contacts between the conical surfaces of pintles, rudder stocks and rudder axles are to be checked before the final mounting.

8.3 Trial Trip and operational tests

8.3.1 The items listed in the Table 1.8.1 are to be tested on completion of the installation or at sea trials.

Table 1.8.1 Trial trip and operational tests

Item	Requirement
Sliding watertight doors	To be operated under working conditions.
Windlass	An anchoring test is to be carried out in the presence of the Surveyor. The test should demonstrate that the windlass with brakes, etc., functions satisfactorily, and that the power to raise anchor can be developed and satisfies the Rule requirements. For Rule requirements, *see* Ch 13,7.
Steering gear, main and auxiliary	To be tested under working conditions, to the satisfaction of the Surveyors,to demonstrate that the Rule requirements are met. For Rule requirements, *see* Pt 5, Ch 19.
Bilge suctions in holds, and hand pumps in peak spaces	To be tested under working conditions to the satisfaction of the Surveyors.

Section 9
Procedures for testing tanks and tight boundaries

9.1 General

9.1.1 The test procedures detailed in this Section are to be used to confirm the watertightness of tanks and watertight boundaries, the structural adequacy of tanks and weather-tightness of structures.

9.2 Application

9.2.1 The testing requirements for gravity tanks, defined as tanks subject to a vapour pressure not greater than 70 kN/m^2, and other boundaries required to be watertight or weathertight, are to be tested in accordance with this Section. Tests are to be carried out in the presence of a Surveyor at a stage sufficiently close to completion such that the strength and tightness are not subsequently impaired and prior to any sealing and cement work being applied over joints.

9.2.2 The testing of cargo containment systems of liquefied gas carriers are to be in accordance with the requirements of Ch 4,10 of the *Rules and Regulations for the Classification of Ships for the Carriage of Liquefied Gases in Bulk*.

9.2.3 The testing of structures not listed in this Section are to be specially considered.

Table 1.9.1 **Testing requirements** (*see continuation*)

Item to be tested	Testing procedure	Test requirement
Double bottom tanks, *see* Note 1	Leak and structural	The greater of: • head of water up to the top of the overflow • head of water 2,4 m above top of tank, *see* Note 2 • head of water up to bulkhead deck
Combined double bottom and hopper side tanks	Leak and structural	The greater of: • head of water up to the top of the overflow • head of water representing the maximum pressure experienced in service
Double bottom voids, *see* Note 3	Leak	
Double side tanks	Leak and structural	The greater of: • head of water up to the top of the overflow • head of water 2,4 m above top of tank, *see* Note 2 • head of water up to bulkhead deck
Combined double bottom, lower hopper and topside tanks	Leak and structural	
Topside tanks	Leak and structural	
Double side voids	Leak	
Deep tanks (other than those listed elsewhere)	Leak and structural	The greater of: • head of water up to the top of the overflow • head of water 2,4 m above top of tank, *see* Note 2
Cargo oil tanks, and fuel oil bunkers	Leak and structural	The greater of: • head of water up to the top of the overflow • head of water 2,4 m above top of tank, *see* Note 2 • head of water up to top of tank, *see* Note 2, plus setting of fitted pressure-relief valve
Scupper and discharge pipes in way of tanks	Leak and structural	
Ballast hold of bulk carriers	Leak and structural	The greater of: • head of water up to the top of the overflow • head of water up to the top of cargo hatch coaming
Peak tanks, *see* Note 4	Leak and structural	The greater of: • head of water up to the top of the overflow • head of water 2,4 m above top of tank, *see* Note 2
Fore peak voids	Leak	
Aft peak voids, *see* Note 4	Leak	
Cofferdams	Leak	
Watertight bulkheads	Leak	*See* Note 5
Superstructure end bulkhead	Leak	
Watertight doors below freeboard or bulkhead deck	Leak	*See* Notes 5 and 6
Double plate rudder blade	Leak	
Shaft tunnel clear of deep tanks	Leak	*See* Note 5
Shell doors when fitted in place	Leak	*See* Notes 5 and 7
Weathertight hatch covers and closing appliances	Leak	*See* Note 5
Steel hatch covers fitted to the cargo oil tanks and cargo holds of ships used for the alternate carriage of oil cargo and dry bulk cargo	Leak	*See* Note 5
Chain locker	Leak and structural	Head of water up to top of chain pipe
Independent tanks, and edible liquid tanks	Leak and structural	The greater of: • head of water up to the top of the overflow • head of water 0,9 m above top of tank, *see* Note 2
Ballast ducts	Leak and structural	The greater of: • ballast pump maximum pressure • setting of pressure-relief valve
Chemical tanker cargo tanks	Leak and structural	The greater of: • head of water 2,4 m above top of tank, *see* Note 2 • head of water up to top of tank, *see* Note 2, plus setting of fitted pressure-relief valve

Table 1.9.1 Testing requirements (*conclusion*)

NOTES
1. Including tanks arranged in accordance with the provisions of SOLAS Reg. II-1/9/4.
2. Top of tank is the deck forming the top of the tank, excluding any hatchways. In holds for liquid cargo or ballast with large hatch openings, the top of tank is to be taken to the top of the hatch.
3. Including duct keels and dry compartments arranged in accordance with the provisions of SOLAS Reg. II-1/9.4.
4. Testing of the aft peak is to be carried out after the sterntube has been fitted.
5. A hose test will be considered, *see* 9.5.2 and 9.6.3.
6. Watertight doors not confirmed watertight by a prototype test are to be subject to a hydrostatic test, *see* SOLAS Reg. II-1/16.2.
7. For shell doors providing watertight closure, watertightness is to be demonstrated through prototype testing before installation. The testing procedure is to be agreed with LR prior to testing.
8. Other testing methods listed in 9.6.7 and 9.6.8 may be considered, subject to adequacy of such testing methods being verified, *see* SOLAS Reg. II-1/11.1.

9.3 Test types

9.3.1 The types of test specified in this Section are:

(a) **Structural test**: which is to be conducted to verify the tightness and structural adequacy of the construction of tanks. This may be a hydrostatic test or, where the situation warrants, a hydropneumatic test.

(b) **Leak test**: which is to be used to verify the tightness of a boundary. Unless a specific test is indicated, this may be a hydrostatic, hydropneumatic test, air or other medium test.

9.4 Structural test procedures

9.4.1 Where a structural test is specified in Table 1.9.1, unless specified otherwise, a hydrostatic test is to be carried out in accordance with 9.6.1. Where practical limitations prevent a hydrostatic test being carried out, a hydropneumatic test in accordance with 9.6.2 is to be conducted.

9.4.2 A hydrostatic test may be carried out afloat to confirm the structural adequacy of tanks, provided a leak test is carried out beforehand and the results are confirmed as satisfactory.

9.4.3 For tanks of the same structural design, configuration and the same general workmanship, as determined by the attending Surveyor, a structural test may be carried out on only one tank, provided all subsequent tanks are tested for leaks by an air test. The relaxation to accept leak testing using an air test instead of a structural test does not apply to cargo space boundaries in tankers and combination carriers and tanks for segregated cargoes or pollutants.

9.4.4 Where the structural adequacy of a tank has been verified by structural testing on a previous vessel in a series, tanks of structural similarity on subsequent vessels within that series may be exempt from such testing, provided that the watertightness of all exempt tanks is verified by leak tests and thorough inspection. For sister ships built several years after the last ship in a series, such exemptions may be reconsidered. However, structural testing is to be carried out for at least one tank on each vessel in the series in order to verify structural fabrication adequacy. The relaxation to accept leak testing and thorough inspections instead of a structural test on subsequent vessels in a series does not apply to cargo space boundaries in tankers and combination carriers and tanks for segregated cargoes or pollutants.

9.4.5 Tanks exempted from structural testing in 9.4.3 and 9.4.4 may require structural testing if found necessary after the structural testing of the first tank.

9.4.6 For watertight boundaries of spaces other than tanks, excluding chain lockers, structural testing may be exempted, provided that the watertightness in all boundaries of exempted spaces are verified by leak tests and thorough inspection.

9.4.7 Consideration is to be given to the selection of tanks to be structurally tested. Selected tanks should be chosen so that all representative structural members are tested for the expected tension and compression.

9.5 Leak test procedures

9.5.1 Where a leak test is specified in Table 1.9.1, unless specified otherwise, a tank air test, compressed air fillet weld test, or vacuum box test is to be carried out in accordance with the applicable requirements of 9.6.4 to 9.6.6. A hydrostatic or hydropneumatic test conducted in accordance with the applicable requirements of 9.6.1 and 9.6.2 will be accepted as a leak test.

9.5.2 A hose test will be accepted as means of verifying the tightness of joints only in specific locations, identified in Table 1.9.1.

9.5.3 Air tests of joints may be conducted at any stage during construction provided that all work that might affect the tightness of the joint is completed before the test is carried out.

9.6 Definitions and details of tests

9.6.1 **Hydrostatic test** is a test conducted by filling a space with a liquid to a specified head. Unless another liquid is approved, the hydrostatic test is to consist of filling a space with either fresh or sea-water, whichever is appropriate for the space being tested, to the level specified in Table 1.9.1. For tanks intended to carry cargoes of a higher density than the test liquid, the head of the liquid is to be specially considered.

9.6.2 **Hydropneumatic test** is a combination of a hydrostatic test and a tank air test, consisting of partially filling a tank with water and conducting a tank air test on the unfilled portion of the tank. A hydropneumatic test, where approved, is to be such that the test condition in conjunction with the approved liquid level and air pressure will simulate the actual loading as far as practicable. The requirements for tank air testing shown in 9.6.4 are to be adhered to.

9.6.3 **Hose test** is a test used to verify the tightness of joints with a jet of water. It is to be carried out with the pressure in the hose nozzle maintained at not less than 2,0 bar during the test. The hose nozzle is to have a minimum inside diameter of 12 mm and is to be situated no further than 1,5 m from the joint. Where a hose test is not practical because of possible damage to machinery, electrical equipment insulation or outfitting items, it may be replaced by a careful visual examination of welded connections, supported by an ultrasonic or penetration leak test, or an equivalent, *see* SOLAS Reg. II-1/11.1.

9.6.4 **Tank air test** is to be used to verify the tightness of a compartment by means of an air pressure differential and leak detection solution. An efficient indicating solution (e.g., soapy water) is to be applied to the weld or penetration being tested and is to be examined whilst an air pressure differential of not less than 0,15 bar is applied by pumping air into the compartment. It is recommended that the air pressure in the tank be raised to and maintained at 0,20 bar above atmospheric pressure for one hour, with a minimum number of personnel in the vicinity of the tank, before being lowered to 0,15 bar above atmospheric pressure. Arrangements are to be made to ensure that any increase in air pressure does not exceed 0,30 bar. A U-tube with a height sufficient to hold a head of water corresponding to the required test pressure is to be used for verification and to avoid overpressure. The cross-sectional area of the U-tube is not to be less than that of the pipe supplying air to the tank. In addition, the test pressure is to be verified by means of a pressure gauge, or alternative equivalent system. All boundary welds, erection joints and penetrations including pipe connections in the compartment are to be examined.

9.6.5 **Compressed air fillet weld test**. This test consists of compressed air being injected into one end of a fillet welded joint and the pressure verified at the other end of the joint by a pressure gauge on the opposite side. Pressure gauges are to be arranged so that an air pressure of at least 0,15 bar above atmospheric pressure can be verified at each end of all passages within the portion being tested. A leak indicator solution is to be applied and the weld line examined for leaks. A compressed air test may be carried out for partial penetration welds where the root face is greater than 6 mm.

9.6.6 **Vacuum box test** is a test used to verify the tightness of joints by means of a localised air pressure differential and indicator solution. The test is to be conducted with the use of a box with air connections, gauges and an inspection window that is to be placed over the joint being tested with a leak indicator solution applied. Air within the box is to be removed by an ejector to create a reduction in pressure. The pressure inside the box during the test is to be maintained between 0,20 to 0,26 bar.

9.6.7 **Ultrasonic test** may be used where a hose test is not practical to verify the tightness of a boundary, *see* 9.6.3. An arrangement of ultrasonic echo transmitters is to be placed inside a compartment and a receiver outside. The receiver is to be used to detect any leaks in the compartment.

9.6.8 **Penetration test** may be used where a hose test is not practical to assess butt welds, *see* 9.6.3, by applying a low surface tension liquid to one side of a compartment boundary. When no liquid is detected on the opposite side of the boundary after expiration of a definite time, the verification of tightness of the compartment's boundary may be assumed.

9.6.9 Other methods of testing may be considered and are to be agreed by LR prior to commencement of testing.

9.7 Application of coating

9.7.1 A final coating may be applied over automatic butt welds before the completion of a leak test, provided that careful visual inspections show continuous uniform weld profile shape, free from repairs, and the results of selected NDE testing show no significant defects. For all other joints, the final coating is to be applied after the completion of a leak test. The Surveyor reserves the right to require a leak test prior to the application of the final coating over automatic erection butt welds.

9.7.2 Any temporary coating which may conceal defects or leaks is to be applied at a time as specified for the final coating, *see* 9.7.1. This requirement does not apply to shop primer.

9.8 Safe access to joints

9.8.1 For leak tests, safe access to all joints under examination is to be provided.

Section

Section 1 Materials of construction

1.1 General

1.1.1 The Rules relate in general to the construction of steel ships, although consideration will be given to the use of other materials.

1.1.2 The materials used in the construction of the ship are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). Materials for which provision is not made therein may be accepted, provided that they comply with an approved specification and such tests as may be considered necessary.

1.1.3 The requirements in this Chapter are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation (*see* Pt 1, Ch 2,2.3) with the exception of 1.2.6 and 3.2 which are to be complied with.

1.2 Steel

1.2.1 Steel having a specified minimum yield stress of 235 N/mm^2 (24 kgf/mm^2) is regarded as mild steel. Steel having a higher specified minimum yield stress is regarded as higher tensile steel.

1.2.2 For the determination of the hull girder section modulus, where higher tensile steel is used, a higher tensile steel factor, k_L, is given in Table 2.1.1.

1.2.3 The local scantling requirements of higher tensile steel plating, longitudinals, stiffeners and girders may be based on a k factor determined as follows:

$$k = \frac{235}{\sigma_o} \left(k = \frac{24}{\sigma_o}\right)$$

or 0,66, whichever is the greater,
where

σ_o = specified minimum yield stress in N/mm^2 (kgf/mm^2).

1.2.4 For the application of the requirements of 1.2.2 and 1.2.3, special consideration will be given to steel where $\sigma_o \geq 355$ N/mm^2 (36 kgf/mm^2). Where such steel grades are used in areas which are subject to fatigue loading, the structural details are to be verified using fatigue design assessment methods.

Table 2.1.1 Values of k_L

Specified minimum yield stress in N/mm^2 (kgf/mm^2)	k_L
235 (24)	1,0
265 (27)	0,92
315 (32)	0,78
355 (36)	0,72
390 (40)	0,68 (0,66 *see* Note 3)
460 (47) *see* Note 3	0,62 *see* Note 3

NOTES
1. Intermediate values by linear interpolation.
2. For the purpose of calculating hull moment of inertia as specified in Ch 4,5.8.1, k_L = 1,0.
3. Grade only applies to thickness above 50 mm for decks and hatch coamings of container ships. The requirements specified in Ch 3,3 of the Rules for Materials apply, *see* 1.2.4 and 1.2.5.

1.2.5 For container ships only, a k_L factor of 0,66 may be applied to steel with a specified minimum yield stress of 390 N/mm^2 (40 kgf/mm^2), or a k_L factor of 0,62 may be applied to steel with a specified minimum yield stress of 460 N/mm^2 (47 kgf/mm^2) for structural members that contribute to the ship's longitudinal strength, provided that:

(a) the member's plate or web thickness is greater than 50 mm;

(b) the requirements of 1.2.4 are satisfied; and

(c) a spectral fatigue assessment is carried out in accordance with *ShipRight Fatigue Design Assessment* (FDA level 3) procedure, to demonstrate that key structural details sensitive to the hull girder loads have satisfactory fatigue performance. The assessment should normally include the following:
   - Hatch corners in way of cross-deck strips;
   - Hatch corners at the forward region;
   - Hatch corners forward and aft of the engine room and the accommodation blocks;
   - Connection of hatch coaming to supporting structure; and
   - Other critical locations subject to dynamic hull girder bending and torsional effects.

In addition, the ShipRight Construction Monitoring (CM) procedure is to be applied to the fatigue critical locations described above.

1.2.6 Where steel castings or forgings are used for sternframes, rudder frames, rudder stocks, propeller shaft brackets and other major structural items, they are to comply with Chapters 4 or 5 of the Rules for Materials, as appropriate.

1.3 Aluminium

1.3.1 The use of aluminium alloy is permitted for superstructures, deckhouses, hatch covers, helicopter platforms, or other local components on board ships.

1.3.2 Aluminium is not to be used for the crowns or casings of Category A machinery spaces, *see* Pt 5, Ch 1,4.8.1.

1.3.3 Except where otherwise stated, equivalent scantlings are to be derived as follows:

Plating thickness;

$t_a = t_s \sqrt{k_a}\, c$

Section modulus of stiffeners;

$Z_a = Z_s\, k_a\, c$

where

c = 0,95 for high corrosion resistant alloy
= 1,00 for other alloys

$k_a = \dfrac{245}{\sigma_a}$

t_a = thickness of aluminium plating
t_s = thickness of mild steel plating
Z_a = section modulus of aluminium stiffener
Z_s = section modulus of mild steel stiffener
σ_a = 0,2 per cent proof stress or 70 per cent of the ultimate strength of the material, whichever is the lesser.

1.3.4 In general, for welded structure, the maximum value of σ_a to be used in the scantlings derivation is that of the aluminium in the welded condition. However, consideration will be given to using unwelded values depending upon the weld line location, other heat affected zones, in relation to the maximum applied stress on the member (e.g., extruded sections).

1.3.5 A comparison of the mechanical properties for selected welded and unwelded alloys is given in Ch 13,8.3.2 of the Rules for Materials.

1.3.6 Where strain hardened grades (designated Hxxx) are used, adequate protection by coating is to be provided to avoid the risk of stress corrosion cracking.

■ *Section 2*
Fracture control

2.1 Grades of steel

2.1.1 The resistance to fracture is controlled, in part, by the notch toughness of the steel used in the structure. Steels with different levels of notch toughness are specified in the Rules for Materials. The grade of steel to be used is, in general, related to the thickness of the material and the stress pattern associated with its location.

2.1.2 In order to distinguish between the material grade requirements for different hull members at varying locations along the ship, material classes are assigned as shown in Table 2.2.1. For each class, depending on thickness, the material grade requirements are not to be lower than those given in Table 2.2.2.

2.1.3 Where tee or cruciform connections employ full penetration welds, and the plate material is subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, as detailed in Ch 3,8 of the Rules for Materials.

2.1.4 Design for normal worldwide service assumes the navigation to areas of minus 10°C, where the design air temperature is to be taken as the lowest mean daily average air temperature in the area of operation:

where

Mean = statistical mean over a minimum of 20 years
Average = average during one day and one night
Lowest = lowest during the year
MDHT = Mean Daily High Temperature
MDAT = Mean Daily Average Temperature
MDLT = Mean Daily Low Temperature

Fig. 2.1.1 shows the definition graphically.

The material grade of exposed structure of ships intended to operate in external air temperatures below minus 10°C will be specially considered, *see also The Provisional Rules for the Winterisation of Ships*.

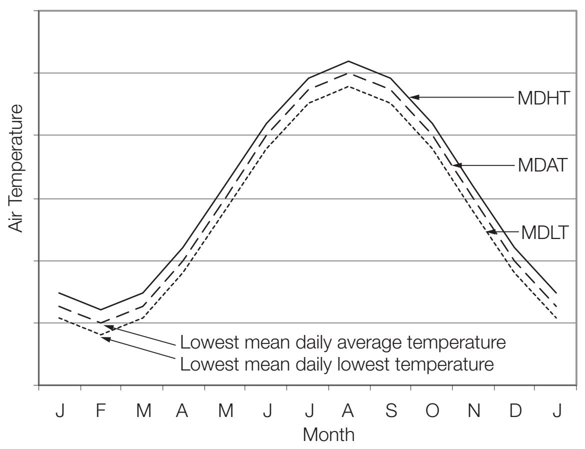


Fig. 2.1.1 Design air temperature

2.2 Refrigerated spaces

2.2.1 Where the minimum design temperature of the steel falls below 0°C in refrigerated spaces, in addition to the requirements of 2.1.2, the grade of steel for the following items is to comply, in general, with the requirements of Table 2.2.3:

- Deck plating.
- Webs of deck girders.
- Longitudinal bulkhead strakes attached to deck.
- Shelf plates and their face bars supporting hatch covers.

2.2.2 Unless a temperature gradient calculation is carried out to assess the design temperature in the items defined in 2.2.1, the temperature to which the steel deck may be subjected is to be assessed as shown in Table 2.2.4.

Table 2.2.1 Material classes and grades (*see continuation*)

Structural member category	Material class/Minimum grade
SECONDARY	
A1. Longitudinal bulkhead strakes, other than belonging to the Primary category A2. Deck plating exposed to weather, other than that belonging to the Primary or Special category A3. Side plating	Class I within 0,4*L* amidships Grade A/AH outside 0,4*L* amidships
PRIMARY	
B1. Bottom plating, including keel plate B2. Strength deck plating, excluding that belonging to the Special category B3. Continuous longitudinal plating of strength members above strength deck, excluding hatch coamings B4. Uppermost strake in longitudinal bulkhead B5. Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank	Class II within 0,4*L* amidships Grade A/AH outside 0,4*L* amidships
SPECIAL	
C1. Sheerstrake (or rounded gunwale) and stringer plate at strength deck, *see* Note 1 C2. Deck strake at longitudinal bulkhead excluding deck plating in way of inner skin bulkhead of double hull ships, *see* Note 1	Class III within 0,4*L* amidships Class II outside 0,4*L* amidships Class I outside 0,6*L* amidships
C3. Strength deck plating at outboard corners of cargo hatch openings (and plating intersections of the longitudinal underdeck girders and the cross-deck strips) in container carriers and other ships with similar hatch opening configurations	Class III within 0,4*L* amidships Class II outside 0,4*L* amidships Class I outside 0,6*L* amidships Minimum Class III within cargo region
C4. Strength deck plating at corners of cargo hatch openings in bulk carriers (*see* 1.1.3), ore carriers, combination carriers and other ships with similar hatch opening configurations C5. Trunk deck and inner deck plating at corners of openings for liquid and gas domes in membrane type liquefied gas carriers	Class III within 0,6*L* amidships Class II within rest of cargo region
C6. Bilge strake in ships with double bottom over the full breadth and length less than 150 m	Class II within 0,6*L* amidships Class I outside 0,6*L* amidships
C7. Bilge strake in other ships , *see* Note 1	Class III within 0,4*L* amidships Class II outside 0,4*L* amidships Class I outside 0,6*L* amidships
C8. Longitudinal hatch coamings of length greater than 0,15*L* including coaming top plate and flange C9. End brackets and deck house transition of longitudinal cargo hatch coamings	Class III within 0,4*L* amidships Class II outside 0,4*L* amidships Class I outside 0,6*L* amidships Not to be less than Grade D/DH
ADDITIONAL REQUIREMENTS FOR SINGLE STRENGTH DECK SHIPS OF LENGTH GREATER THAN 150 m.	
D1. Longitudinal plating of strength deck where contributing to the longitudinal strength D2. Continuous longitudinal plating of strength members above strength deck	Grade B/AH within 0,4*L* amidships
D3. Continuous longitudinal trunk deck plating of membrane type liquefied gas carriers	Class II within 0,4*L* amidships
D4. Single side strakes for ships without inner continuous longitudinal bulkhead(s) between bottom and strength deck	Grade B/AH within cargo region
ADDITIONAL REQUIREMENTS FOR SHIPS OF LENGTH GREATER THAN 250 m.	
E1. Sheerstrake (or rounded gunwale) and stringer plate at strength deck, *see* Note 2	Grade E/EH within 0,4*L* amidships
E2. Bilge strake, *see* Note 2	Grade D/DH within 0,6*L* amidships
SINGLE SKIN BULK CARRIERS SUBJECTED TO SOLAS REGULATION XII/6.5	
F1. Lower bracket of ordinary side frame, *see* Notes 6 and 7	Grade D/DH
F2. Side shell strakes included totally or partially between the two points located to 0,125*l* above and below the intersection of side shell and bilge hopper sloping plate or inner bottom plate, *see* Note 7	Grade D/DH

Table 2.2.1 Material classes and grades (*conclusion*)

NOTES
1. Single strakes required to be of Class III and within 0,4*L* amidships are to have breadths not less than 800 + 5*L* mm, but need not be greater than 1800 mm, unless limited by the geometry of the ship's design.
2. Single strakes required to be of Grade E/EH and within 0,4*L* amidships are to have breadths not less than 800 + 5*L* mm, but need not be greater than 1800 mm, unless limited by the geometry of the ship's design.
3. For strength members not mentioned, Grade A/AH may be generally used.
4. Steel grade is to correspond to the as-fitted thickness.
5. Plating materials for sternframes supporting the rudder and propeller boss, rudders, rudder horns and shaft brackets are, in general, not to be of lower grades than corresponding to Class II. For rudder and rudder body plates subjected to stress concentrations (e.g., in way of lower support of semi-spade rudders or at upper part of spade rudders) Class III is to be applied.
6. The term 'lower bracket' means webs of lower brackets and webs of the lower part of side frames up to the point of 0,125*l* above the intersection of side shell and bilge hopper sloping plate or inner bottom plate.
7. The span of the side frame, *l*, is defined as the distance between the supporting structures.
8. Corner inserts in way of complex openings such as for lifts and side doors which may impinge on the deck plating or stringer plate are to be of Grade D/DH for $t \leq 20$ mm and Grade E/EH for $t > 20$ mm.
9. The material class used for reinforcement and the quality of material (i.e., whether mild or higher tensile steel) used for welded attachments, such as waterway bars and bilge keels, is to be similar to that of the hull envelope plating in way. Where attachments are made to rounded gunwale plates, special consideration will be given to the required grade of steel, taking account of the intended structural arrangements and attachment details.
10. The material class for deck plating, sheerstrake and upper strake of longitudinal bulkhead within 0,4*L* amidships is also to be applied at structural breaks of the superstructure, irrespective of position.
11. Engine seat top plates outside 0,6*L* amidships may be Grade A/AH. Steel grade requirement for top plates within 0,6*L* amidships will be specially considered.

Table 2.2.2 Steel grades

Thickness, *t*, in mm	Material class					
	I		II		III	
	Mild steel	H.T. steel	Mild steel	H.T. steel	Mild steel	H.T. steel
$t \leq 15$	A	AH	A	AH	A	AH
$15 < t \leq 20$	A	AH	A	AH	B	AH
$20 < t \leq 25$	A	AH	B	AH	D	DH
$25 < t \leq 30$	A	AH	D	DH	D	DH
$30 < t \leq 35$	B	AH	D	DH	E	EH
$35 < t \leq 40$	B	AH	D	DH	E	EH
$t > 40$	D	DH	E	EH	E	EH

NOTE
See Notes under Table 2.2.1

Table 2.2.3 Grades of steel for refrigerated spaces with a minimum design temperature below 0°C

Minimum design temperature, in °C	Thickness, in mm	Grades of steel
< 0 to –10	$t \leq 12{,}5$ $12{,}5 < t \leq 25{,}5$ $t > 25{,}5$	B/AH D/DH E/EH
< –10 to –25	$t \leq 12{,}5$ $t > 12{,}5$	D/DH E/EH
< –25 to –40	$t \leq 12{,}5$ $t > 12{,}5$	E/EH FH/LT–FH, *see also* Ch 3,6 of the Rules for Materials

Table 2.2.4 Assessment of deck temperature

Arrangement	Deck temperature
(1) Deck not covered with insulation in the refrigerated space	Temperature of the refrigerated space
(2) Deck covered with insulation in the refrigerated space and not insulated on the other side	Temperature of the space on the uninsulated side
(3) Deck covered with insulation on both sides	
(a) Temperature difference not greater than 11°C	Mean of the temperatures of the spaces above and below the deck
(b) Temperature difference greater than 11°C but not greater than 33°C	Mean of the temperatures of the spaces above and below the deck less 3°C
(c) Temperature difference greater than 33°C	Deck temperature will be specially assessed
NOTE Where one of the internal spaces concerned is not refrigerated, the temperature of the space is to be taken as 5°C.	

■ *Section 3*
Corrosion protection

3.1 General

3.1.1 Where bimetallic connections are made, measures are to be incorporated to mitigate galvanic corrosion.

3.2 Prefabrication primers

3.2.1 Where a primer is used to coat steel after surface preparation and prior to fabrication, the composition of the coating is to be such that it will have no significant deleterious effect on subsequent welding work and that it is compatible with the paints or other coatings subsequently applied in association with an approved system of corrosion control.

3.2.2 To determine the influence of the primer coating on the characteristics of welds, tests are to be made as detailed in 3.2.3 and 3.2.5.

3.2.3 Three butt weld assemblies are to be tested using plate material 20 to 25 mm thick. A 'V' preparation is to be used and, prior to welding, the surfaces and edges are to be treated as follows:
(a) Assembly 1 – Coated in accordance with the manufacturer's instructions.
(b) Assembly 2 – Coated to a thickness approximately twice the manufacturer's instructions.
(c) Assembly 3 – Uncoated.

3.2.4 Tests as follows are to be taken from each test assembly:
(a) Radiographs. These are to have a sensitivity of better than two per cent of the plate thickness under examination, as shown by an image quality indicator.
(b) Photo-macrographs. These may be of actual size and are to be taken from near each end and from the centre of the weld.
(c) Face and reverse bend test. The test specimens are to be bent by pressure or hammer blows round a former of diameter equal to three times the plate thickness.
(d) Impact tests. These are to be carried out at ambient temperature on three Charpy V-notch test specimens prepared in accordance with Ch 2,3 of the Rules for Materials. The specimens are to be notched at the centreline of the weld, perpendicular to the plate surface.

3.2.5 The tests are to be carried out in the presence of a Surveyor to Lloyd's Register or by an independent laboratory specialising in such work. A copy of the test report is to be submitted, together with radiographs and macrographs.

3.2.6 Aluminium coatings intended for oil tankers and chemical tankers used in way of the cargo oil tanks, cargo tank deck areas, pump-rooms, cofferdams or any other area where oil vapour may accumulate are to be coated using systems containing less than 10 per cent aluminium by weight in the dry film.

3.3 Internal cathodic protection

3.3.1 When a cathodic protection system is to be fitted in tanks for the carriage of liquid cargo with flash point not exceeding 60°C, a plan showing details of the locations and attachment of anodes is to be submitted. The arrangements will be considered for safety against fire and explosion aspects only. Impressed current cathodic protection systems are not permitted in any tank.

3.3.2 Particular attention is to be given to the locations of anodes in relation to the structural arrangements and openings of the tank.

3.3.3 Anodes are to be of approved design and sufficiently rigid to avoid resonance in the anode support. Steel cores are to be fitted, and these are to be so designed as to retain the anode even when the latter is wasted.

3.3.4 Anodes are to be attached to the structure in such a way that they remain secure both initially and during service. The following methods of attachment would be acceptable:
(a) Steel core connected to the structure by continuous welding of adequate section.
(b) Steel core bolted to separate supports, provided that a minimum of two bolts with lock nuts is used at each support. The separate supports are to be connected to the structure by continuous welding of adequate section.
(c) Approved means of mechanical clamping.

3.3.5 Anodes are to be attached to stiffeners, or may be aligned in way of stiffeners on plane bulkhead plating, but they are not to be attached to the shell. The two ends are not to be attached to separate members which are capable of relative movement.

3.3.6 Where cores or supports are welded to the main structure, they are to be kept clear of the toes of brackets and similar stress raisers. Where they are welded to asymmetrical stiffeners, they are to be connected to the web with the welding kept at least 25 mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the face plate but well clear of the free edges. However, it is recommended that anodes are not fitted to face plates of higher tensile steel longitudinals.

3.4 Aluminium and magnesium anodes

3.4.1 Aluminium and aluminium alloy anodes are permitted in tanks used for the carriage of oil, but only at locations where the potential energy does not exceed 275 J (28 kgf m). The weight of the anode is to be taken as the weight at the time of fitting, including any inserts and fitting devices.

3.4.2 The height of the anode is, in general, to be measured from the bottom of the tank to the centre of the anode. Where the anode is located on, or closely above, a horizontal surface (such as a bulkhead girder) not less than 1 m wide, provided with an upstanding flange or face plate projecting not less than 75 mm above the horizontal surface, the height of the anode may be measured above that surface.

3.4.3 Aluminium anodes are not to be located under tank hatches or Butterworth openings unless protected by adjacent structure.

3.4.4 Magnesium or magnesium alloy anodes are permitted only in tanks intended solely for water ballast.

3.5 External hull protection

3.5.1 Suitable protection of the underwater portion of the hull is to be provided.

3.5.2 Where an impressed current cathodic protection system is fitted, plans showing the proposed layout of anodes and hull penetrations are to be submitted.

3.5.3 The arrangements for glands, where cables pass through the shell, are to include a small cofferdam. Cables to anodes are not to be led through tanks intended for the carriage of low flash point oils. Where cables are led through cofferdams or clean ballast tanks of tankers, they are to be enclosed in a substantial steel tube of about 10 mm thickness, *see also* Pt 6, Ch 2,14.10.

3.5.4 Where an ***IWS** (In-water Survey) notation is to be assigned, *see* Pt 1, Ch 2,2.3.11, protection of the underwater portion of the hull is to be provided by means of a suitable high resistant paint applied in accordance with the manufacturer's requirements. Details of the high resistant paint are to be submitted for information.

3.6 Application of coatings and alternative means of protection

3.6.1 For ships that are required to comply with IMO Resolution MSC.215(82), *Performance Standards for Protective Coatings* (PSPC), all dedicated sea-water ballast tanks of all types of ships and double-side skin spaces of bulk carriers are to comply with all of the requirements of the Resolution, *see* ShipRight Procedure *Anti-Corrosion Systems Notation*.

3.6.2 For ships that are required to comply with IMO Resolution MSC.288(87), *Performance Standard for Protective Coatings for Cargo Oil Tanks of Crude Oil Tankers*, all cargo oil tanks are to comply with all of the requirements of the Resolution, *see* ShipRight Procedure *Anti-Corrosion System Notation*.

3.6.3 For ships that are required to comply with the IMO Resolution MSC.289(87), *Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks of Crude Oil Tankers*, by application of Corrosion Resistant Steel, *see* Ch 3,1.3 of the Rules for Materials, all cargo oil tanks are to comply with all of the requirements of the Resolution, *see* ShipRight Procedure *Anti-Corrosion System Notation*.

3.6.4 For ships that are required to comply with IMO Resolution MSC.244(83), *Adoption of Performance Standard for Protective Coatings for Void Spaces on Bulk Carriers and Oil Tankers*, all void spaces are to comply with all of the requirements of the Resolution, *see* ShipRight Procedure *Anti-Corrosion System Notation*.

3.6.5 For ships that are not required to comply with the IMO Resolution MSC.215(82), *Performance Standards for Protective Coatings*, all sea-water ballast spaces having boundaries formed by the hull envelope are to have an efficient protective coating, epoxy or equivalent, applied in accordance with the manufacturer's recommendations, *see* ShipRight Procedure *Protective Coatings in Water Ballast Tanks (PCWBT)*.

3.6.6 The following tanks are not considered to be dedicated sea-water ballast tanks and are therefore exempted from the application and requirement of the IMO PSPC:

(a) ballast tanks identified as 'Spaces included in Net Tonnage' in the 1969 ITC Certificate;
(b) sea-water ballast tanks in passenger vessels also designated for the carriage of grey water or black water; or
(c) sea-water ballast tanks in livestock carriers also designated for the carriage of the livestock dung.

Alternative provisions are to be made for the protection of these tanks.

Section 4
Deck covering

4.1 General

4.1.1 Where plated decks are sheathed with wood or an approved composition, reductions in plate thickness may be allowed.

4.1.2 The steel deck is to be coated with a suitable material in order to prevent corrosive action, and the sheathing or composition is to be effectively secured to the deck.

4.1.3 Primary deck coverings within accommodation spaces, control stations or service spaces are to be of a type which will not readily ignite or give rise to smoke or toxic or explosive hazards at elevated temperatures in accordance with the requirements of the *International Code for the Application of Fire Test Procedures*.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter illustrates the general principles to be adopted in applying the Rule structural requirements given in Parts 3 and 4. In particular, consideration has been given to the layout of the Rules as regards the different regions of the ship, principles for taper of hull scantlings, definition of span point, derivation of section moduli and basic design loading for deck structures. Principles for subdivision are also covered.

1.1.2 Where additional requirements relating to particular ship types apply, these are, in general, dealt with under the relevant ship type Chapter in Part 4.

1.1.3 The requirements in this chapter are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation (*see* Pt 1, Ch 2,2.3) with the exception of 4.7 which is to be complied with.

■ *Section 2* Rule structural concepts

2.1 Definition of requirements

2.1.1 In Fig. 3.2.1 the breakdown of the ship into regions is shown. Within each region, the applicable Parts and Chapters of the Rules are indicated.

2.2 Definition of fore end region

2.2.1 The fore end region structure is considered to include structure forward of the midship 0,4L region.

2.3 Definition of aft end region

2.3.1 The aft end region structure is considered to include all structure aft of the midship 0,4L region.

2.4 Symbols

2.4.1 The symbols used in this Section are defined as follows:

F_D, F_B = local scantling reduction factor as defined in Ch 4,5.7

k_L, k = higher tensile steel factor, *see* Ch 2,1.2

z_D, z_B = vertical distance, in metres, from the hull transverse neutral axis to the moulded deck line at side and to the top of keel respectively

Z_{ht} = vertical extent of higher tensile steel.

2.5 Taper requirements for hull envelope

2.5.1 The thickness of the shell envelope and strength deck plating, and the modulus and sectional area of strength deck longitudinals are to taper gradually from the midship region to the fore and aft ends. For the requirements, *see* Table 3.2.1.

2.5.2 Outside the line of openings where higher tensile steel is used amidships and mild steel at the ends, the equivalent mild steel midship thickness for plating, equivalent mild steel midship deck longitudinal area and equivalent mild steel midship total deck area, for taper purposes are to be determined as follows:

(a) Equivalent mild steel value

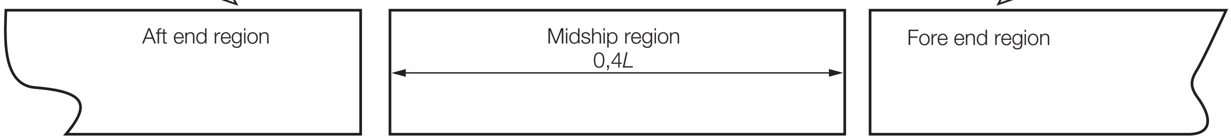
$$= \frac{\text{H.T. steel value}}{k_L}$$

(b) If the higher tensile steel plating is based on minimum thickness requirements, then:
Equivalent mild steel midship plating thickness determined from Pt 4, Ch 1 and Ch 9.

2.5.3 The transition from higher tensile steel to mild steel is to be as shown in Fig. 3.2.2 for the forward region. The transition in the aft region is to be similar to the forward region.

2.5.4 Where the higher tensile steel longitudinals extend beyond the point of transition from higher tensile to mild steel plating, the modulus of the composite section is not to be taken less than the required mild steel value at the deck plate flange, and k times the mild steel value at the higher tensile flange.

Sections covered	Part	Chapter
Rule applicability, general	3	1
Structural arrangement and taper, general	3	3
Longitudinal strength	3	4
Material and grades of steel	3	2
Corrosion control	3	2
Ice strengthening	8	1
Decks, special features	3	9



Sections covered	Part	Ch
Deck structure	3	6
Shell structure	3	6
Strengthening in panting region	3	6
After peak structure	3	6
Sternframes, shaft brackets and bossings	3	6
Rudder	3	13
Propeller hull clearances	3	6

Sections covered	Part	Ch
Deck structure	4	–
Shell structure	4	–
Hull girder section modulus	3	4
Longitudinal bulkheads	4	–
Deck girders and supporting structure	4	–
Transverse bulkheads	4	–
Inner bottom	4	–

Sections covered	Part	Ch
Deck structure	3	5
Shell structure	3	5
Stems	3	5
Deep tank forward	3	5
Strengthening in panting region	3	5
Bottom strengthening forward	3	5
Fore peak structure	3	5

Sections covered	Part	Chapter
Control systems	3	13
Superstructures, deckhouses and forecastles	3	8
Welding and structural details	3	10
Machinery space additional requirement	3	7
Hatch covers	3	11
Scuppers and sanitary discharges	3	12
Testing	3	1

Fig. 3.2.1 Rule scantlings – Schematic layout of requirements

Table 3.2.1 Taper requirements for hull envelope

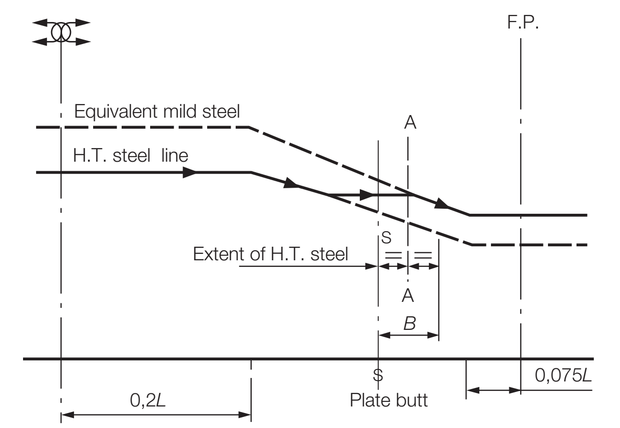
Item	Location	Requirement
Plating		
(1) Shell envelope plating, *see* Notes 1 and 2	Fore and aft ends	The thickness, in mm, is to be the greater of the following: (a) $t_t = \left[(t_c - t_{e1})\left(1 - \frac{d}{0{,}225L}\right) + t_{e1}\right]$ (*see* Note 3) (b) $t_t = (6{,}5 + 0{,}033L)\sqrt{\frac{k\,s_1}{s_b}}$
(2) Strength deck plating, *see* Notes 1 and 2	Fore and aft ends	The thickness, in mm, is to be the greater of the following: (a) $t_t = \left[(t_c - t_{e2})\left(1 - \frac{d}{0{,}225L}\right) + t_{e2}\right]$ (*see* Note 3) (b) $t_t = (5{,}5 + 0{,}02L)\sqrt{\frac{k\,s_1}{s_b}}$
Longitudinals outside 0,4*L* amidships		
(3) Strength deck, *see* Notes 1 and 2	Fore and aft ends	MODULUS The section modulus in association with deck plating, in cm^3, is to be the greater of the following: (a) $Z_t = \left[(Z_c - Z_e)\left(1 - \frac{d}{0{,}225L}\right) + Z_e\right]$ (*see* Note 3) (b) As determined by Table 5.2.3 in Chapter 5, Table 6.2.3 in Chapter 6, and Pt 4, Ch 9, as appropriate
		SECTIONAL AREA The deck longitudinals may be gradually tapered outside the 0,4*L* midships region in association with the deck plating on the basis of area. The sectional area of one longitudinal without plating, in cm^2, is to be not less than the following: $A_t = \left[(A_c - A_e)\left(1 - \frac{d}{0{,}225L}\right) + A_e\right]$ (*see* Note 3)
Strength deck area		
(4) Deck area taper, *see* Notes 1 and 2	Fore and aft ends	The total area of longitudinals and deck plating outside line of openings at midship region should have a linear taper from 0,2*L* from midships to 0,075*L* from F.P. or A.P. such that the area at 0,075*L* and 0,15*L* from F.P. or A.P. is not less than 30 and 50 per cent respectively of the total midships area, *see* Note 3.

Symbols

L, k, s as defined in Ch 5,1.4.1

d = distance, in m, from 0,2*L* forward or aft of amidships to the mid-length of the building block, strake, or longitudinal under consideration
s_b = standard frame spacing, in mm, as given in Tables 5.2.1 and 5.3.1 in Chapter 5, and Tables 6.2.1 and 6.3.1 in Chapter 6, as appropriate
s_1 = s, but is to be taken not less than s_b
t_c = actual thickness of deck or shell plating within the 0,4*L* midships region
t_{e1} = basic shell end thickness for taper and is $(6{,}5 + 0{,}033L)\sqrt{k}$ at 0,075*L* from the A.P. or F.P.
t_{e2} = basic strength deck end thickness for taper and is $(5{,}5 + 0{,}02L)\sqrt{k}$ at 0,075*L* from the A.P. or F.P.
t_t = taper thickness for strength deck and shell plating
Z_c = section modulus of deck longitudinal in association with deck plating, in cm^3, within the 0,4*L* midships region
Z_e = section modulus of deck longitudinal in association with deck plating, in cm^3, at 0,075*L* from the ends
Z_t = taper section modulus of deck longitudinal in association with deck plating, in cm^3
A_c = cross-sectional area of one longitudinal without attached plating, in cm^2, within the 0,4*L* midships region
A_e = cross-sectional area of one longitudinal without attached plating, in cm^2, at 0,075*L* from the ends
A_t = taper cross-sectional area of one longitudinal without attached plating, in cm^2

NOTES
1. For thickness of strength deck and shell plating in way of cargo tanks of double hull oil tankers, single hull oil tankers or ore carriers, *see also* Pt 4, Ch 9, Ch 10, or Ch 11 as appropriate.
2. The taper requirement does not apply to container ships or open type ships, *see* Ch 4,2.3, where the requirements of Pt 4, Ch 8,3.2 are applicable, nor to fast cargo ships where the requirements of Pt 4, Ch 1,3 are applicable. *See also* Ch 4,5 for hull section modulus requirement away from the midship area.
3. The formulae for the taper values are based on the assumption that the quality of steel is the same at amidships and ends. Where higher tensile steel is used in the midship region and mild steel at the ends, the taper values should be calculated for both qualities of steel in way of the transition from higher tensile to mild steel, and applied as determined by 2.5.2 and 2.5.3.



A – A centre of aftermost mild steel plate
B = length of aftermost mild steel plate

Fig. 3.2.2 Transition of steel grades

2.6 Vertical extent of higher tensile steel

2.6.1 Higher tensile steel may be used for both deck and bottom structures or deck structure only. Where fitted, it is to be used for the whole of the longitudinal continuous material for the following vertical distances:

(a) from the line of deck at side

$$z_{ht} = \left(1 - \frac{k_L}{F_D}\right) z_D$$

(b) from the top of keel

$$z_{ht} = \left(1 - \frac{k_L}{F_B}\right) z_B$$

In the above formulae F_D and F_B are to be taken not less than k_L.

2.7 Grouped stiffeners

2.7.1 Where stiffeners are arranged in groups of the same scantling, the section modulus requirement of each group is to be based on the greater of the following:

(a) the mean value of the section modulus required for individual stiffeners within the group;

(b) 90 per cent of the maximum section modulus required for individual stiffeners within the group.

■ *Section 3* **Structural idealisation**

3.1 General

3.1.1 For derivation of scantlings of stiffeners, beams, girders, etc., the formulae in the Rules are normally based on elastic or plastic theory using simple beam models supported at one or more points and with varying degrees of fixity at the ends, associated with an appropriate concentrated or distributed load.

3.1.2 Apart from local requirement for web thickness or flange thicknesses, the stiffener, beam or girder strength is defined by a section modulus and moment of inertia requirement.

3.2 Geometric properties of section

3.2.1 The symbols used in this sub-Section are defined as follows:

b = the actual width, in metres, of the load-bearing plating, i.e., one-half of the sum of spacings between parallel adjacent members or equivalent supports

f = $0{,}3\left(\dfrac{l}{b}\right)^{2/3}$, but is not to exceed 1,0. Values of this factor are given in Table 3.3.1

l = the overall length, in metres, of the primary support member, *see* Fig. 3.3.3

t_p = the thickness, in mm, of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

Table 3.3.1 Load bearing plating factor

$\frac{l}{b}$	f	$\frac{l}{b}$	f
0,5	0,19	3,5	0,69
1,0	0,30	4,0	0,76
1,5	0,39	4,5	0,82
2,0	0,48	5,0	0,88
2,5	0,55	5,5	0,94
3,0	0,62	6 and above	1,00

NOTE
Intermediate values to be obtained by linear interpolation.

3.2.2 The effective geometric properties of rolled or built sections may be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the attached plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

3.2.3 The geometric properties of rolled or built stiffener sections and of swedges are to be calculated in association with effective area of attached load bearing plating of thickness t_p mm and of width 600 mm or $40t_p$ mm, whichever is the greater. In no case, however, is the width of plating to be taken as greater than either the spacing of the stiffeners or the width of the flat plating between swedges, whichever is appropriate. The thickness, t_p, is the actual thickness of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

3.2.4 The effective section modulus of a corrugation over a spacing p is to be calculated from the dimensions and, for symmetrical corrugations, may be taken as:

$$Z = \frac{d_w}{6000}(3bt_p + ct_w) \quad \text{cm}^3$$

where d_w, b, t_p, c and t_w are measured, in mm, and are as shown in Fig. 3.3.1. The value of b is to be taken not greater than:

$50t_p\sqrt{k}$ for welded corrugations

$60t_p\sqrt{k}$ for cold formed corrugations

The value of θ is to be not less than 40°. The moment of inertia is to be calculated from:

$$I = \frac{Z}{10}\left(\frac{d_w}{2}\right) \text{cm}^4$$

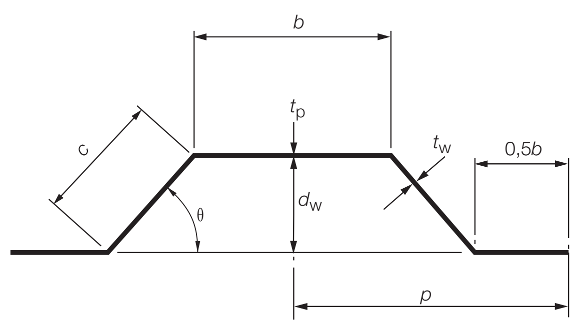


Fig. 3.3.1 Corrugation dimensions

3.2.5 The section modulus of a double plate bulkhead over a spacing b may be calculated as:

$$Z = \frac{d_w}{6000}(6f\,b\,t_p + d_w\,t_w) \quad \text{cm}^3$$

where d_w, b, t_p and t_w are measured, in mm, and are as shown in Fig. 3.3.2.

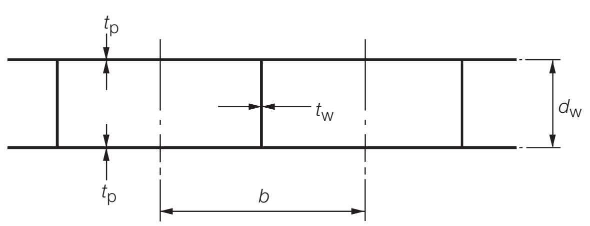


Fig. 3.3.2 Double plate bulkhead dimensions

3.2.6 The effective section modulus of a built section may be taken as:

$$Z = \frac{ad_w}{10} + \frac{t_w d_w^2}{6000}\left(1 + \frac{200\,(A - a)}{200A + t_w\,d_w}\right) \quad \text{cm}^3$$

where

a = the area of the face plate of the member, in cm^2

d_w = the depth, in mm, of the web between the inside of the face plate and the attached plating. Where the member is at right angles to a line of corrugations, the minimum depth is to be taken

t_w = the thickness of the web of the section, in mm

A = the area, in cm^2, of the attached plating, *see* 3.2.7. If the calculated value of A is less than the face area a, then A is to be taken as equal to a.

3.2.7 The geometric properties of primary support members (i.e., girders, transverses, webs, stringers, etc.) are to be calculated in association with an effective area of attached load bearing plating, A, determined as follows:

(a) For a member attached to plane plating:

$A = 10f\,b\,t_p \quad \text{cm}^2$

(b) For a member attached to corrugated plating and parallel to the corrugations:

$A = 10b\,t_p \quad \text{cm}^2$

See Fig. 3.3.1

(c) For a member attached to corrugated plating and at right angles to the corrugations:
A is to be taken as equivalent to the area of the face plate of the member.

3.3 Determination of span point

3.3.1 The effective length, l_e, of a stiffening member is generally less than the overall length, l, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined as follows:

(a) For rolled or built secondary stiffening members:
The span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member is equal to the depth of the member. Where there is no end bracket, the span point is to be measured between primary member webs. For double skin construction, the span may be reduced by the depth of primary member web stiffener, *see* Fig. 3.3.3.

(b) For primary support members:
The span point is to be taken at a point distant from the end of the member,

where $b_e = b_b\left(1 - \frac{d_w}{d_b}\right)$

See also Fig. 3.3.3.

3.3.2 Where the end connections of longitudinals are designed with brackets to achieve compliance with the *ShipRight FDA Procedure*, no reduction in span is permitted for such brackets unless the fatigue life is subsequently reassessed and shown to be adequate for the resulting reduced scantlings.

3.3.3 Where the stiffener member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

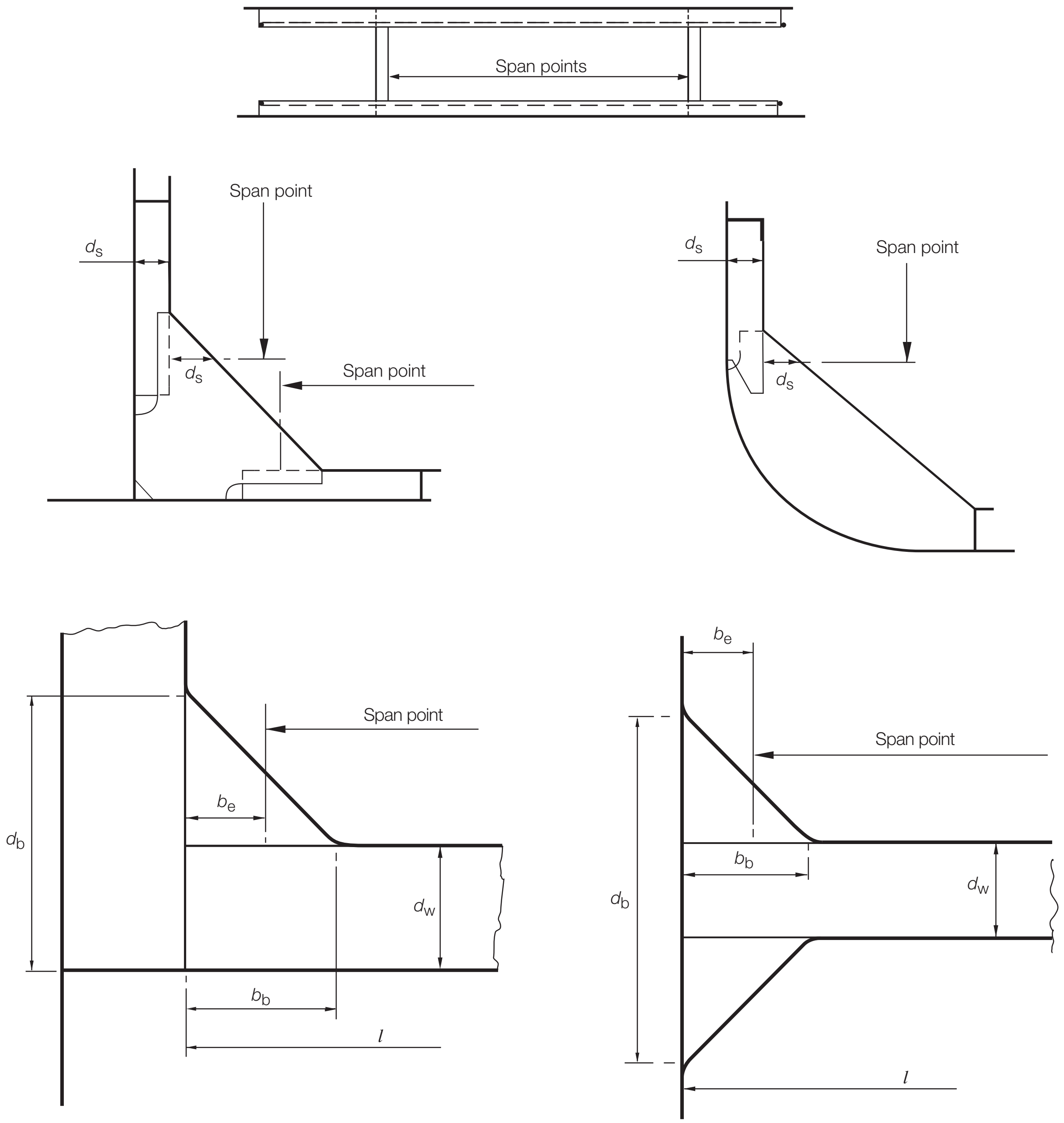


Fig. 3.3.3 Span points

3.3.4 It is assumed that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, consideration will be given to the effective span to be used for the stiffener.

3.4 Calculation of hull section modulus

3.4.1 All continuous longitudinal structural material is to be included in the calculation of the inertia of the hull midship section, and the lever *z* is, except where otherwise specified for particular ship types, to be measured vertically from the neutral axis to the top of keel and to the moulded strength deck line at the side. The strength deck is to be taken as follows:

(a) Where there is a complete upper deck and no effective superstructure, the strength deck is the upper deck.
(b) Where the upper deck is stepped, as in the case of raised quarter deck ships, or there is an effective superstructure on the upper deck, the strength deck is stepped as shown in Fig. 3.3.4.

3.4.2 An effective superstructure is one which exceeds 0,15*L* in length and extends inside the midship 0,5*L* region. Superstructure decks less than 12 m in length are not to be considered as strength deck.

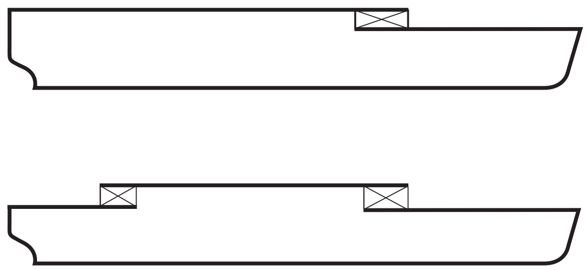


Fig. 3.3.4 Strength deck stepping

3.4.3 Openings having a length in the fore and aft direction exceeding 2,5 m or 0,1*B* m or a breadth exceeding 1,2 m or 0,04*B* m, whichever is the lesser, are always to be deducted from the sectional areas used in the section modulus calculation.

3.4.4 Smaller openings (including manholes, lightening holes, single scallops in way of seams, etc.) need not be deducted provided they are isolated and the sum of their breadths or shadow area breadths (*see* 3.4.7), in one transverse section does not reduce the section modulus at deck or bottom by more than 3 per cent.

3.4.5 Where B_1 equals the breadth of the ship at the section considered and Σb_1 equals the sum of breadths of deductible openings, the expression 0,06 ($B_1 - \Sigma b$) may be used for deck openings in lieu of the 3 per cent limitation of reduction of section modulus in 3.4.4.

3.4.6 Where a large number of openings are proposed in any transverse space, special consideration will be required.

3.4.7 When calculating deduction-free openings, the openings are assumed to have longitudinal extensions as shown by the shaded areas in Fig. 3.3.5. The shadow area is obtained by drawing two tangent lines to an opening angle of 30°. The section to be considered should be perpendicular to the centreline of the ship and should result in the maximum deduction in each transverse space.

3.4.8 Isolated openings in longitudinals or longitudinal girders need not be deducted if their depth does not exceed 25 per cent of the web depth with a maximum depth for scallops of 75 mm.

3.4.9 Openings are considered isolated if they are spaced not less than 1 m apart.

3.4.10 For compensation that may be required for openings, *see* individual ship Chapters.

3.4.11 Where trunk decks or continuous hatch coamings are effectively supported by longitudinal bulkheads or deep girders, they are to be included in the longitudinal sectional area when calculating the hull section modulus. The lever z_t is to be taken as:

$$z_t = z_c \left(0,9 + 0,2\,\frac{y}{B}\right) \text{ m but not less than } z$$

y = horizontal distance from top of continuous strength member to the centreline of the ship, in metres

z = vertical distance from the neutral axis to the moulded deck line at side, in metres

z_c = vertical distance from the neutral axis to the top of the continuous strength member, in metres

z_c and y are to be measured to the point giving the largest value of z_t.

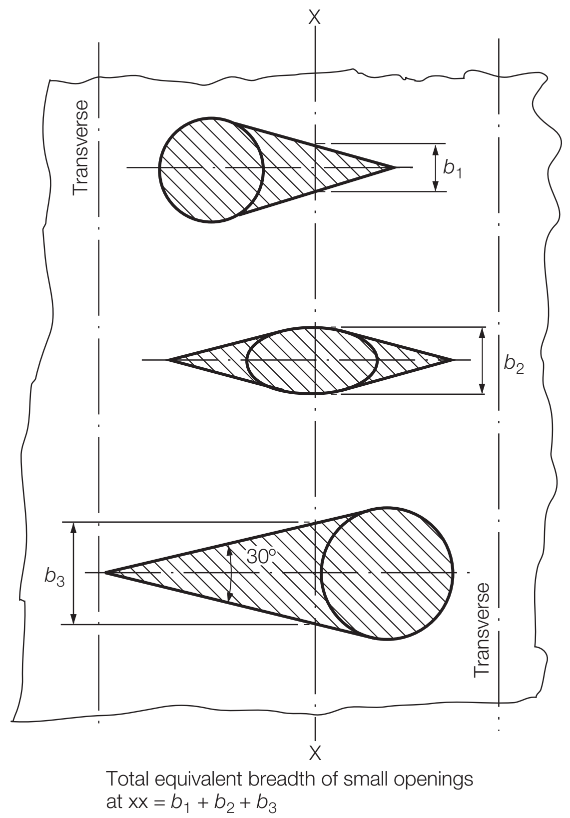


Fig. 3.3.5 Deduction free openings shadow areas

3.4.12 Where continuous hatch coamings are effectively supported (except inboard coamings of multi-hatch arrangements, *see* 3.4.14), 100 per cent of their sectional area may be included in the calculation of the hull section modulus.

3.4.13 Where a continuous longitudinal underdeck girder, or girders, are arranged to support the inboard hatch coamings, 50 per cent of their sectional area may be included. If the girder is fitted in conjunction with a longitudinal centreline bulkhead, 100 per cent of the sectional area may be included. In cases where the girders are enclosed box sections, or where the girders are effectively tied to the bottom structure, the area to be included will be specially considered.

3.4.14 The percentage of the sectional area to be included for inboard continuous hatch side coamings should be the same percentage as that of the longitudinal girder under.

3.4.15 Where continuous deck longitudinals or deck girders are arranged above the strength deck, the sectional area may be included in the calculation of the hull section modulus. The lever is to be taken to a position corresponding to the depth of the longitudinal member above the moulded deckline at side amidships.

■ *Section 4* Bulkhead requirements

4.1 Number and disposition of bulkheads

4.1.1 All ships are to have a collision bulkhead, an after peak bulkhead, generally enclosing the sterntubes in a watertight compartment, and a watertight bulkhead at each end of the machinery space. Additional watertight bulkheads are to be fitted so that the total number of bulkheads is at least in accordance with Table 3.4.1.

Table 3.4.1 Total number of bulkheads

Length, L, in metres	Total number of bulkheads	
	Machinery amidships	Machinery aft, *see* Note
≤ 65	4	3
> 65 ≤ 85	4	4
> 85 ≤ 90	5	5
> 90 ≤ 105	5	5
> 105 ≤ 115	6	5
> 115 ≤ 125	6	6
> 125 ≤ 145	7	6
> 145 ≤ 165	8	7
> 165 ≤ 190	9	8
> 190	To be considered individually	
NOTE With after peak bulkhead forming after boundary of machinery space.		

4.1.2 The bulkheads in the holds should be spaced at reasonably uniform intervals. Where non-uniform spacing is unavoidable and the length of a hold is unusually great, the transverse strength of the ship is to be maintained by fitting web frames, increased framing, etc., and details are to be submitted.

4.1.3 Proposals to dispense with one or more of these bulkheads will be considered, subject to suitable structural compensation, if they interfere with the requirements of a special trade.

4.1.4 Where applicable, the number and disposition of bulkheads are to be arranged to suit the requirements for subdivision, floodability and damage stability, and are to be in accordance with the requirements of the National Authority in the country in which the ship is registered.

4.2 Collision bulkhead

4.2.1 A collision bulkhead shall be fitted which shall be watertight up to the bulkhead deck. This bulkhead shall be located at a distance from the forward side of the stem, on the waterline on which L_L is measured, of not less than $0{,}05L_L$ or 10 m, whichever is the less, and, except as may be permitted by the Administration, not more than $0{,}08L_L$ or $0{,}05L_L$ + 3 m, whichever is the greater.

4.2.2 Where any part of the ship below the waterline extends forward of the forward side of the stem, on the waterline on which L_L is measured, e.g., a bulbous bow, the distances stipulated in 4.2.1 are to be measured from a point either:

(a) at the mid-length of such extension;
(b) at a distance $0{,}015L_L$ forward of the forward side of the stem, on the waterline on which L_L is measured; or
(c) at a distance 3 m forward of the forward side of the stem, on the waterline on which L_L is measured, whichever is the least.

4.2.3 No doors, manholes, access openings, ventilation ducts or any other openings shall be fitted in the collision bulkhead below the bulkhead deck.

4.3 After peak bulkhead

4.3.1 All ships are to have an after peak bulkhead generally enclosing the sterntube and rudder trunk in a watertight compartment. In twin screw ships where the bossing ends forward of the after peak bulkhead, the sterntubes are to be enclosed in suitable watertight spaces inside or aft of the shaft tunnels. The sterntubes are to be enclosed in watertight spaces of moderate volume. In passenger ships, the stern gland is to be situated in a watertight shaft tunnel or other watertight space separate from the stern tube compartment and of such volume that, if flooded by leakage through the stern gland, the bulkhead deck will not be submerged.

4.4 Height of bulkheads

4.4.1 The collision bulkhead is normally to extend to the uppermost continuous deck or, in the case of ships with combined bridge and forecastle or a long superstructure which includes a forecastle, to the superstructure deck. However, if a ship is fitted with more than one complete superstructure deck, the collision bulkhead may be terminated at the deck next above the freeboard deck. Where the collision bulkhead extends above the freeboard deck, the extension need only be to weathertight standards.

4.4.2 The after peak bulkhead may terminate at the first deck above the load waterline, provided that this deck is made watertight to the stern or to a watertight transom floor. In passenger ships, the after peak bulkhead is to extend watertight to the bulkhead deck. However, it may be stepped below the bulkhead deck provided the degree of safety of the ship as regards watertight subdivision is not thereby diminished.

4.4.3 The remaining watertight bulkheads are to extend to the freeboard deck. In passenger ships of restricted draught and all ships of unusual design, the height of the bulkheads will be specially considered.

4.5 Watertight recesses, flats and loading ramps

4.5.1 Watertight recesses in bulkheads are generally to be so framed and stiffened as to provide strength and stiffness equivalent to the requirements for watertight bulkheads.

4.5.2 In collision bulkheads, any recesses or steps in the bulkhead are to fall within the limits of bulkhead positions given in 4.2.1. Where the bulkhead is extended above the freeboard deck or bulkhead deck, the extension need only be to weathertight standards. If a step occurs at that deck, the deck need also only be to weathertight standards in way of the step, unless the step forms the crown of a tank, *see* Pt 4, Ch 1,4.

4.5.3 Where bow doors are fitted and a sloping loading ramp forms part of the extension of the collision bulkhead above the bulkhead deck the ramp shall be weathertight over its complete length. In cargo ships the part of the ramp which is more than 2,3 m above the bulkhead deck may extend forward of the limit specified in 4.2.1 or 4.2.2. Ramps not meeting the above requirements shall be disregarded as an extension of the collision bulkhead.

4.5.4 The number of openings in the extension of the collision bulkhead above the freeboard deck shall be restricted to the minimum compatible with the design and normal operation of the ship. All such openings shall be capable of being closed weathertight.

4.6 Longitudinal subdivision

4.6.1 When timber load lines are to be assigned, double bottom tanks within the midship half-length are to have adequate longitudinal subdivision.

4.7 Protection of tanks carrying fuel oil, lubricating oil, vegetable or similar oils

4.7.1 Tanks carrying fuel oil or lubricating oil are to be separated by cofferdams from those carrying feed water, fresh water, edible oil or similar oils. Similarly, tanks carrying vegetable or similar oils are to be separated from those carrying fresh or feed water.

4.7.2 Lubricating oil compartments are also to be separated by cofferdams from those carrying fuel oil. However these cofferdams need not be fitted provided that:

(a) Common boundaries of lubricating oil and fuel oil tanks have full penetration welds.

(b) The tanks are arranged such that the fuel oil tanks are not generally subjected to a head of oil in excess of that in the adjacent lubricating oil tanks.

4.7.3 Cofferdams are not required between fuel oil double bottom tanks and deep tanks above, provided that the inner bottom plating is not subjected to a head of fuel oil.

4.7.4 Where fitted, cofferdams are to be suitably ventilated.

4.7.5 If fuel oil tanks are necessarily located within or adjacent to the machinery spaces, their arrangement is to be such as to avoid direct exposure of the bottom from rising heat resulting from an engine room fire, *see* SOLAS 1974 as amended Reg. II–2/B4.2.2.3.2.

4.7.6 In passenger ships, water ballast is, in general, not to be carried in tanks intended for fuel oil. Attention is drawn to the Statutory Regulations issued by National Authorities in connection with the *International Convention for the Prevention of Pollution of the Sea by Oil*, 1973/78.

4.7.7 For vessels which do not comply with the accidental fuel oil outflow performance standard given in MARPOL Annex 1, Regulation 12A-11, fuel oil tanks are to be bounded by double bottom and double side tanks or void spaces such that the distance between the fuel oil tank boundary and the shell plating is not less than that given in Table 3.4.2 and Fig. 3.4.1. For double hull oil tankers where the requirements of Pt 4, Ch 9,1.2.17 conflict with this requirement Pt 4, Ch 9,1.2.17 is to take precedent. Alternatively the accidental oil outflow performance standard specified in MARPOL Annex 1 Regulation 12A may be complied with.

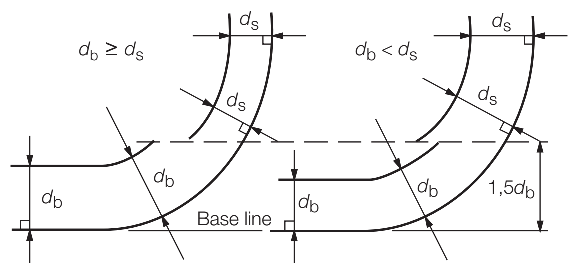


Fig. 3.4.1 Fuel oil tank boundary lines

4.7.8 No individual fuel oil tank is to have a capacity greater than 2,500 m^3.

Table 3.4.2 Fuel oil tank boundary requirements

Fuel oil tank capacity (C), m^3	Minimum double side width (d_s) metres	Minimum double bottom depth (d_b) metres
$C \geq 5000$	$d_s = 0{,}5 + \dfrac{C}{20000}$ or $d_s = 2{,}0$ whichever is the lesser, but not less than 1,0	$d_b = \dfrac{B}{20}$ or $d_b = 2{,}0$ whichever is the lesser, but not less than 0,76
$600 \leq C < 5000$	$d_s = 0{,}4 + \dfrac{2{,}4C}{20000}$ or $d_s = 1{,}0$ whichever is the greater, *see* Note	$d_b = \dfrac{B}{20}$ or $d_b = 2{,}0$ whichever is the lesser, but not less than 0,76
$C < 600$	$d_s = 0$	$d_b = 0$

Symbols

C = the ship's total volume of fuel oil, including that of small fuel oil tanks, in m^3, at 98 per cent tank filling

d_b = the distance, in metres, between the bottom of the fuel oil tank and the moulded line of the bottom shell plating. In the turn of bilge area and at locations without a clearly defined turn of bilge, the fuel oil tank boundary line shall run parallel to the line of the midship flat bottom as shown in Fig. 3.4.2

d_s = the distance, in metres, between the side of the fuel oil tank and the moulded line of the side shell plating, *see* Fig. 3.4.1

NOTES
1. However, for individual tanks with an fuel oil capacity of less than 500 m^3, the minimum distance is 0,76 m.
2. Fuel oil tanks with a maximum individual capacity not greater than 30 m^3 need not comply with the requirements of this Table, provided the aggregate capacity of such excluded tanks is not greater than 600 m^3.
3. Suction wells in fuel oil tanks may protrude into the double bottom below the boundary line defined by the distance d_b, provided that such wells are as small as practicable and the distance between the well bottom and the bottom shell plating is not less than $0{,}5d_b$.

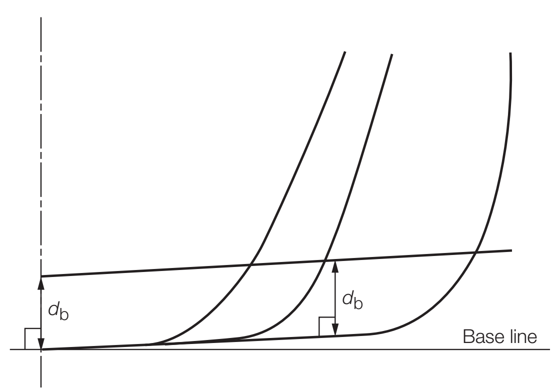


Fig. 3.4.2 Definition of d_b

4.8 Watertight tunnels and passageways

4.8.1 Where a machinery space is situated with a compartment or compartments between it and the after peak bulkhead, the shafting is to be enclosed in a watertight tunnel large enough to permit proper examination and repair of shafting. A sliding watertight door, capable of being operated locally from both sides, is to be provided at the forward end of the tunnel. Consideration may, however, be given to the omission of the watertight door, subject to satisfactory compliance with any relevant statutory requirements. Where two or more shafts are fitted, the tunnels shall be connected by an interconnecting passage. There shall be only one door between the machinery space and the tunnel spaces where two shafts are fitted and only two doors where there are more than two shafts.

4.8.2 Pipe tunnels are to have dimensions adequate for reasonable access.

4.8.3 Where fore and aft underdeck passageways are arranged at the ship's side, the after access thereto is to be by a watertight trunk led to the upper deck. Alternative arrangements to prevent the engine room being flooded, in the event of a collision or if the passageway doors are left open, will be considered.

4.9 Means of escape

4.9.1 For the requirements for means of escape, *see* SOLAS 1974 as amended Reg. II–2/D,13.

4.10 Oil tankers

4.10.1 For subdivision requirements within the cargo tank region for oil tankers, *see* Pt 4, Ch 9,1.

■ *Section 5* Design loading

5.1 General

5.1.1 This Section contains the design heads/pressures to be used in the derivation of scantlings for decks, tank tops and transverse bulkheads. These are given in Table 3.5.1.

Table 3.5.1 Design heads and permissible cargo loadings (SI units) (*see continuation*)

Structural item and position	Component	Standard stowage rate C, in m^3/tonne	Design loading p, in kN/m^2	Equivalent design head h_i in metres	Permissible cargo loading in kN/m^2	Equivalent permissible head, in metres
Weather deck (general cargo)				h_1		
(a) Loading for minimum scantlings						
Forward of 0,075*L* from F.P.	Beams and longitudinals	1,39	12,73	1,8	8,5	1,2
	Primary structure		29,64 + 14,41*E*	4,2 + 2,04*E*		
Between 0,12*L* and 0,075*L* from F.P.	Beams and longitudinals	1,39	10,61	1,5	8,5	1,2
	Primary structure		22,59 + 14,41*E*	3,2 + 2,04*E*		
Aft of 0,12*L* from F.P.	Beams and longitudinals	1,39	8,5 + 14,41*E*	1,2 + 2,04*E*	8,5	1,2
	Primary structure					
(b) Specified cargo loading						
Forward of 0,075*L* from F.P.	Beams and longitudinals	1,39	$2{,}47p_a + 14{,}41E$ or as (a), whichever is larger (Note 1)	$0{,}35p_a + 2{,}04E$ (Note 1)	p_a	$0{,}14p_a$
	Primary structure		$3{,}5p_a + 14{,}41E$ or as (a), whichever is larger (Note 1)	$0{,}5p_a + 2{,}04E$ (Note 1)		
Between 0,12*L* and 0,075*L* from F.P.	Beams and longitudinals	1,39	$1{,}98p_a + 14{,}41E$ or as (a), whichever is larger (Note 1)	$0{,}28p_a + 2{,}04E$ (Note 1)	p_a	$0{,}14p_a$
	Primary structure		$2{,}67p_a + 14{,}41E$ or as (a), whichever is larger (Note 1)	$0{,}38p_a + 2{,}04E$ (Note 1)		
Aft of 0,12*L* from F.P.	Beams and longitudinals	1,39	$p_a + 14{,}41E$ (Note1)	$0{,}14p_a + 2{,}04E$ (Note 1)	p_a	$0{,}14p_a$
	Primary structure					
Cargo decks				h_2		
General cargo (standard loads)	All structure	1,39	$7{,}07H_{td}$	H_{td}	$7{,}07H_{td}$	H_{td}
Special cargo (specified loads)		C	p_a	$\frac{Cp_a}{9{,}82}$	p_a	$\frac{Cp_a}{9{,}82}$
Machinery space, workshop and stores		1,39	18,37	2,6	—	—
Ship stores		1,39	14,14	2,0	—	—
Accommodation decks (clear of tanks)	All structure	1,39	8,5	h_3	—	—
				1,2		

Table 3.5.1 Design heads and permissible cargo loadings (SI units) *(continued)*

Structural item and position	Component	Standard stowage rate C, in m^3/tonne	Design loading p, in kN/m^2	Equivalent design head h_i in metres	Permissible cargo loading in kN/m^2	Equivalent permissible head, in metres
Superstructure decks (Note 2)				h_3		
1st tier	Beams and longitudinals	—	—	0,9 — Where the deck is exposed to the weather, add 2,04E	—	—
2nd tier				0,6		
3rd tier and above				0,45		
Decks forming crown of tunnels and deep tanks	Plating and stiffeners	C	$\frac{9,82h}{C}$ where h = 1/2 height of stand pipe above crown	h_4 h	—	—
(c) Bulk carrier (*see* 1.1.3) with topside tanks						
Weather deck outside line of hatchways in way of cargo hold region, when topside tanks empty	Beams and longitudinals	1,39	—	—	7,06h	h = the lesser of (i) 0,22B (ii) $1,2 + 0,14 \frac{W_b}{A}$ where W_b = weight of water ballast in the topside tank per frame space, in kN A = Corresponding area, (m^2), of deck in way over one hold frame space
	Primary structure	1,39	—	—		
Cargo hatch covers (standard loading)				h_H		
Steel cover	Webs, stiffeners and plating	1,39	7,07H_{td}	H_{td}	7,07H_{td}	H_{td}
Wood cover	—	1,39	—	—	7,07H_{td}	H_{td}
Inner bottom				H		
Ship without heavy cargo notation	Plating and stiffeners	1,39	—	—	9,82T	1,39T
Ship with heavy cargo notation		C but ≤ 0,865	$\frac{H}{C}$	H	$\frac{H}{C}$	H

Table 3.5.1 Design heads and permissible cargo loadings (SI units) (*conclusion*)

Structural item and position	Component	Standard stowage rate C, in m^3/tonne	Design loading p, in kN/m^2	Equivalent design head h_i in metres	Permissible cargo loading in kN/m^2	Equivalent permissible head, in metres
Watertight bulkheads	Plating and stiffeners	0,975	$10{,}07h_4$	h_4 from Fig. 3.5.2	—	—
Deep tank bulkhead	Plating and stiffeners	C but ≤ 0,975	$\dfrac{9{,}82h_4}{C}$	h_4 from Fig. 3.5.2	—	—

NOTES
1. In the case of beams and longitudinals, the equivalent design head is to be used in conjunction with the appropriate formulae.
2. For forecastle decks forward of 0,12*L* from F.P., *see* Weather decks.
3. For hatch covers of non-CSR bulk carriers, ore carriers and combination carriers, *see* Pt 4, Ch 7,12.
4. For hatch covers of ship types excluding non-CSR bulk carriers, ore carriers and combination carriers, *see* Ch 11,2.
5. For pontoon hatch covers, *see* Ch 11,2.17.

Table 3.5.1 Design heads and permissible cargo loadings (metric units) (*see continuation*)

Structural item and position	Component	Standard stowage rate C, in m^3/tonne	Design loading p, in tonne-f/m^2	Equivalent design head h_i in metres	Permissible cargo loading in tonne-f/m^2	Equivalent permissible head, in metres
Weather deck (general cargo)				h_1		
(a) Loading for minimum scantlings						
Forward of 0,075L from F.P.	Beams and longitudinals	1,39	1,296	1,8	0,865	1,2
	Primary structure		3,02 + 1,467E	4,2 + 2,04E		
Between 0,12L and 0,075L from F.P.	Beams and longitudinals	1,39	1,08	1,5	0,865	1,2
	Primary structure		2,30 + 1,467E	3,2 + 2,04E		
Aft of 0,12L from F.P.	Beams and longitudinals	1,39	0,865 + 1,467E	1,2 + 2,04E	0,865	1,2
	Primary structure					
(b) Specified cargo loading						
Forward of 0,075L from F.P.	Beams and longitudinals	1,39	2,5p_a + 1,467E or as (a), whichever is larger (Note 1)	3,5p_a + 2,04E (Note 1)	p_a	1,39p_a
	Primary structure		3,5p_a + 1,467E or as (a), whichever is larger (Note 1)	4,87p_a + 2,04E (Note 1)		
Between 0,12L and 0,075L from F.P.	Beams and longitudinals	1,39	2,0p_a + 1,467E or as (a), whichever is larger (Note 1)	2,78p_a + 2,04E (Note 1)	p_a	1,39p_a
	Primary structure		2,67p_a + 1,467E or as (a), whichever is larger (Note 1)	3,71p_a + 2,04E (Note 1)		
Aft of 0,12L from F.P.	Beams and longitudinals	1,39	p_a + 1,467E (Note 1)	1,39p_a + 2,04E (Note 1)	p_a	1,39p_a
	Primary structure		p_a + 1,467E (Note 1)	1,39p_a + 2,04E (Note 1)		
Cargo decks				h_2		
General cargo (standard loads)	All structure	1,39	$\frac{H_{td}}{1,39}$	H_{td}	$\frac{H_{td}}{1,39}$	H_{td}
Special cargo (specified loads)		C	p_a	Cp_a	p_a	Cp_a
Machinery space, workshop and stores		1,39	1,87	2,6	—	—
Ship stores		1,39	1,44	2,0	—	—
Accommodation decks (clear of tanks)	All structure	1,39	0,865	h_3	—	—
				1,2		

Table 3.5.1 Design heads and permissible cargo loadings (metric units) *(continued)*

Structural item and position	Component	Standard stowage rate C, in m^3/tonne	Design loading p, in tonne-f/m^2	Equivalent design head h_i in metres		Permissible cargo loading in tonne-f/m^2	Equivalent permissible head, in metres
Superstructure decks (Note 2)				h_3			
1st tier	Beams and longitudinals	—	—	0,9	Where the deck is exposed to the weather, add 2,04E	—	—
2nd tier				0,6			
3rd tier and above				0,45			
Decks forming crown of tunnels and deep tanks	Plating and stiffeners	C	$\dfrac{h}{C}$	h_4		—	—
				h			
			where h = 1/2 height of stand pipe above crown				
(c) Bulk carrier (*see* 1.1.3) with topside tanks							
Weather deck outside line of hatchways in way of cargo hold region, when topside tanks empty	Beams and longitudinals	1,39	—	—		$\dfrac{h}{1{,}39}$	h = the lesser of (i) 0,22B (ii) $1{,}2 + 0{,}39\dfrac{W_b}{A}$ where W_b = weight of water ballast in the topside tank per frame space, tonne-f; A = Corresponding area, (m^2), of deck in way over one hold frame space
	Primary structure	1,39	—	—			
Cargo hatch covers (standard loading)				h_H			
Steel cover	Webs, stiffeners and plating	1,39	$\dfrac{H_{td}}{1{,}39}$	H_{td}		$\dfrac{H_{td}}{1{,}39}$	H_{td}
Wood cover	—	1,39	—	—		$\dfrac{H_{td}}{1{,}39}$	H_{td}
Inner bottom				H			
Ship without heavy cargo notation	Plating and stiffeners	1,39	—	—		T	1,39T
Ship with heavy cargo notation		C but ≤ 0,865	$\dfrac{H}{C}$	H		$\dfrac{H}{C}$	H

Table 3.5.1 Design heads and permissible cargo loadings (metric units) *(conclusion)*

Structural item and position	Component	Standard stowage rate C, in m^3/tonne	Design loading p, in tonne-f/m^2	Equivalent design head h_i in metres	Permissible cargo loading in tonne-f/m^2	Equivalent permissible head, in metres
Watertight bulkheads	Plating and stiffeners	0,975	$\dfrac{h_4}{0{,}975}$	h_4 from Fig. 3.5.2	—	—
Deep tank bulkhead	Plating and stiffeners	C but ≤ 0,975	$\dfrac{h_4}{C}$	h_4 from Fig. 3.5.2	—	—

NOTES
1. In the case of beams and longitudinals, the equivalent design head is to be used in conjunction with the appropriate formulae.
2. For forecastle decks forward of 0,12*L* from F.P., *see* Weather decks.
3. For hatch covers of non-CSR bulk carriers, ore carriers and combination carriers, *see* Pt 4, Ch 7,12.
4. For hatch covers of ship types excluding non-CSR bulk carriers, ore carriers and combination carriers, *see* Ch 11,2.
5. For pontoon hatch covers, *see* Ch 11,2.17.

5.2 Symbols

5.2.1 The symbols used in this Section are defined as follows:

L, L_{pp}, C_b, B, D and T as defined in Ch 1,6.1

h_i = appropriate design head, in metres

l_e = span of stiffener

p = design loading, in kN/m^2 (tonne-f/m^2)

p_a = applied loading, in kN/m^2 (tonne-f/m^2)

C = stowage rate, in m^3/tonne

= $\dfrac{h_i}{p}$ generally

= volume of the hold, in m^3 excluding the volume contained within the depth of the cargo hatchway, divided by the weight of cargo, in tonnes, stowed in the hold, for inner bottom

E = correction factor for height of platform

$$\frac{0{,}0914 + 0{,}003L}{D - T} - 0{,}15, \text{ but not less than zero}$$

nor more than 0,147

H = height from tank top to deck at side, in metres

H_c = 'tween deck height measured vertically on the centreline of the ship from 'tween deck to underside of hatch cover stiffeners on deck above, in metres

H_{td} = cargo head in 'tween deck, in metres, as defined in Fig. 3.5.1.

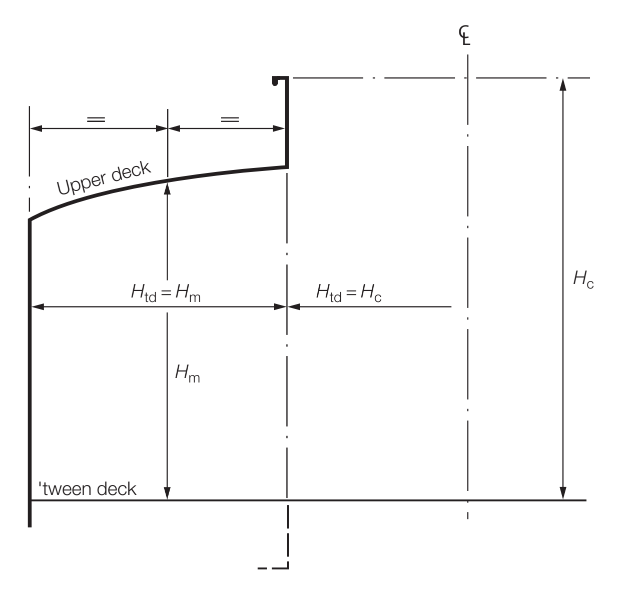
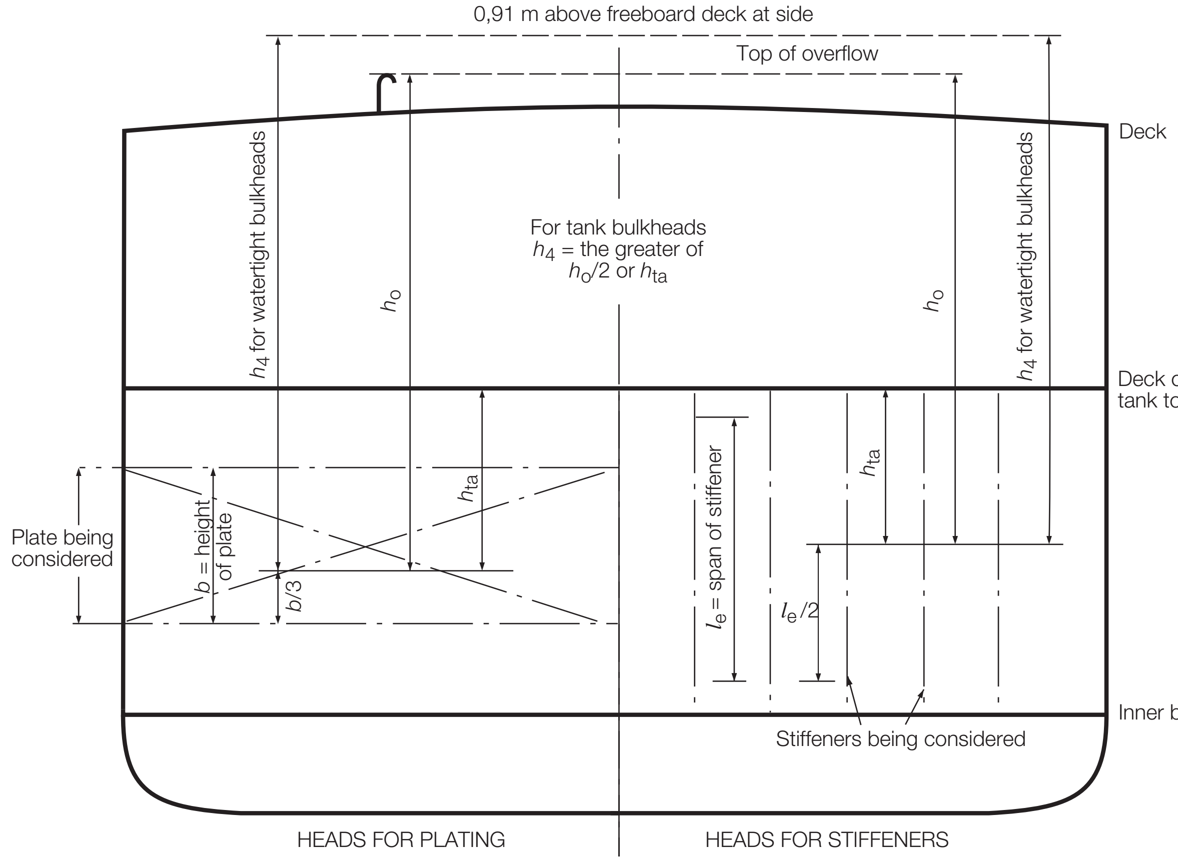
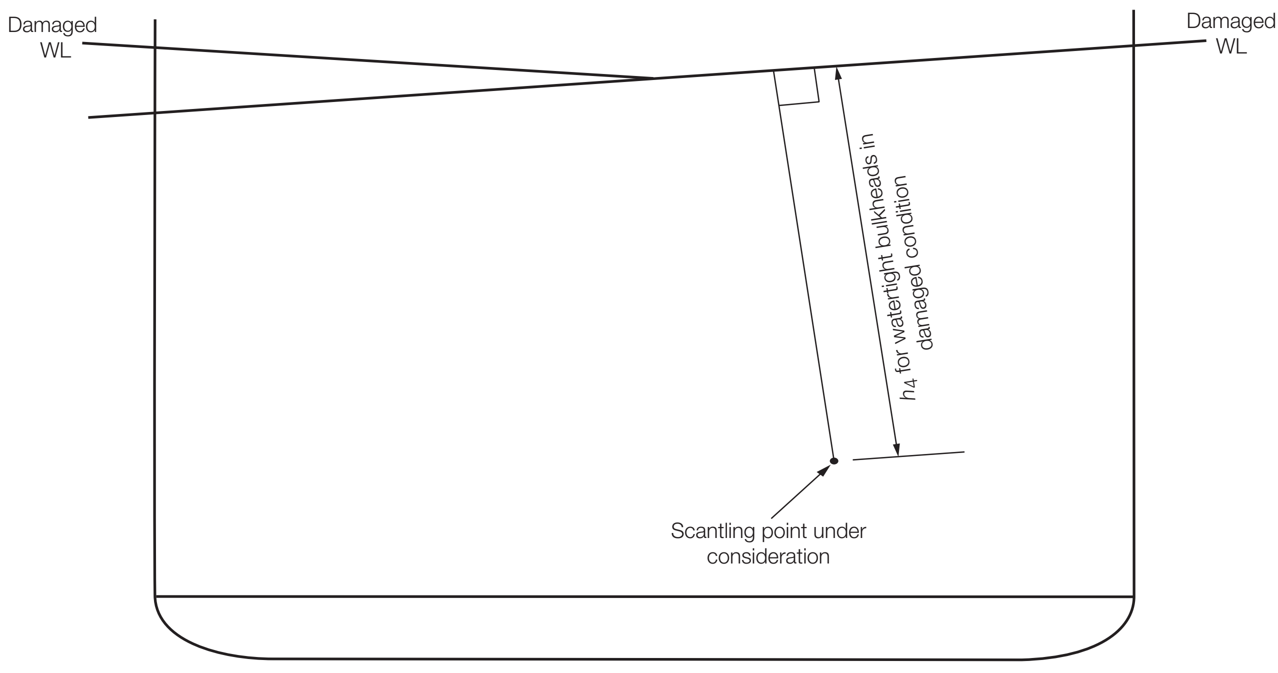


Fig. 3.5.1 Heads for 'tween decks



(a) Heads for watertight and deep tank bulkheads in intact condition



(b) Heads for watertight bulkheads in damaged condition

Fig. 3.5.2 Heads for watertight and deep tank bulkheads

5.2.2 The following symbols and definitions apply in particular to the design pressures for partially filled tanks:

L_{pp} and C_b as defined in Ch 1,6.1

b = height of internal primary bottom members, in metres

F = fill height, in metres

F_r = effective filling ratio

$= \dfrac{\pi}{L_s}\left(F - b\sqrt{\dfrac{n}{n+1}}\right)$

GM = transverse metacentric height, in metres, including free surface correction, for the loading condition under consideration

H_t = tank depth, in metres, measured from the bottom of the tank to the underside of the deck at side. In the case of holds, the depth is measured from the inner bottom to the underside of the deck at hatch side, except in double skin ships with hatch coaming in line with the inner skin, in which case, the depth is measured to the top of the hatch coaming

n = number of internal primary bottom members

L_s = the effective horizontal free surface length, in metres, in the direction of angular motion (i.e., tank breadth for roll, tank length for pitch)

S_{nr} = ship's natural rolling period

$= \dfrac{2{,}35r}{\sqrt{GM}}$ seconds

for ships for which either r or GM varies significantly between loading conditions (for example, bulk carriers and tankers, *see* 1.1.3), S_{nr} should be evaluated for each representative loading condition considered

r = radius of gyration of roll, in metres, and may be taken as $0{,}34B$

S_{np} = ship's natural pitching period

$= 3{,}5\sqrt{TC_b}$ seconds

for ships for which either T or C_b varies significantly between loading conditions (for example, bulk carriers and tankers, *see* 1.1.3), S_{np} should be evaluated for each representative loading condition considered

T_{np} = fluid natural period of pitch

$= \sqrt{\dfrac{4\pi\, L_s}{g.\tanh(F_r)}}$ seconds

T_{nr} = fluid natural period of roll

$= \sqrt{\dfrac{4\pi\, L_s}{g.\tanh(F_r)}}$ seconds

θ_{max} = maximum 'lifetime' pitch angle, in degrees:

$(32{,}7 - 8{,}2C_b)\; e^{-0{,}001L_{pp}(4{,}9\,+\,0{,}5C_b)}$

ϕ_{max} = maximum 'lifetime' roll angle, in degrees:

$\left(14{,}8 + 3{,}7\dfrac{L_{pp}}{B}\right)\; e^{-0{,}0023L_{pp}}$

5.3 Stowage rate and design loads

5.3.1 Unless it is specifically requested otherwise, the following standard stowage rates are to be used:

(a) 1,39 m^3/tonne for weather or general cargo loading on deck and inner bottom.

(b) 0,975 m^3/tonne for liquid cargo of density 1,025 tonne/m^3 or less on watertight and tank divisions. For liquid of density greater than 1,025 tonne/m^3 the corresponding stowage rates are to be adopted.

5.3.2 Proposals to use a stowage rate greater than 1,39 m^3/tonne for permanent structure will require special consideration, and will normally be accepted only in the case of special purpose designs such as fruit carriers, etc.

5.3.3 The design head and permissible cargo loading are shown in Table 3.5.1.

5.4 Design pressure for partially filled tanks

5.4.1 When partial filling of tanks or holds is contemplated for sea-going conditions, the risk of significant loads due to sloshing induced by any of the ship motions is to be considered. An initial assessment is to be made to determine whether or not a higher level of sloshing investigation is required, using the following procedure which corresponds to the Level 1 Investigation outlined in the *SDA Procedure for Sloshing loads and scantling assessment,* on tanks partially filled with liquids.

5.4.2 In general, significant dynamic magnifications of the sloshing pressures are considered unlikely for the following cases:

(a) For internally stiffened tanks:

(i) where two (or more) deck girders (in the case of rolling) or deck transverses (in the case of pitching) are located not more than 25 per cent of the tank breadth or length respectively from the adjacent tank boundary, and the fill level is greater than the tank depth minus the height of the deck girders or transverses;

(ii) where the deck girders or transverses, at any location, are less than 10 per cent of the tank depth, and the fill level is greater than the tank depth minus the height of the deck girders or transverses;

(iii) where the fill level is less than the height of any bottom girders or transverses.

(b) For smooth tanks: where the fill level is less than 10 per cent or more than 97 per cent of the tank depth.

5.4.3 Significant dynamic magnification of the fluid motions, and hence the sloshing pressure, can occur if either of the following conditions exist:

(a) The natural rolling period, T_{nr}, of the fluid and the ship's natural rolling period, S_{nr}, are within five seconds of each other.

(b) The natural pitching period, T_{np}, of the fluid is greater than a value of three seconds below the ship natural pitching period, S_{np}.

These values define the limits of the critical fill range for each tank.

5.4.4 The critical fill range, F_{crit}, is to be determined using the following formula:

$$F_{crit} = \left(\frac{100}{H_t}\right)\left[\left(\frac{L_s}{2\pi}\right) ln \left(\frac{(1+\eta)}{(1-\eta)}\right) + b\sqrt{\frac{n}{n+1}}\right] \%$$

where

ln = natural logarithm to base e

$\eta = \dfrac{4\pi L_s}{[(S_{nr} - 5)^2 g]}$ for fill level at S_{nr} – 5 seconds

upper bound roll critical fill level

or $\eta = \dfrac{4\pi L_s}{[(S_{nr} + 5)^2 g]}$ for fill level at S_{nr} + 5 seconds

lower bound roll critical fill level

or $\eta = \dfrac{4\pi L_s}{[(S_{np} - 3)^2 g]}$ for fill level at S_{np} – 3 seconds

upper bound pitch critical fill level

or $\eta = \dfrac{4\pi L_s}{[(S_{np})^2 g]}$ for fill level at S_{np} seconds

The lower bound pitch critical fill level is 0,1 per cent fill.
The value of F_{crit} is limited to the range 0 to 100 per cent, *see also* 5.4.6.

5.4.5 The natural periods of the ship for a given motion type are to be determined for the service loading conditions agreed between the Shipbuilder and Lloyd's Register. From this aspect, the storm-ballast and the segregated ballast conditions and the condition with all tanks partially filled could be the most critical.

5.4.6 When a ship is to be approved for Unrestricted Filling Levels – Unspecified Loading Conditions, many arbitrary ship loading conditions are possible. In order to cover the complete range of loading conditions, the fully loaded and ballast conditions are to be considered. These two conditions give an upper and lower limit for the possible range of natural periods of the ship as shown in Fig. 3.5.3. Both the roll and pitch motion modes are to be examined.

Because of the unrestricted filling level requirement, the critical sloshing ranges extend from [$S_{nrBallast}$ – 5] to [$S_{nrLoaded}$ + 5] seconds in roll and from [$S_{npBallast}$ – 3] to [$S_{npLoaded}$] in pitch. Also, because of unrestricted filling levels, the ship natural period range extends from [$S_{nBallast}$] to [$S_{nLoaded}$] for both pitch and roll.

For sloshing in the roll motion mode shown in Fig. 3.5.3(a), the critical fill range extends from F_1 to F_4. All fill levels between F_1 and F_4 are to be investigated:

- For fill levels between F_1 and F_2, $S_{nrBallast}$ is to be used.
- For fill levels between F_3 and F_4, $S_{nrLoaded}$ is to be used.
- For fill levels between F_2 and F_3, S_{nr} is to be equal to T_{nr}.

Similarly, for sloshing in the pitch motion mode shown in Fig. 3.5.3(b), the critical fill range extends from F_1 to F_4. All fill levels between F_1 and F_4 are to be investigated:

- For fill levels between F_1 and F_2, $S_{npBallast}$ is to be used.
- For fill levels between F_2 and F_3, S_{np} is to be equal to T_{np}.
- For fill levels between F_3 and F_4, $S_{npLoaded}$ is to be used.

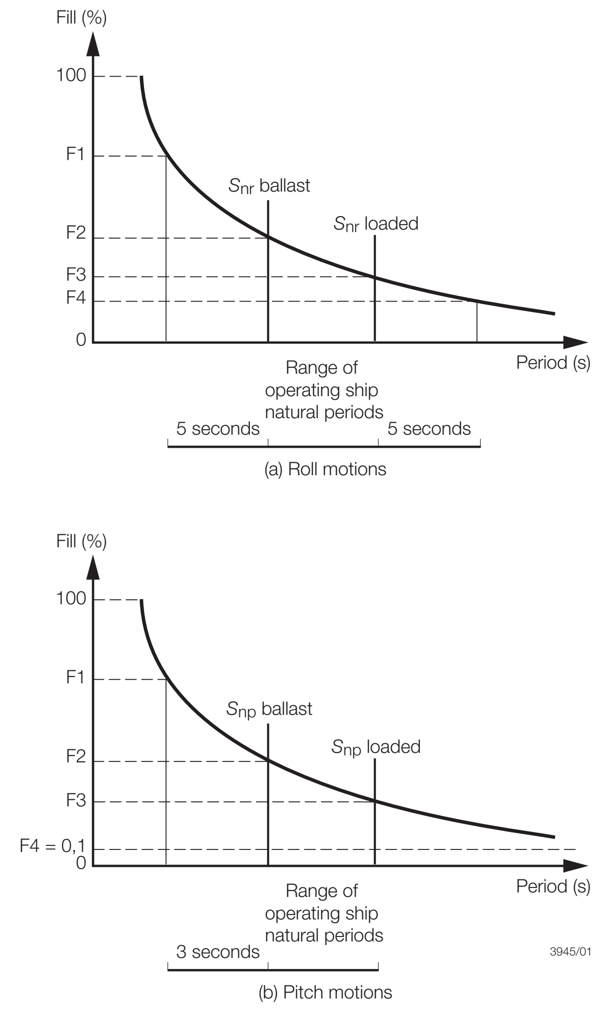


Fig. 3.5.3 Natural periods diagrams

5.4.7 When a ship is to be approved for Restricted Filling Levels – Unspecified Loading Conditions, many arbitrary ship loading conditions are possible within the restrictions imposed. In order to cover the complete range of loading conditions, the fully loaded and ballast conditions are to be considered. These two conditions give an upper and lower limit for the possible range of ship natural period. It is recognised that there might be ship natural period bands which will not be applicable as a result of the limitations on the fill levels. However, it is recommended that the Unrestricted Filling Levels – Unspecified Loading Conditions procedure outlined in 5.4.6 be applied.

5.4.8 When a ship is to be approved for Unrestricted Filling Levels – Specified Loading Conditions, each specified loading condition is to be examined for the complete fill ranges to determine the critical sloshing fill range for each tank in both roll and pitch motion modes.

5.4.9 When a ship is to be approved for Restricted Filling Levels – Specified Loading Conditions, each specified loading condition is to be examined for the restricted fill ranges to determine the critical sloshing fill range for each tank in both roll and pitch motion modes.

5.4.10 Where the assessment indicates that all the intended fill levels are outside the critical fill ranges and, therefore, significant sloshing will not occur, no further evaluation is required with regard to sloshing pressure. In such cases, the scantlings of the tank boundaries are to be determined in accordance with the relevant Rule requirements.

5.4.11 Where the separation of periods defined in 5.4.3 is not met, other levels of assessment will be required as given in the *SDA Procedure for Sloshing loads and scantling assessment,* on tanks partially filled with liquids.

5.4.12 The structural capability of the tank boundaries to withstand the dynamic sloshing pressures is to be examined. The magnitude of the predicted loads, together with the scantling calculations may be required to be submitted.

■ *Section 6* Minimum bow heights, reserve buoyancy and extent of forecastle

6.1 Minimum bow heights

6.1.1 Ships are to comply with the Load Lines conventions, so far as these are applicable.

6.1.2 Bulk carriers, ore carriers and combination carriers are also to comply with the requirements of Pt 4, Ch 7,14.

6.2 Extent of forecastle

6.2.1 Forecastles are to extend from the stem to a point at least $0,07L_L$ abaft the forward end of L_L (as defined in Ch 1,6.1). If the minimum bow height is obtained by increasing the sheer of the upper deck, the sheer is to extend for at least $0,15L_L$ abaft the forward end of L_L.

6.2.2 Bulk carriers, ore carriers and combination carriers are also to comply with the requirements of Pt 4, Ch 7,14.

6.2.3 Forecastles are to be enclosed; that is with enclosing bulkheads of efficient construction and access openings complying with Pt 3, Ch 11 and all other openings in sides or ends fitted with efficient weathertight means of closing.

Section

■ *Section 1* Definitions

1.1 List of symbols

1.1.1 The following symbols and definitions are applicable to this Chapter, unless otherwise stated:

L, B, D, C_b and V are as defined in Ch 1,6.1

k_L, k = higher tensile steel factor, *see* Ch 2,1.2.

■ *Section 2* General

2.1 Longitudinal strength calculations

2.1.1 Longitudinal strength calculations are to be carried out for all ships where L is greater than 65 m, covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. The calculations of still water shear forces and bending moments are to cover both departure and arrival conditions and any special mid-voyage conditions caused by changes in ballast distribution.

2.1.2 For ships where L is equal to or less than 65 m, longitudinal strength calculations may be required, dependent upon proposed loading.

2.1.3 Specific information regarding required loading conditions is given in the individual ship type Chapters.

2.2 Erections contributing to hull strength

2.2.1 In general, where a long superstructure or deckhouse of length greater than 0,15L is fitted, extending within the 0,5L amidships, the requirements for longitudinal strength in the hull and erection will be considered in each case.

2.3 Open type ships

2.3.1 For ships other than container ships which have large deck openings and where the structural configuration is such that warping stresses in excess of 14,7 N/mm^2 are likely to occur, local increases in section modulus, based normally on the combined stress diagram undertaken for container ships, may be required. For calculations for container ships, *see* Pt 4, Ch 8,3.

2.3.2 For ships with large deck openings such as containerships, sections at or near to the aft and forward quarter length positions are to be checked. For such ships with cargo holds aft of the superstructure, deckhouse or engine room, strength checks of sections in way of the aft end of the aft-most holds, and the aft end of the deckhouse or engine room are to be performed.

2.4 Ships with large flare

2.4.1 In ships of length between 120 and 170 m and maximum service speed greater than 17,5 knots, in association with a bow shape factor of more than 0,15, the Rule hull midship section modulus and the distribution of longitudinal material in the forward half-length will be specially considered, *see* Pt 4, Ch 1,3.

2.5 Direct calculation procedures

2.5.1 In direct calculation procedures capable of deriving the wave induced loads on the ship, and hence the required modulus, account is to be taken of the ship's actual form and weight distribution.

2.5.2 Lloyd's Register's (hereinafter referred to as 'LR') direct calculation method involves derivation of response to regular waves by appropriate sea keeping software, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval should normally contain these three elements and produce similar and consistent results when compared with LR's methods.

2.6 Approved calculation systems

2.6.1 Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from LR, calculations using the system for a particular ship may be submitted.

Section 3
Application

3.1 Symbols

3.1.1 The symbols used in this Section are defined as follows:

b = breadth, in metres, of the hatch opening. Where there are multiple openings abreast, these are regarded as a single opening, and b is to be the sum of the individual breadths of these openings

l_H = length of the hatch opening, in metres

l_{BH} = distance, in metres, between centres of the deck strip at each end of the hatch opening. Where there is no further opening beyond the one under consideration, the point to which l_{BH} is measured will be considered, *see also* Fig. 4.3.1

B_1 = extreme breadth of deck including hatch opening, measured at the mid-length of the opening, in metres.

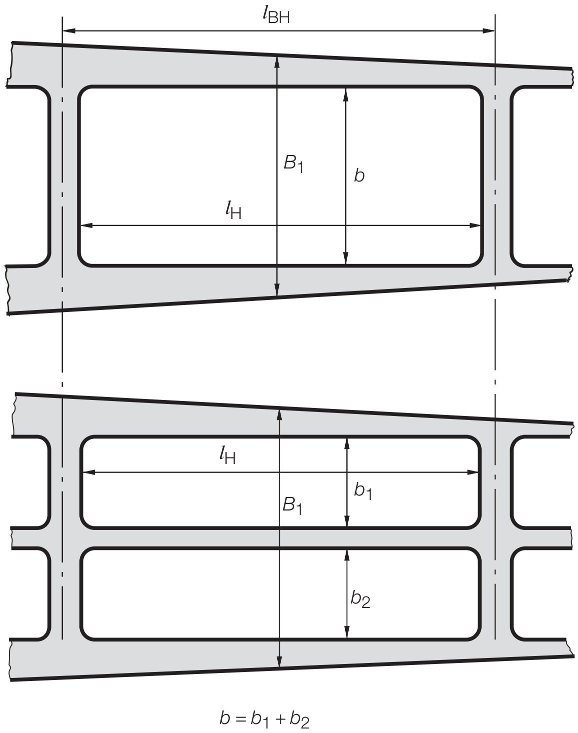


Fig. 4.3.1 Deck opening size

3.2 General

3.2.1 The requirements of this Chapter apply to sea-going steel ships, of normal form, proportions and speed, unless direct calculation procedures are adopted, in which case the assumptions made and the calculations performed are to be submitted for approval.

3.2.2 The requirements in this Chapter are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation. *See* Pt 1, Ch 2,2.3.

3.3 Exceptions

3.3.1 Individual consideration based on direct calculation procedures will generally be required for ships having one or more of the following characteristics:

- Length L greater than 400 m.
- Speed V greater than that defined in Table 4.3.1 for the associated block coefficient.
- Unusual type or design.
- Unusual hull weight distribution.
- $\frac{L}{B} \leq 5$, or $\frac{B}{D} \geq 2,5$
- Large deck openings, or where warping stresses in excess of 14,7 N/mm^2 (1,5 kgf/mm^2) are likely to occur.
- Openings for side loading in way of both sheerstrake and stringer.
- $C_b < 0,6$
- Carriage of heated cargo, *see* Pt 4, Ch 9,12.

Table 4.3.1 Ship speed criteria

Ship length L, metres	C_b	Speed, knots
≤ 200	> 0,80 = 0,70 < 0,60	17 19,5 22
> 200	> 0,80 = 0,70 < 0,60	18 21,5 25
NOTE Intermediate values of speed to be obtained by linear interpolation for C_b.		

3.3.2 A ship is regarded as having large deck openings if both the following conditions apply to any one opening:

$$\frac{b}{B_1} > 0,6$$

$$\frac{l_H}{l_{BH}} > 0,7$$

See also Fig. 4.3.1.

Section 4
Information required

4.1 List of requirements

4.1.1 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in LR's standard format where appropriate.

(a) General arrangement and capacity plan or list, showing details of the volume and position of centre of gravity of all tanks and compartments.
(b) Bonjean data, in the form of tables or curves, for at least 21 equally spaced stations along the hull. A lines plan and/or tables of offsets may also be required.
(c) Details of the calculated lightweight and its distribution.
(d) Loading Manual.
(e) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions for individual ship types specified in Part 4. It is recommended that this information be submitted in the form of a preliminary Loading Manual, and that it includes the calculated still water bending moments and shear forces.

4.1.2 For final Loading Manual, *see* Section 8.

Section 5
Hull bending strength

5.1 Symbols

5.1.1 The symbols used in this Section are defined as follows:

f_1 = ship service factor
f_2 = wave bending moment factor
F_B = local scantling reduction factor for hull members below the neutral axis, *see* 5.7
F_D = local scantling reduction factor for hull members above the neutral axis, *see* 5.7
I_{min} = minimum moment of inertia, of the hull midship section about the transverse neutral axis, in m^4
M_s = design still water bending moment, sagging (negative) and hogging (positive), in kN m (tonne-f m), to be taken negative or positive according to the convention given in 5.3.2
$\overline{M}_s$ = maximum permissible still water bending moment, sagging (negative) and hogging (positive), in kN m (tonne-f m), *see* 5.4
M_w = design hull vertical wave bending moment amidships, sagging (negative) and hogging (positive), in kN m (tonne-f m), to be taken negative or positive according to the convention given in 5.3.2
Z_c = actual hull section modulus, in m^3, at continuous strength member above strength deck, calculated with the lever specified in Ch 3,3.4
Z_D, Z_B = actual hull section moduli, in m^3, at strength deck and keel respectively, *see* Ch 3,3.4
Z_{min} = minimum hull midship section modulus about the transverse neutral axis, in m^3
σ = permissible combined stress (still water plus wave), in N/mm^2 (kgf/mm^2), *see* 5.5
σ_D, σ_B = maximum hull vertical bending stress at strength deck and keel respectively, in N/mm^2 (kgf/mm^2)
z = vertical distance from the hull transverse neutral axis to the position considered, in metres
z_M = vertical distance, in metres, from the hull transverse neutral axis to the minimum limit of higher tensile steel, as defined in Ch 3,2.6, above or below the neutral axis as appropriate.

5.2 Design vertical wave bending moments

5.2.1 The appropriate hogging or sagging design hull vertical wave bending moment at amidships is given by the following:

$M_w = f_1 \, f_2 \, M_{wo}$

where

C_b is to be taken not less than 0,60
C_1 is given in Table 4.5.1
C_2 = 1, (also defined in 5.2.2 at other positions along the length L)
f_1 = ship service factor. To be specially considered depending upon the service restriction and in any event should be not less than 0,5. For unrestricted sea-going service $f_1 = 1,0$
f_2 = –1,1 for sagging (negative) moment
$f_2 = \dfrac{1,9C_b}{(C_b + 0,7)}$ for hogging (positive) moment
$M_{wo} = 0,1C_1 \, C_2 \, L^2 \, B \, (C_b + 0,7)$ kN m
($0,0102C_1 \, C_2 \, L^2 \, B \, (C_b + 0,7)$ tonne-f m)

Consideration will be given to direct calculations of long-term vertical wave bending moments, *see* 2.6.

Table 4.5.1 Wave bending moment factor

Length L, in metres	Factor C_1
<90	$0,0412L + 4,0$
90 to 300	$10,75 - \left(\dfrac{300 - L}{100}\right)^{1,5}$
>300 ≤350	10,75
>350 ≤500	$10,75 - \left(\dfrac{L - 350}{150}\right)^{1,5}$

5.2.2 The longitudinal distribution factor, C_2, of wave bending moment is to be taken as follows:

- 0 at the aft end of L
- 1,0 between 0,4L and 0,65L from aft
- 0 at the forward end of L

Intermediate values are to be determined by linear interpolation.

5.2.3 For operation in sheltered water or short voyages, a higher permissible still water bending moment can be assigned based on a reduced vertical wave bending moment given by:

(a) For operating in sheltered water:
$M_w = 0{,}5 f_2 M_{wo}$

(b) For short voyages:
$M_w = 0{,}8 f_2 M_{wo}$

These expressions can only be used in the expression for permissible still water bending moment, *see* 5.4, and the relevant loading conditions are to be included in the Loading Manual, *see* 8.1.

5.2.4 'Short voyages' are defined as voyages of limited duration in reasonable weather. 'Reasonable weather' and 'sheltered water' are defined in Pt 1, Ch 2,2.

5.3 Design still water bending moments

5.3.1 The design still water bending moment, M_s, hogging and sagging is the maximum moment calculated from the loading conditions, given in 5.3.3, and is to satisfy the following relationship:

$| M_s | \leq | \overline{M}_s |$

5.3.2 Still water bending moments are to be calculated along the ship length. For these calculations, downward loads are to be taken as positive values and are to be integrated in the forward direction from the aft end of L. Hogging bending moments are positive.

5.3.3 In general, the following loading conditions, based on amount of bunkers, fresh water and stores at departure and arrival, are to be considered.

(a) General cargo ships, container ships, passenger ships, roll on-roll off ships and refrigerated cargo carriers:
  (i) Homogeneous loading conditions, at maximum draught.
  (ii) Ballast conditions.
  (iii) Special loading conditions, e.g., container or light load conditions at less than the maximum draught, heavy cargo, empty holds or non-homogeneous cargo conditions, deck cargo conditions, etc., where applicable.

(b) Bulk carriers (*see* 3.2.2), ore carriers and combination carriers
  (i) For ships of length, L, less than 150 m:
  Alternate hold loading conditions at maximum draught, where applicable.
  Homogeneous loading conditions at maximum draught.
  Ballast conditions, including intermediate conditions associated with ballast exchange at sea.
  Special conditions, e.g. deck cargo conditions.
  For combination carriers, the conditions as specified in (c) for oil tankers are also to be considered.
  (ii) For ships of length, L, 150 m or above:
  Alternate light and heavy cargo loading conditions at maximum draught, where applicable.
  Homogeneous light and heavy cargo loading conditions at maximum draught.
  Ballast conditions. Where vessels are designed with a ballast hold adjacent to topside wing, hopper and double bottom tanks, the structure design is to be such that the ballast hold can be filled with all adjacent tanks empty.
  Short voyage conditions where the ship is loaded to maximum draught with reduced bunkers, where applicable.
  Multiple port loading/unloading conditions, where applicable.
  Deck cargo conditions, where applicable.
  Typical loading and discharging sequences from commencement to end of cargo operation, for homogeneous, alternate and part load conditions, where applicable.
  Typical sequences for exchange of ballast at sea, where applicable.
  For combination carriers, the conditions as specified in (c) for oil tankers are also to be considered.
  For bulk carriers, the conditions as specified in 5.4 for the relevant notation are also to be considered.

(c) Oil tankers (*see* 3.2.2):
  (i) Homogeneous loading conditions (excluding dry and clean ballast tanks) and ballast or part loaded conditions.
  (ii) Any specified non-uniform distribution of loading.
  (iii) Mid-voyage conditions relating to tank cleaning or other operations where these differ significantly from the ballast conditions.

(d) Chemical tankers:
  (i) Conditions as specified for oil tankers.
  (ii) Conditions for high density or segregated cargo.

(e) Liquefied gas carriers:
  (i) Homogeneous loading conditions for all approved cargoes.
  (ii) Ballast conditions.
  (iii) Cargo conditions where one or more tanks are empty or partially filled or where more than one type of cargo having significantly different densities is carried.

(f) All ships:
  (i) Any other loading condition likely to result in high bending moments and/or shear forces (including docking conditions, as appropriate).

5.3.4 Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted in addition to those for departure and arrival conditions. Also, where any ballasting and/or de-ballasting is intended during voyage, calculations of the intermediate condition just before and just after ballasting and/or de-ballasting any tank are to be submitted and, where approved, included in the loading manual for guidance.

5.3.5 Ballast loading conditions involving partially filled peak and/or other ballast tanks at departure, arrival or during intermediate conditions are not permitted as design conditions unless the design stress limits are satisfied for all filling levels between empty and full, and for bulk carriers the requirements of Pt 4, Ch 7,3, as applicable, are to be complied with for all filling levels between empty and full.

To demonstrate compliance with all filling levels between empty and full, it will be acceptable if, in each condition at departure, arrival and where required by 5.3.3, any intermediate condition, the tanks intended to be partially filled are assumed to be:

- empty
- full
- partially filled at intended level.

Where multiple tanks are intended to be partially filled, all combinations of empty, full or partially filled at intended level for those tanks are to be investigated. However, for conventional ore carriers with large wing water ballast tanks in cargo area, where empty or full ballast water filling levels of one or maximum two pairs of these tanks lead to the ship's trim exceeding one of the following conditions, it is sufficient to demonstrate compliance with maximum, minimum and intended partial filling levels of these one or maximum two pairs of ballast tanks such that the ship's condition does not exceed any of these trim limits. Filling levels of all other wing ballast tanks are to be considered between empty and full.
The trim conditions mentioned above are:

- trim by stern of 3 per cent of the ship's length, or
- trim by bow of 1,5 per cent of ship's length, or
- any trim that cannot maintain propeller immersion (I/D) not less than 25 per cent, where;
  - I = the distance from propeller centreline to the waterline, *see* Fig. 4.5.1
  - D = propeller diameter, *see* Fig. 4.5.1

The maximum and minimum filling levels of the above mentioned pairs of side ballast tanks are to be indicated in the loading manual.

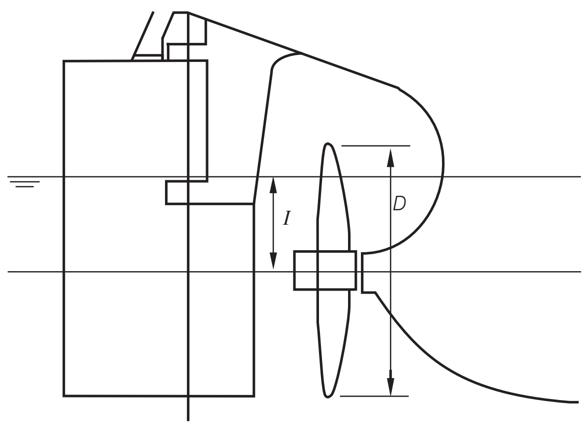


Fig. 4.5.1 Propeller immersion

5.3.6 When considering cargo loading conditions, the requirements of 5.3.5 apply to peak tanks only.

5.3.7 When considering ballast water exchange using the sequential method, the requirements of 5.3.5 and 5.3.6 do not apply. However, bending moment and shear force calculations for each de-ballasting or ballasting stage in the ballast water exchange sequence are to be included in the loading manual or ballast water management plan of any vessel that intends to employ the sequential ballast water exchange method.

5.4 Minimum hull section modulus

5.4.1 The hull midship section modulus about the transverse neutral axis, at the deck or the keel, is to be not less than:

$$Z_{min} = f_1 k_L C_1 L^2 B (C_b + 0,7) \times 10^{-6} \quad m^3$$

and

f_1 is to be taken not less than 0,5.

5.4.2 For materials to be included in the calculation of actual hull section properties, *see* Ch 3,3.

5.4.3 The midship section modulus for ships with a service restriction notation is to be not less than half the minimum value required for unrestricted service.

5.4.4 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section modulus requirements given in 5.4.1 are to be maintained within 0,4L amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the 0,4L part, bearing in mind the desire not to inhibit the vessel's loading flexibility.

5.4.5 Outside 0,4L amidships, as a minimum, hull girder bending strength checks are to be carried out at the following locations:

(a) In way of the forward end of the engine room.
(b) In way of the forward end of the foremost cargo hold.
(c) At any locations where there are significant changes in hull cross-section.
(d) At any locations where there are changes in the framing system.

5.5 Permissible still water bending moments

5.5.1 The permissible still water bending moments sagging and hogging are to be taken as the lesser of the following:

(a) $|\overline{M}_s| = F_D \sigma Z_D \times 10^3 - |M_w|$ kN m (tonne-f m)

(b) $|\overline{M}_s| = F_B \sigma Z_B \times 10^3 - |M_w|$ kN m (tonne-f m)

where

σ = the permissible combined stress in N/mm^2 (kgf/mm^2) is given in 5.6 and F_D and F_B are defined in 5.7.2. M_w is the design wave bending moment, sagging or hogging as appropriate, in accordance with 5.2.

5.6 Permissible hull vertical bending stresses

5.6.1 The permissible combined (still water plus wave) stress for hull vertical bending, σ, is given by:

(a) Within 0,4L amidships

$$\sigma = \frac{175}{k_L} \text{ N/mm}^2 \quad \left(\frac{17,84}{k_L} \text{ kgf/mm}^2\right)$$

(b) for continuous longitudinal structural members outside 0,4L amidships

$$\sigma = \left(75 + 543\frac{d}{L} - 699\left(\frac{d}{L}\right)^2\right)\frac{1}{k_L} \quad \text{N/mm}^2$$

$$\left(\sigma = \left(75 + 543\frac{d}{L} - 699\left(\frac{d}{L}\right)^2\right)\frac{0{,}102}{k_L} \quad \text{kgf/mm}^2\right)$$

where d is the distance, in metres, from the F.P. (for the fore end region) or from the A.P. (for the aft end region), as appropriate, to the location under consideration.

Special consideration will be given to increasing the permissible stress outside 0,4L amidships to

$$\frac{175}{k_L} \text{ N/mm}^2 \left(\frac{17{,}84}{k_L} \text{ kgf/mm}^2\right)$$

provided that sufficient buckling checks are carried out.

5.6.2 The requirements for ships of special or unusual design and for the carriage of special cargoes will be individually considered.

5.7 Local reduction factors

5.7.1 The maximum hull vertical bending stresses at deck, σ_D, and keel, σ_B, are given by the following, using the appropriate combination of bending moments to give sagging and hogging stresses:

$$\sigma_D = \frac{|\overline{M}_s + M_w|}{Z_D} \times 10^{-3} \quad \text{N/mm}^2 \ (\text{kgf/mm}^2)$$

$$\sigma_B = \frac{|\overline{M}_s + M_w|}{Z_B} \times 10^{-3} \quad \text{N/mm}^2 \ (\text{kgf/mm}^2)$$

Where the ship is always in the hogging condition, the sagging bending moment is to be specially considered.

5.7.2 Where the maximum hull vertical bending stress at deck or keel is less than the permissible combined stress, σ, reductions in local scantlings within 0,4L amidships may be permitted. The reduction factors applicable in Part 4 are defined as follows:

For hull members above the neutral axis

$$F_D = \frac{\sigma_D}{\sigma}$$

For hull members below the neutral axis

$$F_B = \frac{\sigma_B}{\sigma}$$

In general, the values of σ_D and σ_B to be used are the greater of the sagging or hogging stresses, and F_D and F_B are not to be taken less than 0,67 for plating and 0,75 for longitudinal stiffeners.

5.7.3 Where higher tensile steel is used in the hull structure, the values of F_D and F_B for the mild steel part are to be taken as not less than $\frac{z}{z_M}$.

5.8 Hull moment of inertia

5.8.1 The hull midship section moment of inertia about the transverse neutral axis is to be not less than the following using the maximum total bending moment, sagging or hogging:

$$I_{min} = \frac{3L\left(|\overline{M}_s + M_w|\right)}{k_L\,\sigma} \times 10^{-5} \quad \text{m}^4$$

where values of σ are given in 5.6.1.

5.9 Continuous strength members above strength deck

5.9.1 Where trunk decks or continuous hatch coamings are effectively supported or deck longitudinals or girders are fitted above the strength deck, the modulus Z_c is to be not less than Z_{min}. The scantling reduction factor, F_D, referred to strength deck at side, is applicable and, in addition to the requirement given in 5.5.1, the permissible still water bending moments, sagging and hogging, are not to exceed:

$$|\overline{M}_s| = \sigma Z_c \times 10^3 - |M_w| \quad \text{kN m (tonne-f m)}$$

where

M_w is the design wave bending moment sagging or hogging, as appropriate, in accordance with 5.2.

■ Section 6
Hull shear strength

6.1 Symbols

6.1.1 The symbols used in this Section are defined as follows:

- I = the inertia of the hull about the horizontal neutral axis at the section concerned, in cm^4
- Az = the first moment, in cm^3, about the neutral axis, of the area of the effective longitudinal members between the vertical level under consideration, and the vertical extremity of the effective longitudinal members, taken at the section under consideration
- Q_s = design hull still water shear force, in kN (tonne-f), to be taken as negative or positive according to the convention given in 6.4.2
- $\overline{Q_s}$ = permissible hull still water shear force, in kN (tonne-f), *see* 6.5
- Q_w = design hull wave shear force, in kN (tonne-f), to be taken as negative or positive according to the convention given in 6.4.2
- τ = permissible combined shear stress (still water plus wave), in N/mm^2 (kgf/mm^2), *see* 6.6
- τ_A = design shear stress, in N/mm^2 (kgf/mm^2), as given in 6.7.1 for use in 7.4.

6.2 General

6.2.1 For ships with length L greater than 65 m, the shear forces on the hull structure are to be investigated.

6.2.2 For L greater than 200 m, where double skin construction of the side shell in association with topside and hopper tanks is proposed, shear flow calculations may be required to be submitted.

6.2.3 Where shear flow calculation procedures other than those available within ShipRight are employed, the requirements of Ch 1,3 are to be complied with.

6.2.4 For passenger ships, the assessment of permissible still water shear forces is to take into consideration the effectiveness of the continuous superstructures and the sizes and arrangements of window and door openings.

6.2.5 Where longitudinal bulkheads are perforated by cut-outs, the assessment of permissible still water shear forces is to take into consideration the loss of material.

6.3 Design wave shear force

6.3.1 The design hull wave shear force, Q_w, at any position along the ship is given by:

$Q_w = K_1 K_2 Q_{wo}$ kN (tonne-f)

where

$Q_{wo} = 0{,}3C_1 LB (C_b + 0{,}7)$ kN
($0{,}0306C_1 LB (C_b + 0{,}7)$ tonne-f)

and C_b is to be taken not less than 0,6

K_1 is to be taken as follows, *see also* Fig. 4.6.1:

(a) Positive shear force

K_1 = 0 at aft end of L

$= \dfrac{1{,}589C_b}{(C_b + 0{,}7)}$ between 0,2L and 0,3L from aft

= 0,7 between 0,4L and 0,6L from aft

= 1,0 between 0,7L and 0,85L from aft

= 0 at forward end of L

(b) Negative shear force

K_1 = 0 at aft end of L

= –0,92 between 0,2L and 0,3L from aft

= –0,7 between 0,4L and 0,6L from aft

$= \dfrac{-1{,}727C_b}{(C_b + 0{,}7)}$ between 0,7L and 0,85L from aft

= 0 at forward end of L

Intermediate values to be determined by linear interpolation

K_2 = 1,0 for unrestricted sea-going service conditions

= 0,8 for short voyages

= 0,5 for operating in sheltered water.

6.4 Design still water shear force

6.4.1 The design still water shear force, Q_s, at each transverse section along the hull is to be taken as the maximum positive and negative value found from the longitudinal strength calculations for each of the loading conditions given in 5.3.3 and is to satisfy the following relationship:

$|Q_s| \leq |\overline{Q_s}|$

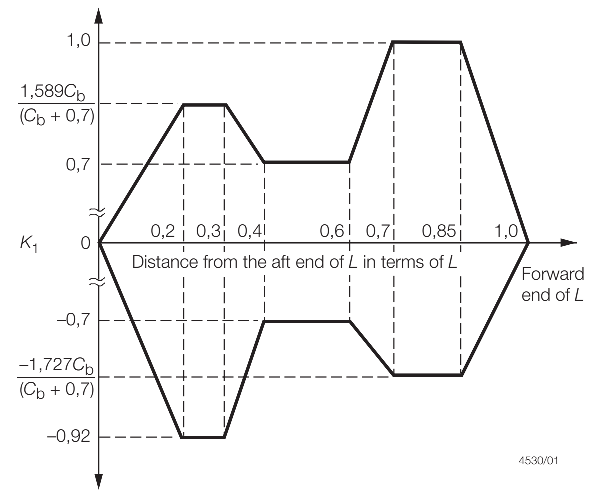


Fig. 4.6.1 Shear force factor K_1

6.4.2 Still water shear forces are to be calculated at each section along the ship length. For these calculations, downward loads are to be taken as positive values and are to be integrated in a forward direction from the aft end of L. The shear force is positive when the algebraic sum of all vertical forces aft of the section is positive.

6.4.3 For hull configuration Types A, D, G, H and I, as indicated in Table 4.6.1, where loading conditions are featuring either:

- cargo loading with specified or alternate cargo holds (or cargo tanks) empty; or
- ballasting of cargo hold(s);

the actual shear forces obtained from the longitudinal strength calculations may be corrected for the effect of local forces at the transverse bulkheads. The calculation of these local forces is to be submitted for approval or, alternatively, the proportion of the double bottom load carried by the transverse bulkhead may be arrived at by using the following bulkhead factor F:

$$F = \frac{1}{1 + 1{,}5\alpha^{1{,}65}}$$

where

l_F = span of floors measured to intersection of hopper side or ship's side, and inner bottom, in metres

S_H = length of hold measured between bulkhead stools, where fitted, at the level of the inner bottom on the centreline, in metres

$$\alpha = \frac{S_H}{l_F}$$

6.4.4 If the hull shear forces in kN (tonne-f) at transverse bulkheads A and B are calculated to be Q_A and Q_B respectively (with appropriate algebraic signs), the excess load or buoyancy over hold AB is given by $Q_B - Q_A$ and the load transmitted to each bulkhead is:

$0{,}5F (Q_B - Q_A)$ kN (tonne-f)

where F is the bulkhead factor as given in 6.4.3.

See Fig. 4.6.2.

Table 4.6.1 **f_i factors** (*see continuation*)

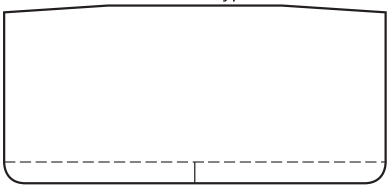
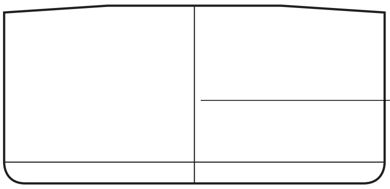
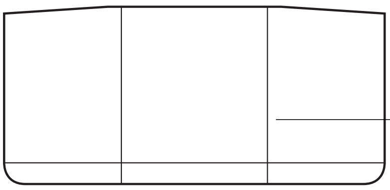
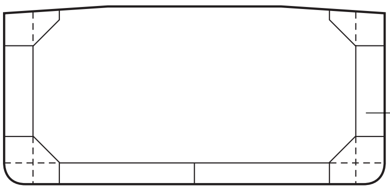
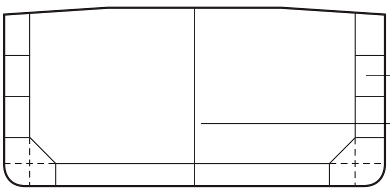
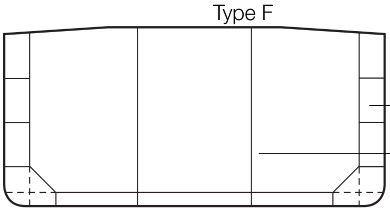
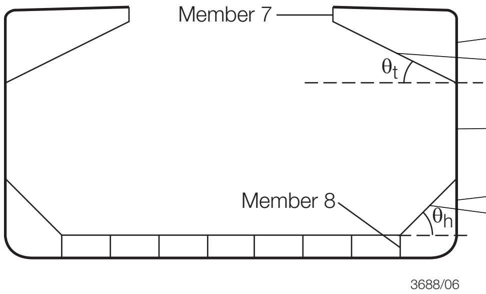
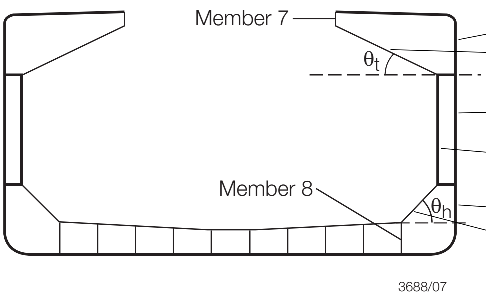
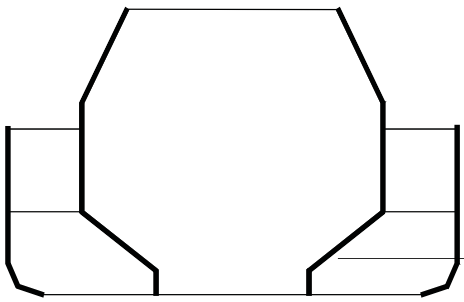
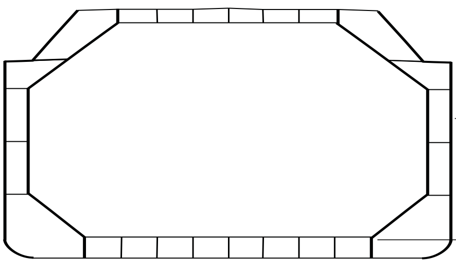
Hull configuration	f_i factors
Type A 	Member 1 f_1 = 0,5
Type B 	Member 1 $f_1 = 0{,}231 + 0{,}076\, A_1/A_2$ Member 2 $f_2 = 0{,}538 - 0{,}152\, A_1/A_2$
Type C 	Member 1 $f_1 = 0{,}135 + 0{,}088\, A_1/A_2$ Member 2 $f_2 = 0{,}365 - 0{,}088\, A_1/A_2$
Type D 	Member 1 $f_1 = 0{,}128 + 0{,}105\, A_1/A_2$ Member 2 $f_2 = 0{,}372 - 0{,}105\, A_1/A_2$
Type E 	Member 1 $f_1 = 0{,}055 + 0{,}097\, A_1/A_2 + 0{,}020\, A_2/A_3$ Member 2 $f_2 = 0{,}193 - 0{,}059\, A_1/A_2 + 0{,}058\, A_2/A_3$ Member 3 $f_3 = 0{,}504 - 0{,}076\, A_1/A_2 - 0{,}156\, A_2/A_3$
Type F 	Member 1 $f_1 = 0{,}028 + 0{,}087\, A_1/A_2 + 0{,}023\, A_2/A_3$ Member 2 $f_2 = 0{,}119 - 0{,}038\, A_1/A_2 + 0{,}072\, A_2/A_3$ Member 3 $f_3 = 0{,}353 - 0{,}049\, A_1/A_2 - 0{,}095\, A_2/A_3$
Type G 	Member 1 $f_1 = 0{,}139 + 0{,}099\, A_1/A_2$ Member 2 $f_2 = 0{,}361 - 0{,}099\, A_1/A_2$

Table 4.6.1 **f_i factors** (*continued*)

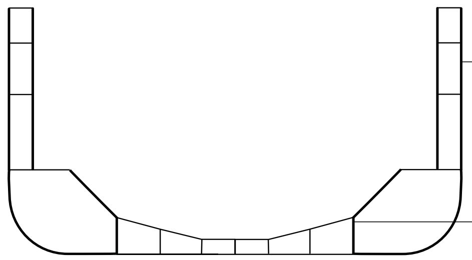
Hull configuration	f_i factors
Type H 	Member 1 $f_1 = 0{,}216 + 0{,}087\, A_1/(A_7 + A_2 \sin \theta_t)$ Member 2 $f_2 = 0{,}284 - 0{,}087\, A_1/(A_7 + A_2 \sin \theta_t)$ Member 3 $f_3 = 0{,}5$ Member 5 $f_5 = 0{,}155 + 0{,}087\, A_5/(A_8 + A_6 \sin \theta_h)$ Member 6 $f_6 = 0{,}345 - 0{,}087\, A_5/(A_8 + A_6 \sin \theta_h)$ $f_7 = f_2, \quad f_8 = f_6$
Type I 	Member 1 $f_1 = 0{,}216 + 0{,}087\, A_1/(A_7 + A_2 \sin \theta_t)$ Member 2 $f_2 = 0{,}284 - 0{,}087\, A_1/(A_7 + A_2 \sin \theta_t)$ Member 3 $f_3 = 0{,}143 + 0{,}104\, A_3/A_4$ Member 4 $f_4 = 0{,}357 - 0{,}104\, A_3/A_4$ Member 5 $f_5 = 0{,}155 + 0{,}087\, A_5/(A_8 + A_6 \sin \theta_h)$ Member 6 $f_6 = 0{,}345 - 0{,}087\, A_5/(A_8 + A_6 \sin \theta_h)$ $f_7 = f_2, \quad f_8 = f_6$
Type J 	Member 1 $f_1 = 0{,}153 + 0{,}105\, A_1/A_2$ Member 2 $f_2 = 0{,}347 - 0{,}105\, A_1/A_2$
Type K 	Member 1 $f_1 = 0{,}128 + 0{,}105\, A_1/A_2$ Member 2 $f_2 = 0{,}372 - 0{,}105\, A_1/A_2$

6.4.5 The corrected shear forces, Q_A' and Q_B', at bulkheads A and B with respect to hold AB are then obtained from:

$Q_A' = Q_A + 0{,}5F\,(Q_B - Q_A)$ kN (tonne-f)

$Q_B' = Q_B - 0{,}5F\,(Q_B - Q_A)$ kN (tonne-f)

Table 4.6.1 **f_i factors** (*conclusion*)

Hull configuration	f_i factors
Type L 	Member 1 $f_1 = 0{,}093 + 0{,}162\, A_1/A_2$ Member 2 $f_2 = 0{,}407 - 0{,}162\, A_1/A_2$
Symbols	
i = structural member index for different hull configurations for types A, B, C, D, E, F and G, i may take the value of 1, 2 or 3. for i = 1, the side shell at the section is under consideration for i = 2 and 3, the longitudinal bulkheads at the section are under consideration for types H and I, i may take the value of 1, 2, 3, 4, 5, 6, 7 or 8 for i = 1, the part of side shell in way of topside tank is under consideration for i = 2, the topside slope is under consideration for i = 3, the part of side shell between topside tank and hopper tank is under consideration for i = 4, the inner hull is under consideration for i = 5, the part of side shell in way of hopper tank is under consideration for i = 6, the hopper slope is under consideration for i = 7, the vertical strake at topside tank is under consideration for i = 8, the double bottom girder at hopper tank is under consideration for types J, K and L, i may take the value of 1 or 2: for i = 1, the side shell at the section is under consideration for i = 2, the longitudinal bulkheads at the section are under consideration A_i = the area of structural member i at the section under consideration, in cm^2 In the event of part of the structural member being non-vertical, A_i is to be calculated using the projected area in the vertical direction, *see* Fig. 4.6.4, except for members 2 and 6 for types H and I, where the inclined area is to be applied.	
NOTES 1. For hull configurations not included above, f_i factors are to be specially considered. 2. Where it is necessary to increase the thickness of the side shell or longitudinal bulkhead(s) to meet these requirements, the original thicknesses are to be used in the calculation of the cross-sectional areas A_i.	

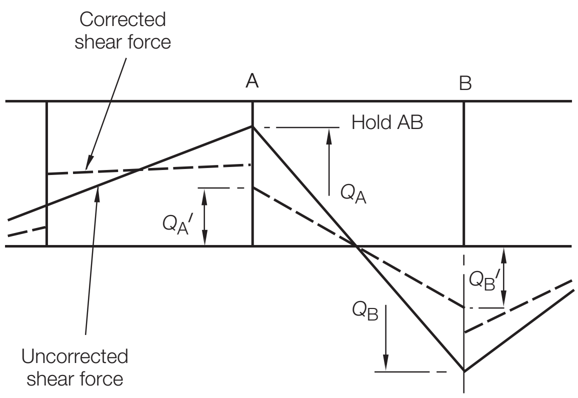


Fig. 4.6.2 Shear force correction

6.5 Permissible still water shear force

6.5.1 The permissible hull still water shear force is given by the minimum value obtained from:

$$|Q_s| = \tau \frac{I\,\delta_i}{100Az} - |Q_w| \quad \text{kN (tonne-f)}$$

when

$$\delta_i = \frac{t_i}{f_i + m_i}$$

i = structural member index for the hull configuration under consideration, *see* Table 4.6.1

t_i = the plate thickness of the structural member at the vertical level and section under consideration, in mm

f_i, m_i = factors determined from Tables 4.6.1 and 4.6.2 respectively, for the hull configuration under consideration.

Table 4.6.2 **m_i factors**

Hull configuration, *see* Table 4.6.1	m_i factors
Type A	$m_1 = 0$
Type B	$m_1 = \dfrac{m_2}{2}$, $m_2 = (0,1 + r)\,0,5$
Type C	$m_1 = m_2$, $m_2 = (0,1 + r)\,\dfrac{b_2}{B}$
Type D	$m_i = 0$
Type E	$m_1 = \dfrac{m_3}{4}$, $m_2 = \dfrac{m_3}{4}$, $m_3 = (0,1 + r)\,0,5\left(1 - \dfrac{b_2}{B}\right)$
Type F	$m_1 = \dfrac{m_3}{2}$, $m_2 = \dfrac{m_3}{2}$, $m_3 = (0,1 + r)\left(\dfrac{b_3 - 0,5b_2}{B}\right)$
Type G	$m_i = 0$
Type H	$m_i = 0$
Type I	$m_i = 0$
Type J	$m_i = 0$
Type K	$m_i = 0$
Type L	$m_i = 0$
Symbols	
i = structural member index for different hull configurations, *see* Table 4.6.1 b_i = the horizontal distance of the structural member *i* from the side shell, at the section under consideration, in metres r = 0,15 within $0,20L_T$ from the transverse bulkhead position for loading conditions where the cargo region between two consecutive bulkheads is unevenly loaded in the transverse direction = 0 within $0,20L_T$ from the transverse bulkhead position for loading conditions where the cargo region between two consecutive bulkheads is evenly loaded in the transverse direction = 0 elsewhere L_T = cargo hold length, in metres	
NOTE For hull configurations not included above, m_i factors are to be specially considered.	

6.5.2 The permissible shear forces assigned for approved loading instruments will normally be based on 6.5.1. However, where use is made of an approved loading instrument incorporating a facility to calculate the transverse distribution of shear forces, separate permissible still water shear forces, Q_{si} may be assigned for the structural members indicated in Table 4.6.1 for the hull configuration under consideration.

$$|Q_{si}| = (f_i + m_i)\,|Q_s| \text{ kN (tonne-f)}$$

6.5.3 Individual loading conditions in the ship's loading manual may be specially considered on a similar basis to that in 6.5.2 with the factors being determined by direct calculation.

6.5.4 For hull configuration types B and E (*see* Table 4.6.1), where loading conditions are such that hull girder torsion may be induced, direct calculations may be required.

6.5.5 The calculation of shear forces immediately beyond the ends of the longitudinal bulkheads will be considered in relation to the arrangement of structure in these regions.

6.6 Permissible shear stress

6.6.1 The permissible combined shear stress (still water plus wave) is to be taken as:

$$\tau = \frac{110}{k_L} \text{ N/mm}^2 \quad \left(\frac{11,2}{k_L} \text{ kgf/mm}^2\right)$$

6.6.2 Where a plate is tapered, the permissible combined shear stress is not to be exceeded at any point in way of the taper, *see* Fig. 4.6.3.

6.7 Design shear stress

6.7.1 The design shear stress for use in 7.4 is to be taken as:

$$\tau_A = 100Az\,\frac{|Q_s| + |Q_w|}{I\,\delta_i} \text{ N/mm}^2$$

$$= \left(10,2Az\,\frac{|Q_s| + |Q_w|}{I\,\delta_i} \text{ kgf/mm}^2\right)$$

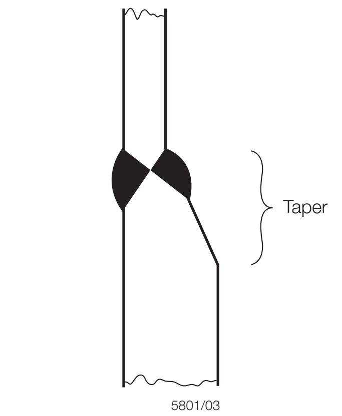


Fig. 4.6.3 Tapered plates

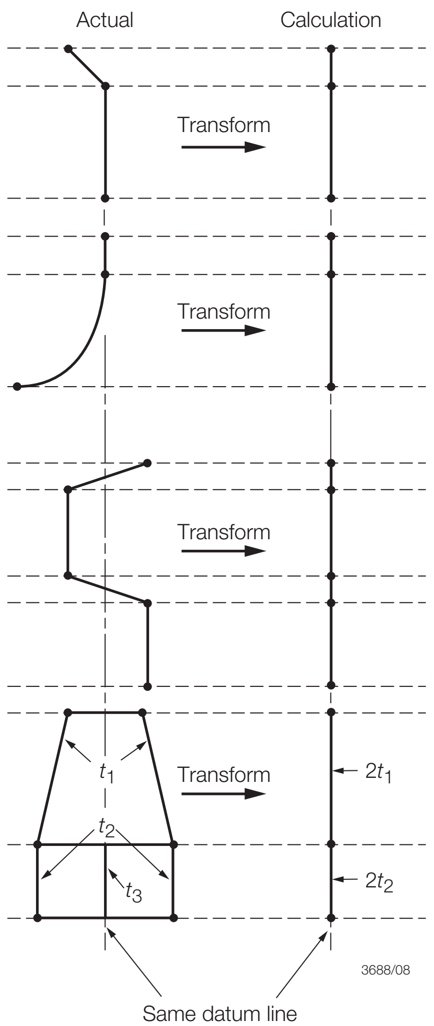


Fig. 4.6.4
Calculation of A_i for non-vertical parts of structural members

■ *Section 7* Hull buckling strength

7.1 Application

7.1.1 These requirements apply to plate panels and longitudinals subjected to hull girder compression and shear stresses based on design values for still water and wave bending moments and shear forces.

7.1.2 The hull buckling strength requirements are applicable within 0,4*L* amidships to ships of 90 m or greater in length.

7.1.3 Hull buckling strength for ships less than 90 m in length will be specially considered.

7.1.4 Hull buckling strength outside 0,4*L* amidships of members contributing to the longitudinal strength and subjected to compressive and shear stresses is to be checked, in particular in regions where changes in the framing system or significant changes in the hull cross-section occur.

7.2 Symbols

7.2.1 The symbols used in this Section are defined as follows:

d_t = standard deduction for corrosion, *see* Table 4.7.1
s = spacing of secondary stiffeners, in mm. In the case of symmetrical corrugations, s is to be taken as b or c in Fig. 3.3.1 in Chapter 3, whichever is the greater
t = as built thickness of plating, stiffener flange and web used in Table 4.7.1 in calculating standard deduction d_t, in mm
t_p = as built thickness of plating less standard deduction d_t, in mm, (i.e., $t_p = t - d_t$)
E = modulus of elasticity, in N/mm^2 (kgf/mm^2)
= 206000 N/mm^2 (21000 kgf/mm^2) for steel
S = spacing of primary members, in metres
σ_o = specified minimum yield stress, in N/mm^2 (kgf/mm^2)
σ_A = design longitudinal compressive stress in N/mm^2 (kgf/mm^2)
σ_{CRB} = critical buckling stress in compression, in N/mm^2 (kgf/mm^2) corrected for yielding effects
σ_E = elastic critical buckling stress in compression, in N/mm^2 (kgf/mm^2)
τ_A = design shear stress, in N/mm^2 (kgf/mm^2)
τ_{CRB} = critical buckling stress in shear, in N/mm^2 (kgf/mm^2) corrected for yielding effects
τ_E = elastic critical buckling stress in shear, in N/mm^2 (kgf/mm^2)

$$\tau_o = \frac{\sigma_o}{\sqrt{3}}$$

7.3 Elastic critical buckling stress

7.3.1 The elastic critical buckling stress of plating is to be determined from Table 4.7.2.

Table 4.7.1 Standard deduction for corrosion, d_t

Structure		d_t mm	d_t range mm min. – max.
(a) Compartments carrying dry bulk cargoes		0,05t	0,5 – 1
(b) One side exposure to water ballast and/or liquid cargo.	Vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line.		
(c) One side exposure to water ballast and/or liquid cargo.	Horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line.	0,10t	2 – 3
(d) Two side exposure to water ballast and/or liquid cargo.	Vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line.		
(e) Two side exposure to water ballast and/or liquid cargo.	Horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line.	0,15t	2 – 4

NOTES
1. The standard deduction d_t is to be taken as appropriate and within the range given above.
2. For direct calculation purposes, standard deductions will be specially considered.

Table 4.7.2 Elastic critical buckling stress of plating

Mode	Elastic critical buckling stress, N/mm^2 (kgf/mm^2)
(a) Compression of plating with longitudinal stiffeners (parallel to compressive stress), *see* Note	$\sigma_E = 3{,}6E\left(\frac{t_p}{s}\right)^2$
(b) Compression of plating with transverse stiffeners (perpendicular to compressive stress), *see* Note	$\sigma_E = 0{,}9c\left[1 + \left(\frac{s}{1000S}\right)^2\right]^2 E\left(\frac{t_p}{s}\right)^2$ where c = 1,3 when plating stiffened by floors or deep girders = 1,21 when stiffeners are built up profiles or rolled angles = 1,10 when stiffeners are bulb plates = 1,05 when stiffeners are flat bars
(c) Shear, *see* Note	$\tau_E = 3{,}6\left[1{,}335 + \left(\frac{s}{1000S}\right)^2\right] E\left(\frac{t_p}{s}\right)^2$

NOTE
Where the elastic critical buckling stress, as evaluated from (a), (b) or (c), exceeds 50 per cent of specified minimum yield stress of the material, the corrected critical buckling stresses in compression (σ_{CRB}) and shear (τ_{CRB}) are given by:

$$\sigma_{CRB} = \sigma_E \quad \text{when } \sigma_E \leq \frac{\sigma_o}{2}$$

$$= \sigma_o\left(1 - \frac{\sigma_o}{4\sigma_E}\right) \quad \text{when } \sigma_E > \frac{\sigma_o}{2} \quad \text{N/mm}^2 \ (\text{kgf/mm}^2)$$

$$\tau_{CRB} = \tau_E \quad \text{when } \tau_E \leq \frac{\tau_o}{2}$$

$$= \tau_o\left(1 - \frac{\tau_o}{4\tau_E}\right) \quad \text{when } \tau_E > \frac{\tau_o}{2} \quad \text{N/mm}^2 \ (\text{kgf/mm}^2)$$

7.3.2 The elastic critical buckling stress of longitudinals is to be determined from Table 4.7.3.

Table 4.7.3 Elastic critical buckling stress of longitudinals (*see continuation*)

Mode	Elastic critical buckling stress, N/mm^2 (kgf/mm^2)
(a) Column buckling (perpendicular to plane of plating) without rotation of cross section, *see* Note 1	$\sigma_E = 0{,}001E \dfrac{I_a}{A_t S^2}$
(b) Torsional buckling, *see* Note 1	$\sigma_E = \dfrac{0{,}001\,E\,I_w}{I_p S^2}\left(m^2 + \dfrac{K}{m^2}\right) + 0{,}385E\dfrac{I_t}{I_p}$
(c) Web buckling, *see* Notes 1 and 3 (flat bars are excluded)	$\sigma_E = 3{,}8E\left(\dfrac{t_w}{d_w}\right)^2$

Symbols and Parameters

d_w = web depth, in mm

t_w = as built web thickness less standard deduction d_t as specified in Table 4.7.1, in mm, (i.e., $t_w = t - d_t$). For webs in which the thickness varies, a mean thickness is to be used

b_f = flange width, in mm

t_f = as built flange thickness less standard deduction d_t as specified in Table 4.7.1, in mm, (i.e., $t_f = t - d_t$). For bulb plates, the mean thickness of the bulb may be used, *see* Fig. 4.7.1

A_t = cross-sectional area, in cm^2, of longitudinal, including attached plating, taking account of standard deductions, *see* Note 4

I_a = moment of inertia, in cm^4, of longitudinal, including attached plating, taking account of standard deductions, *see* Note 4

I_t = St.Venant's moment of inertia, in cm^4, of longitudinal (without attached plating)

$= \dfrac{d_w t_w^3}{3} 10^{-4}$ for flat bars

$= \dfrac{1}{3}\left[d_w t_w^3 + b_f t_f^3\left(1 - 0{,}63\dfrac{t_f}{b_f}\right)\right] 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_p = polar moment of inertia, in cm^4, of profile about connection of stiffener to plating

$= \dfrac{d_w^3 t_w}{3} 10^{-4}$ for flat bars

$= \left(\dfrac{d_w^3 t_w}{3} + d_w^2 b_f t_f\right)10^{-4}$ for built up profiles, rolled angles and bulb plates

I_w = sectorial moment of inertia, in cm^6, of profile about connection of stiffener to plating

$= \dfrac{d_w^3 t_w^3}{36} 10^{-6}$ for flat bars

$= \dfrac{t_f b_f^3 d_w^2}{12} 10^{-6}$ for 'Tee' profiles

$= \dfrac{b_f^3 d_w^2}{12(b_f + d_w)^2}\left[t_f\left(b_f^2 + 2b_f d_w + 4d_w^2\right) + 3t_w b_f d_w\right] 10^{-6}$ for 'L' profiles, rolled angles and bulb plates

$K = \dfrac{1{,}03C\,S^4}{E\,I_w} 10^4$

7.4 Design stress

7.4.1 Design longitudinal compressive stress, σ_A, is to be determined in accordance with Section 5:

minimum $\sigma_A = \dfrac{30}{k_L}$ N/mm^2 $\left(\dfrac{3{,}06}{k_L}\right.$ kgf/mm$^2\left.\right)$

for structural members above the neutral axis,

$$\sigma_A = \sigma_D \frac{z}{z_D}$$

for structural members below the neutral axis,

$$\sigma_A = \sigma_B \frac{z}{z_B}$$

σ_D based on sagging moment and σ_B based on hogging moment are determined in 5.8.1.

where

z = vertical distance from the hull transverse neutral axis to the position considered, excluding deck camber, in metres

z_D, z_B = vertical distances from the hull transverse neutral axis to the deck and keel respectively, in metres

Table 4.7.3 Elastic critical buckling stress of longitudinals (*conclusion*)

m is determined as follows:

m	*K* range
1	$0 < K \leq 4$
2	$4 < K \leq 36$
3	$36 < K \leq 144$
4	$144 < K \leq 400$
5	$400 < K \leq 900$
6	$900 < K \leq 1764$
m	$(m-1)^2 m^2 < K \leq m^2 (m+1)^2$

C = spring stiffness exerted by supporting plate panel

$$= \frac{k_p E t_p^3}{3s\left(1 + \dfrac{1{,}33 k_p d_w t_p^3}{s t_w^3}\right)}$$

k_p = $1 - \eta_p$, and is not to be taken less than zero. For built up profiles, rolled angles and bulb plates, k_p need not be taken less than 0,1

η_p = $\dfrac{\sigma_A}{\sigma_{Ep}}$ where σ_{Ep} = elastic critical buckling stress (σ_E) of supporting plate derived from Table 4.7.2

All other symbols as defined in 7.2.1.

NOTES

1. Where the elastic critical buckling stress, as evaluated from (a), (b) or (c), exceeds 50 per cent of specified minimum yield stress of the material, the corrected critical buckling stress in compression (σ_{CRB}) is given by:

$$\sigma_{CRB} = \sigma_o \left(1 - \frac{\sigma_o}{4\sigma_E}\right) \text{ N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

2. Fig. 4.7.1 shows the dimensions of longitudinals.
3. For flanges on angles and T-sections of longitudinals, the following requirement is to be satisfied:

$\dfrac{b_f}{t} \leq 15$ for angles, $\dfrac{b_f}{t} \leq 30$ for 'Tee' profiles,

where

t = as built flange thickness, in mm

4. The area of attached plating is to be calculated using actual spacing of secondary stiffeners.

For initial design purposes, the hull transverse neutral axis may be taken at a distance $\dfrac{D}{2}$ above keel, where D is the depth of the ship, in metres, as defined in Ch 1,6.

7.4.2 Design shear stress, τ_A, is to be determined in accordance with Section 6.

For initial design purposes, τ_A may be taken as:

$$\tau_A = \frac{110}{k_L} \text{ N/mm}^2 \left(\frac{11{,}2}{k_L} \text{ kgf/mm}^2\right)$$

7.5 Scantling criteria

7.5.1 The corrected critical buckling stress in compression, σ_{CRB}, of plate panels and longitudinals, as derived from Tables 4.7.2 and 4.7.3, is to satisfy the following:

$$\sigma_{CRB} \geq \beta \sigma_A$$

where

β = 1 for plating and for web plating of longitudinals (local buckling)

β = 1,1 for longitudinals

7.5.2 The corrected critical buckling stress in shear, τ_{CRB}, of plate panels, as derived from Table 4.7.2(c), is to satisfy the following:

$$\tau_{CRB} \geq \tau_A$$

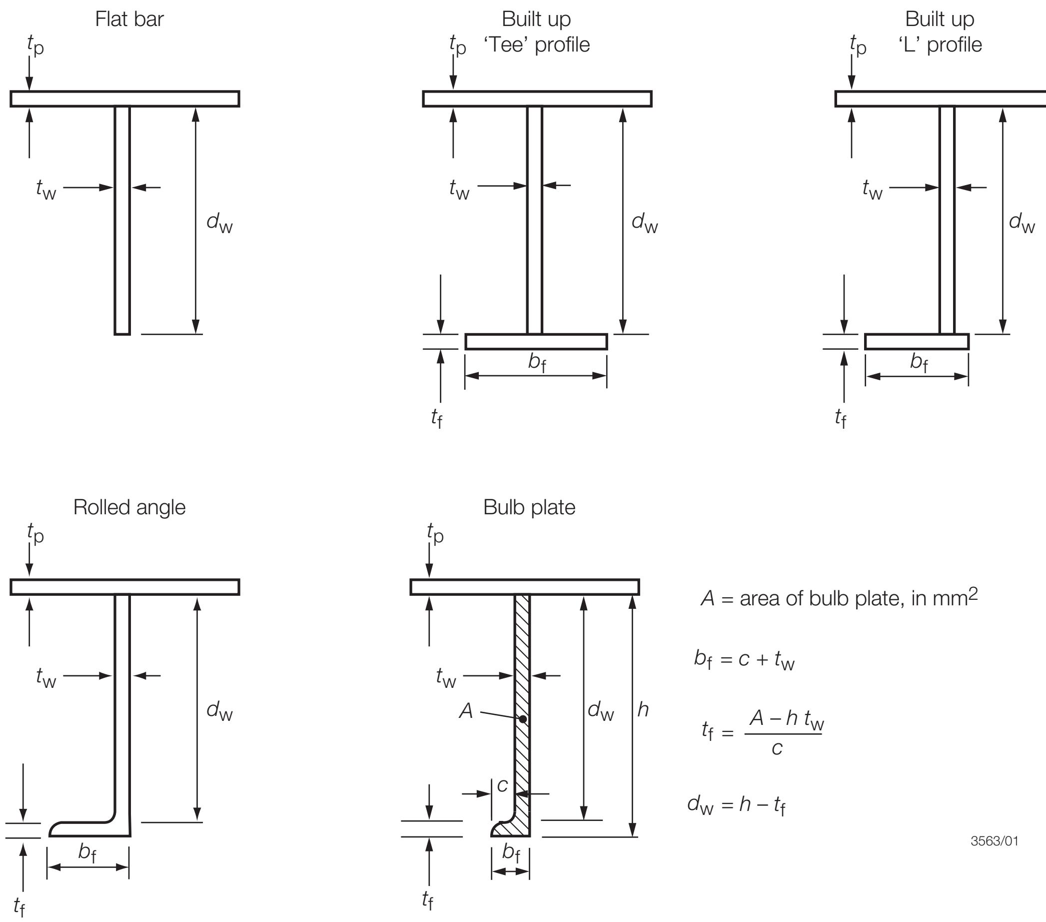


Fig. 4.7.1 Dimensions of longitudinals

■ *Section 8*

Loading guidance information

8.1 General

8.1.1 Sufficient information is to be supplied to the Master of every ship to enable him to arrange loading and ballasting in such a way as to avoid the creation of unacceptable stresses in the ship's structure.

8.1.2 This information is to be provided by means of a Loading Manual and in addition, where required, by means of an approved loading instrument.

8.2 Loading Manual

8.2.1 A Loading Manual is to be supplied to all ships where longitudinal strength calculations have been required, *see* Section 2. The Manual is to be submitted for approval in respect of strength aspects. Where both Loading Manual and loading instrument are supplied, the Loading Manual must nevertheless be approved from the strength aspect. In this case, the Manual is to be endorsed to the effect that any departures from these conditions in service are to be arranged on the basis of the loading instrument and the allowable local loadings shown in the Manual, *see* 8.2.4.

8.2.2 The Manual is to be based on the final data of the ship and is to include well-defined lightweight distribution and buoyancy data.

8.2.3 Details of the loading conditions given in 5.3.3 are to be included in the Manual as applicable.

8.2.4 The Manual is also to contain the following:

(a) Values of actual and permissible still water bending moments and shear forces and, where applicable, limitations due to torsional loads.

(b) The allowable local loadings for the structure such as the hatch covers, decks and double bottoms. If the ship is not approved to carry load on the deck or hatch covers, this is to be clearly stated.
(c) Details of cargo carriage constraints imposed by the use of an accepted coating in association with a system of corrosion control, *see* Ch 2,3.6.
(d) A note saying:
 'Scantlings approved for minimum draught forward of …m with ballast tanks No… filled. In heavy weather conditions the forward draught should not be less than this value. If, in the opinion of the Master, sea conditions are likely to cause regular slamming, then other appropriate measures such as change in speed, heading or an increase in draught forward may also need to be taken.'
(e) The maximum unladen weight, in tonnes, of grab that is considered suitable for the approved thickness of the hold inner bottom for bulk carriers and ore or oil carriers that are regularly discharged by grabs. This maximum unladen weight may differ for adjacent holds, *see* Ch 9,9.2 and Pt 4, Ch 7,8.1. This weight does not preclude the use of heavier grabs, but is intended as an indication to the Builders, Owners and operators of the increased risk of local damage and the possibility of accelerated diminution of the plating thickness if grabs heavier than this are used regularly to discharge cargo.

8.2.5 In addition to the requirements of 8.2.4, the Manual is to contain the following information for bulk carriers (*see* 3.2.2), ore carriers and combination carriers of length, *L*, 150 m or above:
(a) The cargo hold(s) or combination of cargo holds that may be empty at maximum draught. If no cargo hold is permitted to be empty at maximum draught, this is to be clearly stated in the Manual.
(b) Maximum allowable and minimum required mass of cargo and double bottom ballast for each hold as a function of the draught at mid-hold position.
(c) Maximum allowable and minimum required mass of cargo and double bottom ballast for any two adjacent holds as a function of the mean draught in way of these holds. The mean draught may be calculated by averaging the draught at the two mid-hold positions.
(d) Maximum allowable inner bottom loading together with specification of the nature of the cargo, for cargoes other than bulk cargoes.
(e) The maximum rate of ballast exchange, together with advice that a load plan is to be agreed with the terminal on the basis of achievable rates of exchange.

For bulk carriers for which it is required to undertake longitudinal strength calculations in the flooded condition, *see* Pt 4, Ch 7,3.1.2, the Manual is also to contain envelope results and permissible limits of still water bending moments and shear forces for hold flooded conditions, *see* Pt 4, Ch 7,3.4.

8.2.6 Where applicable, the Manual is also to contain the procedure for ballast exchange and sediment removal at sea.

8.2.7 Where alteration to structure, lightweight, cargo distribution or draught is proposed, revised information is to be submitted for approval.

8.3 Loading instrument

8.3.1 In addition to a Loading Manual, an approved type loading instrument is to be provided for all ships where *L* is greater than 65 m and which are approved for non-uniform distribution of loading. The following ships are exempt from this requirement:
(a) Ships with very limited possibilities for variations in the distribution of cargo and ballast.
(b) Ships with a regular or fixed trading pattern.
(c) Ships exempt by individual Chapters in Part 4.

8.3.2 The loading instrument is to be capable of calculating shear forces and bending moments, in any load or ballast condition at specified readout points and is to indicate the permissible values. On container ships and other ships with large deck openings (*see* 3.3.2), cargo torque is also to be calculated.

8.3.3 For bulk carriers, ore carriers and combination carriers of length, *L*, 150 m or above, the loading instrument is to be additionally capable of verifying that the following are within permissible limits:
(a) the mass of cargo and double bottom ballast in way of each hold as a function of the draught at the mid-hold position.
(b) the mass of cargo and double bottom ballast for any two adjacent holds as a function of the mean draught in way of these holds. The mean draught may be calculated by averaging the draught at the two mid-hold positions.

For bulk carriers for which it is required to undertake longitudinal strength calculations in the flooded condition, *see* Pt 4, Ch 7,1.2.2, the loading instrument is also to be capable of verifying that the still water bending moments and shear forces in hold flooded conditions (*see* Pt 4, Ch 7,3.4), are within permissible limits.

8.3.4 If the approved loading manual utilises bulkhead correction factors for shear force distribution, then the loading instrument must also have the capability to account for the bulkhead correction factors.

8.3.5 The instrument is to be certified in accordance with LR's document entitled *Approval of Longitudinal Strength and Stability Calculations Programs*.

8.3.6 The instrument readout points are usually selected at the position of the transverse bulkheads or other obvious boundaries. As many readout points as considered necessary by LR are to be included, e.g., between bulkheads.

8.3.7 A notice is to be displayed on the loading instrument stating:
 'Scantlings approved for minimum draught forward of …m with ballast tanks No… filled. In heavy weather conditions, the forward draught should not be less than this value. If, in the opinion of the Master, sea conditions are likely to cause regular slamming, then other appropriate measures such as change in speed, heading or an increase in draught forward may also need to be taken.'

8.3.8 Where alteration to structure, lightweight or cargo distribution is proposed, the loading instrument is to be modified accordingly and details submitted for approval.

8.3.9 The operation of the loading instrument is to be verified by the Surveyors upon installation and at Annual and Periodical Surveys as required in Pt 1, Ch 3. An Operation Manual for the instrument is to be verified as being available on board.

8.3.10 Where an onboard computer system having a strength computation capability is provided as an Owner's option, it is recommended that the system be certified in accordance with LR's document entitled *Approval of Longitudinal Strength and Stability Calculations Programs*. For systems having a stability computation capability and installed on a new ship, *see also* Pt 1, Ch 2,1.1.11. For systems having a stability computation capability and installed on an existing ship, it is recommended that the system be certified in accordance with LR's document entitled *Approval of Longitudinal Strength and Stability Calculation Programs.*

8.4 Onboard lashing program

8.4.1 An onboard lashing program to calculate forces acting on the container stowage arrangement may be provided, *see* Chapter 14. This may be an extension to the loading instrument covered under Ch 4,8.3. If the software to carry out lashing calculations is installed and maintained in accordance with the Rules, the ship will be eligible to be assigned the special features notation **BoxMax**, with one or more of the supplementary letters **V** and **W**.

8.4.2 To qualify for the notation **BoxMax** the following requirements must be satisfied:

(a) The onboard lashing program is to be certified in accordance with LR's *Approval of Longitudinal Strength and Stability Calculation Programs*.
(b) Where alteration to the container stowage arrangements is proposed, the onboard lashing program is to be modified accordingly and details submitted for approval.
(c) The operation of the onboard lashing program is to be verified by the Surveyors upon installation and at Annual and Periodical Surveys as required in Pt 1, Ch 3. An Operation Manual for the onboard lashing program is to be verified as being available on board.

8.4.3 The onboard lashing program may also have the capability to take account of the various sea areas through which the container ship may trade. If the software to carry out lashing calculations is installed and maintained in accordance with the Rules and includes the functionality to take account of voyage route using the methodology and factors supplied by LR, the ship will be eligible to be assigned the special features notation **BoxMax(V)**.

8.4.4 To qualify for the notation **BoxMax(V)** the following requirements must be satisfied:

(a) The requirements for **BoxMax** must be satisfied.
(b) The benefits of the notation may only be applied in sea areas for which LR has provided the factors for the ship. Elsewhere, the weather-dependent factors must be set to the values defined for unrestricted worldwide service, *see* Pt 3, Ch 14,1.5.
(c) The voyage-specific aspects of the onboard lashing program are to be verified by the Surveyors upon installation and at Annual and Periodical Surveys as required in Pt 1, Ch 3. An Operations Manual for these aspects of the onboard lashing program is to be verified as being available on board.

8.4.5 The onboard lashing program may also have the capability to take account of the various seasons during which the container ship may trade. If the software to carry out lashing calculations is installed and maintained in accordance with the Rules and includes the functionality to take account of voyage route and season using the methodology and factors supplied by LR, the ship will be eligible to be assigned the special features notation **BoxMax(V,W)**

8.4.6 To qualify for the notation **BoxMax(V,W)** the following requirements must be satisfied:

(a) The requirements for **BoxMax(V)** must be satisfied.
(b) The benefits of the notation may only be applied in sea areas and during seasons for which LR has provided the factors for the ship. If the required sea areas and seasons are not fully covered by the factors provided by LR, the weather-dependent factors must be set to the values defined for the notation **BoxMax(V)**, if available, or for unrestricted worldwide service, *see* Pt 3, Ch 14,1.5.
(c) The voyage- and season-specific aspects of the onboard lashing program are to be verified by the Surveyors upon installation and at Annual and Periodical Surveys as required in Pt 1, Ch 3. An Operation Manual for these aspects of the onboard lashing program is to be verified as being available on board.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all types of ship covered by Part 4 except where specifically stated otherwise.

1.1.2 The requirements given are those specific to fore ends and relate to structure situated in the region forward of 0,3*L* from the forward perpendicular.

1.1.3 Requirements for cargo space structure within this region not dealt with in this Chapter are to be as detailed in the relevant Chapter of Part 4 for the particular ship type.

1.1.4 The requirements in this chapter are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation. *See* Pt 1, Ch 2,2.3.

1.2 Structural configuration

1.2.1 The Rules provide for both longitudinal and transverse framing systems.

1.2.2 In the case of container ships and open type ships, additional requirements may apply as detailed in Pt 4, Ch 8.

1.2.3 In the case of fast cargo ships, the additional requirements given in Pt 4, Ch 1,3 are to be complied with where applicable.

1.2.4 The requirements regarding minimum bow height given in Ch 3,6 are to be complied with where applicable.

1.3 Structural continuity

1.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes.

1.3.2 Where longitudinal framing terminates and is replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover. Where a forecastle is fitted extending aft of 0,15*L* from the F.P., longitudinal framing at the upper deck and topsides is generally to be continued forward of the end bulkhead of this superstructure. In bulk carriers and oil tankers (*see* 1.1.4) the longitudinal framing at the upper deck is to be maintained over the cargo space region and continued over the fore peak region.

1.3.3 In container or similar ships having continuous side tanks or double skin construction in way of the cargo spaces, the longitudinal bulkheads are to be continued as far forward as is practicable and are to be suitably tapered at their ends. Where, due to the ship's form, such bulkheads are stepped, suitable scarfing is to be arranged.

1.3.4 In bulk carriers (*see* 1.1.4) the topside tank and double bottom hopper tank structures are to be maintained over the cargo space region, and suitable taper brackets are to be arranged in line with the end of these tank structures in the fore peak region. In addition, in way of the cargo space forward bulkhead, a girder or intercostal bulb plate stiffeners (fitted between and connected to the bulkhead vertical stiffeners), are to be arranged on the forward side in line with the sloped bulkheads of the topside and hopper tanks clear of the taper brackets.

1.4 Symbols and definitions

1.4.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, D, T, C_b and V as defined in Ch 1,6.1

k_L, k = higher tensile steel factor, *see* Ch 2,1.2

l = overall length of stiffening member, in metres, *see* Ch 3,3.3

l_e = effective length of stiffening member, in metres, *see* Ch 3,3.3

s = spacing of secondary stiffeners, in mm

t = thickness of plating, in mm

I = inertia of stiffening member, in cm^4, *see* Ch 3,3.2

S = spacing, or mean spacing, of primary members, in metres

Z = section modulus of stiffening member, in cm^3, *see* Ch 3,3.2

ρ = relative density (specific gravity) of liquid carried in a tank and is to be taken not less than 1,025.

1.4.2 For the purpose of this Chapter the forward perpendicular, F.P., is defined as the forward limit of the Rule length *L*.

1.5 Strengthening of bottom forward

1.5.1 The bottom forward of a sea-going ship is to be additionally strengthened, except where the ship is so designed that a minimum draught forward, T_{FB}, of 0,045*L* can be achieved for any ballast or part loaded condition. This draught is to be indicated on the shell expansion plan, the plan showing the internal strengthening, the Loading Manual and loading instrument, where fitted, *see* Ch 4,8.

1.5.2 The requirements for the additional strengthening apply to ships where L is greater than 65 m. Where a ship is classed for service in protected waters or extended protected waters, compliance with the requirements of this Section may be modified or waived altogether.

1.5.3 The additional strengthening is to extend forward of 0,3L from the F.P. over the flat of bottom and adjacent plating with attached stiffeners up to a height of 0,002L above the base line or 300 mm whichever is the lesser.

1.5.4 The scantling requirements outside the areas defined in 1.5.3 are to be suitably tapered to maintain adequate continuity of strength in both longitudinal and transverse directions.

1.5.5 The requirements for the additional strengthening within the region defined in 1.5.3 are given in Table 5.1.1, or may be obtained by direct calculation. Where T_{FB} is less than 0,01L, the additional strengthening is to be specially considered.

1.5.6 Bottom longitudinals are to pass through and be supported by the webs of primary members. The vertical web stiffeners are to be connected to the bottom longitudinals. The cross-sectional area of the connections is to comply with the requirements given in Table 5.1.1.

1.5.7 The scantlings required by this Section must in no case be less than those required by the remaining Sections in Chapter 5.

1.5.8 For minimum draught forward, T_{FB} between 0,01L and 0,045L, the equivalent slamming pressure expressed as a head of water, h_s, is to be obtained from Fig. 5.1.1, where h_{max} is calculated from the following expressions:

$65 < L \leq 169$ m, $h_{max} = 10\sqrt{L}\ F$ m

$169 < L \leq 180$ m, $h_{max} = 130\,F$ m

$L > 180$ m, $h_{max} = 130\,Fe^{-0{,}0125(L-180)^{0{,}705}}$ m

where

$$F = 5{,}95 - 10{,}5\left(\frac{T_{FB}}{L}\right)^{0{,}2}$$

and

e = base of natural logarithm, 2,7183

(a) The application of the maximum pressure for forward of 0,3L from the F.P. is as indicated in Fig. 5.1.1. For C_b between 0,70 and 0,80 its position may be obtained by linear interpolation.

(b) Where the bottom plating forms the boundary of a double bottom tank, deep tank or double skin tank which is full in all ballast conditions, then for such conditions the head, h_s, may be reduced by 1,25 times the head, in metres, of ballast water to top of tank.

(c) For bulk carriers (*see* 1.1.4) the reduction to the head, h_s, is not to exceed the head, in metres, of ballast water to the top of the hopper tank or 1,25 times the depth, in metres, of the double bottom tank, whichever is the greater.

(d) For ballast and part loaded conditions where the draught forward is less than 0,045L and the reduction to the head, h_s, has been applied, the ballast tanks are to be filled and a note added to the loading booklet to this effect, *see* Ch 4,8.2.4(d).

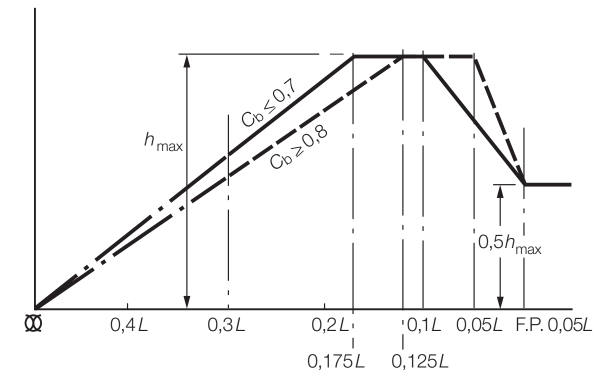


Fig. 5.1.1 Pressure heads

1.6 Strengthening against bow flare slamming

1.6.1 The requirements of this Section apply to all ships except those defined in Pt 4, Ch 2 and Pt 4, Ch 8.

1.6.2 The side structure in the area forward of 0,075L from the F.P. and above the summer load waterline is to be strengthened against bow flare impact pressure. The strengthening is to extend vertically to the uppermost deck level, including the forecastle deck, if fitted, but need not exceed the level of $T + 1{,}65H_b$ above the base line, where H_b is the minimum bow height, in metres, as derived in Ch 1,6.1.11.

1.6.3 The flare angle, α, is the angle between the vertical axis and the tangent of the outer shell measured normal to the shell in a vertical plane, at the point under consideration. The entry angle, β, is the angle between the longitudinal axis and the waterplane tangent measured on the outer shell, at the point under consideration. The flare angle may normally be derived in accordance with Fig. 5.1.2.

1.6.4 The equivalent bow flare slamming head, h_S, is to be taken as:

$$h_S = 0{,}8\left(0{,}2 + 1{,}5\tan\alpha\right)\left(0{,}51V\sin\beta\cos\alpha + \frac{\pi}{\sqrt{L}}\,\delta\right)^2 \text{ m}$$

where

V = as defined in 1.4.1

α = flare angle, in degrees, at the point under consideration

β = entry angle, in degrees, at the point under consideration

δ = $\left(\frac{\pi}{30}\,L\,e^{-0{,}0033L} - 0{,}5d\right)$ and is not to be taken less than zero

e = base of natural logarithms 2,7183

d = vertical distance, in metres, between the waterline at draught T and the point under consideration.

Table 5.1.1 Additional strengthening of bottom forward (*see continuation*)

Item	Requirements	
(1) Longitudinally framed bottom shell plating (including keel), *see* Notes 1 and 2	$t = 0{,}003 s f \sqrt{h_s k}$	
(2) Bottom longitudinals – other than flat bars	$\dfrac{d_w}{t_w} \le 55\sqrt{k}$ $\dfrac{d_w t_w}{100} \ge 0{,}00033\, k\, h_s\, s\, c \left(S - \dfrac{s}{2000}\right)$ cm^2 $Z \ge 6{,}8 \times 10^{-6}\, h_s\, s\, k \left[(17{,}5 l_s)^2 - (0{,}01 s)^2 + d_w\, c \left(S - \dfrac{s}{2000}\right)\right]$ cm^3 $\dfrac{(A_1\, \overline{\tau} + \alpha)}{p} \times 10^{-1} \ge 1$ $A_w \ge 0{,}84 A_1$	
(3) Bottom longitudinals – flat bars	Will be specially considered	
(4) Primary structure in way of single bottoms	Transverse framing	Longitudinal framing
	(a) Centre girder: Scantlings as required by item (1) in Table 5.5.1,except that in determining Z in way of a deep tank forward of 0,2L from the F.P. the value of h_5 is to be increased by the following percentages: where $T_{FB} \le 0{,}03L_2$, 30 per cent where $T_{FB} \ge 0{,}04L_2$, 0 per cent The increase in h_5 for intermediate values of T_{FB} is to be obtained by interpolation (b) Floors: Scantlings as required by item (2) in Table 5.5.1, except that in way of dry cargo spaces the minimum face area is to be increased by the following percentages: where $T_{FB} \le 0{,}03L_2$, 50 per cent where $T_{FB} \ge 0{,}04L_2$, 0 per cent The increase of minimum face area for intermediate values of T_{FB} is to be obtained by interpolation (c) Side girders: Arrangement and scantlings as required by 5.2.2 and 5.2.3, with the addition of intermediate half-height girders or equivalent fore and aft stiffening	(a) Ships having one or more longitudinal bulkheads: (i) Centre girder Scantlings as required by item (4) in Table 5.5.1 and (iii) (ii) Bottom transverses Maximum spacing As for midships region Scantlings as required by Pt 4, Ch 9,9 or Pt 4, Ch 10,2 (iii) For horizontally stiffened longitudinal bulkheads and girders the depth to thickness ratio of the panel attached to the bottom shell plate is not to exceed 55 $\sqrt{k}$ (iv) Where T_{FB}, < 0,025L_2 the scantlings and arrangements will receive individual consideration (b) Other ship arrangements will receive individual consideration
(5) Primary structure in way of double bottoms, *see* Note 3	(a) Plate floors: Maximum spacing, every frame Scantlings as required by Pt 4, Ch 1,8 (b) Centre and side girders: Maximum spacing, 0,003s_F m Scantlings as required by Pt 4, Ch 1,8 (c) Intermediate half-height girders to be arranged midway between side girders: Scantlings as required for non watertight side girders by Pt 4, Ch 1,8	(a) Plate floors: Maximum spacing: 0,002s_F m for $T_{FB} < 0{,}04L_2$ 0,003s_F m for $T_{FB} \ge 0{,}04L_2$ but not to exceed that required by item (2) in Table 5.5.2 Scantlings as required by Pt 4, Ch 1,8 (b) Centre and side girders: Maximum spacing: 0,003s_L m for $T_{FB} < 0{,}04L_2$ 0,004s_L m for $T_{FB} > 0{,}04L_2$ but not to exceed that required by item (4) in Table 5.5.2 Scantlings as required by Pt 4, Ch 1,8
(6) Primary structure in way of double bottoms supported by longitudinal bulkheads	—	The scantlings and arrangements will receive individual consideration on the basis of direct calculations using, if necessary, a suitably defined two-dimensional grillage model, *see* Ch 1,3

Table 5.1.1 Additional strengthening of bottom forward (*conclusion*)

Symbols

L, T, s, k as defined in 1.4.1

c = 1,0 for $S \leq 2,5$ m

= $(0,87 + 0,16S)\, c_1$ for $S > 2,5$ m

c_1 = 1,0 for $S \leq 1,0$ m

= $(1,14 - 0,14S)$ for $1,0 \text{ m} < S \leq 4,0$ m

= $\dfrac{2,32}{S}$ for $S > 4,0$ m

d_w = web depth, in mm, which for bulb flats may be taken as 0,9 times the section height

f = $\left(1,1 - \dfrac{s}{2500S}\right)$ but not greater than 1,0

h_s = equivalent slamming pressure, in metres obtained from 1.5.8

l_s = l_e, in metres, as defined in 1.4.1 where in way of a double bottom

= S, in metres, where in way of a single bottom

S = spacing of primary members, in metres

p = $9,81\, h_s\, s\, c_1 \left[S - \dfrac{s}{2000}\right] \times 10^{-3}$ kN

= $\left(h_s\, s\, c_1 \left[S - \dfrac{s}{2000}\right] \times 10^{-3} \text{ tonne-f}\right)$

s_F = spacing of transverse frames, in mm, for longitudinally framed side and bottom construction s_F may be taken as s_L

s_L = spacing of bottom longitudinals, in mm

t_w = web thickness, in mm

A_f = cross-sectional area of primary member web stiffener, in cm^2

A_{fc} = effective area of primary member web stiffener in way of butted end connection to the longitudinal, in cm^2

A_L = area of weld of lapped connection, in cm^2, calculated as total length of weld, in cm x throat thickness, in cm

A_w = area of weld of lug and web connection to the longitudinal, in cm^2, calculated as total length of weld in cm x throat thickness, in cm

A_1 = effective total cross-sectional area of the lug and web connection to the longitudinal, in cm^2

L_2 = L but need not be taken greater than 215 m

T_{FB} = draught, in metres, at the F.P., as defined in 1.5.1

α = $A_f \overline{\sigma}$ for the web stiffeners

= $A_{fc} \overline{\sigma}$ for a butted connection to the longitudinals

= $A_L \overline{\tau}$ for a lapped connection

$\overline{\sigma}$ = permissible direct stress, in N/mm^2 (kgf/mm^2), given in Table 5.1.2

$\overline{\tau}$ = permissible shear stress, in N/mm^2 (kgf/mm^2), given in Table 5.1.2

NOTES
1. If intermediate stiffening is fitted the thickness of the bottom shell plating may be 80 per cent of that required by (1) but is to be not less than the normal taper thickness.
2. For transverse framing the bottom shell plating is to be specially considered.
3. Particular care is to be taken to limit the size and number of openings in way of the ends of floors or girders or to fit suitable reinforcement where such openings are essential.
4. The welding requirements of Ch 10, and in cargo oil tanks of tankers, the requirements of Pt 4, Ch 9,10.14 or Pt 4, Ch 10,7.14, are also to be complied with.

1.6.5 The thickness of the side shell is to be not less than:

$$t = 3,2 s_C \sqrt{k\, h_S}\, C_R \times 10^{-2} \text{ mm}$$

where

s_C = spacing of secondary stiffeners, in mm, measured along a chord between parallel adjacent members or equivalent supports, as shown in Fig. 5.1.3

h_S = bow flare slamming head, in metres, as defined in 1.6.4

C_R = panel ratio factor

= $\left(\dfrac{l}{s_c}\right)^{0,41}$ but is not to be taken less than 0,06 or greater than 0,1

l = overall panel length, in metres, measured along a chord between the primary members.

1.6.6 The scantlings of secondary stiffeners are not to be less than:

(a) Section modulus of secondary stiffeners

$$Z = 3,6 s_{CM}\, k\, h_S\, l_e^2 \times 10^{-3} \text{ cm}^3$$

(b) Web area of secondary stiffeners

$$A = 3,7 s_{CM}\, k\, h_S\, (l_e - s_{CM}/2000) \times 10^{-4} \text{ cm}^2$$

where

s_{CM} = mean spacing of secondary stiffeners, in mm, measured along a chord between parallel adjacent members or equivalent supports, as shown in Fig. 5.1.3

h_S = bow flare slamming head, in metres, as defined in 1.6.4

Other symbols are as defined in 1.4.1.

1.6.7 The scantlings of primary members are not to be less than:

(a) Section modulus of primary members

$$Z = 2S_{CM}\, k\, h_S\, l_e^2 \text{ cm}^3$$

(b) Web area of primary members

$$A = 0,2S_{CM}\, k\, h_S\, l_e \text{ cm}^2$$

where

S_{CM} = mean spacing of primary members, in metres, measured along a chord between parallel adjacent members or equivalent supports, as shown in Fig. 5.1.4

h_S = bow flare slamming head, in metres, as defined in 1.6.4

Other symbols are as defined in 1.4.1.

Table 5.1.2 Permissible stresses

Item		Direct stress, $\bar{\sigma}$ in N/mm^2 (kgf/mm^2) *see* Note	Shear stress, $\bar{\tau}$ in N/mm^2 (kgf/mm^2)
Primary member web stiffener on area A_f	(a) Flat bars, *see* Note	$\frac{10,3}{k}\left[33 - \frac{d}{t\sqrt{k}}\right]$ $\left(\frac{1,05}{k}\left[33 - \frac{d}{t\sqrt{k}}\right]\right)$	— —
	(b) Bulb plates, *see* Note	$\frac{8,6}{k}\left[40 - \frac{d}{\left(\frac{100A_f}{d} - \frac{t}{6}\right)\sqrt{k}}\right]$ $\left(\frac{0,88}{k}\left[40 - \frac{d}{\left(\frac{100A_f}{d} - \frac{t}{6}\right)\sqrt{k}}\right]\right)$	— —
	(c) Inverted angles	$\frac{220}{k}\left(\frac{22,4}{k}\right)$	—
Primary member web stiffener on area A_{fc}		$\frac{245}{k}\left(\frac{25}{k}\right)$	—
Primary member web stiffener lapped to secondary member on area A_L		—	$\frac{167}{k}\left(\frac{17}{k}\right)$
Lug or web connection on area A_1	Single	—	$\frac{124}{k}\left(\frac{12,6}{k}\right)$
	Double	—	$\frac{141}{k}\left(\frac{14,4}{k}\right)$
Symbols			
A_f, A_L, A_1 as defined in Table 5.1.1 d = stiffener depth, in mm k = as defined in 1.4.1 t = stiffener web thickness, in mm			
NOTE $\bar{\sigma}$ to be taken not greater than $\frac{220}{k}\left(\frac{22,4}{k}\right)$			

1.6.8 For primary members with cut-outs for the passage of secondary stiffeners, and which may have web stiffeners connected to the secondary stiffener, buckling checks are to be carried out to ensure that the primary member web plating and web stiffener will not buckle under the design load. The buckling procedure to be followed is given in Table 5.1.3. Where the web stiffener is fitted with a bracket, the buckling capability of the web stiffener in way of the cut-out is to take account of the bracket. Where no web stiffener is fitted, the buckling capability of the primary member web plating is to be checked for the total load transmitted to the connection.

1.6.9 The structural scantlings required in areas strengthened against bow flare slamming are to be tapered from 0,075L aft of fore perpendicular to meet the normal requirements at 0,15L aft of the fore perpendicular.

1.6.10 Where the stiffener web is not perpendicular to the plating, tripping brackets may need to be fitted in order to obtain adequate lateral stability.

1.6.11 For stiffeners and primary structure, where the angle between the stiffener web and the plating is less than 70°, the effective section modulus and shear area are to take account of the non-perpendicularity.

1.6.12 The side structure scantlings required by this Section must in no case be taken less than those required by the remaining Sections of Chapter 5.

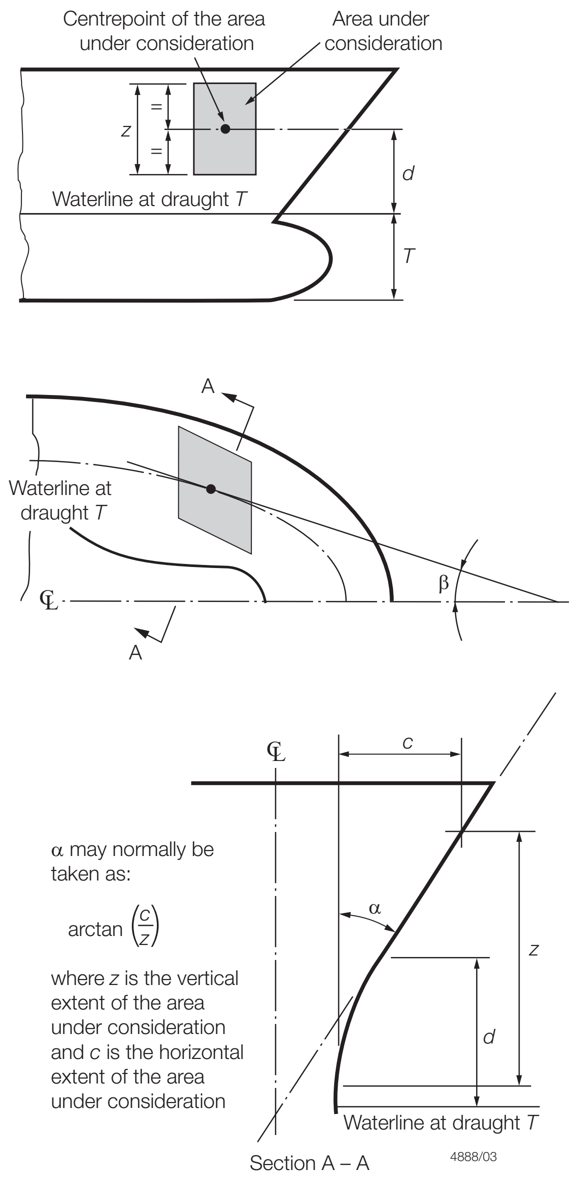


Fig. 5.1.2 Flare angle determination

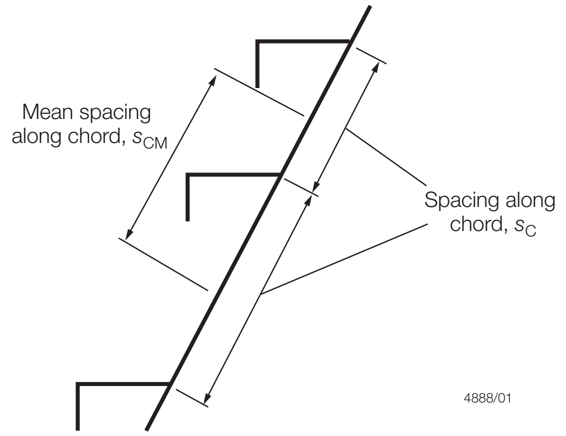


Fig. 5.1.3
Chord spacing and mean chord spacing for secondary members

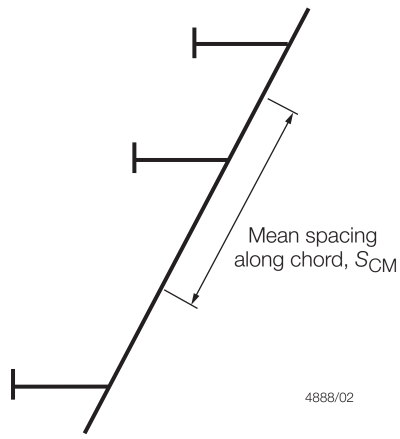


Fig. 5.1.4
Mean chord spacing for primary members

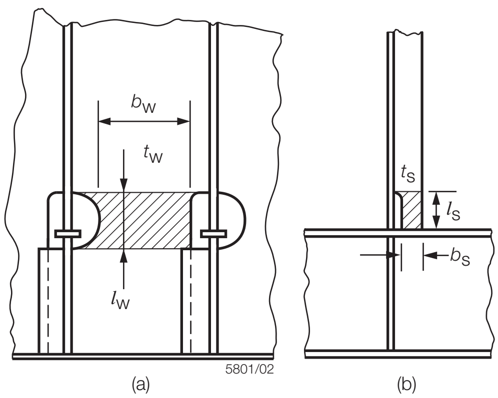


Fig. 5.1.5
Dimensions of critical areas of (a) primary member web plating and (b) primary web stiffener

Table 5.1.3 Buckling procedure for primary member web plating and web stiffener

Steps	Members	
	Primary member web plating	Primary member web stiffener
Determination of the design compressive stress, σ_A, N/mm^2 (kgf/mm^2)	$\sigma_A = \dfrac{1000 P_W}{A_W}$	$\sigma_A = \dfrac{1000 P_S}{A_S}$
Determination of the elastic critical buckling stress, σ_E, in compression, N/mm^2 (kgf/mm^2)	$\sigma_E = \dfrac{9{,}87 E\, I_W}{l_W^2 A_W}$	$\sigma_E = \dfrac{9{,}87 E\, I_S}{l_S^2 A_S}$
Determination of the corrected critical buckling stress, σ_{CR}, in compression, N/mm^2 (kgf/mm^2)	$\sigma_{CR} = \sigma_o \left(1 - \dfrac{\sigma_o}{4\sigma_E}\right)$ where $\sigma_E > \dfrac{\sigma_o}{2}$ $\sigma_{CR} = \sigma_E$ where $\sigma_E \leq \dfrac{\sigma_o}{2}$	
Requirement	$\sigma_{CR} \geq \sigma_A$	
Symbols		

b_W, b_S, l_W, and l_S are dimensions, in mm, as shown in Fig. 5.1.5

h_S = equivalent bow flare slamming head, in metres, as defined in 1.6.4

s_{CM} = mean spacing of secondary stiffeners, in mm, as defined in 1.6.6

t_W = thickness of primary member web plating, in mm

t_S = thickness of primary member web stiffener, in mm

A_W = $b_W\, t_W$ mm^2

A_S = $b_S\, t_S$ mm^2

E = modulus of elasticity, in N/mm^2 (kgf/mm^2)
= 206000 N/mm^2 (21000 kgf/mm^2) for steel

$I_W = \dfrac{b_W\, t_W^3}{12}$ mm^4

$I_S = \dfrac{b_S\, t_S^3}{12}$ mm^4

P = total load transmitted to the connection
= 10,06 $S_{CM}\, s_{CM}\, h_S \times 10^{-3}$ kN

(P = 1,025 $S_{CM}\, s_{CM}\, h_S \times 10^{-3}$ tonne-f)

P_W = load transmitted through the primary member web plating, in kN (tonne-f)
= $P - P_S$, or by direct calculations

P_S = load transmitted through the primary member web stiffener, in kN (tonne-f), to be determined from Ch 10,5.2.7(b), or by direct calculations

S_{CM} = mean spacing of primary members, in metres, as defined in 1.6.7

σ_o = specified minimum yield stress, in N/mm^2 (kgf/mm^2)

■ *Section 2* Deck structure

2.1 General

2.1.1 Where the upper deck is longitudinally framed outside the line of openings in the midship region, this system of framing is to be carried as far forward as possible. In the case of oil tankers (*see* 1.1.4), longitudinal framing is to extend to at least the forward end of the cargo tank section.

2.2 Deck plating

2.2.1 The thickness of strength/weather deck plating is to comply with the requirements of Table 5.2.1.

2.2.2 The thickness of lower deck plating is to comply with the requirements of Table 5.2.2.

2.2.3 The taper thickness of the strength deck stringer plate is to be increased by 20 per cent at the end of a forecastle or bridge where the end bulkhead is situated aft of 0,25L from the F.P. No increase is required where the end bulkhead lies forward of 0,2L from the F.P. The increase at intermediate positions is to be determined by interpolation.

2.2.4 The deck plating thickness and supporting structure are to be suitably reinforced in way of the anchor windlass and other deck machinery, and in way of cranes, masts or derrick posts.

2.2.5 Where long, wide hatchways are arranged at lower decks, it may be necessary to increase the deck plating thickness to ensure effective support for side framing.

Table 5.2.1 Strength/weather deck plating forward (excluding forecastle deck)

Symbols	Location	Thickness, in mm
L, D, T, s, S, k, ρ as defined in 1.4.1 $C = \left(\dfrac{D + 2{,}3 - T}{\text{height of deck above load waterline at F.P.}}\right)$ but is to be taken not greater than 1,0 nor less than 0,9 s_1 = s, but to be taken not less than s_b s_b = standard frame spacing as follows: (a) forward of 0,05L from the F.P.: $s_b = \left(470 + \dfrac{L}{0{,}6}\right)$ mm or 600 mm, whichever is the lesser (b) between 0,05L and 0,2L from the F.P.: $s_b = \left(470 + \dfrac{L}{0{,}6}\right)$ mm or 700 mm, whichever is the lesser $f = 1{,}1 - \dfrac{s}{2500S}$ but to be taken not greater than 1,0 h_4 = tank head, in metres, as defined in Ch 3,5	(1) Forward of 0,075L from the F.P.	$t = \left(6{,}5 + 0{,}02L\right) C \sqrt{\dfrac{ks_1}{s_b}}$
	(2) Between 0,075L and 0,2L from the F.P.	The greater of the following: (a) $t = \left(5{,}5 + 0{,}02L\right) C \sqrt{\dfrac{ks_1}{s_b}}$ (b) the taper thickness (*see* Notes 1, 2 and 3) (c) for oil tankers, the thickness is also to be in accordance with Pt 4, Ch 9,4.3.3
	(3) Aft of 0,2L from the F.P.	The taper thickness (*see* Notes 1, 2 and 3) or as (2) (c) whichever is the greater
	(4) Inside forecastle extending aft of 0,15L from the F.P.	As for a lower deck (*see* Note 4)
	(5) In way of crown of a tank	$t = 0{,}004 s f \sqrt{\dfrac{\rho\, k\, h_4}{1{,}025}} + 3{,}5$ or as in (1) to (4) as applicable, whichever is the greater but not less than: 7,5 mm where $L \geq 90$ m, or 6,5 mm where $L < 90$ m

NOTES
1. The taper thickness is to be determined from Table 3.2.1 in Chapter 3.
2. For taper area requirements, *see* Table 3.2.1 in Chapter 3.
3. For thickness of upper deck plating in way of the cargo and fore peak tanks of oil tankers or ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11, as applicable.
4. The exposed deck taper thickness is to extend into a forecastle or bridge for at least one-third of the breadth of the ship from the superstructure end bulkhead.

Table 5.2.2 Lower deck plating forward

Symbols	Location	Thickness, in mm
L, s, S, k, ρ as defined in 1.4.1 b = breadth of increased plating, in mm $f = 1{,}1 - \dfrac{s}{2500S}$ but is to be taken not greater than 1,0 h_4 = tank head, in metres, as defined in Ch 3,5 K_2 = 2,5 mm at bottom of tank, or = 3,5 mm at crown of tank s_1 = s, but is to be taken not less than $\left(470 + \dfrac{L_1}{0{,}6}\right)$ mm A_f = girder face area, in cm^2 L_1 = L but need not be taken greater than 190 m	(1) Forward of 0,075L from the F.P.	$t = 0{,}01\, s_1 \sqrt{k}$ but not less than 6,5 mm
	(2) Aft of 0,075L from the F.P., inside line of openings	$t = 0{,}01\, s_1 \sqrt{k}$ but not less than 6,5 mm
	(3) Aft of 0,075L from the F.P., outside line of openings	As determined by a taper line from the midship thickness to the end thickness given by (1)
	(4) In way of crown or bottom of tank	$t = 0{,}004\, f\, s \sqrt{\dfrac{\rho\, k\, h_4}{1{,}025}} + K_2$ or as in (1), (2) or (3) as applicable, whichever is the greater but not less than: 7,5 mm where $L \geq 90$ m, or 6,5 mm where $L < 90$ m
NOTES 1. Where the deck loading exceeds 43,2 kN/m^2 (4,4 $tonne\text{-}f/m^2$), the thickness of plating will be specially considered. This is equivalent to a 'tween deck height of 6,1 m in association with the standard stowage rate of 1,39 m^3/tonne. 2. For minimum thickness of deck plating in oil tankers, *see* Pt 4, Ch 9,10.2.	(5) Plating forming the upper flange of underdeck girders	Clear of cargo hatches: $t = \sqrt{\dfrac{A_f}{1{,}8k}}$ In way of hatch side girders: $t = 1{,}1 \sqrt{\dfrac{A_f}{1{,}8k}}$ Minimum breadth: b = 760 mm

2.3 Deck stiffening

2.3.1 The scantlings of strength/weather deck longitudinals are to comply with the requirements of Table 5.2.3.

2.3.2 The scantlings of cargo and accommodation deck longitudinals are to comply with the requirements given in Table 1.4.4 in Pt 4, Ch 1.

2.3.3 End connections of longitudinals to bulkheads are to provide adequate fixity, lateral support and, so far as practicable, direct continuity of longitudinal strength.

2.3.4 The scantlings of weather deck beams are to comply with the requirements of Table 5.2.4.

2.3.5 The scantlings of lower deck beams are to comply with the requirements of Table 1.4.5 in Pt 4, Ch 1.

2.3.6 End connections of beams are to be in accordance with the requirements of Ch 10,3.

Table 5.2.3 Strength/weather deck longitudinals forward

Location	Modulus, cm^3	Inertia, cm^4
(1) Forward of 0,075*L* from the F.P.	The greater of the following: (a) $Z = s\,k\,(635h_1 + 0{,}0078\,(l_e\,L_1)^2) \times 10^{-4}$ (b) $Z = 0{,}0127s\,k\,h_1\,l_e^2$	–
(2) At 0,075*L* from the F.P., for end modulus for taper	The greater of the following: (a) $Z_e = s\,k\,(485h_o + 0{,}0062\,(l_{e1}\,L_1)^2) \times 10^{-4}$ (b) $Z_e = 0{,}009s\,k\,h_o\,l_{e1}^2$	–
(3) Aft of 0,075*L* from the F.P., outside line of openings	As given by (4) or as determined from Table 3.2.1 in Chapter 3 whichever is the greater, *see* Note 1	–
(4) At 0,075*L* and between 0,075*L* and 0,12*L* from the F.P.	The greater of the following: (a) $Z = s\,k\,(570h_1 + 0{,}0072\,(l_e\,L_1)^2) \times 10^{-4}$ (b) $Z = 0{,}0127s\,k\,h_1\,l_e^2$	–
(5) Aft of 0,12*L* from the F.P., inside line of main cargo hatchways openings	The greater of the following: (a) $Z = s\,k\,(400h_1 + 0{,}005\,(l_e\,L_1)^2) \times 10^{-4}$ (b) $Z = 0{,}007s\,k\,h_1\,l_e^2$	–
(6) In way of the crown of a tank	As (1) to (5), as applicable, or $Z = \dfrac{0{,}0113\rho\,s\,k\,h_4\,l_e^2}{b}$ whichever is the greater	$I = \dfrac{2{,}3}{k}\,l_e\,Z$

Symbols

L, s, k_L*, k,* ρ as defined in 1.4.1
- b = 1,4 for rolled or built sections
- = 1,6 for flat bars
- d_w = web depth of longitudinal, in mm
- h_o = 1,2 m for dry cargo ships
- = $\dfrac{L_1}{56}$ m for oil tankers (*see* 1.1.4)
- = $\dfrac{L_1}{70}$ m for oil tankers (*see* 1.1.4)
- h_1 = weather head, in metres, as defined in Ch 3,5 for dry cargo ships
- h_4 = tank head, in metres, as defined in Ch 3,5
- l_e as defined in 1.4.1, but is to be taken not less than 1,5 m
- l_{e1} is to be taken as the maximum span in metres in the midship cargo tank region for oil tankers (*see* 1.1.4) and equal to l_e for dry cargo ships
- L_1 = *L* but need not be taken greater than 190 m

NOTES
1. For area taper requirements, *see also* Table 3.2.1 in Chapter 3.
2. Where weather decks are intended to carry deck cargo and the loading is in excess of 8,5 kN/m^2 (0,865 tonne-f/m^2), the scantlings of longitudinals may be required to be increased to comply with the requirements for location (1) in Table 1.4.4 in Pt 4, Ch 1 using the equivalent design head, for specified cargo loadings, for weather decks given in Table 3.5.1 in Chapter 3.
3. For the scantlings of deck longitudinals forward in way of the cargo tanks of oil tankers (*see* 1.1.4) or ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11, as applicable.
4. The thickness of flat bar longitudinals situated outside the line of openings is to be not less than the following:
   (a) $t = \dfrac{d_w}{18\sqrt{k_L}}$ mm
   where longitudinal continuous through bulkhead
   (b) $t = \dfrac{d_w}{15\sqrt{k_L}}$ mm
   where longitudinal cut at bulkhead
5. The web depth of longitudinal, d_w, is to be not less than 60 mm.

Table 5.2.4 Weather deck beams forward

Location	Modulus, cm^3	Inertia, cm^4
(1) Forward of 0,075*L* from the F.P.	The lesser of the following: (a) $Z = k\,(800K_1\,T\,D + 5{,}4B_1 s\,h_1\,l_e^{\,2}) \times 10^{-4}$ (b) $Z = 10{,}8B_1\,s\,k\,h_1\,l_e^{\,2} \times 10^{-4}$	–
(2) Between 0,075*L* and 0,12*L* from the F.P.	The lesser of the following: (a) $Z = k\,(800K_1\,T\,D + K_3\,B_1\,s\,h_1\,l_e^{\,2}) \times 10^{-4}$ (b) $Z = 2K_3\,B_1\,s\,k\,h_1\,l_e^{\,2} \times 10^{-4}$	–
(3) Aft of 0,12*L* from the F.P.	As required for location (1) of Table 1.4.5 in Pt 4, Ch 1	–
(4) In way of the crown of a tank	As (1), (2) or (3), as applicable, or $Z = \dfrac{0{,}0113\rho\,s\,k\,h_4\,l_e^{\,2}}{b}$ whichever is the greater	$I = \dfrac{2{,}3}{k}\,l_e\,Z$

Symbols

*B, D, T, s,*ρ, *k* as defined in 1.4.1
b = 1,4 for rolled or built sections
= 1,6 for flat bars
h_1 = weather head, in metres, as defined in Ch 3,5
h_4 = tank head, in metres, as defined in Ch 3,5
l_e as defined in 1.4.1, but is to be taken not less than 1,83 m

K_1 = a factor dependent on the number of decks (including a bridge superstructure) at the position of the beam under consideration as follows:

1 deck	20,0
2 decks	13,3
3 decks	10,5
4 decks or more	9,3

For a forecastle deck, K_1 is to be taken as 13,3
K_3 = a factor dependent on the location of the beam as follows:

Span adjacent to ship's side	3,6
Elsewhere	3,3

B_1 = B, but need not be taken greater than 21,5 m

NOTES
1. Beams at the upper deck inside superstructures are to have scantlings determined as for a lower deck, *see* Table 1.4.5 in Pt 4, Ch 1.
2. Where weather decks are intended to carry deck cargo and the loading is in excess of 8,5 kN/m^2 (0,865 $tonne\text{-}f/m^2$), the scantlings of beams are also to comply with the requirements for location (2) in Table 1.4.5 of Pt 4, Ch 1 using the equivalent design head, for specified cargo loadings, for weather decks given in Table 3.5.1 in Chapter 3.
3. The web depth of beams, d_w, is to be not less than 60 mm.
4. The scantlings of deck beams forward in way of the cargo tanks of oil tankers or ore carriers will be specially considered, *see* Pt 4, Ch 9,1.3.10.

2.4 Deck supporting structure

2.4.1 The arrangements and scantlings of supporting structure are generally to be in accordance with the requirements given in Pt 4, Ch 1,4 using the heads given in Ch 3,5 for the particular region concerned, except as required by 2.4.2 to 2.4.4.

2.4.2 The spacings of girders and transverses are generally not to exceed the values given in Table 5.2.5.

2.4.3 Primary structure in the topside tanks of bulk carriers is to comply with the requirements of Pt 4, Ch 7,7.

2.4.4 Primary structure in the cargo tanks of oil tankers and ore carriers is to be determined from Pt 4, Ch 9, Ch 10 or Ch 11, as applicable.

2.5 Deck openings

2.5.1 In dry cargo ships the requirements for deck openings given in Pt 4, Ch 1,4 are generally applicable throughout the forward region, except that forward of 0,25*L* from the F.P.:

(a) The radii or dimensions of the corners of main cargo hatchway openings on the strength deck are to be in accordance with the requirements of Pt 4, Ch 1,4.5. The thickness of the insert plates, where required, is not to be less than 20 per cent greater than the adjacent deck thickness outside the line of openings, with a minimum increase of 3 mm.
(b) Insert plates will be required at lower decks in way of any rapid change in hull form to compensate for loss of deck cross-sectional area. Otherwise, insert plates will not normally be required.
(c) Compensation and edge reinforcement for openings outside the line of main hatchways will be considered, bearing in mind their position, the deck arrangements and the type of ship concerned.

Table 5.2.5 Spacing of girders and transverses under strength/weather decks forward

Location	Maximum spacing	
	Girders in association with transverse framing system	Transverses in association with longitudinal framing system
(1) Forward of the collision bulkhead	3,7 m	2,5 m where $L \leq 100$ m 3,5 m where $L \geq 300$ m Intermediate values by interpolation
(2) Between the collision bulkhead and 0,075*L* from the F.P.	3,7 m	
(3) In way of a deep tank, forward of 0,2*L* from the F.P.	–	3,0 m where $L \leq 100$ m 4,2 m where $L \geq 300$ m Intermediate values by interpolation
(4) Elsewhere in way of dry cargo spaces or deep tanks, *see* Note 1	–	3,8 m where $L \leq 100$ m (3,2 + 0,006*L*) m where $L > 100$m

NOTES
1. For the maximum spacing of transverses in the cargo tanks of oil tankers or ore carriers, *see* Pt 4, Ch 9,9.
2. For the maximum spacing of transverses in dredgers, *see* Pt 4, Ch 12,5.

2.5.2 For deck openings in way of the cargo tanks in oil tankers and ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11, as applicable. For main cargo hatchway openings on bulk carriers and container ships, *see also* Pt 4, Ch 7 and Ch 8, as applicable.

■ *Section 3*
Shell envelope plating

3.1 General

3.1.1 Where the shell is longitudinally framed in the midship region, this system of framing is to be carried as far forward as practicable. In the case of oil tankers (*see* 1.1.4), longitudinal framing is to extend at least to the forward end of the cargo tanks.

3.2 Keel

3.2.1 The scantlings of bar keels at the fore end are to be the same as in the midship region as required by Pt 4, Ch 1,5.

3.2.2 The thickness and width of plate keels in the forward region are to be the same as required in the midship region for the particular type of ship concerned, *see* Part 4.

3.3 Stem

3.3.1 Bar stems may be either steel castings or steel forgings complying with the requirements of Chapter 3 of the Rules for Materials for rolled steel flat bars or Chapter 5 of the Rules for Materials for solid round bars. The scantlings of bar stems are to comply with Table 5.3.1.

3.3.2 The scantlings of plate stems are to be determined from Table 5.3.1. Plate stems are to be supported by horizontal diaphragms positioned in line with the side stringers or perforated flats with intermediate breasthook diaphragms. Diaphragms are to be spaced not more than 1,5 m apart, measured along the stem. Where the stem plate radius is large, a centreline stiffener or web will be required.

3.4 Bottom shell and bilge

3.4.1 The thickness of bottom shell and bilge plating in the forward region for ships not requiring additional strengthening of bottom is to comply with Table 5.3.1.

3.4.2 For thickness of bottom shell and keel when additional bottom strengthening is required, *see* 1.5.

3.4.3 Where longitudinals are omitted in way of radiused bilge plating amidships, the plating thickness forward will be considered in relation to the support derived from the hull form and internal stiffening arrangements.

3.5 Side shell and sheerstrake

3.5.1 The thickness of side shell and sheerstrake plating in the forward region is to be not less than the values given in Table 5.3.1, but may be required to be increased locally on account of high shear forces, in accordance with Ch 4,6.5.

3.5.2 For transversely framed side shells where panting stringers are omitted, *see* 4.4, the side shell plating in the region concerned is to be increased in thickness by the percentages given below:
(a) 15 per cent, where $L \leq 150$ m
(b) 5 per cent, where $L \geq 215$ m
For intermediate values of *L*, the percentage increase is to be obtained by interpolation.

Table 5.3.1 Shell plating forward

Location	Thickness, in mm
(1) Bottom shell and bilge, *see also* 1.5 and Note 5:	
(a) Forward of 0,075L from the F.P.	$t = (6{,}5 + 0{,}033L)\sqrt{\dfrac{k\,s_1}{s_b}}$ (*see* Note 1)
(b) Between 0,075L and 0,25L from the F.P., *see* Note 7	As (1)(a) or the taper thickness, whichever is the greater
(c) Aft of 0,25L from the F.P., *see* Note 7	The taper thickness (*see* Note 2)
(2) Side shell, *see* Notes 4 and 5:	
(a) Forward of 0,075L from the F.P.	$t = (6{,}5 + 0{,}033L)\sqrt{\dfrac{k\,s_1}{s_b}}$ (*see* Note 1)
(b) Between 0,075L and 0,2L from the F.P., *see also* 3.5.2	As (2)(a) or the taper thickness, whichever is the greater
(c) Aft of 0,2L from the F.P.	The taper thickness (*see* Note 2)
(3) Sheerstrake, *see* Notes 4 and 5:	
(a) Forward of 0,075L from the F.P.: where $\dfrac{T}{D} > 0{,}7$	As (2)(a) for side shell
where $\dfrac{T}{D} \leq 0{,}7$	As (4) for a forecastle
(b) Between 0,075L and 0,2L from the F.P., *see* Note 7	As (3)(a) or as determined from Table 3.2.1 in Chapter 3
(c) Aft of 0,2L from the F.P., *see* Note 7	The taper thickness (*see* Note 2)
(4) Forecastle, *see* Notes 4 and 5	$t = (7{,}0 + 0{,}02L)\sqrt{\dfrac{k\,s_1}{s_b}}$
(5) Stem, *see* Notes 4 and 5:	
(a) Bar stem: below load waterline	$A_1 = (1{,}6L - 32)$ cm^2 or L cm^2 whichever is the greater
at stem head	$A_2 = 0{,}75\,A_1$ cm^2
(b) Plate stem: below load waterline	$t = (5{,}0 + 0{,}083L_2)\sqrt{k}$ mm
at stem head	t = as (2)(a) for side shell

Symbols

L, B, D, T, s, k as defined in 1.4.1

s_1 = s, but to be taken as not less than s_b

s_b = standard frame spacing, in mm, as follows:

Region	Bottom shell s_b	Side shell s_b
Forward of 0,05L from the F.P.	$\left(470 + \dfrac{L}{0{,}6}\right)$ or 600*	$\left(470 + \dfrac{L}{0{,}6}\right)$ or 600*
Between 0,05L and 0,2L from the F.P.	$\left(470 + \dfrac{L}{0{,}6}\right)$ or 700*	$\left(470 + \dfrac{L}{0{,}6}\right)$ or 700*
Between 0,2L and 0,25L from the F.P.	$\left(510 + \dfrac{L_2}{0{,}6}\right)$	*whichever is the lesser

A_1 = cross-sectional area of bar stem below load waterline, in cm^2

A_2 = cross-sectional area of bar stem at stem head, in cm^2

L_2 = L, but need not be taken greater than 215 m

NOTES
1. For ships where $L \leq 70$ m this thickness may be reduced by 1 mm, but it is to be not less than 6 mm.
2. The taper thickness is to be determined from Table 3.2.1 in Chapter 3.
3. For thickness of shell plating in way of the cargo and fore peak tanks of oil tankers or ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11, as appropriate.
4. In offshore supply ships the thickness of side shell is to be not less than 9 mm.
5. For trawlers and fishing vessels, *see* Pt 4, Ch 6,5.
6. For fast cargo ships, *see* Pt 4, Ch 1,3.
7. For oil tankers the thickness is also to be in accordance with Pt 4, Ch 9,4.3.3.

3.5.3 The side shell plating of increased thickness required by 3.5.2 is to be continued forward past the fore peak or collision bulkhead. In addition, horizontal brackets in line with the fore peak stringers are to be fitted at the aft side of the bulkhead where practicable. The brackets are to be the same thickness as the side shell and are to extend from the bulkhead to the adjacent shell frame and be connected thereto. Transversely the toes of the brackets are to extend past the outboard stiffener of the bulkhead to clear any cut out in the bulkhead stringer.

3.5.4 The sheerstrake taper thickness is to be increased by 20 per cent at the ends of a bridge superstructure extending out to the ship's side irrespective of position. Similar strengthening is to be fitted in way of the end of a forecastle if this occurs at a position aft of 0,25*L* from the F.P. No increase is required if the forecastle end bulkhead lies forward of 0,2*L* from the F.P. The increase at intermediate positions of end bulkhead is to be obtained by interpolation.

3.5.5 The shell plating may be required to be increased in thickness locally in way of hawse pipes, *see* Ch 13,8.10.

3.5.6 The shell plating is to be increased in thickness locally in way of a bulbous bow, *see* 6.5.6.

3.6 Shell openings

3.6.1 In general, compensation will not be required for holes in the sheerstrake which are clear of the gunwale, or for any deck openings situated outside the line of main hatchways and whose depth does not exceed 20 per cent of the depth of the sheerstrake or 380 mm, whichever is the lesser. Openings are not to be cut in a rounded gunwale. Cargo door openings are to have well rounded corners, and the proposed compensation for the door openings will be individually considered.

3.6.2 Sea inlet and other openings are to have well rounded corners. The thickness of sea inlet box plating is generally to be the same as the adjacent shell. It is however, to be not less than 12,5 mm, and need not exceed 25 mm.

■ *Section 4* Shell envelope framing

4.1 General

4.1.1 Requirements are given in this Section for both longitudinal and transverse framing systems. Where longitudinal framing is adopted in the midship region it is to be carried as far forward as practicable. In the case of oil tankers (*see* 1.1.4), longitudinal framing is to be continued at least to the fore end of the cargo tanks.

4.1.2 End connections of longitudinals to bulkheads are to provide adequate fixity, lateral support and, so far as practicable, direct continuity of longitudinal strength, *see also* Ch 10,3. Where *L* exceeds 215 m, the bottom longitudinals are to be continuous in way of both watertight and non-watertight floors, but alternative arrangements will be considered. Higher tensile steel longitudinals within 10 per cent of the ship's depth at the bottom and deck are to be continuous irrespective of the ship length.

4.1.3 Stiffeners and brackets on side transverses, where fitted on one side and connected to higher tensile steel longitudinals between the base line and 0,8*D* above the base line, are to have their heels well radiused to reduce stress concentrations. Where a symmetrical arrangement is fitted, i.e., bracket or stiffening on both sides, and it is connected to higher tensile steel longitudinals, the toes of the stiffeners or brackets are to be well radiused. Alternative arrangements will be considered if supported by appropriate direct calculations.

4.1.4 Where higher tensile steel side longitudinals pass through transverse bulkheads in the cargo area, well radiused brackets of the same material are to be fitted on both the fore and aft side of the connection between the upper turn of bilge and 0,8*D* above the base line. Particular attention is to be given to ensuring the alignment of these brackets. Alternative arrangements will be considered if supported by appropriate direct calculations.

4.1.5 For ships intended to load or unload while aground, *see* Ch 9,8.

4.2 Shell longitudinals

4.2.1 The scantlings of bottom and side shell longitudinals in the forward region are to comply with the requirements given in Table 5.4.1. For the scantlings of bottom shell longitudinals where additional bottom strengthening is required, *see* 1.5.

4.2.2 End connections of longitudinals to bulkheads are to provide adequate fixity, lateral support and so far as practicable, direct continuity of longitudinal strength, *see also* Ch 10,3.

4.3 Shell framing

4.3.1 The scantlings of side frames in the forward region are to comply with the requirements given in Table 5.4.2.

4.3.2 The scantlings of main frames are normally to be based on Rule standard brackets at top and bottom, whilst the scantlings of 'tween deck frames are normally to be based on a Rule standard bracket at the top only.

Table 5.4.1 Shell framing (longitudinal) forward

Location	Modulus, in cm^3
(1) Side longitudinals in forecastle	$Z = 0{,}0075 s\, k\, l_e^2\ (0{,}6 + 0{,}167 D_1)$
(2) Side longitudinals in way of dry spaces including double skin construction:	
(a) Forward of the collision bulkhead	$Z = 0{,}007 s\, k\, h_{T1}\, l_e^2\, F_s$ but not to be less than as required by (1)
(b) Between the collision bulkhead and 0,2*L* from the F.P.	As (a) above or as required in the midship region for the particular type of ship concerned, whichever is the greater. However, not to be taken less than as required by (1).
(c) Aft of 0,2*L* from the F.P.	As required in the midship region for the particular type of ship concerned.
(3) Side longitudinals in way of double skin tanks or deep tanks	The greater of the following: (a) *Z* as from (2) (b) As required by Pt 4, Ch 1,9 for deep tanks.
(4) Bottom and bilge longitudinals	The greater of the following: (a) As required in the midship region for the particular type of ship concerned. (b) As required by 1.5, strengthening of bottom forward, where applicable.

Symbols

L, *D*, *T*, *s*, *k*, as defined in 1.4.1

l_e = as defined in 1.4.1, but is to be taken not less than 1,5 m

L_1 = *L* but need not be taken greater than 190 m

F_s is a fatigue factor to be taken as follows:

(a) For built sections and rolled angle bars:

$$F_s = \frac{1{,}1}{k}\left[1 - \frac{2b_{f1}}{b_f}(1-k)\right] \text{ at } 0{,}6D_1 \text{ above the base line}$$

= 1,0 at D_1 and above, and F_{sb} at the base line intermediate values by linear interpolation

F_{sb} is a fatigue factor for bottom longitudinals

= $0{,}5\ (1 + F_s$ at $0{,}6D_1)$

(b) For flat bars and bulb plates $\dfrac{b_{f1}}{b_f}$ may be taken as 0,5

where

b_{f1} = the minimum distance, in mm, from the edge of the face plate of the side longitudinal under consideration to the centre of the web plate, *see* Fig. 9.5.1 in Pt 4, Ch 9

b_f = the width of the face plate, in mm, of the side longitudinal under consideration, *see* Fig. 9.5.1 in Pt 4, Ch 9

T_1 = *T* but not to be taken less than $0{,}65D_1$

D_1 = $T + H_b$ metres, where H_b is the minimum bow height, in metres, obtained from Ch 1,6.1.11

$$h_{T1} = f_w\, C_w\left(1 - \frac{h_6}{D_1 - T_1}\right)F_\lambda$$, in metres, for longitudinals above the waterline at draught T_1 where

$f_w\left(1 - \dfrac{h_6}{D_1 - T_1}\right)$ is not to be taken less than 0,7

$$= \left[h_6 + f_w\, C_w\left(1 - \frac{h_6}{2T_1}\right)\right]F_\lambda$$, in metres, for longitudinals below the waterline at draught T_1

where

f_w = 1,0 at 0,2*L* from the F.P. and 1,71 at, and forward of, 0,15*L* from the F.P. Intermediate positions by interpolation

h_6 = vertical distance, in metres, from the waterline at draught T_1, to the longitudinal under consideration

F_λ = 1,0 for $L \leq 200$ m

= $[1{,}0 + 0{,}0023\ (L - 200)]$ for $L > 200$ m

C_w = a wave head, in metres = $7{,}71 \times 10^{-2}\, L e^{-0{,}0044L}$

where

e = base of natural logarithms 2,7183

NOTE

Where struts are fitted midway between transverses in double skin construction, the modulus of the side longitudinals may be reduced by 50*k* per cent from that obtained for locations (2) and (3) as applicable.

4.3.3 End connections of transverse main and 'tween deck frames are to be in accordance with Ch 10,3. For bulk carriers the end connections of main frames in cargo holds are to be in accordance with Pt 4, Ch 7,6.2.5 to 6.2.12. Where brackets are omitted at the foot of main frames in cargo spaces, small easing brackets are to be fitted forward of 0,15*L* from the F.P.

4.4 Panting stringers in way of transverse framing

4.4.1 In lower hold or deep tank spaces panting stringers are generally to be fitted in line with each stringer or flat in the fore peak space and extending back to 0,15*L* from the F.P. These stringers may be omitted if the shell plating is increased in thickness as required by 3.5.2. Where the span of the main frames exceeds 9 m, panting stringers are to be fitted irrespective of whether the shell plating is increased in thickness or not. These stringers are to be arranged in line with alternate stringers or flats in the fore peak and are to extend back to 0,2*L* from the F.P.

Table 5.4.2 Shell framing (transverse) forward

Location	Modulus, in cm^3	Inertia, in cm^4
(1) Frames in fore peak spaces and lower 'tween decks over, *see* Note 1	$Z = K_1 \, s \, k \, T \, D_2 \, S_1 \times 10^{-3}$	$I = \dfrac{3{,}5}{k} S_1 Z$
(2) Frames in upper 'tween decks and forecastles forward of the collision bulkhead, *see* Notes 1, 2 and 8	The greater of the following: (a) $Z = C \, s \, k \, h_{T1} \, H^2 \times 10^{-3}$ (b) $Z = 9{,}1 \, s \, k \, D_1 \times 10^{-3}$	$I = \dfrac{3{,}5}{k} HZ$
(3) Main and 'tween deck frames (including forecastle) between the collision bulkhead and 0,15L from the F.P., *see* Notes 1 to 4 and 8	The greater of the following: (a) $Z = C \, s \, k \, h_{T1} \, H^2 \times 10^{-3}$ (b) $Z = 9{,}1 \, s \, k \, D_1 \times 10^{-3}$	$I = \dfrac{3{,}5}{k} HZ$
(4) Main and 'tween deck frames between 0,15L and 0,2L from the F.P. in dry cargo spaces, *see* Notes 1 to 4 and 8	The greater of the following: (a) $Z = C \, s \, k \, h_{T1} \, H^2 \times 10^{-3}$ (b) $Z = 9{,}1 \, s \, k \, D_1 \times 10^{-3}$	$I = \dfrac{3{,}2}{k} HZ$
(5) Panting stringers, *see* Note 5	Web depth, d_w, same depth as frames Web thickness, $t = 6 + 0{,}025L_2$ mm Face area, $A = kS_2 \, (H + 1)$ cm^2	
(6) Main and 'tween deck frames elsewhere, *see* Notes 1 to 4	As required in the midship region for the particular type of ship concerned	

Symbols

L, D, T, s, k as defined in 1.4.1

L_2 = L but need not be taken greater than 215 m

D_1 = $T + H_b$, in metres, where H_b is defined in Ch 1,6.1.11

D_2 = D_1, but is to be taken not greater than 16 m, nor less than 6,0 m

H = H_{MF} or H_{TF} as applicable, *see* Note 7

H_{MF} = vertical framing depth, in metres, of main frames as shown in Fig. 5.4.1 but is to be taken not less than 3,5 m, *see* Note 6

H_{TF} = vertical framing depth, in metres, of 'tween deck frames as shown in Fig. 5.4.1 but is to be taken not less than 2,5 m

K_1 = 2,3 for peak tanks
= 1,87 for 'tween decks over peak tanks

S_1 = vertical spacing of peak stringers or height of lower 'tween deck above the peak, in metres, as applicable

S_2 = vertical spacing of panting stringers, in metres

C = end connection factor
= 3,4 where two Rule standard brackets fitted
= 3,4 (1,8 – 0,8(l_a/l)) where one Rule standard bracket and one reduced bracket is fitted
= 3,4 (2,15 – 1,15 (l_{amean}/l)) where two reduced brackets are fitted
= 6,1 where one Rule standard bracket is fitted
= 6,1 (1,2 – 0,2 (l_a/l)) where one reduced bracket is fitted
= 7,3 where no brackets are fitted.
The requirements for frames where brackets larger than Rule standard are fitted will be specially considered

l = length, in mm, as derived from Ch 10,3.4.1

l_a = equivalent arm length, in mm, as derived from Ch 10,3.4.1

l_{amean} = mean equivalent arm length, in mm, for both brackets

T_1 = T but not to be taken less than 0,65D_1

h_{T1} = head, in metres, at mid-length of H

$= f_w \, C_w \left(1 - \dfrac{h_6}{D_1 - T}\right) F_\lambda$, in metres for frames where the mid-length of frame is above the waterline at draught T_1

where $f_w \left(1 - \dfrac{h_6}{D_1 - T_1}\right)$ is not to be taken less than 0,7

$= \left[h_6 + f_w \, C_w \left(1 - \dfrac{h_6}{2T_1}\right)\right] F_\lambda$, in metres for frames where the mid-length of frame is below the waterline at draught T_1

where

f_w = 1,0 at 0,2L from F.P. and 1,71 at, and forward of, 0,15L from F.P. Intermediate positions by interpolation

h_6 = vertical distance, in metres, from the waterline at draught T_1 to the mid-length of H

F_λ = 1,0 for $L \leq 200$ m
= [1,0 + 0,0023 (L – 200)] for $L > 200$ m

C_w = a wave head , in metres
= $7{,}71 \times 10^{-2} \, Le^{-0{,}0044L}$
where e = base of natural logarithms 2,7183

NOTES

1. For framing in the fore end of fishing vessels, *see* Pt 4, Ch 6,6.
2. In offshore supply ships the moduli of main and 'tween deck frames are to be 25 per cent greater than given in (2), (3) and (4).
3. In way of the cargo tanks of oil tankers or ore carriers, the scantlings of frames are also to comply with the requirements for frames in the midship region of such ships, *see* Pt 4, Ch 9, Ch 10 or Ch 11, as applicable.
4. In bulk carriers the scantlings of frames are also to comply with the requirements of Pt 4, Ch 7,6 in which the requirements of Table 7.6.1 location (1) are to be multiplied by the following factor:
   Between 0,15L and 0,2L from the F.P., $C_1 = (0{,}018D_2 + 0{,}82)$, but not to be taken less than 1,0.
   Between collision bulkhead and 0,15L from the F.P., $C_1 = (0{,}021D_2 + 0{,}96)$.
5. Panting stringers are not required in tugs less than 46 m in length, *see* Pt 4, Ch 3,4.
6. Where the frames are supported by fully effective horizontal stringers, these may be considered as decks for the purpose of determining H_{MF}.
7. Where frames are inclined at more than 15° to the vertical, H_{MF} or H_{TF} is to be measured along a chord between span points of the frame.
8. Except for main frames the modulus for these members need not exceed that derived from (1) using H_{TF} in place of S_1.

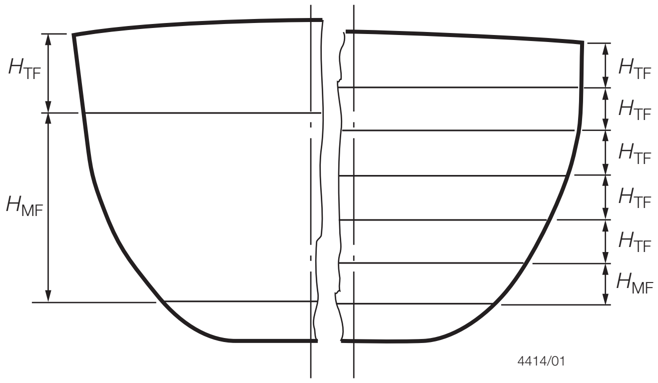


Fig. 5.4.1 Framing depths for transverse frames

4.4.2 In 'tween deck spaces in the region forward of 0,15*L* from the F.P., where the unsupported length of frame exceeds 2,6 m in a lower 'tween deck or 3,0 m in an upper 'tween deck, intermediate panting stringers are generally to be fitted. These stringers may be omitted if the shell plating is increased in thickness as required by 3.5.2.

4.4.3 The scantlings of panting stringers are to be determined from Table 5.4.2.

4.5 Primary structure at sides

4.5.1 For the arrangement of primary structure in peak tanks and deep tanks forward, *see also* Sections 6 and 7.

4.5.2 The spacing of side transverses and web frames is generally not to exceed the values given in Table 5.4.3.

4.5.3 The scantlings of side transverses supporting longitudinal framing and stringers and webs supporting transverse framing in the forward region are to be determined from Table 5.4.4.

4.5.4 The web thickness, stiffening arrangements and end connections of primary supporting members are to be in accordance with the requirements of Ch 10,4.

Table 5.4.3 Spacing of side transverses and web frames forward

Location	Maximum spacing	
	Web frames in association with transverse framing system	Side transverses in association with longitudinal framing system
(1) Forward of the collision bulkhead	5 frame spaces	2,5 m where $L \leq 100$ m 3,5 m where $L \geq 300$ m Intermediate values by interpolation
(2) In way of a forward deep tank adjacent to the collision bulkhead	5 frame spaces	3,0 m where $L \leq 100$ m 4,2 m where $L \geq 300$ m Intermediate values by interpolation
(3) Elsewhere in way of dry cargo spaces or deep tanks	*See* Note 1	3,8 m where $L \leq 100$ m $(0{,}006L + 3{,}2)$ m where $L > 100$m
(4) In way of the cargo tanks of oil tankers, chemical tankers or ore or oil carriers	–	3,6 m where $L \leq 180$ m $0{,}02L$ where $L > 180$ m

NOTES
1. In 'tween decks above deep tanks situated adjacent to the collision bulkhead, web frames are to be fitted in line with those in the tanks.
2. For the maximum spacing of transverses in dredgers, *see* Pt 4, Ch 12,5.

Table 5.4.4 Primary structure forward

Item and location	Modulus, in cm^3	Inertia, in cm^4
Longitudinal framing system		
(1) Side transverses in dry spaces forward of 0,2*L* from the F.P., *see* Note 5: (a) Holds (b) 'tween decks	 $Z = 10\,k\,S\,h_{T1}\,l_e^2$ $Z = C_2\,k\,S\,T\,H_{TF}\sqrt{D}$	—
(2) Side transverses in peak and deep tanks forward of 0,2*L* from the F.P., *see* Notes 1 and 4: (a) where no struts fitted (b) where struts fitted	 $Z = 14{,}1\rho\,k\,S\,h_4\,l_e^2\,\gamma$ or as (1) above, whichever is the greater As in Pt 4, Ch 9,9	$I = \dfrac{2{,}5}{k}\,l_e\,Z$
(3) Side transverses in dry spaces and deep tanks aft of 0,2*L* from the F.P.	As in Pt 4, Ch 1,6, *see* Notes 1 and 2	
Transverse framing system		
(4) Side stringers supported by webs in dry spaces forward of 0,2*L* from the F.P., *see* Note 3	$Z = 7{,}75\,k\,S\,h_{T1}\,l_e^2$	—
(5) Side stringers supported by webs in peak or deep tanks forward of 0,2*L* from the F.P., *see* Notes 1 and 3	$Z = 11{,}7\rho\,k\,S\,h_4\,l_e^2$ or as (4) above, whichever is the greater	$I = \dfrac{2{,}5}{k}\,l_e\,Z$
(6) Web frames supporting side stringers forward of 0,2*L* from the F.P., *see* Notes 1, 2 and 3	*Z* to be determined from the calculations based on the following assumptions: (a) Fixed ends (b) Point loadings from stringers (c) Head $\gamma\,h_4$ or $\gamma\,h_{T1}$ as applicable (d) Bending stress $\dfrac{93{,}2}{k}$ N/mm² $\left(\dfrac{9{,}5}{k}\ \text{kgf/mm}^2\right)$ (e) Shear stress $\dfrac{83{,}4}{k}$ N/mm² $\left(\dfrac{8{,}5}{k}\ \text{kgf/mm}^2\right)$	In deep tanks $I = \dfrac{2{,}5}{k}\,l_e\,Z$
(7) Web frames in 'tween decks, not supporting side stringers, forward of 0,2*L* from the F.P.	$Z = C_3\,k\,S\,T\,H_{TF}\sqrt{D}$	—
(8) Side stringers and web frames in dry spaces and deep tanks aft of 0,2*L* from the F.P.	As in Pt 4, Ch 1,6, *see* Notes 1 and 2	

Symbols

D, T, S, l_e, *k*, ρ as defined in 1.4.1

B_f = bow fullness factor determined from Fig. 5.4.3 to be taken as 1,0 for framing members located at and abaft 0,2*L* from the forward perpendicular

h_4 = tank head, in metres, as defined in Ch 3,5

h_{T1} = head, in metres, at mid-length of span

$= f_w\,C_w\left(1 - \dfrac{h_6}{D_1 - T_1}\right)F_\lambda$, in metres, where the mid-length of span is above the waterline at draught T_1

where $f_w\left(1 - \dfrac{h_6}{D_1 - T_1}\right)$ is not to be taken less than 0,7

$= \left[h_6 + f_w\,C_w\left(1 - \dfrac{h_6}{2T_1}\right)\right]F_\lambda$, in metres, where the mid-length of span is below the waterline at draught T_1

where

f_w = 1,0 at 0,2*L* from F.P. and 1,71 at, and forward of, 0,15*L* from F.P. Intermediate positions by interpolation

h_6 = vertical distance, in metres, from the waterline at draught T_1 to the mid-length of span

F_λ = 1,0 for $L \le 200$ m

= $[1{,}0 + 0{,}0023\,(L - 200)]$ for $L > 200$ m

C_w = a wave head, in metres

= $7{,}71 \times 10^{-2}\,L\,e^{-0{,}0044L}$

where e = base of natural logarithms 2,7183

D_1 = $T + H_b$, in metres, where H_b is defined in Ch 1,6.1.11

T_1 = *T* but not to be taken less than $0{,}65D_1$

C_2, C_3 = factors obtained from Fig. 5.4.2

H_{TF} = vertical height of 'tween decks, in metres, as shown in Fig. 5.4.1

γ is to be measured at the mid-span of the member as follows:

γ_1 = 1,0 at base line

γ_2 = bow fullness factor (B_f) at 0,6*D* above base

$\gamma_3 = \left(\dfrac{B_f - 1}{2}\right) + 1{,}0$ at depth *D* above base

Intermediate values are to be determined by interpolation.
Minimum value = 1,0

NOTES

1. In way of the cargo tanks, fore peak tanks and dry spaces of oil tankers or ore carriers the scantlings of primary structure are to comply with the requirements of Pt 4, Ch 9, Ch 10 or Ch 11, as appropriate.
2. For bulk carriers *see* Pt 4, Ch 7,6.2.
3. For stringers and webs in fore peaks or deep tanks, *see also* 6.3 and 7.3.
4. In the fore peak, the breadth *S* should be measured along the line of shell. The effective length l_e of the vertical webs should be measured along the line of shell from horizontal flat to horizontal flat, except that it may be taken to the underside of a transverse or strut where fitted.
5. The web depth of side transverses forward of 0,2*L* from the F.P. is to be not less than 2,5 times the depth of the longitudinals supported. The web depth of stringers forward of 0,2*L* is to be not less than 2,2 times the depth of the frames supported.
6. For the primary structure at sides in dredgers with restricted service notations, *see* Table 12.5.2 in Pt 4, Ch 12.

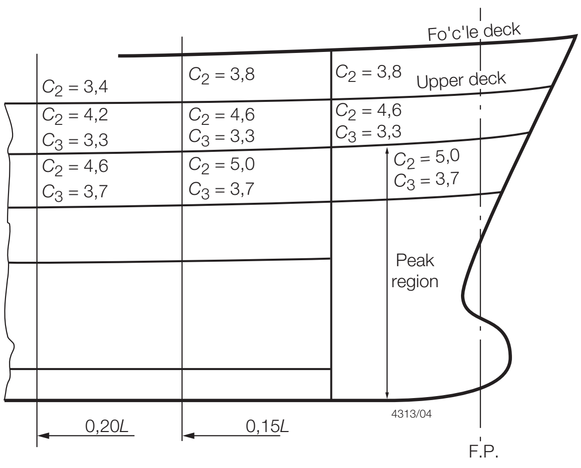


Fig. 5.4.2
Framing factors for primary members

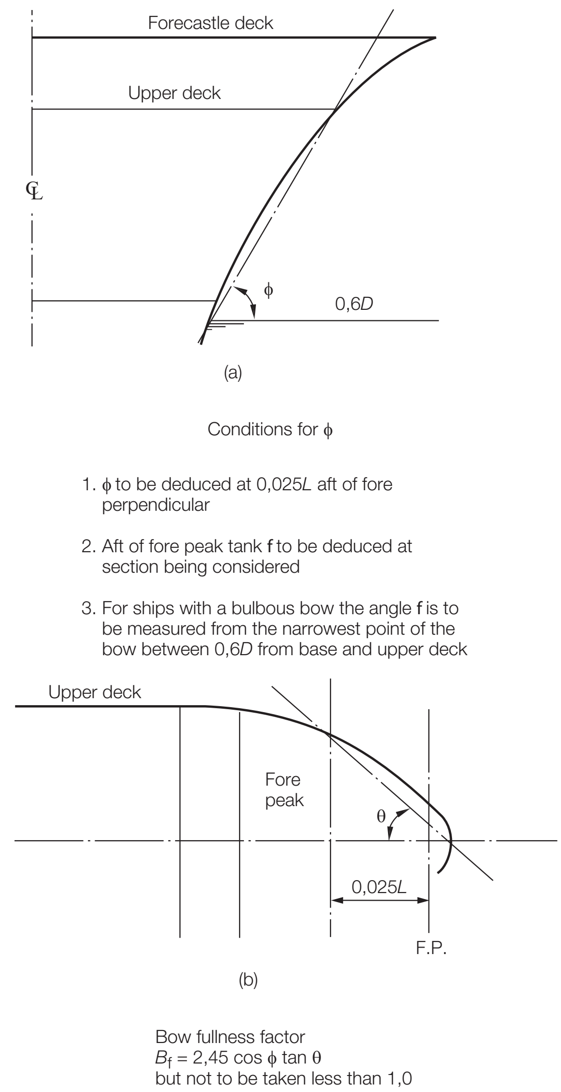


Fig. 5.4.3
Illustration of bow fullness factor determination

■ *Section 5* Single and double bottom structure

5.1 General

5.1.1 For dry cargo ships exceeding 120 m in length and for all ships which have the notation 'strengthened for heavy cargoes', longitudinal framing is, in general, to be adopted, *see also* Pt 4, Ch 9,1.3 and Pt 4, Ch 10.

5.1.2 For ships requiring additional strengthening of bottom forward the requirements given in 1.5 are also to be complied with, as applicable.

5.1.3 For ships having the notation 'strengthened for heavy cargoes' the requirements of Pt 4, Ch 7,8 are also to be complied with, as applicable.

5.1.4 For ships intended to load or unload while aground, *see* Ch 9,9.

5.1.5 Provision is to be made for the free passage of water and/or air from all parts of single or double bottoms to bilge or tank suctions, account being taken of the pumping rates required.

5.1.6 For passenger ships, *see* Pt 4, Ch 2,6.

5.2 Single bottoms – Transverse framing

5.2.1 In fore peak spaces, for ships of full form the floors are to be supported by a centreline girder or a centreline wash bulkhead. In other cases the centreline girder is to be carried as far forward as practicable.The arrangement and scantlings of the floors and centreline girder are to be sufficient to give adequate stiffness to the structure, but are to be not less than required by Table 5.5.1. The floor panels and the upper edges of the floors and centreline girder are to be suitably stiffened.

5.2.2 In deep tanks forward of 0,2*L* from the F.P. floors are to be supported by a primary centreline girder or centreline bulkhead together with intercostal side girders. In the case of an oil tanker (*see* 1.1.4) or similar ship having longitudinal bulkheads port and starboard, these may be extended to the fore end of the deep tank in lieu of a centreline bulkhead. The arrangement and scantlings of centreline girder, floors and side girders are to be determined from Table 5.5.1, but in way of web frames the depth of the floor and size of the face bar are to be not less than those of the web frame. In general, floors are not to be flanged.

5.2.3 In way of dry cargo spaces forward, the arrangement and scantlings of transversely framed single bottoms are to be generally as required in the midship region as given in Pt 4, Ch 1,7, except as required by Table 5.1.1. The girders forward are to scarf into the normal girder arrangement in the midship region. In ships having considerable rise of floor towards the fore end, the depth of the floors may be required to be increased or the top edge sloped upwards towards the outboard end. In general, floors are not to be flanged.

Table 5.5.1 Single bottom construction forward

Item	Parameter	Requirement
Transverse framing system		
(1) Centre girder: (a) In fore peak tank, or deep tank, forward of 0,2*L* from the F.P.	Modulus Inertia Web thickness	The greater of the following: $Z = 8,5\, k\, S\, h_5\, l_e^2$ cm³, or $Z = 9,75\, \rho\, k\, S\, h_4\, l_e^2$ cm³ $I = \frac{2,5}{k}\, l_e\, Z$ cm⁴ $t = t_w$ as in Ch 10,4.4
(b) In dry spaces	Web thickness Web depth and face area	Forward of 0,075*L* from the F.P., $t = (\sqrt{Lk} + 0,5)$ mm or 6 mm, whichever is the greater. Between 0,075*L* and 0,3*L* from the F.P. the thickness may taper from the midship thickness to the end thickness above As in Pt 4, Ch 1,7
(2) Floors: (a) In fore peak tank, or deep tank, forward of 0,2*L* from the F.P.	Maximum spacing Web depth (at centreline) Web thickness Minimum face plate area in deep tank	Every frame d_f = (83*D* + 150) mm or 1400 mm, whichever is the lesser $t = (6,0 + 0,025 L_2) \sqrt{\frac{s_2}{800}}$ mm $A_f = 0,85 kB$ cm²
(b) In dry cargo spaces	Maximum spacing Scantlings	Every frame As in Pt 4, Ch 1,7.2
(3) Intercostal side girders: (a) In deep tank, forward of 0,2*L* from the F.P.	Maximum spacing Web depth Web thickness Minimum face plate area	$0,003 s_F$ m As floors $t = t_w$ as in Ch 10,4.4 Suitable stiffener
(b) In dry cargo spaces	Maximum spacing Scantlings	$0,003 s_F$ m As in Pt 4, Ch 1,7
Longitudinal framing system		
(4) Centre girder: (a) In deep tanks forward of 0,2*L* from the F.P.	Scantlings	As in Pt 4, Ch 9,9
(b) In dry spaces	Scantlings	To be specially considered
(5) Bottom transverses: (a) In deep tanks forward of 0,2*L* from the F.P., *see* Note 4	Maximum spacing Scantlings	3,0 m for $L \leq 100$ m 4,2 m for $L \geq 300$ m Spacing at intermediate lengths by interpolation As in Pt 4, Ch 9,9
(b) In dry spaces	Scantlings	To be specially considered
(6) Intercostal side girders	Scantlings	To be specially considered

Symbols

$L, B, D, S, s, l_e, k, \rho$ as defined in 1.4.1
h_4 = tank head, in metres, as defined in Ch 3,5
h_5 = distance, in metres, from mid-point of span to the following positions:
(a) forward of 0,15*L* from the F.P., 3 m above the deck height obtained from Ch 1,6.1.11
(b) at 0,2*L* from the F.P., the upper deck at side
(c) between 0,15*L* and 0,2*L* from the F.P., by interpolation between (a) and (b)
s_F = transverse frame spacing, in mm
s_2 = spacing of stiffener, in mm, but to be taken not less than 800 mm
L_2 = *L* but need not be taken greater than 215 m

NOTES
1. For single bottom construction in way of the cargo tanks of oil tankers, *see* Pt 4, Ch 9,1.3 and Pt 4, Ch 10.
2. For minimum thickness of structure within cargo tanks and fore peak tanks in oil tankers, *see* Pt 4, Ch 9,10.2 and Pt 4, Ch 10,7.2
3. For single bottom construction in dredgers, *see* Pt 4, Ch 12,6.
4. For ships having one or more longitudinal bulkheads the maximum spacing may be increased but is not to exceed that for the midship region.

5.3 Single bottoms – Longitudinal framing

5.3.1 In deep tanks forward of 0,2*L* from the F.P., bottom transverses are to be supported by a primary centreline girder or a centreline bulkhead. In addition, an intercostal side girder is generally to be fitted port and starboard. In the case of an oil tanker (*see* 1.1.4) or similar ship having longitudinal bulkheads port and starboard, these may be extended to the fore end of the deep tank in lieu of a primary centreline support and intercostal girders. The spacing of bottom transverses and scantlings of the centreline girder, bottom transverses and side girders are to be as required by Table 5.5.1.

5.3.2 The requirements for longitudinally framed single bottoms in way of dry cargo spaces will be specially considered.

5.4 Double bottoms

5.4.1 The minimum depth of centre girder forward is generally to be the same as that required in the midship region by Part 4 for the particular type of ship concerned, but in ships with considerable rise of floor, a greater depth may be required at the fore end to provide adequate access throughout the double bottom tank.

5.4.2 Where the height of the double bottom varies, this variation is generally to be made gradual by sloping the inner bottom over an adequate longitudinal extent. Knuckles in the plating are to be arranged close to plate floors. Otherwise, suitable scarfing arrangements are to be made.

5.4.3 The arrangement and scantlings of girders, floors and inner bottom plating and the section modulus of inner bottom stiffening are to be determined from Table 5.5.2. In other respects the structural arrangements are to be as detailed in Part 4 for the particular type of ship concerned.

5.4.4 For double bottom construction in way of the cargo tanks of oil tankers or ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11, as appropriate.

Table 5.5.2 Double bottom construction forward

<table>
<tr><th rowspan="2">Item and parameter</th><th colspan="2">Requirements</th></tr>
<tr><th>Transverse framing</th><th>Longitudinal framing</th></tr>
<tr><td>(1) Centre girder:
(a) Thickness forward of 0,075L from the F.P.
(b) Thickness between 0,075L and 0,3L from the F.P.</td><td colspan="2">$t = (0{,}008\ d_{DB} + 2)\sqrt{k}$ mm
As determined by a taper line from the midship thickness given in Pt 4, Ch 1,8 to the end thickness as for (1) (a)</td></tr>
<tr><td>(2) Plate floors:
(a) Maximum spacing forward of 0,2L from the F.P.
(b) Maximum spacing aft of 0,2L from the F.P.
(c) Scantlings</td><td>$0{,}002 s_F$ m
As for midship region
As in Pt 4, Ch 1,8</td><td>2,5 m
As for midship region, see Note 5
As in Pt 4, Ch 1,8</td></tr>
<tr><td>(3) Watertight floors and bracket floors</td><td>As in Pt 4, Ch 1,8</td><td>As in Pt 4, Ch 1,8</td></tr>
<tr><td>(4) Side girders, see Note 1:
(a) Maximum spacing forward of 0,2L from the F.P.
(b) Maximum spacing aft of 0,2L from the F.P.
(c) Scantlings</td><td>$0{,}003 s_F$ m
As for midship region
As in Pt 4, Ch 1,8</td><td>$0{,}004 s_L$ or 3,7 m whichever is the lesser
As for midship region, see Note 5
As in Pt 4, Ch 1,8</td></tr>
<tr><td>(5) Inner bottom plating, see Note 2:
(a) Thickness at or forward of 0,075L from the F.P.
(b) Thickness between 0,075L and 0,3L from the F.P.
(c) In way of deep tanks or holds used for the carriage of water ballast or where the double bottom tank is common with a wing ballast tank</td><td colspan="2">$t = (0{,}00127(s + 660)\sqrt[4]{k^2 LT})$ mm or 6,5 mm, whichever is the greater, see Notes 3, 4 and 5
As determined by a taper line from the midship thickness given in Pt 4, Ch 1,8 to the end thickness as for (5) (a), but not less than 6,5 mm, see Notes 3, 4 and 5
$t = \left(0{,}004\ s\ f\sqrt{\dfrac{\rho\ k\ h_4}{1{,}025}} + 2{,}5\right)$ mm or 6,5 mm, whichever is the greater</td></tr>
<tr><td>(6) Inner bottom longitudinals</td><td colspan="2">As in Pt 4, Ch 1,8, see Notes 2 and 5</td></tr>
<tr><td colspan="3">Symbols</td></tr>
<tr><td colspan="3">L, T, S, s, k, ρ as defined in 1.4.1
d_{DB} = minimum depth of centre girder as required by Pt 4, Ch 1,8
$f = 1{,}1 - \dfrac{s}{2500S}$ but to be taken not greater than 1,0
h_4 = tank head, in metres, as defined in Ch 3,5
s_F = transverse frame spacing, in mm
s_L = spacing of bottom longitudinals, in mm</td></tr>
<tr><td colspan="3">NOTES
1. The girders forward of 0,2L are to be suitably scarfed into the midship girder arrangement.
2. For double bottom construction in way of the cargo tanks of oil tankers or ore carriers, see also Pt 4, Ch 9, Ch 10 or Ch 11, as appropriate.
3. In way of hatches the tank top taper thickness is to be increased by 2 mm if no ceiling is fitted, but is to be taken not less than 7,5 mm.
4. Where cargo is to be regularly discharged by grabs the tank top taper thickness is to be increased by 5,0 mm if no ceiling is fitted, or by 3,0 mm where ceiling is fitted.
5. For ships having the notation ‘strengthened for heavy cargoes’, the requirements of Pt 4, Ch 7,8 are also to be complied with.</td></tr>
</table>

■ *Section 6* **Fore peak structure**

6.1 General

6.1.1 The requirements given in this Section apply to the arrangement of primary structure supporting the peak side framing and bulbous bow, the arrangement and scantlings of wash bulkheads and perforated flats, and the scantlings of collision bulkheads.

6.1.2 In ships of very full form it is recommended that transverse framing and side transverses supporting longitudinal framing, together with attached floors and beams, be inclined at an angle to the centreline of ship so that the frames or transverses lie as near normal to the shell plating as possible.

6.2 Bottom structure

6.2.1 The bottom of the peak space is generally to be transversely framed with arrangements and scantlings as detailed in 5.2.1. Longitudinally framed bottom structure will be specially considered.

6.3 Side structure – Transverse framing

6.3.1 Above the floors, transverse side framing is to be supported by one of the following arrangements:

(a) Side stringers spaced about 2,0 m apart and supported by struts fitted at alternate frames. The struts are to be bracketed to the frames and where the span is long, supported at the centreline by a complete or partial wash bulkhead or equally effective structure. Intermediate frames are to be bracketed to the stringer plates.

(b) Side stringers spaced about 2,0 m apart and supported by web frames. The upper ends of the web frames are to be supported under the tank top by suitable deep beams or buttresses which should generally form a ring structure.

(c) Perforated flats spaced not more than 2,5 m apart. The area of perforations in each flat is to be not less than 10 per cent of the total area of the flat. The plating is to be suitably framed in way of openings.

(d) A combination of the above arrangements.

6.3.2 Where the depth of the peak space exceeds 10 m, a perforated flat is to be arranged at about mid-depth.

6.3.3 Where the length of the space exceeds 10 m and the side framing is supported as required by 6.3.1(a) or (c), additional transverse strengthening in the form of transverse wash bulkheads or web frames is to be provided.

6.3.4 The scantlings of side stringers supported by struts, and also of the struts and their brackets, are to be determined from Table 5.6.1.

6.3.5 The scantlings of side stringers supported by web frames, and also of the web frames, are to be determined from 4.5.

6.3.6 The scantlings of perforated flats are to be determined from Table 5.6.1.

6.4 Side structure – Longitudinal framing

6.4.1 The spacing and scantlings of side transverses supporting longitudinal framing are to be as required by 4.5.

6.4.2 Where the depth of a tank exceeds 10 m, side transverses are generally to be supported by one or more perforated flats or an arrangement of struts.

6.4.3 Suitable transverses or deep beams are to be arranged at the top of the tank and at perforated flats to provide end rigidity to the side transverses.

6.5 Bulbous bow

6.5.1 Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure.

6.5.2 At the fore end of the bulb the structure is generally to be supported by horizontal diaphragm plates spaced about 1,0 m apart in conjunction with a deep centreline web.

6.5.3 In general, vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing.

6.5.4 In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is generally to be fitted.

6.5.5 In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or substantial web frames spaced about five frame spaces apart are generally to be fitted.

6.5.6 The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness is to be the same as that required for plated stems by 3.3.2.

6.6 Wash bulkhead

6.6.1 Where a fore peak space is used as a tank and the breadth of the tank at its widest point exceeds 0,5B, a complete or partial centreline wash bulkhead is to be fitted.

6.6.2 Wash bulkheads are to have an area of perforations not less than five per cent nor more than 10 per cent of the area of the bulkhead. The plating is to be suitably stiffened in way of openings.

6.6.3 The scantlings of wash bulkheads are to be determined from Table 5.6.1. Stiffeners are to be bracketed at top and bottom.

6.7 Collision bulkhead

6.7.1 The position and height of the collision bulkhead are to be in accordance with the requirements of Ch 3,4.

6.7.2 The scantlings are to comply with the requirements of Pt 4, Ch 1,9 except that the thickness of plating and modulus of stiffeners are to be not less than 12 per cent greater and 25 per cent greater, respectively, than would be required for a dry space. If the collision bulkhead forms the boundary of a cargo tank or cofferdam in an oil tanker or ore carrier the minimum thickness requirements of Pt 4, Ch 9,10 are also to be complied with.

Table 5.6.1 Fore peak structure

Item	Parameter	Requirement
(1) Unflanged stringers supported by panting beams at alternate frames	Web thickness Web depth	$t = (6{,}0 + 0{,}025L_2)\sqrt{\dfrac{s_1}{600}}$ mm $d_w = (400 + 3{,}3L)\,\dfrac{S_1}{2{,}0}$ mm
(2) Struts	Cross-sectional area Least inertia	$A = (2{,}5B_1 - 0{,}04L_2)\,k$ cm^2 $I = S_1\,S_2\,h_5\,l_e^2$ cm^4
(3) Brackets supporting stringers and beams	Thickness Arm length	$t = (6{,}0 + 0{,}025L_2)\sqrt{\dfrac{s_1}{600}}$ mm $l_e = \dfrac{150A}{t}$ mm in way of struts $l_e = 0{,}5d_w$ mm at intermediate frames
(4) Perforated flats and wash bulkheads (excluding lowest strake of plating), *see* Notes 1, 2 and 3	Plating thickness Stiffener modulus	$t = (6{,}0 + 0{,}015L)\sqrt{\dfrac{s_2}{800}}$ mm $Z = \dfrac{0{,}0057\,s\,k\,h_6\,l_e^2}{b}$ cm^3
(5) Diaphragms in bulbous bows and lowest strake of wash bulkhead	Plating thickness	$t = (6{,}0 + 0{,}025L_2)\sqrt{\dfrac{s_2}{800}}$ mm

Symbols

L, B, S, s, k as defined in 1.4.1
b = 1,4 for rolled or built sections
= 1,6 for flat bars
h_5 = vertical distance, in metres, from the stringer to a position 3 m above the deck height obtained from Ch 1,6.1.11
h_6 = vertical distance, in metres, from mid-depth of tank to top of tank
l_e = effective length of stiffening member, in metres, *see* Tables 1.9.1 and 1.9.3 in Pt 4, Ch 1
s_1 = spacing of peak frames, in mm, but to be taken not less than 600 mm
s_2 = spacing of stiffeners, in mm, but to be taken not less than 800 mm
B_1 = B but need not be taken greater than 32 m
L_2 = L but need not be taken greater than 215 m
S_1 = vertical spacing or mean spacing of stringers, in metres
S_2 = horizontal spacing of struts, in metres

NOTES
1. For oil tankers, *see also* Pt 4, Ch 9,10.7.
2. For horizontal flats supporting vertical webs in the fore peak tank, the thickness of the flat in way of the web is to comply with Table 9.7.1(b)(ii) in Pt 4, Ch 9.
3. For minimum thickness within fore peak tanks of oil tankers, *see also* Pt 4, Ch 9,10.2.

6.7.3 Doors, manholes, permanent access openings or ventilation ducts are not to be cut in the collision bulkhead below the freeboard deck, *see also* Pt 5, Ch 13,3. The number of openings in collision bulkheads above the freeboard deck is to be kept to a minimum compatible with the design and proper working of the ship. All such openings are to be fitted with means of closing to weathertight standards.

■ *Section 7*
Forward deep tank structure

7.1 General

7.1.1 The requirements given in this Section apply to the arrangement of primary structure supporting the side framing, the arrangement and scantlings of wash bulkheads and perforated flats, and the scantlings of boundary bulkheads in way of deep tanks situated forward of 0,2L from the F.P.

7.1.2 For deep tanks situated aft of this position, *see* Pt 4, Ch 1,9.

7.2 Bottom structure

7.2.1 The bottom structure is to comply with the requirements given in 5.2.2, 5.3.1 and 5.4, as applicable.

7.3 Side structure – Transverse framing

7.3.1 Above the floors, transverse framing is to be supported by one of the following arrangements:

(a) Side stringers spaced not more than 5 m apart and supported by web frames. The upper ends of the web frames are to be supported under the tank top by suitable deep beams or buttresses which should generally form a ring system.

(b) Side stringers spaced not more than 5 m apart and spanning from bulkhead to bulkhead. The ends of these stringers are to be connected to horizontal stringers on the transverse bulkheads to form a ring system.

(c) In the case of narrow tanks, perforated flats spaced not more than 5 m apart. The area of perforations is to be not less than 10 per cent of the area of the flat, and the plating is to be suitably stiffened in way of openings.

7.3.2 Where the side framing is supported as required by 7.3.1(a) and the depth of the tank exceeds 16 m, the web frames are to be supported by one of the following:

(a) One or more side stringers spanning from bulkhead to bulkhead.

(b) One or more perforated flats having deep beams or transverses in way of the web frames.

(c) One or more cross ties.

7.3.3 Where the side framing is supported as required by 7.3.1(c) and the length of the tank exceeds 14 m, additional transverse strengthening in the form of transverse wash bulkheads or web frames is to be provided.

7.3.4 The scantlings of stringers and web frames as required by 7.3.1(a) are to be determined from 4.5.

7.3.5 The scantlings of side stringers supporting framing as required by 7.3.1(b) are to be determined from Item (5) in Table 5.4.4.

7.3.6 The scantlings of side stringers supporting web frames as required by 7.3.2(a) are to be determined from Item (6) in Table 5.4.4.

7.3.7 The scantlings of perforated flats as required by 7.3.1(c) or 7.3.2(b) are to be determined from Table 5.6.1.

7.3.8 The scantlings of cross ties are to be determined as for cross ties in the cargo tanks of oil tankers, *see* Pt 4, Ch 9.9. Where the span between the side shell and longitudinal bulkhead exceeds 0,3*B*, additional fore and aft or vertical support for the struts may be required.

7.4 Side structure – Longitudinal framing

7.4.1 The spacing and scantlings of side transverses supporting longitudinal framing are to be as required by 4.5.

7.4.2 Where the depth of the tank exceeds 16 m, the side transverses are to be supported as required by 7.3.2.

7.5 Wash bulkheads

7.5.1 Where the breadth of the tank at its widest point exceeds 0,5*B*, a centreline wash bulkhead is generally to be fitted. If the maximum breadth of tank exceeds 0,7*B*, it is recommended that the centreline bulkhead be made intact. In the case of an oil tanker or similar ship having longitudinal bulkheads port and starboard, these may be extended to the fore end of the deep tank in lieu of a centreline bulkhead.

7.5.2 Wash bulkheads are to have an area of perforations not less than 5 per cent nor more than 10 per cent of the area of the bulkhead. The plating is to be suitably stiffened in way of openings.

7.5.3 The scantlings of wash bulkheads are generally to be as required by Table 5.6.1, but *see also* 7.5.4 to 7.5.6. Stiffeners are to be bracketed at top and bottom.

7.5.4 The thickness of longitudinal bulkheads may be required to be increased to ensure compliance with the shear strength requirements of Ch 4,6. In the case of a centreline or perforated wing bulkhead, the proportion of the total shear force absorbed by the bulkhead will be specially considered.

7.5.5 The thickness of plating of wash bulkheads may also be required to be increased to take account of shear buckling.

7.5.6 Where longitudinal wash bulkheads support bottom transverses, the lower section of the bulkhead is to be kept free of non-essential openings for a depth equal to 1,75 times the depth of the transverses, and the plating thickness may be required to be increased to meet local buckling requirements.

7.6 Transverse boundary bulkheads

7.6.1 The transverse bulkheads forming the forward and after boundaries of the tank are generally to comply with the requirements of Pt 4, Ch 1,9, except that when the after bulkhead forms the boundary of a cargo tank or cofferdam in an oil tanker or ore carrier, the minimum thickness requirements of Pt 4, Ch 9,10 are also to be complied with.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all types of ship covered by Part 4, except where specifically stated otherwise.

1.1.2 The requirements given are those specific to aft ends and relate to structure situated in the region aft of 0,3*L* from the after perpendicular.

1.1.3 Requirements for cargo space structure within this region not dealt with in this Chapter are to be as detailed in the relevant Chapter of Part 4 for the particular ship type.

1.1.4 The requirements in this chapter are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation. *See* Pt 1, Ch 2,2.3.

1.2 Structural configuration

1.2.1 The Rules provide for both longitudinal and transverse framing systems.

1.2.2 In the case of container ships and open type ships additional requirements may apply as detailed in Pt 4, Ch 8.

1.3 Structural continuity

1.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes.

1.3.2 Where longitudinal framing terminates and is replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover. Where a poop is fitted extending forward of 0,15*L* from the A.P., longitudinal framing at the upper deck and topsides is generally to be continued aft of the forward bulkhead of this superstructure. In bulk carriers and oil tankers (*see* 1.1.4) the longitudinal framing at the upper deck is to be maintained over the cargo space region and continued over the aft end region.

1.3.3 In oil tankers (*see* 1.1.4) with machinery aft, continuity of the longitudinal bulkheads is to be maintained as far as is practicable into the machinery space, and suitable taper brackets are to be fitted at their ends.

1.3.4 In bulk carriers (*see* 1.1.4) with machinery aft, continuity of the topside tank and double bottom hopper tank structure is to be maintained over the cargo space region and as far as is practicable continued into the machinery space, and suitable taper brackets are to be arranged at their ends. Also a vertical taper bracket in line with the vertical strake of the topside tank is to be fitted at the forward side of the aft bulkhead of the cargo space region. Where the topside tank and double bottom hopper tank structures terminate at the cargo space aft bulkhead, the vertical strake of the topside tank is to be arranged with an integral taper bracket and continued through the bulkhead into the machinery space for a distance of 0,2*B*, and the ends of the hopper and topside structures are to be arranged with suitable taper brackets. In addition, in way of the cargo space aft bulkhead, a girder or intercostal bulb plate stiffeners (fitted between and connected to the bulkhead vertical stiffeners), are to be arranged on the aft side in line with the sloped bulkheads of the topside and hopper tanks clear of the taper brackets.

1.3.5 In container or similar ships having continuous side tanks or double skin construction in way of the cargo spaces, the longitudinal bulkheads are to be continued as far aft as is practicable and are to be suitably tapered at their ends. Where, due to the ship's form, such bulkheads are stepped, suitable scarfing is to be arranged.

1.4 Symbols and definitions

1.4.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, D, T as defined in Ch 1,6.1

k_L, k = higher tensile steel factor as defined in Ch 2,1.2

l = overall length of stiffening member, in metres, *see* Ch 3,3.3

l_e = effective length of stiffening member, in metres, *see* Ch 3,3.3

s = spacing of secondary stiffeners, in mm

t = thickness of plating, in mm

S = spacing, or mean spacing, of primary members, in metres

Z = section modulus of stiffening member, in cm^3, *see* Ch 3,3.2

ρ = relative density (specific gravity) of liquid carried in a tank and is to be taken not less than 1,025

I = inertia of stiffening member, in cm^4, *see* Ch 3,3.2.

1.4.2 For the purpose of this Chapter, the after perpendicular, A.P., is defined as the after limit of the Rule length *L*.

Section 2 Deck structure

2.1 General

2.1.1 Where the upper deck is longitudinally framed outside the line of openings in the midship region, this system of framing is to be carried as far aft as possible, *see also* Pt 4, Ch 9,1.3.

2.2 Deck plating

2.2.1 The thickness of strength/weather deck plating is to comply with the requirements of Table 6.2.1.

2.2.2 The thickness of lower deck plating is to comply with the requirements of Table 6.2.2.

2.2.3 The taper thickness of the strength deck stringer plate is to be increased by 20 per cent at the ends of a poop or bridge where the end bulkhead is situated forward of 0,25*L* from the A.P. No increase is required where the end bulkhead lies aft of 0,2*L* from the A.P. The increase at intermediate positions is to be determined by interpolation.

2.2.4 The deck plating thickness and supporting structure are to be suitably reinforced in way of deck machinery, and in way of cranes, masts or derrick posts.

2.2.5 Where long, wide hatchways are arranged at lower decks it may be necessary to increase the deck plating thickness to ensure effective support for side framing.

2.3 Deck stiffening

2.3.1 The scantlings of strength/weather deck longitudinals are to comply with the requirements of Table 6.2.3.

2.3.2 The scantlings of cargo and accommodation deck longitudinals are to comply with the requirements given in Table 1.4.4 in Pt 4, Ch 1.

2.3.3 End connections of longitudinals to bulkheads are to provide adequate fixity, lateral support and so far as practicable, direct continuity of longitudinal strength.

2.3.4 The scantlings of weather deck beams are to comply with the midship requirements for the particular ship type.

2.3.5 The scantlings of lower deck beams are to comply with the requirements of Table 1.4.5 in Pt 4, Ch 1.

2.3.6 End connections of beams are to be in accordance with the requirements of Ch 10,3.

Table 6.2.1 Strength/weather deck plating aft (excluding poop deck)

Symbols	Location	Thickness, in mm
L, s, S, k, ρ as defined in 1.4.1 $f = 1{,}1 - \dfrac{s}{2500S}$ but is to be taken not greater than 1,0 h_4 = tank head, in metres, as defined in Ch 3,5 s_b = standard frame spacing as follows: Aft of 0,15*L* from the A.P.: $s_b = \left(510 + \dfrac{L}{0{,}6}\right)$ mm or 850 mm, whichever is the lesser s_1 = s, but is to be taken not less than s_b	(1) Aft of 0,075*L* from the A.P.	$t = (5{,}5 + 0{,}02L)\sqrt{\dfrac{ks_1}{s_b}}$
	(2) Between 0,075*L* and 0,15*L* from the A.P.	The greater of the following: (a) $t = (5{,}5 + 0{,}02L)\sqrt{\dfrac{ks_1}{s_b}}$ (b) the taper thickness, *see* Notes 1, 2 and 3 (c) for oil tankers, the thickness is also to be in accordance with Pt 4, Ch 9,4.3.3
	(3) Forward of 0,15*L* from the A.P.	The taper thickness, *see* Notes 1, 2 and 3, or as 2(c) whichever is the greater
	(4) Inside poop extending forward of 0,15*L*	As for a lower deck, *see* Note 4
	(5) In way of the crown of a tank	$t = 0{,}004sf\sqrt{\dfrac{\rho k h_4}{1{,}025}} + 3{,}5$ or (1) to (4) as applicable, whichever is the greater but not less than 7,5 mm where $L \geq 90$ m, or 6,5 mm where $L < 90$ m

NOTES
1. The taper thickness is to be determined from Table 3.2.1 in Chapter 3.
2. For taper area requirements, *see* Table 3.2.1 in Chapter 3.
3. For thickness of upper deck plating in way of the cargo tanks of oil tankers or ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11.
4. The exposed weather deck taper thickness is to extend into a poop or bridge for at least one-third of the breadth of the ship from the superstructure end bulkhead.

Table 6.2.2 Lower deck plating aft

Symbols	Location	Thickness, in mm
L, s, S, k, ρ as defined in 1.4.1 b = breadth of increased plating, in mm $f = 1{,}1 - \frac{s}{2500S}$ but is to be taken not greater than 1,0 h_4 = tank head, in metres, as defined in Ch 3,5 K_2 = 2,5 mm at bottom of tank or 3,5 mm at crown of tank s_1 = s, but is to be taken not less than $\left(470 + \frac{L_1}{0{,}6}\right)$ mm A_f = girder face area, in cm² L_1 = L, but need not be taken greater than 190 mm	(1) Aft of 0,075L from the A.P.	$t = 0{,}01 s_1 \sqrt{k}$ but not less than 6,5 mm
	(2) Forward of 0,075L from the A.P., inside line of openings	$t = 0{,}01 s_1 \sqrt{k}$ but not less than 6,5 mm
	(3) Forward of 0,075L from the A.P., outside line of openings	As determined by a taper line from the midship thickness to the end thickness given by (1)
	(4) In way of the crown or bottom of a tank	$t = 0{,}004 s f \sqrt{\frac{\rho k h_4}{1{,}025}} + K_2$ or (1), (2) or (3) as applicable, whichever is the greater but not less than 7,5 mm where $L \geq 90$ m, or 6,5 mm where $L < 90$ m
NOTE Where the deck loading exceeds 43,2 kN/m², (4,4 tonne-f/m²), the thickness of plating will be specially considered. This is equivalent to a 'tween deck height of 6,1 m in association with the standard stowage rate of 1,39 m³/tonne.	(5) Plating forming upper flange of underdeck girders	Clear of cargo hatches $t = \sqrt{\frac{A_f}{1{,}8k}}$ In way of hatch side girders $t = 1{,}1\sqrt{\frac{A_f}{1{,}8k}}$ Minimum breadth $b = 760$ mm

Table 6.2.3 Strength/weather deck longitudinals aft

Location	Modulus, in cm³	Inertia, in cm⁴
(1) Aft of 0,075L from the A.P.	The greater of the following: (a) $Z = s\,k\,(400h_1 + 0{,}005\,(l_e\,L_1)^2) \times 10^{-4}$ (b) $Z = 0{,}0074 s\,k\,h_1\,l_e^2$	–
(2) Forward of 0,075L from the A.P., inside line of openings	As (1)	–
(3) Forward of 0,075L from the A.P., outside line of openings	As determined from Table 3.2.1 in Chapter 3, *see* Note 1 For oil tankers (*see* 1.1.4) and dry cargo ships the end modulus for taper at 0,075L from the A.P. is to be derived from Table 5.2.3 item (2)	–
(4) In way of the crown of a tank	$Z = \frac{0{,}0113\rho\,s\,k\,h_4\,l_e^2}{b}$ or as (1) to (3) as applicable, whichever is the greater	$I = \frac{2{,}3}{k} l_e Z$

Symbols

L, s, k_L*, k,* ρ as defined in 1.4.1
b = 1,4 for rolled or built sections
= 1,6 for flat bars
d_w = web depth of longitudinal, in mm
h_1 = weather head, in metres, as defined in Ch 3,5
h_4 = tank head, in metres, as defined in Ch 3,5
l_e = as defined in 1.4.1 but is to be taken not less than 1,5 m
L_1 = L but need not be taken greater than 190 m

NOTES
1. For taper area requirements, *see* Table 3.2.1 in Chapter 3.
2. Where weather decks are intended to carry deck cargo and the loading is in excess of 8,5 kN/m² (0,865 tonne-f/m²) the scantlings of longitudinals are also to comply with the requirements for location (1) in Table 1.4.4 in Pt 4, Ch 1 using the equivalent design head, for specified cargo loadings, for weather decks given in Table 3.5.1 in Chapter 3.
3. For the scantlings of deck longitudinals aft in way of the cargo tanks of oil tankers (*see* 1.1.4) or ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11, as applicable.
4. The thickness of flat bar longitudinals, situated outside the line of openings is to be not less than the following:
   (a) $t = \frac{d_w}{18\sqrt{k_L}}$ mm
   where longitudinal continuous through bulkhead
   (b) $t = \frac{d_w}{15\sqrt{k_L}}$ mm
   where longitudinal cut at bulkhead
5. The web depth of longitudinal, d_w, to be not less than 60 mm.

2.4 Deck supporting structure

2.4.1 The arrangements and scantlings of supporting structure are generally to be in accordance with the requirements given in Pt 4, Ch 1,4 except as required by 2.4.2 to 2.4.4.

2.4.2 At upper and lower decks above the after peak, deep beams are generally to be fitted in way of web frames. Deck girders are generally to be spaced not more than 3,0 m apart.

2.4.3 Primary structure in the topside tanks of bulk carriers is to comply with the requirements of Pt 4, Ch 7,7.

2.4.4 Primary structure in the cargo tanks of oil tankers, or ore carriers, is to be determined from Pt 4, Ch 9, Ch 10 or Ch 11, as applicable.

2.5 Deck openings

2.5.1 In dry cargo ships, the requirements for deck openings given in Pt 4, Ch 1,4 are generally applicable throughout the aft region except that aft of 0,25*L* from the A.P.:

(a) The radii or dimensions of the corners of main cargo hatchway openings of the strength deck are to be in accordance with the requirements of Pt 4, Ch 1,4.5. The thickness of the insert plates, where required, is not to be less than 20 per cent greater than the adjacent deck thickness outside the line of openings, with a minimum increase of 3 mm.

(b) Insert plates will be required at lower decks in way of any rapid change in hull form to compensate for loss of deck cross-sectional area. Otherwise, insert plates will not normally be required.

(c) Compensation and edge reinforcement for openings outside the line of main hatchways will be considered, bearing in mind their position, the deck arrangements and the type of ship concerned.

2.5.2 For deck openings in way of cargo tanks in oil tankers and ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11, as applicable. For main cargo hatchway openings on bulk carriers and container ships, *see also* Pt 4, Ch 7 and Ch 8, as applicable.

■ *Section 3* Shell envelope plating

3.1 General

3.1.1 Where the shell is longitudinally framed in the midship region, this system of framing is to be carried as far aft as practicable.

3.2 Keel

3.2.1 The scantlings of bar keels at the aft end are to be the same as in the midship region as required by Pt 4, Ch 1,5.

3.2.2 The thickness and width of plate keels in the aft region are to be the same as required in the midship region for the particular type of ship concerned, *see* Part 4.

3.3 Bottom shell and bilge

3.3.1 The thickness of bottom shell and bilge plating in the aft region is to comply with the requirements of Table 6.3.1.

3.3.2 Where the bottom is transversely framed and there are large flat areas of shell plating, the buckling stability of the plating will be specially considered, and increased plate thickness or additional stiffening may be required, *see also* 5.2.3.

3.3.3 Where longitudinals are omitted in way of radiused bilge plating amidships, the plating thickness aft will be considered in relation to the support derived from the hull form and internal stiffening arrangements.

3.4 Side shell and sheerstrake

3.4.1 The thickness of side shell and sheerstrake plating in the aft region is to be not less than the values given in Table 6.3.1, but may be required to be increased locally on account of high shear forces, in accordance with Ch 4,6.5.

3.4.2 Increased shell plate thickness may be required where the panting stringers required by 4.4.1 are omitted. The extent and amount of the increase will be specially considered.

3.4.3 The thickness of shell plating is to be increased locally in way of the sternframe, propeller brackets or rudder horn. The increased plate thickness is to be not less than 50 per cent greater than the basic shell end thickness.

3.4.4 The sheerstrake thickness is to be increased by 20 per cent at the ends of a bridge superstructure extending out to the ship's side, irrespective of position. Similar strengthening is to be fitted in way of the end of a poop if this occurs at a position forward of 0,25*L* from the A.P. No increase is required if the poop end bulkhead lies aft of 0,2*L* from the A.P. The increase at intermediate positions of end bulkhead is to be obtained by interpolation.

3.5 Shell openings

3.5.1 In general, compensation will not be required for holes in the sheerstrake which are clear of the gunwale, or for any deck openings situated outside the line of main hatchways and whose depth does not exceed 20 per cent of the depth of the sheerstrake or 380 mm, whichever is the lesser. Openings are not to be cut in a rounded gunwale. Cargo door openings are to have well rounded corners, and the proposed compensation for the door openings will be individually considered.

Table 6.3.1 Shell plating aft

Location	Thickness, in mm	NOTES
(1) Bottom shell and bilge, *see* Notes 4 and 5: (a) Aft of 0,075L from the A.P. (b) Between 0,075L and 0,15L from the A.P., *see* Note 6 (c) Forward of 0,15L from the A.P., *see* Note 6	$t = (6{,}5 + 0{,}033L)\sqrt{\dfrac{k\,s_1}{s_b}}$ (*see* Note 1) As (1) (a) or the taper thickness, whichever is the greater, *see* Note 2 The taper thickness, *see* Note 2	1. For ships where $L \leq 70$ m this thickness may be reduced by 1 mm, but it is to be not less than 6 mm. 2. The taper thickness is to be determined from Table 3.2.1 in Chapter 3. 3. For thickness of shell plating in way of the cargo tanks of oil tankers or ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11, as applicable. 4. In offshore supply ships the thickness of side shell is to be not less than 9 mm. 5. For trawlers and fishing vessels *see* Pt 4, Ch 6,5. 6. For oil tankers the thickness is also to be in accordance with Pt 4, Ch 9,4.3.3.
(2) Side shell, *see* Notes 4 and 5: (a) Aft of 0,075L from the A.P. (b) Between 0,075L and 0,15L from the A.P., *see also* 3.4.2 (c) Forward of 0,15L from the A.P.	$t = (6{,}5 + 0{,}033L)\sqrt{\dfrac{k\,s_1}{s_b}}$ (*see* Note 1) As (2) (a) or the taper thickness, whichever is the greater, *see* Note 2 The taper thickness, *see* Note 2	
(3) Sheerstrake, *see* Notes 4 and 5 (a) Aft of 0,075L from the A.P.: where $\dfrac{T}{D} > 0{,}7$ where $\dfrac{T}{D} \leq 0{,}7$ (b) Between 0,075L and 0,15L from the A.P., *see* Note 6 (c) Forward of 0,15L from the A.P., *see* Note 6	 As (2) (a) for side shell As (4) for a poop As (3) (a) or as determined from Table 3.2.1 in Chapter 3 The taper thickness, *see* Note 2	
(4) Poop, *see* Notes 4 and 5	$t = (6{,}5 + 0{,}017L)\sqrt{\dfrac{k\,s_1}{s_b}}$	

Symbols

L, B, D, T, s, k as defined in 1.4.1
s_1 = s but to be taken as not less than s_b
s_b = standard frame spacing, in mm, as follows:

Region	Bottom shell s_b	Side shell s_b
Aft of 0,05L from the A.P.	$\left(470 + \dfrac{L}{0{,}6}\right)$ or 600*	$\left(470 + \dfrac{L}{0{,}6}\right)$ or 600* below the deck next above the load waterline or $\left(470 + \dfrac{L}{0{,}6}\right)$ or 700* above the deck next above the load waterline
Between 0,05L and 0,15L from the A.P.	$\left(510 + \dfrac{L}{0{,}6}\right)$ or 850*	$\left(510 + \dfrac{L}{0{,}6}\right)$ or 850*

*whichever is the lesser

3.5.2 Sea inlet and other openings are to have well rounded corners and so far as possible, should be kept clear of the bilge radius. The thickness of sea inlet box plating is generally to be the same as the adjacent shell. It is not, however, to be less than 12,5 mm, and need not exceed 25 mm.

■ *Section 4*
Shell envelope framing

4.1 General

4.1.1 Requirements are given in this Section for both longitudinal and transverse framing systems. Where longitudinal framing is adopted in the midship region, it is to be carried as far aft as practicable.

4.1.2 End connections of longitudinals to bulkheads are to provide adequate fixity, lateral support and, so far as practicable, direct continuity of longitudinal strength, *see also* Ch 10,3. Where L exceeds 215 m, the bottom longitudinals are to be continuous in way of both watertight and non-watertight floors, but alternative arrangements will be considered. Higher tensile steel longitudinals within 10 per cent of the ship's depth at the bottom and deck are to be continuous irrespective of the ship length.

4.1.3 Stiffeners and brackets on side transverses, where fitted on one side and connected to higher tensile steel longitudinals between the base line and 0,8D above the base line, are to have their heels well radiused to reduce stress concentrations. Where a symmetrical arrangement is fitted, i.e., bracket or stiffening on both sides, and it is connected to higher tensile steel longitudinals, the toes of the stiffeners or brackets are to be well radiused. Alternative arrangements will be considered if supported by appropriate direct calculations.

4.1.4 Where higher tensile steel side longitudinals pass through transverse bulkheads in the cargo area, well radiused brackets of the same material are to be fitted on both the fore and aft side of the connection between the upper turn of bilge and 0,8*D* above the base line. Particular attention is to be given to ensuring the alignment of these brackets. Alternative arrangements will be considered if supported by appropriate direct calculations.

4.1.5 For ships intended to load or unload while aground, *see* Ch 9,9.

4.2 Shell longitudinals

4.2.1 The scantlings of bottom and side shell longitudinals in the aft region are to comply with the requirements given in Table 6.4.1.

4.3 Shell framing

4.3.1 The scantlings of side frames in the aft region are to comply with the requirements given in Table 6.4.2.

Table 6.4.1 Shell framing (longitudinal) aft

Location	Modulus, in cm^3
(1) Side longitudinals in poop	$Z = 0{,}0065\, s\, k\, l_e^2\ (0{,}6 + 0{,}167 D_2)$
(2) Side longitudinals in way of dry spaces including double skin construction:	
(a) Aft of the after peak bulkhead	$Z = 0{,}0085\, s\, k\, h_{T1}\, l_e^2\, F_s$ but not to be less than as required by (1)
(b) Between the after peak bulkhead and 0,2*L* from the A.P.	$Z = 0{,}007\, s\, k\, h_{T1}\, l_e^2\, F_s$ or as required in the midship region for the particular type of ship concerned, whichever is the greater
(c) Forward of 0,2*L* from the A.P.	As required in the midship region for the particular type of ship concerned
(3) Side longitudinals in way of double skin tanks or deep tanks	The greater of the following: (a) *Z* as from (2) (b) As required by Pt 4, Ch 1,9 for deep tanks
(4) Bottom and bilge longitudinals	As required in the midship region for the particular type of ship concerned

Symbols

L, *D*, *T*, *s*, *k*, as defined in 1.4.1

l_e = as defined in 1.4.1, but is to be taken not less than 1,5 m

D_2 = D_1 but need not be taken greater than 20 m

L_1 = *L* but need not be taken greater than 190 m

F_s is a fatigue factor to be taken as follows:

(a) For built sections and rolled angle bars

$$F_s = \frac{1{,}1}{k}\left[1 - \frac{2b_{f1}}{b_f}(1-k)\right] \text{ at } 0{,}6D_1 \text{ above the base line}$$

= 1,0 at D_1 and above, and F_{sb} at the base line intermediate values by linear interpolation

F_{sb} is a fatigue factor for bottom longitudinals

= 0,5 (1 + F_s at 0,6D_1)

(b) For flat bars and bulb plates $\dfrac{b_{f1}}{b_f}$ may be taken as 0,5

where

b_{f1} = the minimum distance, in mm, from the edge of the face plate of the side longitudinal under consideration to the centre of the web plate, *see* Fig. 9.5.1 in Pt 4,Ch 9

b_f = the width of the face plate, in mm, of the side longitudinal under consideration, *see* Fig. 9.5.1 in Pt 4, Ch 9

D_1 = *D* but need not exceed $T + H_b$, in metres, where H_b is the minimum bow height, in metres, obtained from Ch 1,6.1.11

T_1 = *T* but not to be taken less than 0,65D_1

$$h_{T1} = f_w C_w \left(1 - \frac{h_6}{D_1 - T_1}\right) F_\lambda$$, in metres, for longitudinals above the waterline at draught T_1 where $f_w\left(1 - \dfrac{h_6}{D_1 - T_1}\right)$ is not to be taken less than 0,7

$$= \left[h_6 + f_w C_w\left(1 - \frac{h_6}{2T_1}\right)\right] F_\lambda$$, in metres, for longitudinals below the waterline at draught T_1

where

f_w = 1,0 at 0,2*L* from A.P. and 1,32 at and aft of aft peak bulkhead. Intermediate positions by interpolation.

h_6 = vertical distance, in metres, from the waterline at draught T_1, to the longitudinal under consideration

C_w = a wave head, in metres = $7{,}71 \times 10^{-2} L e^{-0{,}0044L}$

where

e = base of natural logarithms 2,7183

F_λ = 1,0 for $L \leq 200$ m

= [1,0 + 0,0023 (L – 200)] for $L > 200$ m

NOTES

1. Where struts are fitted midway between transverses in double skin construction, the modulus of the side longitudinals may be reduced by 50*k* per cent from that obtained for locations (2) and (3) as applicable.
2. For modulus and area of side longitudinals in way of a machinery space, *see* Ch 7,3.1.

Table 6.4.2 Shell framing (transverse) aft

Location	Modulus, in cm^3	Inertia, in cm^4
(1) Frames in after peak spaces and lower 'tween decks over	$Z = 1{,}85 s\, k\, T\, D_2\, S_1 \times 10^{-3}$	$I = \dfrac{3{,}2}{k} S_1 Z$
(2) Frames in upper 'tween decks and poops aft of the after peak bulkhead, *see* Notes 1, 2 and 6	The greater of the following: (a) $Z = C\, s\, k\, h_{T1}\, H^2 \times 10^{-3}$ (b) $Z = 9{,}1 s\, k\, D_1 \times 10^{-3}$	$I = \dfrac{3{,}2}{k} HZ$
(3) Main and 'tween deck frames (including poop) between the after peak bulkhead and 0,2*L* from the A.P., *see* Notes 1, 2 and 3	The greater of the following: (a) $Z = C\, s\, k\, h_{T1}\, H^2 \times 10^{-3}$ (b) $Z = 9{,}1 s\, k\, D_1 \times 10^{-3}$	$I = \dfrac{3{,}2}{k} HZ$
(4) Main and 'tween deck frames elsewhere, *see* Notes 1, 2 and 3	As required in the midship region for the particular type of ship concerned	
(5) Panting stringers, *see* Note 4	Web depth, d_w, same depth as frames Web thickness, $t = t_w$ as in Ch 10,4.4 Face area, $A = k\, S_2 (H + 1)$ cm^2	

Symbols

L, D, T, s, k as defined in 1.4.1
D_1 = D but need not exceed $T + H_b$, in metres, where H_b is the minimum bow height, in metres, obtained from Ch 1,6.1.11
D_2 = D_1 but is to be taken not greater than 16 m nor less than 6 m
H = H_{MF} or H_{TF} as applicable, *see* Note 3
H_{MF} = vertical framing depth, in metres, of main frames as shown in Fig. 6.4.1 but is not to be taken less than 3,5 m, *see* Note 5
H_{TF} = vertical framing depth, in metres, of 'tween deck frames as shown in Fig. 6.4.1, but is not to be taken less than 2,5 m
S_1 = vertical spacing of peak stringers or height of lower 'tween deck above the peak, in metres, as applicable
S_2 = vertical spacing of panting stringers, in metres
C = end connection factor
= 3,4 where two Rule standard brackets fitted
= 3,4 (1,8 – 0,8(l_a/l)) where one Rule standard bracket and one reduced bracket fitted
= 3,4 (2,15 – 1,15 (l_{amean}/l)) where two reduced brackets fitted
= 6,1 where one Rule standard bracket fitted
= 6,1 (1,2 – 0,2 (l_a/l)) where one reduced bracket fitted
= 7,3 where no brackets fitted
The requirements for frames where brackets larger than Rule standard are fitted will be specially considered
l = length, in mm, as derived from Ch 10,3.4.1

l_a = equivalent arm length, in mm, as derived from Ch 10,3.4.1
l_{amean} = mean equivalent arm length, in mm, for both brackets
T_1 = T but not to be taken less than 0,65D_1
h_{T1} = head, in metres, at mid length of H
= $f_w C_w \left(1 - \dfrac{h_6}{D_1 - T_1}\right) F_\lambda$, in metres for frames where the mid-length of frame is above the waterline, at draught T_1
$f_w \left(1 - \dfrac{h_6}{D_1 - T_1}\right)$ is not to be taken less than 0,7
= $\left[h_6 + f_w C_w \left(1 - \dfrac{h_6}{2T_1}\right)\right] F_\lambda$, in metres for frames where the mid-length of frame is below the waterline at draught T_1

where
f_w = 1,0 at 0,2L from A.P. and 1,32 at and aft of aft peak bulkhead Intermediate positions by interpolation.
h_6 = vertical distance in metres from the waterline at draught T_1 to the mid-length of H
F_λ = 1,0 for $L \le 200$ m
= [1,0 + 0,0023 (L – 200)] for $L > 200$ m
C_w = a wave head in metres
= $7{,}71 \times 10^{-2}\, L e^{-0{,}0044L}$
where e = base of natural logarithms 2,7183

NOTES
1. In fishing vessels the modulus of main and 'tween deck frames need not be greater than 80 % of that given in (2).
2. In offshore supply ships the moduli of main and 'tween deck frames are to be 25 % greater than those given in (2), (3) and (4).
3. Where frames are inclined at more than 15° to the vertical, H_{MF} or H_{TF} is to be measured along a chord between span points of the frame.
4. Panting stringers are not required in tugs less than 46 m in length, *see* Pt 4, Ch 3,4.
5. Where the frames are supported by fully effective horizontal stringers, these may be considered as decks for the purpose of determining H_{MF}.
6. Except for main frames the modulus for these members need not exceed that derived from (1) using H_{TF} in place of S_1.

4.3.2 The scantlings of main frames are normally to be based on Rule standard brackets at top and bottom, whilst the scantlings of 'tween deck frames are normally to be based on a Rule standard bracket at the top only.

4.3.3 End connections of transverse main and 'tween deck frames are to be in accordance with Ch 10,3. For bulk carriers (*see* 1.1.4), the end connections of main frames in cargo holds are to be in accordance with Pt 4, Ch 7,6.2.5 to 6.2.12.

4.4 Panting stringers in way of transverse framing

4.4.1 In deep 'tween decks above the after peak space, panting stringers having scantlings as given in Table 6.4.2 or increased shell plate thickness may be required, *see also* 3.4.2.

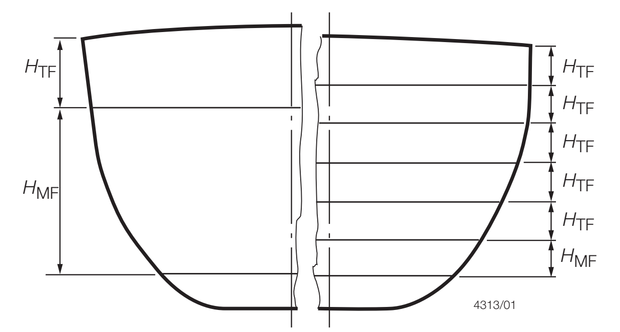


Fig. 6.4.1 Framing depths

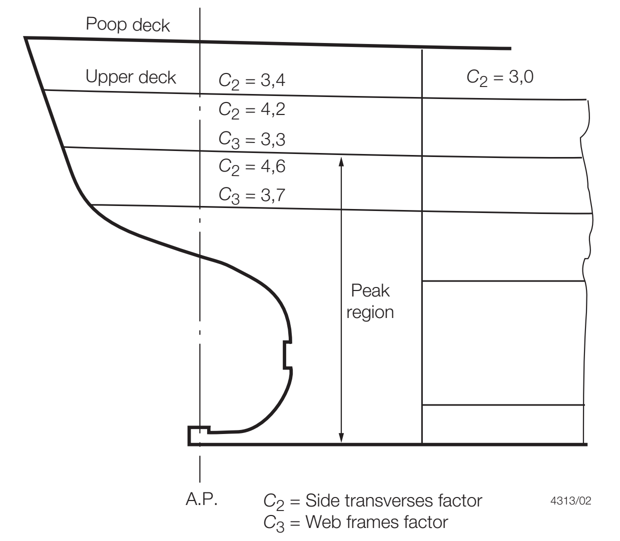


Fig. 6.4.2 Framing factors

4.5 Primary structure at sides

4.5.1 Where the 'tween decks above an after peak space are transversely framed, web frames are to be fitted. Their spacing is generally not to exceed the values given in Table 6.4.3, and their scantlings are to be determined from Table 6.4.4.

4.5.2 Where longitudinal framing is arranged, the spacing of transverses is generally not to exceed the values given in Table 6.4.3, and their scantlings are to be determined from Table 6.4.4.

4.5.3 Where the shape of the after sections is such that there are large sloped flat areas, particularly in the vicinity of the propellers, additional primary supports for the secondary stiffening may be required. Their extent and scantlings will be specially considered.

4.5.4 The web thickness, stiffening arrangements and connections of primary supporting members are to be in accordance with the requirements of Ch 10,4.

Table 6.4.3 Spacing of side transverses and web frames aft

Location	Maximum spacing	
	Web frames in association with transverse framing system	Side transverses in association with longitudinal framing system
(1) Aft of the after peak bulkhead	4 frame spaces	2,5 m where $L \leq 100$ m 3,5 m where $L \geq 300$ m Intermediate values by interpolation
(2) Elsewhere in way of dry cargo spaces or deep tanks, *see* Note	–	3,8 m where $L \leq 100$ m $(0{,}006L + 3{,}2)$ m where $L > 100$ m
(3) In way of cargo tanks of oil tankers, chemical tankers or ore or oil carriers	–	3,6 m where $L \leq 180$ m $0{,}02L$ where $L > 180$ m
NOTE For the maximum spacing of transverses in dredgers, *see* Pt 4, Ch 12,5.		

Table 6.4.4 Primary structure aft

Item and location	Modulus, in cm^3	Inertia, in cm^4
Longitudinal framing system		
(1) Side transverses in dry spaces aft of the after peak bulkhead, *see* Note 4: (a) Lower space (b) 'Tween deck	 $Z = 10\, k\, S\, h_{T1}\, l_e^2$ $Z = C_2\, k\, S\, T\, H_{TF} \sqrt{D}$	—
(2) Side transverses in tanks aft of the after peak bulkhead, *see* Note 4: (a) Lower space (b) 'Tween decks	 $Z = 11{,}7\rho\, k\, S\, h_4\, l_e^2$ $Z = 14{,}1\rho\, k\, S\, h_4\, l_e^2$ or as (1) above, whichever is the greater	$I = \dfrac{2{,}5}{k}\, l_e\, Z$
(3) Side transverses in dry spaces and deep tanks forward of the after peak bulkhead	As in Pt 4, Ch 1,6, *see* Notes 1 and 2	
Transverse framing system		
(4) Side stringers supported by webs in after peak dry space, *see* Note 3	$Z = 7{,}75\, k\, S\, h_{T1}\, l_e^2$	—
(5) Side stringers supported by webs in after peak tank, *see* Note 3	$Z = 11{,}7\, \rho\, k\, S\, h_4\, l_e^2$ or as (4) above, whichever is the greater	$I = \dfrac{2{,}5}{k}\, l_e\, Z$
(6) Web frames supporting side stringers in after peak, *see* Note 3	Z to be determined from the calculations based on following assumptions: (a) Fixed ends (b) Point loadings from stringers (c) Head h_4 or h_{T1} as applicable (d) Bending stress $\dfrac{93{,}2}{k}$ N/mm² $\left(\dfrac{9{,}5}{k}\ \text{kgf/mm}^2\right)$ (e) Shear stress $\dfrac{83{,}4}{k}$ N/mm² $\left(\dfrac{8{,}5}{k}\ \text{kgf/mm}^2\right)$	In deep tanks $I = \dfrac{2{,}5}{k}\, l_e\, Z$
(7) Web frames in 'tween decks aft of the after peak bulkhead not supporting side stringers	$Z = C_3\, k\, S\, T\, H_{TF} \sqrt{D}$	—
(8) Side stringers and web frames in dry spaces and deep tanks forward of the after peak bulkhead	As in Pt 4, Ch 1,6, *see* Notes 1 and 2	

Symbols

D, T, S, l_e, k, ρ as defined in 1.4.1

C_2, C_3 = factors obtained from Fig. 6.4.2

h_4 = tank head, in metres, as defined in Ch 3,5

h_{T1} = head, in metres, at mid-length of span

$$= f_w C_w \left(1 - \frac{h_6}{D_1 - T_1}\right) F_\lambda$$, in metres where the mid-length of span is above the waterline at draught T_1

where $f_w \left(1 - \dfrac{h_6}{D_1 - T_1}\right)$ is not to be taken less than 0,7

$$= \left[h_6 + f_w C_w \left(1 - \frac{h_6}{2T_1}\right)\right] F_\lambda$$, in metres where the mid-length of span is below the waterline at draught T_1

where

f_w = 1,0 at 0,2L from A.P. and 1,32 at and aft of aft peak bulkhead. Intermediate positions by interpolation

h_6 = vertical distance, in metres, from the waterline at draught T_1 to the mid-length of span

F_λ = 1,0 for $L \le 200$ m
= $[1{,}0 + 0{,}0023\,(L - 200)]$ for $L > 200$ m

C_w = a wave head, in metres
= $7{,}71 \times 10^{-2}\, L\, e^{-0{,}0044L}$
where e = base of natural logarithms 2,7183

D_1 = D but need not be taken greater than $T + H_b$, in metres, where H_b is the minimum bow height, in metres, obtained from Ch 1,6.1.11

T_1 = T but not to be taken less than $0{,}65D_1$

H_{TF} = vertical height of 'tween decks, in metres, as shown in Fig. 6.4.1

NOTES

1. In way of the cargo tanks or oil fuel tanks of oil tankers or ore carriers, the scantlings of primary structure are to comply with the requirements of Pt 4, Ch 9, Ch 10 or Ch 11, as appropriate.
2. For bulk carriers, *see* Pt 4, Ch 7,6.
3. For stringers and webs in after peaks, *see also* 6.2.
4. The web depth of side transverses aft of the after peak bulkhead is to be not less than 2,5 times the depth of the longitudinals supported. The web depth of stringers is to be not less than 2,2 times the depth of frames supported.

■ *Section 5*

Single and double bottom structure

5.1 General

5.1.1 For dry cargo ships exceeding 120 m in length, and for all ships which are strengthened for heavy cargoes, longitudinal framing is, in general, to be adopted, *see also* Pt 4, Ch 9,1.3.

5.1.2 For ships having the notation 'strengthened for heavy cargoes', the requirements of Pt 4, Ch 7,8 are also to be complied with, as applicable.

5.1.3 For ships intended to load or unload while aground, *see* Ch 9,9.

5.1.4 Provision is to be made for the free passage of water and/or air from all parts of single or double bottoms to the bilge or tank suctions, account being taken of the pumping rates required.

5.1.5 For passenger ships, *see* Pt 4, Ch 2,6.

5.2 Single bottoms – Transverse framing

5.2.1 In after peak spaces, floors are to be arranged at every frame. For details and scantlings, *see* 6.1.

5.2.2 In way of dry cargo spaces aft, the arrangement and scantlings of transversely framed single bottoms are to be generally as required in the midship region, as given in Pt 4, Ch 1,7, except that the thickness of the centreline girder may be tapered from the midship thickness at 0,3L from the A.P. to $t = (\sqrt{Lk} + 0{,}5)$ mm or 6 mm, whichever is the greater, at 0,075L from the A.P. In ships having considerable rise of floor towards the aft end, the depth of the floors may be required to be increased.

5.2.3 Where the shape of the after sections is such that there are large flat areas of shell plating, additional stiffening and/or increased shell plate thickness may be required, *see* 3.3. The extent of this stiffening will be specially considered.

5.3 Single bottoms – Longitudinal framing

5.3.1 The scantlings and arrangement of longitudinally framed single bottoms in way of dry cargo spaces will be specially considered.

5.4 Double bottoms

5.4.1 The minimum depth of centre girder aft is generally to be the same as that required in the midship region by Part 4 for the particular type of ship concerned, but in ships with considerable rise of floor a greater depth may be required at the aft end to provide adequate access throughout the double bottom tank.

5.4.2 Where the height of the double bottom varies, this variation is generally to be made gradual by sloping the inner bottom over an adequate longitudinal extent. Knuckles in the plating are to be arranged close to plate floors. Otherwise, suitable scarfing arrangements are to be made.

5.4.3 For dry cargo ships, the arrangement and scantlings of girders, floors, inner bottom plating and inner bottom stiffening in the aft end region are to be determined from Pt 4, Ch 1,8.

5.4.4 For double bottom construction in way of the cargo tanks of oil tankers or ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11, as appropriate.

■ *Section 6*

After peak structure

6.1 Bottom structure

6.1.1 Floors are to be arranged at every frame space and are to be carried to a suitable height, and at least to above the sterntube, where fitted. They are to have a thickness as determined from Table 6.6.1 and are to be adequately stiffened. In way of a propeller post, rudder post or rudder horn, the floors are generally to be carried to the top of the space and are to be increased in thickness. The extent and amount of the increase will be specially considered, account being taken of the arrangements proposed.

6.2 Side structure – Transverse framing

6.2.1 Above the floors, transverse side framing is to be supported by one of the following arrangements:

(a) Side stringers spaced not more than 2,5 m apart and supported by web frames. The upper ends of the web frames are to be supported under the tank top by suitable deep beams to form a ring structure.

(b) Perforated flats spaced not more than 2,5 m apart. The area of perforations in each flat is to be not less than 10 per cent of the total area of the flat.

(c) A combination of the above arrangements.

6.2.2 The scantlings of side stringers supported by web frames, and also of the web frames are to be determined from 4.5.

6.2.3 The scantlings of perforated flats are to be determined from Table 6.6.1. Stiffeners are to be fitted at every frame.

6.3 Side structure – Longitudinal framing

6.3.1 The spacing and scantlings of side transverses supporting longitudinal framing are to be as required by 4.5.

6.3.2 Suitable transverses or deep beams are to be arranged at the top of the tank to provide end rigidity to the side transverses.

Table 6.6.1 After peak structure

Item	Parameter	Requirement
(1) Floors	Thickness	$t = (7{,}5 + 0{,}025L_2)\sqrt{\dfrac{s_2}{800}}$ mm
(2) Perforated flats and wash bulkheads	Thickness, *see* Note	$t = (7{,}5 + 0{,}015L)\sqrt{\dfrac{s_2}{800}}$ mm
	Stiffener modulus	$z = \dfrac{0{,}0057\, s\, k\, h_6\, l_e^2}{b}$ cm^3

Symbols

L, s, l_e, k as defined in 1.4.1
b = 1,4 for rolled or built sections
= 1,6 for flat bars
h_6 = vertical distance from middle of effective length of stiffener to top of tank, in metres
s_2 = spacing of stiffeners, in mm, but is to be taken not less than 800 mm
L_2 = L but need not be taken greater than 215 m

NOTE
The thickness for perforated flats and wash bulkheads may be reduced by 1 mm for ships of 40 m and under with no reduction for ships of 90 m and above. Reduction for intermediate lengths to be by linear interpolation.

6.4 Wash bulkheads

6.4.1 A centreline wash bulkhead is to be arranged in the upper part of the after peak space and counter or cruiser stern. Where the overhang is very large, or the breadth of the space at the widest point exceeds 20 m, additional wash bulkheads may be required port and starboard.

6.4.2 Wash bulkheads are to have an area of perforations not less than 5 per cent nor more than 10 per cent of the area of the bulkhead. The plating is to be suitably stiffened in way of openings, and the arrangement of openings is to be such as to maintain adequate shear rigidity.

6.4.3 The scantlings of wash bulkheads are to be determined from Table 6.6.1, and stiffeners are to be fitted at every frame and bracketed top and bottom. The plating thickness may be required to be increased locally in way of the upper part of the sternframe or the rudder horn.

6.5 After peak bulkhead

6.5.1 The position and height of the after peak bulkhead are to be in accordance with the requirements of Ch 3,4.

6.5.2 The scantlings of the after peak bulkhead and of the flat forming the top of the peak space are to be determined from Pt 4, Ch 1,9, but the plating thickness is to be increased locally in way of the sterntube gland.

■ *Section 7* Sternframes and appendages

7.1 General

7.1.1 Sternframes, rudder horns, boss end brackets and shaft brackets may be constructed of cast or forged steel, or may be fabricated from plate.

7.1.2 In castings, sudden changes of section or possible constrictions to the flow of metal during casting are to be avoided. All fillets are to have adequate radii, which should, in general, be not less than 50 to 75 mm, depending on the size of the casting.

7.1.3 Castings and forgings are to comply with the requirements of Chapters 4 and 5 of the Rules for Materials respectively.

7.1.4 Cast sternframes, rudder horns, shaft brackets and solepieces are to be manufactured from special grade material. Cast bossings can be manufactured from normal grade material, *see* Ch 4,2 of the Rules for Materials.

7.1.5 Sternframes, rudder horns, shaft brackets, etc., are to be effectively integrated into the ship's structure, and their design is to be such as to facilitate this.

7.2 Sternframes

7.2.1 The scantlings of sternframes are to be determined from Table 6.7.1. In the case of very large ships, the scantlings and arrangements may be required to be verified by direct calculations.

7.2.2 Fabricated and cast propeller posts and rudder posts of twin screw ships are to be strengthened at intervals by webs. In way of the upper part of the sternframe arch, these webs are to line up with the floors.

7.2.3 Rudder posts and propeller posts are to be connected to floors of increased thickness, *see* 6.1.

7.2.4 The sole piece is to be dimensioned such that the stresses do not exceed the permissible stresses given in Table 6.7.2.

Table 6.7.1 **Sternframes** (*see continuation*)

Item	Parameter	Requirement		
(1) Propeller posts *see* Notes 1 and 2		Cast steel, *see* Fig. 6.7.1(a)	Forged steel, *see* Fig. 6.7.1(b)	Fabricated mild steel, *see* Fig. 6.7.1(c)
	l	$165\sqrt{T}$ mm	—	$200\sqrt{T}$ mm
	r	$20\sqrt{T}$ mm	—	$18\sqrt{T}$ mm
	t_w	$8\sqrt{T}$ mm (need not exceed 38)	— (need not exceed 30)	$6\sqrt{T}$ mm
	t_1	$12\sqrt{T}$ mm (min. 19)	—	$12\sqrt{T}$ mm
	t_2	$16\sqrt{T}$ mm (min. 25)	—	—
	w	$115\sqrt{T}$ mm	$40\sqrt{T}$ mm	$140\sqrt{T}$ mm
	A	—	$\left\{\begin{array}{l}(10 + 0{,}5L)T \text{ cm}^2 \text{ where } L \leq 60 \text{ m} \\ 40T \text{ cm}^2 \text{ where } L > 60 \text{ m}\end{array}\right\}$	—
(2) Propeller boss, *see* Note 3 and Fig. 6.7.2	t_b	$(0{,}1\delta_{TS} + 56)$ mm, but need not exceed $0{,}3\,\delta_{TS}$		
(3) Rudder posts or axles		Single screw with integral solepiece, *see* Fig. 6.7.5(a)	Single screw with bolted rudder axle, *see* Fig. 6.7.3	Twin screw, integral with hull, *see* Fig. 6.7.4
	n	—	6 (*see* Note 4)	—
	r	—	—	$20\sqrt{T}$ mm
	r_b	—	δ_A mm	—
	t_F	—	δ_b mm	—
	t_1	—	—	$12\sqrt{T}$ mm
	t_2	—	—	$15\sqrt{T}$ mm
	t_3	—	—	$18\sqrt{T}$ mm
	w	—	—	$120\sqrt{T}$ mm
	z_{PB1}, z_{PB2}	—	$1{,}2\delta_{PL2}$ mm	—
	Z_T	$0{,}147\left(\dfrac{k_R}{0{,}248}\right)^3 A_R\, c_2\, b\, (V_o + 3)^2$ cm^3	—	—
	δ_A	—	$(25T + 76)$ mm but need not exceed $0{,}9\delta_{PL2}$ mm	—
	δ_b	—	$6{,}25T + 19$ mm or $0{,}225\delta_{PL2}$ mm whichever is the greater	—
	δ_{PL1}, δ_{PL2} bearing pressure and pintle clearance	—	As for rudder pintles (*see* Table 13.2.11 in Chapter 13)	—
(4) Solepieces, *see* Notes 5, 6 and 7	Z_T Z_V A_S	$0{,}0125M_b\,K_o$ $0{,}5Z_T$ $0{,}02B_1\,K_o$		

Table 6.7.1 Sternframes (*conclusion*)

Symbols	
L, *T* as defined in 1.4.1 *a*, *b*, *c* = distances, in metres, as shown in Fig. 6.7.5 B_1 = *see* Table 6.7.2 c_2 = rudder profile coefficient, as given by Table 13.2.1 in Chapter 13 *n* = number of bolts in palm coupling r_b = mean distance of bolt centres from centre of palm, in mm t_b = finished thickness of boss, in mm M_B = *see* Table 6.7.2 *A* = cross-sectional area of forged steel propeller post, in cm^2 A_R = rudder area, in m^2	k_R = rudder coefficient, as given by Table 6.7.4 *V* = maximum service speed, in knots, with the ship in the loaded condition Z_T = section modulus against transverse bending, in cm^3 Z_V = section modulus against vertical bending, in cm^3 δ_b = diameter of coupling bolts, in mm δ_{TS} = diameter of tail shaft, in mm K_o = as defined in 7.3.3 A_s = sectional area, in mm^2
NOTES 1. Where scantlings and proportions of the propeller post differ from those shown in Item (1), the section modulus about the longitudinal axis of the proposed section normal to the post is to be equivalent to that with Rule scantlings. *t* is to be not less than $8\sqrt{T}$ (minimum of 19 mm for cast steel sternframes) or as required by Ch 6,3.4.2, whichever is the greater. 2. On sternframes without solepieces, the modulus of the post below the propeller boss, about the longitudinal axis may be gradually reduced to not less than 85% of that required by Note 1, subject to the same thickness limitations. 3. In fabricated sternframes the connection of the propeller post to the boss is to be by full penetration welds. 4. If more than six bolts are fitted, the arrangements are to provide equivalent strength.	5. In fabricated solepieces, transverse webs are to be fitted spaced not more than 760 mm apart. Where the breadth of the solepiece exceeds 900 mm, a centreline vertical web is also to be fitted. 6. Solepieces supporting fixed or movable nozzles will be specially considered, *see* Ch 13,3.2. 7. For dredging and reclamation craft classed 'A1 protected waters service', the scantlings of an 'open' type solepiece are to be such that: (a) $Z_T = 0{,}625 Z_T$ (b) The cross-sectional area is not less than 18 cm^2 (c) The depth is not less than two-thirds of the width at any point.

Table 6.7.2 Permissible stresses for sole pieces

Mode	Permissible stress
(1) Equivalent stress	$115/K_0$ N/mm^2 $(11{,}7/K_0$ kgf/mm$^2)$

Symbols

σ_e = equivalent stress
$= \sqrt{\sigma_b{}^2 + 3\tau_T{}^2}$ N/mm^2
σ_b = bending stress
$= \dfrac{M_B}{Z_T}$ N/mm^2
τ_T = shear stress
$= \dfrac{B_1}{A_s}$ N/mm^2
K_o = as defined in 7.3.3
M_B = bending moment, in Nm, at the section considered
$= B_1 x$
B_1 = supporting force, in N, in pintle bearing
$= 0{,}5 P_L$
P_L = rudder force, in N, as calculated in Ch 13,2
x = distance, in metres, from centre of rudder stock to section under consideration
Z_T = *see* Table 6.7.1(4)
A_s = sectional area, in mm^2, of solepiece

7.3 Rudder horns

7.3.1 Rudder horns supporting semi-spade type rudders are to be efficiently integrated into the main hull structure, and additional web frames or side transverses may be required in the 'tween deck over.

7.3.2 The shell plating is to be increased in thickness in way of the horn. Where the horn plating is radiused into the shell plating, the radius at the shell connection is to be not less than:

$r = (150 + 0{,}8L)$ mm

7.3.3 The scantlings of the rudder horn are to be such that the section modulus against transverse bending at any section is not less than:

$Z_T = 0{,}015 M_B K_o$ cm^3

where
M_B = bending moment
$= B_{1L}\, z$ Nm
B_{1L} = as calculated in Table 13.2.11 in Ch 13,2
z = *see* Fig. 6.7.6
K_o = k_o *see* Table 13.2.4 in Ch 13,2 for cast steel
K_o = k = 1,0 for fabricated mild steels
= k = 0,78 for high tensile steels with yield stress σ_o = 315 N/mm^2
= k = 0,72 for high tensile steels with yield stress σ_o = 355 N/mm^2.

7.3.4 The rudder horn is to be dimensioned such that the stresses do not exceed the permissible stresses given in Table 6.7.3.

Table 6.7.3 Permissible stresses for rudder horns

Mode	Permissible stress
(1) Shear stress	$48/K_o$ N/mm^2 ($4,9/K_o$ kgf/mm^2)
(2) Equivalent stress	$120/K_o$ N/mm^2 ($12/K_o$ kgf/mm^2)

Symbols

σ_e = equivalent stress

$= \sqrt{\sigma_b^2 + 3\left(\tau^2 + \tau_T^2\right)}$ N/mm^2 (kgf/mm^2)

σ_b = bending stress

$= \dfrac{M_B}{Z_T}$ N/mm^2

τ = shear stress

$= \dfrac{B_{1L}}{A_h}$ N/mm^2

τ_T = torsional stress

$= \dfrac{10^3 M_T}{2A_T t_h}$ N/mm^2

A_h = effective shear area, in mm^2, of rudder horn in y-direction
A_T = area in the horizontal section enclosed by the rudder horn, in mm^2
B_{1L} = as calculated in Table 13.2.11 in Ch 13,2
K_o = as defined in 7.3.3
M_B = bending moment at the section considered, in Nm $= B_{1L}\, z$
M_T = torsional moment at the section considered, in Nm $= B_{1L}\, e$
t_h = plate thickness of rudder horn, in mm
e = *see* Fig. 6.7.6
z = *see* Fig. 6.7.6
Z_T = *see* 7.3.3

Table 6.7.4 Rudder coefficient k_R

Design criteria		k_R
Ahead condition	Rudder in propeller slipstream	0,248
	Rudder out of propeller slipstream	0,235
Astern condition		0,185
Bow rudder		0,226
Barge – non self-propelled		

7.4 Shaft bossing

7.4.1 Where the propeller shafting is enclosed in bossings extending back to the bearings supporting the propellers, the aft end of the bossings and the bearings are to be supported by substantially constructed boss end castings or fabrications. These are to be designed to transmit the loading from the shafting efficiently into the ship's internal structure.

7.4.2 The length of the shaft bracket boss, l_b, is to be sufficient to support the length of the required bearing. In general, l_b is not to be less than $4d_t$, where d_t is the Rule diameter of the screwshaft, in mm, *see* Pt 5, Ch 6,3. Proposals for a reduction in the required length of the shaft bracket boss will be considered in conjunction with details of the bearing material, allowable bearing operating pressure and installation arrangements. However, in no case is l_b to be less than the greater of:
(a) $2d_t$; or
(b) that recommended by the bearing manufacturer; or
(c) that required to accommodate the aftermost bearing and to allow the proper connection of the shaft bracket.

Table 6.7.5 Recommended propeller/hull clearances

Number of blades	Hull clearances for single screw, in metres, *see* Fig. 6.7.7(a)				Hull clearances for twin screw, in metres, *see* Fig. 6.7.7(b)	
	a	*b*	*c*	*d*	*e*	*f*
3	$1,20K\delta$	$1,80K\delta$	$0,12\delta$	$0,03\delta$	$1,20K\delta$	$1,20K\delta$
4	$1,00K\delta$	$1,50K\delta$	$0,12\delta$	$0,03\delta$	$1,00K\delta$	$1,20K\delta$
5	$0,85K\delta$	$1,275K\delta$	$0,12\delta$	$0,03\delta$	$0,85K\delta$	$0,85K\delta$
6	$0,75K\delta$	$1,125K\delta$	$0,12\delta$	$0,03\delta$	$0,75K\delta$	$0,75K\delta$
Minimum value	$0,10\delta$	$0,15\delta$	t_R	—	3 and 4 blades, $0,20\delta$ 5 and 6 blades, $0,16\delta$	$0,15\delta$

Symbols

L as defined in 1.4.1
C_b = moulded block coefficient at load draught

$$K = \left(0,1 + \frac{L}{3050}\right)\left(\frac{3,48 C_b P}{L^2} + 0,3\right)$$

$$\left(K = \left(0,1 + \frac{L}{3050}\right)\left(\frac{2,56 C_b P}{L^2} + 0,3\right)\right)$$

t_R = thickness of rudder, in metres, measured at 0,7Rp above the shaft centreline
P = designed power on one shaft, in kW (shp)
R_P = propeller radius, in metres
δ = propeller diameter, in metres

NOTE
The above recommended minimum clearances also apply to semi-spade type rudders.

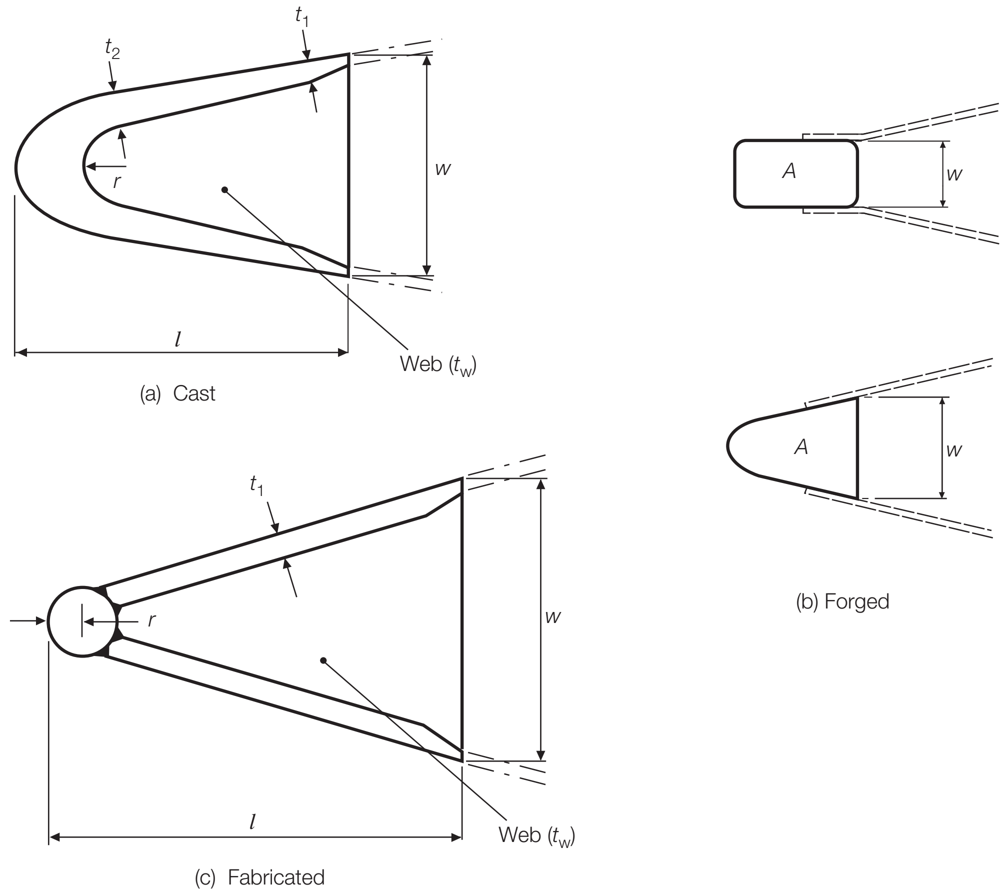


Fig. 6.7.1 Propeller posts

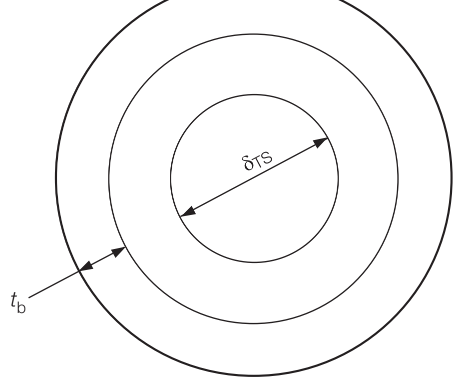


Fig. 6.7.2 Propeller boss

7.4.3 Where the shaft and the shaft bracket boss are of the same material, the thickness of the shaft bracket boss is not to be less than $d_t/4$. Where the shaft and the shaft bracket boss are of dissimilar materials, the thickness of the boss, t_b, is to be not less than:

t_b = $0,75 d_t (f_1^{1/3} - 0,667)$ mm

NOTE
In no case is t_b to be taken as less than 12 mm

where

d_t = Rule diameter of the screwshaft in way of boss, in the appropriate screwshaft material, in mm, *see* Pt 5, Ch 6,3:

f_1 = s_S/s_B but not less than 0,825

s_S = ultimate tensile strength of the shaft material, in N/mm^2

s_B = ultimate tensile strength of the boss material, in N/mm^2.

7.4.4 Cast steel supports are to be suitably radiused where they enter the main hull to line up with the boss plating radius. Where the hull sections are narrow, the two arms are generally to be connected to each other within the ship. The arms are to be strengthened at intervals by webs.

7.4.5 Fabricated supports are to be carefully designed to avoid or reduce the effect of hard spots. Continuity of the arms into the ship is to be maintained, and they are to be attached to substantial floor plates or other structure. The connection of the arms to the bearing boss is to be by full penetration welding.

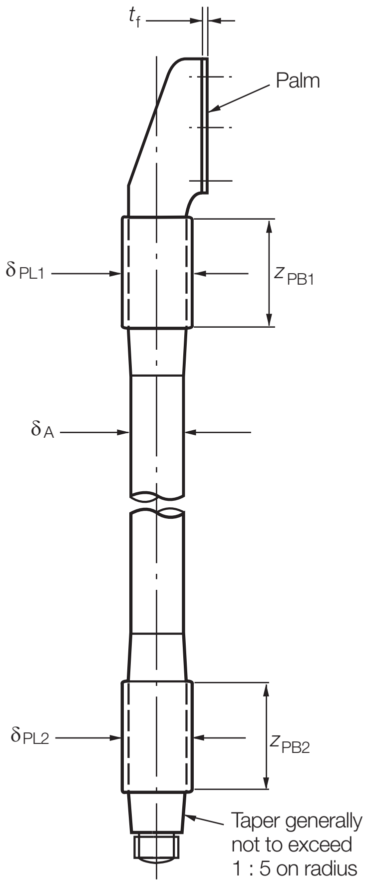


Fig. 6.7.3 Rudder axle

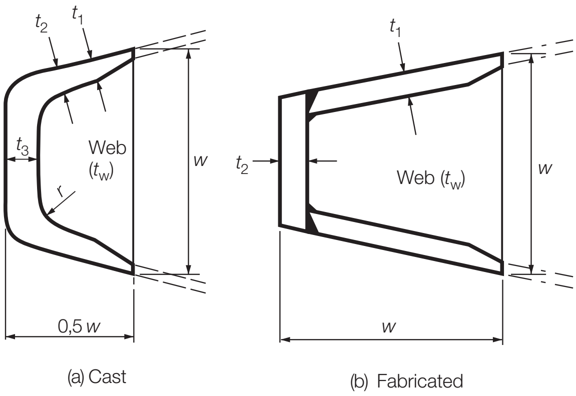


Fig. 6.7.4 Rudder post for twin screw ships

7.4.6 The scantlings of supports will be specially considered. In the case of certain high powered ships, direct calculations may be required.

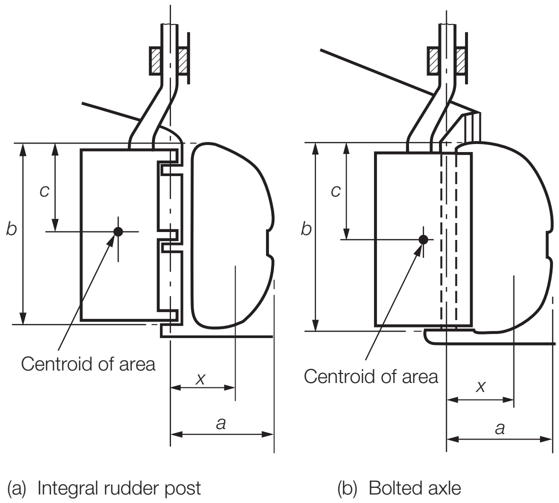


Fig. 6.7.5 Solepieces

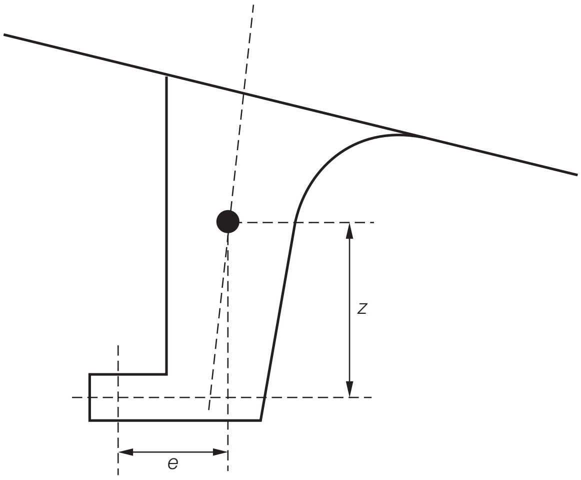


Fig. 6.7.6 Rudder horn

7.4.7 The boss plating is generally to be radiused into the shell plating and supported at the aft end by diaphragms at every frame. These diaphragms are to be suitably stiffened and connected to floors or a suitable arrangement of main and deep web frames. At the forward end, the main frames may be shaped to fit the bossing, but deep webs are generally to be fitted not more than four frame spaces apart.

7.4.8 The region where the shafting enters the ship, and the bearing in way, are to be adequately supported by floors or deep webs.

7.5 Shaft brackets

7.5.1 The scantlings of the arms of shaft brackets, generally based on a breadth to thickness ratio of about five, are to be determined in accordance with 7.6.2.

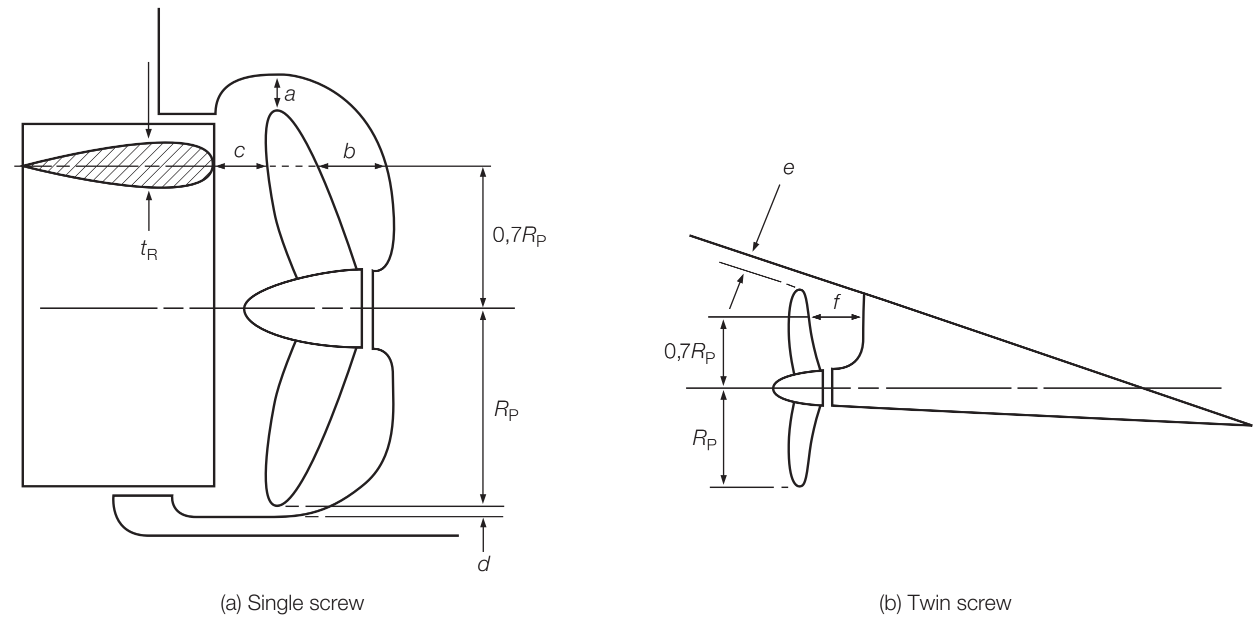


Fig. 6.7.7 Propeller clearances

7.5.2 Where the propeller shafting is exposed to the sea for some distance clear of the main hull, it is generally to be supported adjacent to the propeller by independent brackets having two arms. In very small ships, the use of single arm brackets will be specially considered.

7.5.3 Fabricated brackets are to be designed to avoid or reduce the effect of hard spots and ensure a satisfactory connection to the hull structure. The connection of the arms to the bearing boss is to be by full penetration welding.

7.5.4 Where bracket arms are carried through the shell plating, they are to be attached to floors or girders of increased thickness. The shell plating is to be increased in thickness and connected to the arms by full penetration welding.

7.5.5 In the case of certain high powered ships, direct calculations may be required and scantlings of shaft brackets will be specially considered.

7.5.6 The region where the shafting enters the ship, and the bearing in way, is to be adequately supported by floors or deep webs.

7.6 Double arm shaft brackets ('A' – brackets)

7.6.1 The angle between the arms for double arm shaft brackets is generally to be not less than 50°. Proposals for the angle between the arms to be less than 50° will be specially considered with supporting calculations to be submitted by the designers.

7.6.2 The arms of double arm shaft brackets are to have a section modulus, Z_{xx}, of not less than that determined from the formula:

$$Z_{xx} = 0,45n^3 \text{ cm}^3$$

where

n = the minimum thickness, in cm, of a hydrofoil section obtained from:

$$n = d_{up}\sqrt{\left(\frac{f}{2000}\right)\left(1 + \sqrt{\left(1 + \left(\frac{0,0112}{f}\right)\left(\frac{a_d}{d_{up}}\right)^2\right)}\right)} \text{ cm}$$

a_d = the length of the longer strut, in mm, *see* Fig. 6.7.8

d_{up} = the Rule diameter for an unprotected screwshaft, in mm, or by the applicable Ice Class Rules, *see* Pt 8, Ch 2,7.8, obtained from:

$$d_{up} = 128\sqrt[3]{\frac{P}{R}}$$

P = shaft power, in kW as defined in Pt 5, Ch 1,3.3

R = revolutions per minute, as defined in Pt 5, Ch 1,3.3

f = $400/\sigma_u$

σ_u = ultimate tensile strength of arm material, in N/mm^2.

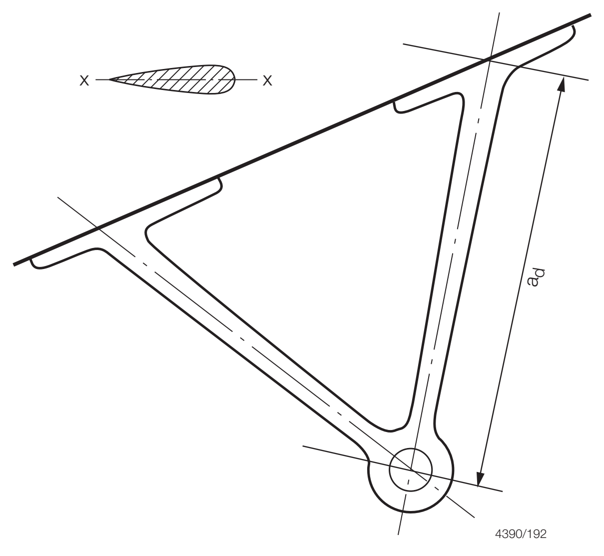


Fig. 6.7.8
Double arm shaft bracket

7.7 Propeller hull clearances

7.7.1 Recommended minimum clearances between the propeller and the sternframe, rudder or hull are given in Table 6.7.5. These are the minimum distances considered desirable in order to expect reasonable levels of propeller excited vibration. Attention is drawn to the importance of the local hull form characteristics, shaft power, water flow characteristics into the propeller disc and cavitation when considering the recommended clearances.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all ship types detailed in Part 4. Only requirements particular to machinery spaces, including protected machinery casings and engine seatings, are given. For other scantlings and arrangement requirements, *see* the relevant Chapter in Part 4 for the particular ship type concerned.

1.1.2 Requirements are given for machinery spaces situated as follows:
(a) In the midship region.
(b) In the aft end region but with a cargo compartment between it and the after peak bulkhead.
(c) In the aft end region where the after peak bulkhead forms the aft end of the machinery space.

1.1.3 The requirements in this Chapter are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation. *See* Pt 1, Ch 2,2.3.

1.2 Structural configuration

1.2.1 Requirements are given for ships constructed using either a transverse framing system or a longitudinal framing system, or a combination of the two.

1.2.2 For midship machinery spaces, where the shell and decks (outside line of openings) are longitudinally framed in way of adjacent cargo spaces, this system of framing is also to be adopted in the machinery space.

1.2.3 For machinery spaces situated aft, where the longitudinal framing terminates and is replaced by transverse framing, a suitable scarfing arrangement of the longitudinal framing is to be arranged, *see also* Ch 6,1.

1.2.4 The maximum spacing, S_{max}, of transverses in longitudinally framed machinery spaces is not to exceed the following:
(a) where $L \leq 100$ m, $S_{max} = 3{,}8$ m
(b) where $L > 100$ m, $S_{max} = (0{,}006L + 3{,}2)$ m
In addition, the spacing in way of a machinery space situated adjacent to the after peak is not to exceed five transverse frame spaces.

1.3 Structural continuity

1.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt discontinuities where structure which contributes to the main longitudinal strength of the ship is omitted in way of a machinery space.

1.3.2 In cargo ships, suitable taper brackets are, in general, to be arranged in way of deck ends.

1.3.3 In oil tankers and bulk carriers with machinery aft (*see* 1.1.3), continuity of the longitudinal bulkheads and topside tank structure is to be maintained as far as possible into the machinery space with suitable taper brackets at the end.

1.3.4 In container or similar ships having side tanks or double skin construction in way of the cargo spaces, the longitudinal bulkheads are generally to be carried through the machinery space where this is situated amidships or separated from the after peak by a cargo compartment. Where the machinery space is situated adjacent to the after peak, the longitudinal bulkheads are to be continued as far aft as possible and suitably tapered at their ends.

1.4 Symbols and definitions

1.4.1 For symbols not defined in this Chapter, *see* Pt 4, Ch 1. L, B, D and T are defined in Ch 1,6.1. Other symbols are defined in the appropriate Sections.

■ *Section 2* Deck structure

2.1 Strength deck – Plating

2.1.1 The corners of machinery space openings are to be of suitable shape and design to minimise stress concentrations.

2.1.2 In the case of oil tankers (*see* 1.1.3), or other ships having small deck openings amidships and machinery aft, where the width of machinery openings exceeds $\frac{B}{2}$ and the opening extends forward beyond a point $\frac{B}{3}$ aft of the poop front, the thickness of deck plating may be required to be increased locally.

2.2 Strength deck – Primary structure

2.2.1 Where a transverse framing system is adopted, deck beams are to be supported by a suitable arrangement of longitudinal girders in association with pillars or pillar bulkheads. Deep beams are to be arranged in way of the ends of engine casings and also in line with web frames where fitted.

2.2.2 Where a longitudinal framing system is adopted, deck longitudinals are to be supported by transverses in association with pillars or pillar bulkheads. For the maximum spacing of transverses, *see* 1.2.4. Deck transverses are to be in line with side transverses or web frames.

2.2.3 Machinery casings are to be supported by a suitable arrangement of deep beams or transverses and longitudinal girders in association with pillars or pillar bulkheads. In way of particularly large machinery casing openings, cross ties may be required, and these are to be arranged in line with deep beams or transverses.

2.3 Lower decks

2.3.1 The scantlings of lower decks or flats are generally to be as detailed in Ch 5,2, Ch 6,2 or Pt 4, Ch 1,4 as appropriate. However, in way of concentrated loads such as those from boiler bearers or heavy auxiliary machinery, etc., the scantlings of deck structure will be specially considered, taking account of the actual loading.

2.3.2 In way of machinery openings, etc., particularly towards the aft end, decks or flats are to have sufficient strength where they are intended as effective supports for side framing, webs or transverses. Web frames and side transverses are to be supported by deep beams or deck transverses.

■ *Section 3*
Side shell structure

3.1 Secondary stiffening

3.1.1 Transverse frames are generally to have scantlings determined as required by Pt 4, Ch 1,6 for cargo spaces, except that where, in a machinery space situated in the midship region, it is desired to omit web frames as permitted by 3.2.3, the section modulus of the ordinary main or 'tween deck frames is to be increased by 50 per cent, up to the level of the lowest deck above the load waterline. Where fully effective stringers supported by web frames are fitted, the stringers may be considered as decks for the purpose of calculating the modulus of the frames.

3.1.2 Longitudinal framing is generally to have scantlings determined as required by Pt 4, Ch 1,6 for machinery spaces in the midship region, and by Table 6.4.1 Location 2(b) in Chapter 6 for machinery spaces clear of and aft of the midship region.

3.2 Primary structure – Transverse framing

3.2.1 Where the space is situated in the aft end region, web frames are to be fitted, spaced in general not more than five frame spaces apart, extending from the tank top to the upper deck and having scantlings as required by Table 7.3.1. However, consideration will be given to a spacing of web frames at not more than seven transverse frame spaces apart, in association with substantially increased ordinary frames to satisfy the overall modulus and inertia requirements. The web frames are to be connected at top and bottom to members of adequate stiffness and supported at lower decks by deep beams. If the span of ordinary frames below the lowest deck or flat exceeds 6,5 m, one or more fully effective side stringers are to be fitted to support the frames. These are to have scantlings as required by Table 7.3.1. Stringers are to be efficiently bracketed to bulkheads, and their connection to the web frames is to be such as to provide adequate continuity of face material.

3.2.2 As an alternative to the fully effective stringers required by 3.2.1, an arrangement of light stringers spaced about 2,5 m apart may be accepted. These stringers are to have scantlings not less than those required in the panting region forward, *see* Ch 5,4.4.

3.2.3 Where the machinery space is situated in the midship region, it is recommended that web frames be fitted in the engine-room, spaced not more than five frame spaces apart and extending from the tank top to the level of the lowest deck above the load waterline. The scantlings of these webs are to be such that the combined section modulus of the web frame and the main or 'tween deck frames is 50 per cent greater than that required for normal transverse framing. These webs may be omitted if the section modulus of the transverse frames is increased as required by 3.1.1.

3.2.4 If an effective side stringer supporting the side frames is fitted, then its scantlings and those of the supporting web frames are to be determined from Table 7.3.1.

3.3 Primary structure – Longitudinal framing

3.3.1 Where the machinery space is longitudinally framed, side transverses are to be fitted having scantlings as required by Table 7.3.1. For the maximum spacing of transverses, *see* 1.2.4. Transverses are to be connected at top and bottom to members of adequate stiffness and supported at lower decks by transverses or deep beams.

Table 7.3.1 Primary structure in machinery spaces

Symbols	Item and position	Scantlings: Section modulus, in cm^3	Scantlings: Min. web depth d_w, in mm
L, D and *T* are as defined in Ch 1,6.1 *h* = load head, in metres, measured from mid-point of span to upper deck at side amidships *k* = higher tensile and steel factor, *see* Ch 2,1.2 l_e = effective length of stiffening member, in metres, *see* Ch 3,3.3 *s* = spacing of floors and longitudinals, in mm *C* = 2,2 for a lower 'tween deck or 2,0 for an upper 'tween deck *S* = spacing or mean spacing of primary supporting members, in metres	TRANSVERSE FRAMING SYSTEM		
	Aft end region: Web frames below lowest deck and not supporting effective stringers	$Z = 5kShl_e^2$	2,5 x depth of adjacent main frames
	Web frames above lowest deck	$Z = 1{,}68CkTSl_e\sqrt{D}$	
	Any region: Fully effective stringers	$Z = 7{,}75kShl_e^2$	2,5 x depth of adjacent main frames
	Web frames below lowest deck supporting effective stringers	Determined from calculation based on following assumptions: (a) Fixed ends (b) Point loadings (c) Head to upper deck at side (d) Bending stress 93,2 N/mm^2 (9,5 kgf/mm^2) (e) Shear stress 83,4 N/mm^2 (8,5 kgf/mm^2)	
	LONGITUDINAL FRAMING SYSTEM Side transverses below lowest deck	$Z = 10kShl_e^2$	2,5 x depth of longitudinals
	Side transverses above lowest deck	$Z = 2{,}1CkTSl_e\sqrt{D}$	

■ *Section 4*
Double and single bottom structure

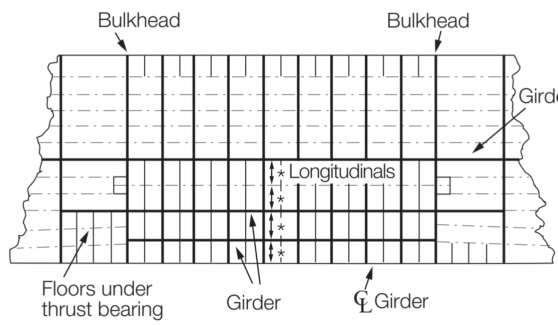
4.1 Double bottom structure

4.1.1 The minimum depth of the centre girder and its thickness are to be at least the same as required in way of cargo space amidships, *see* Pt 4, Ch 1,8. A greater depth is recommended in way of large engine-rooms when the variation in draught between light and load conditions is considerable. For passenger ships, *see* Pt 4, Ch 2,6.

4.1.2 In machinery spaces situated adjacent to the after peak, the double bottom is to be transversely framed. Elsewhere transverse or longitudinal framing may be adopted, but *see also* Pt 4, Ch 1,8.

4.1.3 Where the double bottom is transversely framed, plate floors are to be fitted at every frame in the engine-room. In way of boilers, plate floors are to be fitted under the boiler bearers, and elsewhere as required by Pt 4, Ch 1,8.

4.1.4 Where the double bottom is longitudinally framed, plate floors are to be fitted at every frame under the main engines and thrust bearing. Outboard of the engine seating, floors may be fitted at alternate frames, *see* Fig. 7.4.1.



*Maximum spacing = 1,5 x normal spacing of longitudinals

Fig. 7.4.1 Engine-room with longitudinal framing

4.1.5 The scantlings of floors clear of the main engine seatings, are generally to be as required in way of cargo spaces, *see* Pt 4, Ch 1,8. In way of engine seatings, the floors are to be increased in thickness, *see* 6.2.1.

4.1.6 Sufficient fore and aft girders are to be arranged in way of the main machinery to effectively distribute its weight and to ensure adequate rigidity of the structure. In midship machinery spaces these girders are to extend for the full length of the space and are to be carried aft to support the foremost shaft tunnel bearing. This extension beyond the after bulkhead of the engine-room is to be for at least three transverse frame spaces, aft of which the girders are to scarf into the structure. Forward of the engine-room bulkhead, the girders are to be tapered off over three frame spaces and effectively scarfed into the structure. In machinery spaces situated at the aft end the girders are to be carried as far aft as practicable and the ends effectively supported by web frames or transverses. For recommended scantlings of engine girders, *see* 6.2.1.

4.1.7 Outboard of the engines, side girders are to be arranged, where practicable, to line up with the side girders in adjacent cargo spaces. These are to have scantlings as required by Pt 4, Ch 1,8.

4.1.8 Where the double bottom is longitudinally framed and transverse floors are fitted in way of the engine seatings as required by 4.1.4, no additional longitudinal stiffening is required in way of the engines other than the main engine girders, provided that the spacing of girders does not exceed 1,5 times the normal spacing of longitudinals. Where this spacing of girders is exceeded, shell longitudinals are to be fitted. These are to scarf into the longitudinal framing clear of the machinery spaces. The scantlings of the longitudinals are to be determined as required by Pt 4, Ch 1,6 using a minimum span of 1,3 m, *see* Fig. 7.4.1.

4.1.9 The thickness, *t*, of inner bottom plating in engine-rooms, clear of the engine seatings, is to be not less than:

$$t = 0{,}0015\sqrt[4]{LTk^2}\,(s + 660) \quad \text{mm}$$

and not less than 7,0 mm (symbols as defined in Table 7.3.1). This thickness will be required to be increased in way of engine seatings integral with the tank top, *see* 6.2.1.

4.1.10 Where the height of inner bottom in the machinery spaces differs from that in adjacent spaces, continuity of longitudinal material is to be maintained by sloping the inner bottom over an adequate longitudinal extent. The knuckles in the plating are to be arranged close to plate floors.

4.2 Single bottom structure

4.2.1 In way of machinery spaces situated amidships the minimum depth of floors is to be at least 10 per cent greater than that required elsewhere in general cargo ships, *see* Pt 4, Ch 1,7. If the top of the floors is recessed in way of the engines, the depth of the floors in way of the recess should generally be not less than that required by Pt 4, Ch 1,7, but this will be specially considered in each case in relation to the arrangements proposed.

4.2.2 In way of machinery spaces situated aft, or where there is considerable rise of floor, the depth of the floors will be specially considered.

4.2.3 Clear of the engine seatings the thickness and face plate area of the floor webs are to be 1,0 mm and 10 per cent greater, respectively, than the requirements for general cargo ships as given in Pt 4, Ch 1,7. The floors are not to be flanged.

4.2.4 Sufficient fore and aft girders are to be arranged in way of machinery to effectively distribute its weight and ensure adequate rigidity of the structure. In midship machinery spaces these girders are to extend for the full length of the space and are to be carried aft to support the foremost shaft tunnel bearing and forward to scarf into the structure. In machinery spaces situated at the aft end, the girders are to be carried as far aft as practicable and the ends effectively supported by web frames or transverses. For scantlings of engine girders, *see* 6.2.1.

4.2.5 Outboard of the engines, side girders are to be arranged having scantlings as required by Pt 4, Ch 1,7 and these are to be scarfed into the side girders in adjacent spaces.

■ *Section 5* Machinery casings and fuel oil bunkers

5.1 Machinery casings

5.1.1 The scantlings and arrangements of exposed casings protecting machinery openings are to be in accordance with Ch 8,2.

5.1.2 The minimum scantlings of protected casings are to be in accordance with Table 7.5.1.

Table 7.5.1 Protected machinery casings

Item	Minimum scantlings
Plating: In way of cargo hold spaces	$t = 6{,}5\sqrt{k}$ mm
In way of accommodation spaces	$t = 5{,}0\sqrt{k}$ mm
Stiffeners	$Z = 0{,}008 l_e sk$ cm^3
Symbols	
k = higher tensile steel factor, *see* Ch 2,1.2 l_e = effective length of stiffening member, in metres, *see* Ch 3,3.3 s = spacing of stiffeners, in mm t = thickness, in mm Z = section modulus of stiffening member, in cm^3, *see* Ch 3,3.2	
NOTE In no case is the depth of the stiffener to be less than 60 mm.	

5.1.3 Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably increased, *see also* Pt 4, Ch 1,4.

5.1.4 Where casing sides act as girders supporting decks over, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular attention is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

5.2 Fuel oil bunkers

5.2.1 Fuel oil bunkers situated within the machinery space are generally to comply with the requirements given in Pt 4, Ch 1 or Ch 9, as appropriate.

■ *Section 6* Engine seatings

6.1 General

6.1.1 Main engines and thrust bearings are to be effectively secured to the hull structure by seatings of adequate scantlings to resist the various gravitational, thrust, torque, dynamic and vibratory forces which may be imposed on them.

6.1.2 For initial guidance, recommended scantlings for oil engine seatings are given in 6.2.1.

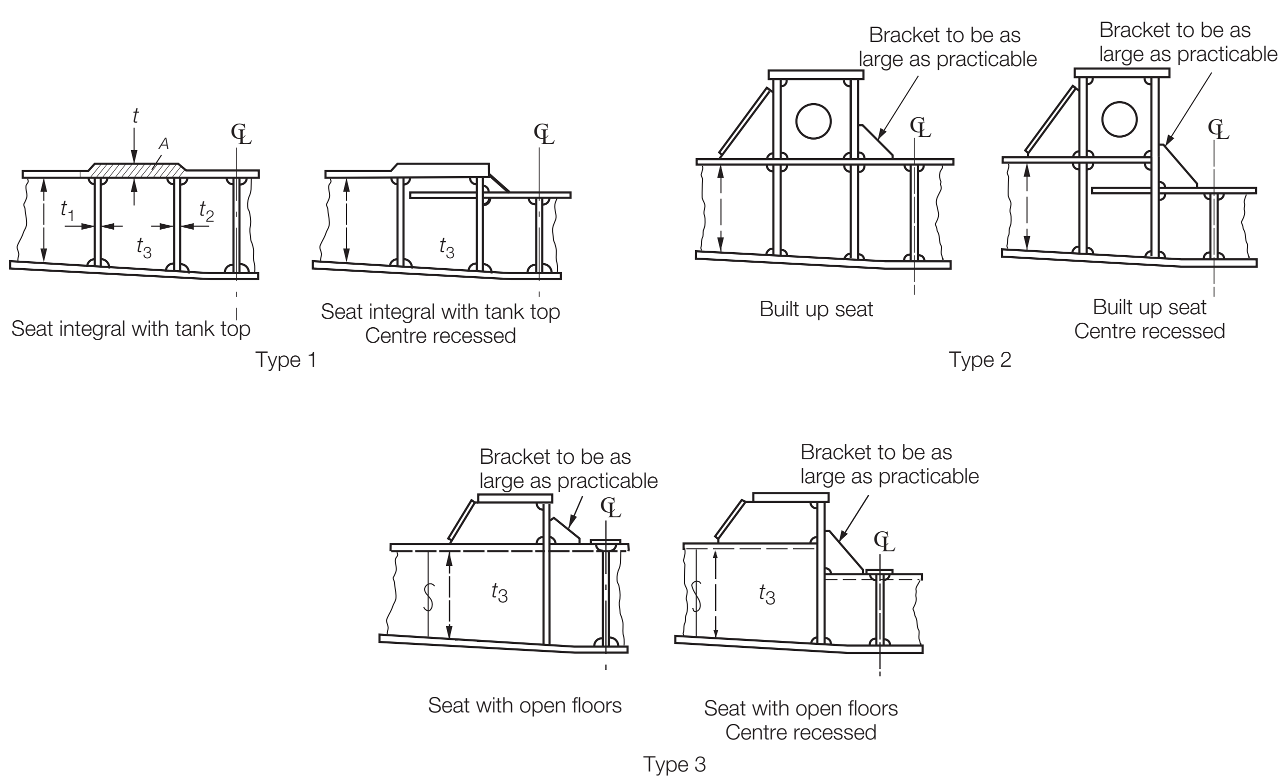
6.1.3 In the case of higher power oil engines or turbine installations the seatings should generally be integral with the double bottom structure. The tank top plating in way of the engine foundation plate or the turbine gear case and the thrust bearing should be substantially increased in thickness, *see* Fig. 7.6.1, Type 1.

6.1.4 If the main machinery is supported on seatings of Type 2 as shown in Fig. 7.6.1, these are to be so designed that they distribute the forces from the engine as uniformly as possible into the supporting structure. Longitudinal members supporting the seating are to be arranged in line with girders in the double bottom, and adequate transverse stiffening is to be arranged in line with floors, *see* Fig. 7.6.1, Type 2.

6.1.5 In ships having open floors in the machinery space the seatings are generally to be arranged above the level of the top of floors and securely bracketed to them, *see* Fig. 7.6.1, Type 3.

6.2 Seats for oil engines

6.2.1 In determining the scantlings of seats for oil engines, consideration is to be given to the general rigidity of the engine itself and to its design characteristics in regard to out of balance forces. As a general guide to designers, recommended scantlings are given in Table 7.6.1.



NOTE: Floors not to be flanged, *see* 4.2.3

Fig. 7.6.1 Engine seatings

Table 7.6.1 Seats for oil engines – Recommended scantlings

Symbols	Item	Scantlings of one seat
L as defined in Ch 1,6.1 f = engine factor = $\frac{P}{Rl}$ t = minimum thickness of top plate, in mm t_1, t_2 = main engine girder thicknesses, in mm t_3 = floor plate thickness under seating, in mm, *see also* Fig. 7.6.1 A = area of top plate for one side of seat, in cm^2 where l = effective length of engine foundation plate, in metres, required for bolting the engine to the seating. The thrust and gearcase seating is to be considered as a separate item P = power of one engine at maximum service speed, in kW (bhp) R = rev/min of engine at maximum service speed	Top plate	$A = (120 + 44{,}2f + 4{,}07f^2)$ cm^2 ($A = (120 + 32{,}5f + 2{,}2f^2)$ cm^2) Minimum thickness: (a) Where two girders fitted $t = (19 + 3{,}4f)$ mm ($t = (19 + 2{,}5f)$ mm) (b) Where one girder fitted $t = (25 + 3{,}4f)$ mm ($t = (25 + 2{,}5f)$ mm)
	Girders (both inside and above double bottom where fitted)	Number: Generally two but a single girder can be accepted where all the following apply: (a) $f <$ 1,84 (2,5) (b) $P <$ 5900 kW (8000 bhp) (c) $L <$ 100 m Total thickness: (a) Where two girders are fitted $t_1 + t_2 = (28 + 4{,}08f)$ mm ($t_1 + t_2 = (28 + 3{,}0f)$ mm) (b) Where one girder is fitted $t_1 = (15 + 4{,}08f)$ mm ($t_1 = (15 + 3{,}0f)$ mm)
	Floors (between girders or under seat where a single girder is fitted)	Thickness: $t_3 = (10 + 1{,}5f)$ mm ($t_3 = (10 + 1{,}1f)$ mm

6.3 Seats for turbines

6.3.1 Seats are to be so designed as to provide effective support for the turbines and ensure their proper alignment with the gearing, and (where applicable) allow for thermal expansion of the casings. In general, the seats are not to be arranged in way of breaks or recesses in the double bottom.

6.4 Seats for boilers

6.4.1 Boiler bearers are to be of substantial construction and efficiently supported by transverse and horizontal brackets. These should generally be arranged in line with plate floors and girders in a double bottom or with suitable deep beams or transverses and girders at boiler flats. Suitable allowance is to be made in the design of the supporting structure for the variation in loading due to thermal expansion effects, *see also* Pt 5, Ch 14,2.

6.5 Seats for auxiliary machinery

6.5.1 Auxiliary machinery is to be secured on seatings, of adequate scantlings, so arranged as to distribute the loadings evenly into the supporting structure.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all types of ships detailed in Part 4, except for deckhouses situated on forecastles of offshore supply ships, which are dealt with separately in Pt 4, Ch 4.

1.1.2 The scantlings of exposed bulkheads and decks of superstructures and deckhouses are generally to comply with the following requirements, but increased scantlings may be required where the structure is subjected to loading additional to Rule. Where there is no access from inside the house to below the freeboard deck, or where a bulkhead is in a particularly sheltered location, the scantlings may be specially considered.

1.1.3 The term 'erection' is used in this Section to include both superstructures and deckhouses.

1.1.4 For requirements relating to companionways, doors, accesses and skylights, *see* Chapter 11.

1.1.5 The requirements in this Chapter are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation with the exception of Section 5 which is to be complied with. *See* Pt 1, Ch 2,2.3.

1.2 Symbols

1.2.1 The following symbols and definitions are applicable to this Chapter, unless otherwise stated:

L, B, T and C_b as defined in Ch 1,6.1

b = breadth of deckhouse, at the positions under consideration, in metres

k = higher tensile steel factor, *see* Ch 2,1.2

l_e = effective length, in metres, of the stiffening member, deck beam or longitudinal measured between span points, *see* Ch 3,3.3

l_s = span, in metres, of stiffeners, and is to be taken as the 'tween deck or house height but in no case as less than 2,0 m

s = spacing of stiffeners, beams or longitudinals, in mm

s_b = standard spacing, in mm, of stiffeners, beams or longitudinals, and is to be taken as:

(a) for 0,05L from the ends:
s_b = 610 mm or that required by (b), whichever is the lesser

(b) elsewhere:
$s_b = 470 + 1{,}67L_2$ mm
but forward of 0,2L from the forward perpendicular s_b is not to exceed 700 mm

B_1 = actual breadth of ship, at the section under consideration, measured at the weather deck, in metres

D = moulded depth of ship, in metres, to the uppermost continuous deck or the deck next above a height of 1,6T from the base line amidships, whichever is the lesser

L_2 = length of ship, in metres, but need not be taken greater than 250 m

L_3 = length of ship, in metres, but need not be taken greater than 300 m

X = distance, in metres, between the after perpendicular and the bulkhead under consideration. When determining the scantlings of deckhouse sides, the deckhouse is to be subdivided into parts of approximately equal length not exceeding 0,15L each, and X is to be measured to the mid-length of each part

α = a coefficient given in Table 8.1.1

$$\beta = 1{,}0 + \left(\frac{\left(\frac{X}{L} - 0{,}45\right)}{(C_b + 0{,}2)}\right)^2 \quad \text{for } \frac{X}{L} \le 0{,}45$$

$$= 1{,}0 + 1{,}5\left(\frac{\left(\frac{X}{L} - 0{,}45\right)}{(C_b + 0{,}2)}\right)^2 \quad \text{for } \frac{X}{L} > 0{,}45$$

C_b is to be taken as not less than 0,6 nor greater than 0,8. Where the aft end of an erection is forward of amidships, the value of C_b used in determining β for the aft end bulkhead need be taken as not less than 0,8

γ = vertical distance, in metres, from the summer load waterline to the mid-point of span of the bulkhead stiffener, or the mid-point of the plate panel, as appropriate

δ = 1,0 for exposed machinery casings and houses protecting openings to pump-rooms

$\left(0{,}3 + 0{,}7\frac{b}{B_1}\right)$ elsewhere, but in no case to be taken less than 0,475

λ = a coefficient given in Table 8.1.2.

Table 8.1.1 Values of α

Position		α
Lowest tier	– unprotected front	$2{,}0 + 0{,}0083L_3$
Second tier	– unprotected front	$1{,}0 + 0{,}0083L_3$
Third tier and above All tiers All tiers	– unprotected front – protected fronts – sides	$0{,}5 + 0{,}0067L_3$
All tiers	– aft end where aft of amidships	$0{,}7 + 0{,}001L_3 - 0{,}8\dfrac{X}{L}$
All tiers	– aft end where forward of amidships	$0{,}5 + 0{,}001L_3 - 0{,}4\dfrac{X}{L}$

Table 8.1.2 Values of λ

Length L metres	λ	Expression for λ
20 30 40 50 60 70 80 90 110 130 150	0,89 1,76 2,57 3,34 4,07 4,76 5,41 6,03 7,16 8,18 9,10	$L \leq 150$ m $\lambda = \left(\dfrac{L}{10} e^{-\frac{L}{300}}\right) - \left(1 - \left(\dfrac{L}{150}\right)^2\right)$
150 170 190 210 230 250 270 290 300	9,10 9,65 10,08 10,43 10,69 10,86 10,98 11,03 11,03	$150 \text{ m} \leq L \leq 300$ m $\lambda = \dfrac{L}{10} e^{-\frac{L}{300}}$
300 and above	11,03	$L \geq 300$ m $\lambda = 11{,}03$

1.3 Definition of tiers

1.3.1 The lowest, or first tier, is normally that which is directly situated on the deck to which D is measured. The second tier is the next tier above the lowest tier and so on.

1.3.2 Where the freeboard corresponding to the required summer moulded draught for the ship can be obtained by considering the ship to have a virtual moulded depth at least one standard superstructure height less than the Rule depth, D, measured to the uppermost continuous deck, proposals to treat the first tier erection as a second tier, and so on, will be specially considered. The standard height of superstructure is the height defined in the *International Convention on Load Lines, 1966*.

1.4 Design pressure head

1.4.1 The design pressure head, h, to be used in the determination of erection scantlings is to be taken as:

$$h = \alpha\, \delta\, (\beta\, \lambda - \gamma) \text{ m}$$

1.4.2 In no case is the design pressure head to be taken as less than the following:

(a) Lowest tier of unprotected fronts:
minimum $h = 2{,}5 + 0{,}01L_2$ m

(b) All other locations:
minimum $h = 1{,}25 + 0{,}005L_2$ m.

Section 2
Scantlings of erections other than forecastles

2.1 Thickness of bulkhead and side plating

2.1.1 The thickness, t, of plating of the fronts, sides and aft ends of all erections, other than the sides of superstructures where these are an extension of the side shell, is to be not less than:

$$t = 0{,}003s\sqrt{kh} \text{ mm}$$

but in no case is the thickness to be less than:

(a) for the lowest tier:

$$t = (5{,}0 + 0{,}01L_3)\sqrt{k} \text{ mm}$$

(b) for the upper tiers:

$$t = (4{,}0 + 0{,}01L_3)\sqrt{k} \text{ mm but not less than 5,0 mm.}$$

2.1.2 The thickness of sides of poops and bridges is to be as required by Ch 6,3 or Pt 4, Ch 1,5, as appropriate.

2.2 Stiffeners and their connections

2.2.1 The modulus of stiffeners, Z, on front, side and end bulkheads of all erections, other than sides of superstructures, is to be not less than:

$$Z = 0{,}0035h\, s\, l_s^2\, k \text{ cm}^3$$

2.2.2 The section modulus of side frames of poops and bridges is to comply with the requirements of Ch 6,4 or Pt 4, Ch 1,6, as appropriate.

2.2.3 The end connections of stiffeners are to be as given in Table 8.2.1.

2.3 Deck plating

2.3.1 The thickness of erection deck plating is to be not less than that required by Table 8.2.2.

Table 8.2.1 Stiffener end connections

Position	Attachment at top and bottom
1. Front stiffeners of lower tiers and of upper tiers when L is 160 m or greater	*See* Chapter 10
2. Front stiffeners of upper tiers when L is less than 160 m	May be unattached
3. Side stiffeners of lower tiers where two or more tiers are fitted	Bracketed, unless stiffener modulus is increased by 20 per cent and ends are welded to the deck all round
4. Side stiffeners if only one tier is fitted, and aft end stiffeners of after deck-houses on deck to which D is measured	*See* Chapter 10
5. Side stiffeners of upper tiers when L is 160 m or greater	*See* Chapter 10
6. Side stiffeners of upper tiers when L is less than 160 m	May be unattached
7. Aft end stiffeners except as covered by item 4	May be unattached
8. Exposed machinery and pump-room casings – Front stiffeners on amid-ship casings and all stiffeners on aft end casings which are situated on the deck to which D is measured	Bracketed
9. All other stiffeners on exposed machinery and pump-room casings	6,5 cm^2 of weld

Table 8.2.2 Thickness of deck plating

Position	Thickness of deck plating, in mm		
	$L \leq 100$ m		$L > 100$ m
Top of first tier erection	$(5{,}5 + 0{,}02L)\sqrt{\dfrac{ks}{s_b}}$	but not less than 5,0 mm	$7{,}5\sqrt{\dfrac{ks}{s_b}}$
Top of second tier erection	$(5{,}0 + 0{,}02L)\sqrt{\dfrac{ks}{s_b}}$		$7{,}0\sqrt{\dfrac{ks}{s_b}}$
Top of third tier and above	$(4{,}5 + 0{,}02L)\sqrt{\dfrac{ks}{s_b}}$		$6{,}5\sqrt{\dfrac{ks}{s_b}}$

2.3.2 When decks are fitted with approved sheathing, the thicknesses derived from Table 8.2.2 may be reduced by 10 per cent for a 50 mm sheathing thickness, or 5 per cent for 25,5 mm, with intermediate values in proportion. The steel deck is to be coated with a suitable material in order to prevent corrosive action, and the sheathing or composition is to be effectively secured to the deck, *see also* Pt 6, Ch 4. Inside deckhouses the thickness may be reduced by a further 10 per cent.

2.4 Deck longitudinals and beams

2.4.1 The section modulus of superstructure deck longitudinals and beams is to be in accordance with the requirements for location (2) in Table 1.4.4 and location (3) in Table 1.4.5 in Pt 4, Ch 1, using design heads not less than those specified in Table 3.5.1 in Chapter 3 for superstructure decks.

2.4.2 Transverse deck beams in deckhouses and deck longitudinals other than as in 2.7 are to have a section modulus, Z, not less than:

$Z = 0{,}0048 h_2 s\, l_e^2\, k$ cm^3, but in no case less than:

$Z = 0{,}025 s$ cm^3

and the value of h_2, the load head, is to be taken as not less than:

on first tier decks	0,9 m
on second tier decks	0,6 m
on third tier decks and above	0,45 m.

2.5 Deck girders and transverses

2.5.1 The section modulus of deck girders and transverses is to be in accordance with the requirements for location (1) in Table 1.4.6 in Pt 4, Ch 1, using design heads not less than those specified in Table 3.5.1 in Chapter 3 for superstructure decks.

2.6 Strengthening at ends and sides of erections

2.6.1 Web frames or partial bulkheads are to be fitted within poops and bridges that have large deckhouses or other erections above.

2.6.2 Web frames or equivalent strengthening are also to be arranged to support the sides and ends of large deck-houses.

2.6.3 These web frames should be spaced about 9 m apart and are to be arranged, where practicable, in line with watertight bulkheads below. Webs are also to be arranged in way of large openings, boats, davits and other points of high loading.

2.6.4 Arrangements are to be made to minimise the effect of discontinuities in erections. All openings cut in the sides are to be substantially framed and have well rounded corners. Continuous coamings or girders are to be fitted below and above doors and similar openings. House tops are to be strengthened in way of davits. Special care is to be taken to minimise the size and number of openings in the side bulkheads in the region of the ends of erections within 0,5L amidships. Account is to be taken of the high vertical shear loading which can occur in these areas.

2.6.5 Adequate support under the ends of erections is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams. At the corners of houses and in way of supporting structures, attention is to be given to the connection to the deck, and inserts or equivalent arrangements are generally to be fitted especially for erections that are effective in resisting vertical hull girder bending as defined in Pt 3, Ch 3,3.4.2.

2.6.6 The side plating of bridges having a length of 0,15*L* or greater is to be increased in thickness by 25 per cent at the ends of the structure, and is to be tapered into the upper deck sheerstrake. This plating is to be efficiently stiffened at the upper edge and supported by web plates not more than 1,5 m from the end bulkhead. Proposals for alternative arrangements, including the use of higher tensile steel, will be individually considered.

2.7 Erections contributing to hull strength

2.7.1 Where a long superstructure or deckhouse is fitted, extending within 0,5*L* amidships, the scantlings of the first tier deck plating and longitudinals may be required to be increased, *see also* Ch 3,3.4 and Ch 4,2.3.

2.8 Unusual designs

2.8.1 Where superstructures or deckhouses are of unusual design, the strength is to be not less than that required by this Chapter for a conventional design.

■ *Section 3* Aluminium erections

3.1 Scantlings

3.1.1 Where an aluminium alloy complying with Chapter 8 of the Rules for Materials is used in the construction of erections, the scantlings of these erections are to be increased (relative to those required for steel construction) by the percentages given in Table 8.3.1.

3.1.2 The thickness, t, of aluminium alloy members is to be not less than:

t = $2{,}5 + 0{,}022 d_w$ mm but need not exceed 10 mm

where

d_w = depth of the section, in mm.

3.1.3 The minimum moment of inertia, I, of aluminium alloy stiffening members is to be not less than:

$$I = 5{,}25 Z\, l_e \quad \text{cm}^4$$

Where l_e is the effective length of the member in metres, as defined in 1.2.1, and Z is the section modulus of the stiffener and attached plating calculated using the formulae in 2.2.1 and 2.4.2 as applicable taking k as 1.

Table 8.3.1 Percentage increase of scantlings

Item	Percentage increase
Fronts, sides, aft ends, unsheathed deck plating	20
Decks sheathed in accordance with 2.3.2	10
Deck sheathed with wood, and on which the plating is fixed to the wood sheathing at the centre of each beam space	Nil
Stiffeners and beams	70
Scantlings of small isolated houses	Nil

3.2 Bimetallic joints

3.2.1 Where aluminium erections are arranged above a steel hull, details of the arrangements in way of the bimetallic connections are to be submitted.

■ *Section 4* Forecastles

4.1 Construction

4.1.1 Side plating and framing of forecastles are to comply with the requirements of Ch 5,3 and Ch 5,4 respectively. The end plating and its stiffening are to comply with the requirements of 2.1.1 and 2.2.1 respectively.

4.1.2 The bow height and the extent of the forecastle are to comply with the requirements of Ch 3,6.

4.1.3 The thickness, t, of forecastle deck plating is to be not less than:

$$t = \left(6 + 0{,}017L\right)\sqrt{\frac{ks}{s_b}} \quad \text{mm}$$

4.1.4 Deck longitudinals and beams are to comply with Ch 5,2.3, using a head of 1,8 m forward of 0,075*L* and 1,5 m between 0,12*L* and 0,075*L*.

4.1.5 Girders, transverses and pillars are to be in accordance with Ch 5,2.4, and the depth of the girder or transverse is to be not less than twice that of the beam or longitudinal supported.

Section 5 Bulwarks, guard rails and other means for the protection of crew

5.1 General requirements

5.1.1 Bulwarks or guard rails are to be provided around all exposed decks. Bulwarks or guard rails are to be not less than 1,0 m in height measured above sheathing, and are to be constructed as required by this Section. Consideration will be given to cases where this height would interfere with the normal operation of the ship.

5.1.2 The freeing arrangements in bulwarks are to be in accordance with 5.3.

5.1.3 Guard rails fitted on superstructure and freeboards decks are to have at least three courses. The opening below the lowest course of guard rails is not to exceed 230 mm. The other courses are to be spaced not more than 380 mm apart. In the case of ships with rounded gunwales, the guard rail supports are to be placed on the flat of the deck. In other locations, guard rails with at least two courses are to be fitted.

5.1.4 Guard rails are to be fitted with fixed, removable or hinged stanchions fitted no more than 1,5 m apart. Removable or hinged stanchions shall be capable of being locked in the upright position.

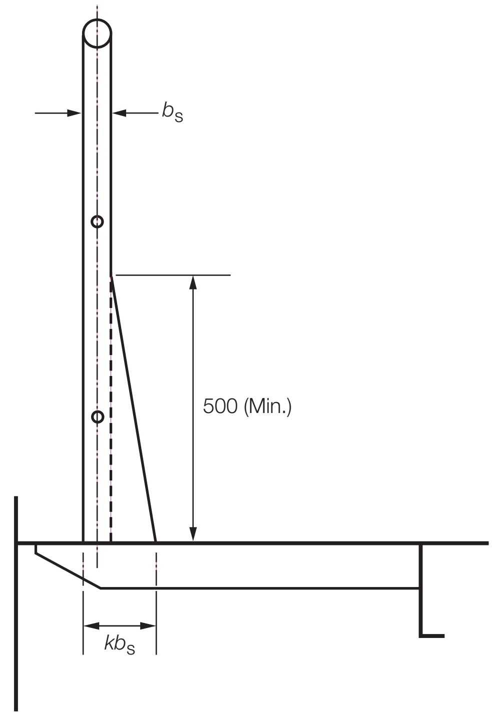
5.1.5 At least every third stanchion is to be supported by a stay. In lieu of this, flat steel stanchions shall be of increased breadth as given in Fig. 8.5.1, and aligned with a member below deck unless the deck plating thickness exceeds 20 mm. Guard rail stanchions of increased breadth are to be welded to the deck with double continuous fillet weld with a minimum leg size of 7 mm or in compliance with a standard recognised by LR.

5.1.6 Where necessary for the normal operation of the ship, steel wire ropes may be accepted in lieu of guard rails. Wires are to be made taut by means of turnbuckles. Chains are only permitted in short lengths in way of access openings.

5.1.7 Satisfactory means, in the form of guard rails, lifelines, handrails, gangways, underdeck passageways or other equivalent arrangements, are to be provided for the protection of the crew in getting to and from their quarters, the machinery space and all other parts used in the necessary work of the ship in accordance with Table 8.5.1.

5.1.8 Where gangways on a trunk are provided by means of a stringer plate fitted outboard of the trunk side bulkheads (port and starboard), each gangway is to be a solid plate, effectively stayed and supported, with a clear walkway at least 450 mm wide, at or near the top of the coaming, with guard rails complying with 5.1.3 and hatch cover securing appliances accessible from the gangway.

5.1.9 Where permitted by the National Authority, gangways or walkways may be omitted on ships engaged on protected or extended protected water service. However, life-lines are to be provided on tankers and flush deck ships, or where the cargo hatch coamings are less than 600 mm high.



In lieu of at least every third stanchion supported by stay, alternatively:

(a) at least every third stanchion shall be of increased breadth: $kb_S = 2{,}9b_S$

(b) at least every second stanchion shall be of increased breadth: $kb_S = 2{,}4b_S$

(c) every stanchion shall be of increased breadth: $kb_S = 1{,}9b_S$

where

b_S breadth of normal stanchion as specified in an appropriate standard recognised by LR

Stanchions with increased breadth are to be aligned with members below deck, minimum 100 x 12 flat bar welded to deck by double continuous fillet weld. Stanchions with increased breadth need not be aligned with under deck structure for deck plating exceeding 20 mm.

Fig. 8.5.1 Support of stanchions

5.1.10 For a Type 'A' ship with freeboards assigned greater than, or equal to, Type 'B', a life-line may be provided in lieu of a walkway.

5.2 Bulwark construction

5.2.1 Plate bulwarks are to be stiffened by a strong rail section and supported by stays from the deck. The spacing of these stays forward of 0,07*L* from the forward perpendicular is to be not more than 1,2 m on Type 'A', Type 'B-60' and Type 'B-100' ships (as defined in Ch 11,1.1), and not more than 1,83 m on other Types. Elsewhere, bulwark stays are to be not more then 1,83 m apart. Where bulwarks are cut to form a gangway or other opening, stays of increased strength are to be fitted at the ends of the openings. Bulwarks are to be adequately strengthened in way of eyeplates for cargo gear, and in way of mooring pipes the plating is to be doubled or increased in thickness and adequately stiffened.

Table 8.5.1 Protection of crew (*see continuation*)

<table>
<tr><th rowspan="2">Ship type</th><th rowspan="2">Location in ship</th><th rowspan="2">Assigned Summer Freeboard, in mm</th><th colspan="4">Acceptable arrangements according to type of freeboard assigned</th></tr>
<tr><th>Type A</th><th>Type (B-100)</th><th>Type (B-60)</th><th>Type (B & B+)</th></tr>
<tr><td rowspan="3">Oil tankers, chemical tankers and gas carriers (see 1.1.5)</td><td rowspan="2">1.1 Access to bow
1.1.1 Between poop and bow or
1.1.2 Between a deckhouse containing living accommodation or navigation equipment, or both, and bow, or
1.1.3 In the case of a flush deck vessel, between crew accommodation and the forward ends of ship</td><td>$\leq (A_f + H_s)$</td><td>a
e
f(1)
f(5)</td><td>a
e
f(1)
f(5)</td><td>a
e
f(1)
f(5)</td><td>a
e
f(1)
f(5)</td></tr>
<tr><td>$>(A_f + H_s)$</td><td colspan="4">a
e
f(1)
f(2)</td></tr>
<tr><td>1.2 Access to after end
In the case of a flush deck vessel, between crew accommodation and the after end of ship</td><td colspan="5">As required in item 2.2.4 in Table 8.5.1 for other types of ships</td></tr>
</table>

Symbols

A_f = the minimum summer freeboard calculated as Type A ship regardless of type freeboard actually assigned
H_s = the standard height of superstructure as defined in *International Convention on Load Lines*, Regulation 33

Acceptable arrangements:
Acceptable arrangements referred to in the Table are defined as follows:

a A well lighted and ventilated under-deck passageway (clear opening 0,8 m wide, 2 m high) as close as practicable to the freeboard deck, connecting and providing access to the locations in question.

b A permanent and efficiently constructed gangway fitted at or above the level of the superstructure deck on or as near as practicable to the centreline of the ship, providing a continuous platform at least 0,6 m in width and a non-slip surface, with guard rails extending on each side throughout its length. Guard rails shall be at least 1 m high with courses as required in 5.1, and supported by stanchions spaced not more than 1,5 m; a foot-stop shall be provided.

c A permanent walkway at least 0,6 m in width fitted at freeboard deck level consisting of two rows of guard rails with stanchions spaced not more than 3 m. The number of courses of rails and their spacing are to be as required by 5.1. On Type B ships, hatchway coamings not less than 0,6 m in height may be regarded as forming one side of the walkway, provided that between the hatchways two rows of guard rails are fitted.

d A 10 mm minimum thickness diameter wire rope life-line supported by stanchions about 10 m apart, or a single hand rail or wire rope attached to hatch coamings, continued and adequately supported between hatchways.

e A permanent and efficiently constructed gangway fitted at or above the level of the superstructure deck on or as near as practicable to the centreline of the ship:
- located so as not to hinder easy access across the working areas of the deck;
- providing a continuous platform at least 1,0 m in width;
- constructed of fire resistant and non-slip material;
- fitted with guard rails extending on each side throughout its length; guard rails should be at least 1,0 m high with courses as required by Regulation 25(3) and supported by stanchions spaced not more than 1,5 m;
- provided with a foot stop on each side;
- having openings, with ladders where appropriate, to and from the deck. Openings should not be more than 40 m apart;
- having shelters of substantial construction set in way of the gangway at intervals not exceeding 45 m if the length of the exposed deck to be traversed exceeds 70 m. Every such shelter should be capable of accommodating at least one person and be so constructed as to afford weather protection on the forward port and starboard sides.

f A permanent and efficiently constructed walkway fitted at freeboard deck level on or as near as practicable to the centre line of the ship having the same specifications as those for a permanent gangway listed in (e) except for foot-stops. On Type B ships (certified for the carriage of liquids in bulk), with a combined height of hatch coaming and fitted hatch cover of together not less than 1 m in height the hatchway coamings may be regarded as forming one side of the walkway, provided that between the hatchways two rows of guard rails are fitted.

Alternative transverse locations for c, d and f:
(1) At or near centreline of ship; or
fitted on hatchways at or near centreline of ship.
(2) Fitted on each side of the ship.
(3) Fitted on one side of the ship, provision being made for fitting on either side.
(4) Fitted on one side of the ship only.
(5) Fitted on each side of hatchways as near to the centreline as practicable.

Table 8.5.1 Protection of crew (*conclusion*)

<table>
<tr><th rowspan="2">Ship type</th><th rowspan="2">Location in ship</th><th rowspan="2">Assigned Summer Freeboard, in mm</th><th colspan="4">Acceptable arrangements according to type of freeboard assigned</th></tr>
<tr><th>Type A</th><th>Type (B-100)</th><th>Type (B-60)</th><th>Type (B & B+)</th></tr>
<tr><td rowspan="2">Other ship type</td><td>2.1 Access to midship quarters
2.1.1 Between poop and bridge, or</td><td>≤ 3000 mm</td><td>a
b
e</td><td>a
b
e</td><td>a
b
c(1)
e
f(1)</td><td rowspan="4">a
b
c(1)
c(2)
c(4)
d(1)
d(2)
d(3)
e
f(1)
f(2)
f(4)</td></tr>
<tr><td>2.1.2 Between poop and deckhouse containing living accommodation or navigation equipment, or both</td><td>> 3000 mm</td><td>a
b
e</td><td>a
b
e</td><td>a
b
c(1)
c(2)
e
f(1)
f(2)</td></tr>
<tr><td rowspan="2"></td><td>2.2 Access to ends
2.2.1 Between poop and bow (if there is no bridge),
2.2.2 Between bridge and bow, or</td><td>≤ 3000 mm</td><td>a
b
c(1)
e
f(1)</td><td>a
b
c(1)
c(2)
e
f(1)
f(2)</td><td>a
b
c(1)
c(2)
e
f(1)
f(2)</td></tr>
<tr><td>2.2.3 Between a deckhouse containing living accommodation or navigation equipment, or both, and bow, or
2.2.4 In the case of a flush deck vessel, between crew accommodation and the forward and after ends of ship</td><td>> 3000 mm</td><td>a
b
c(1)
d(1)
e
f(1)</td><td>a
b
c(1)
c(2)
d(1)
d(2)
e
f(1)
f(2)</td><td>a
b
c(1)
c(2)
c(4)
d(1)
d(2)
d(3)
e
f(1)
f(2)
f(4)</td></tr>
<tr><td colspan="7">NOTES
1. In all cases where wire ropes are fitted, adequate devices are to be provided to ensure their tautness.
2. Wire ropes may only be accepted in lieu of guard rails in special circumstances and then only in limited lengths.
3. Lengths of chain may only be accepted in lieu of guard rails if fitted between two fixed stanchions.
4. Where stanchions are fitted, every third stanchion is to be supported by a bracket or stay.
5. Removable or hinged stanchions shall be capable of being locked in the upright position.
6. A means of passage over obstructions, if any, such as pipes or other fittings of a permanent nature, should be provided.
7. Generally, the width of the gangway or deck-level walkway should not exceed 1,5 m.</td></tr>
</table>

5.2.2 Bulwarks should not be cut for gangway or other openings near the breaks of superstructures, and are also to be arranged to ensure their freedom from main structural stresses. *See* shell plating in appropriate Chapters.

5.2.3 The section modulus, Z, at the bottom of the bulwark stay is to be not less than:

$$Z = (33,0 + 0,44L)\, h^2 s \quad \text{cm}^3$$

where

h = height of bulwark from the top of the deck plating to the top of the rail, in metres

s = spacing of the stays, in metres, in accordance with 5.2.1

L = length of ship, in metres (as defined in Ch 1,6.1), but to be not greater than 100 m.

5.2.4 In the calculation of the section modulus, only the material connected to the deck is to be included. The bulb or flange of the stay may be taken into account where connected to the deck, and where, at the ends of the ship, the bulwark plating is connected to the sheerstrake, a width of plating not exceeding 600 mm may also be included. The free edge of the stay is to be stiffened.

5.2.5 Bulwark stays are to be supported by, or to be in line with, suitable underdeck stiffening, which is to be connected by double continuous fillet welds in way of the bulwark stay connection.

5.2.6 It should be noted that the above requirements do not allow for any loading from deck cargoes.

5.3 Freeing arrangements

5.3.1 The requirements of 5.3.2 to 5.3.11 apply to ships of Type 'B'. Additional requirements applicable to ships of Type 'A', Type 'B-100' and Type 'B-60' are indicated in 5.3.18 and 5.3.20. The ship Types are as defined in Ch 11,1.1.

5.3.2 Where bulwarks on the weather portions of free-board or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of large quantities of water by means of freeing ports, and also for draining them.

5.3.3 The minimum freeing area on each side of the ship, for each well on the freeboard deck or raised quarterdeck, where the sheer in the well is not less than the standard sheer required by the *International Convention on Load Lines,1966*, is to be derived from the following formulae:

(a) where the length, l, of the bulwark in the well is 20 m or less:
area required = $0{,}7 + 0{,}035l$ m^2

(b) where the length, l, exceeds 20 m:
area required = $0{,}07l$ m^2

l need not be taken greater than $0{,}7L_L$, where L_L is the length of the ship as defined in Ch 1,6.1.

5.3.4 If the average height of the bulwark exceeds 1,2 m or is less than 0,9 m, the freeing area is to be increased or decreased, respectively, by 0,004 m^2 per metre of length of well for each 0,1 m increase or decrease in height respectively.

5.3.5 The minimum freeing area for each well on a first tier superstructure is to be half the area calculated from 5.3.3.

5.3.6 Two-thirds of the freeing port area required is to be provided in the half of the well nearest to the lowest point of the sheer curve.

5.3.7 When the deck has little or no sheer, the freeing area is to be spread along the length of the well.

5.3.8 In ships with no sheer the freeing area as calculated from 5.3.3 is to be increased by 50 per cent. Where the sheer is less than the standard, the percentage is to be obtained by linear interpolation.

5.3.9 Where the length of the well is less than 10 m, or where a deckhouse occupies most of the length, the freeing port area will be specially considered but in general need not exceed 10 per cent of the bulwark area.

5.3.10 Where it is not practical to provide sufficient freeing port area in the bulwark, particularly in small ships, credit can be given for bollard and fairlead openings where these extend to the deck.

5.3.11 Where a ship fitted with bulwarks has a continuous trunk, or hatch side coamings that are continuous, or substantially continuous, the minimum freeing area is to be not less than 20 per cent of the total bulwark area where the width of trunk or hatchway is 0,4*B* or less, and not less than 10 per cent of the total bulwark area when the width of the trunk or hatch is 0,75*B* or greater. The freeing area required for an intermediate width of trunk or hatch is to be obtained by linear interpolation.

5.3.12 Where the trunk referred to in 5.3.11 or its equivalent is included in the calculation of freeboard, open rails are to be fitted for at least 50 per cent of the length of the exposed part of the weather deck. Alternatively, if a continuous bulwark is fitted, the minimum freeing area is to be at least 33 per cent of the bulwark area. The freeing area is to be placed in the lower part of the bulwark.

5.3.13 Where a deckhouse has a breadth less than 80 per cent of the beam of the ship, or the width of the side passageways exceeds 1,5 m, the arrangement is considered as one well. Where a deckhouse has a breadth equal to or more than 80 per cent of the beam of the ship, or the width of the side passageways does not exceed 1,5 m, or when a screen bulkhead is fitted across the full breadth of the ship, this arrangement is considered as two wells, before and abaft the deckhouse.

5.3.14 Suitable provision is also to be made for the rapid freeing of water from recesses formed by superstructures, deckhouses and deck cargo arrangements, etc., in which water may be shipped and trapped. Deck gear, particularly on fishing vessels, is not to be stowed in such a manner as to obstruct unduly the flow of water to freeing ports.

5.3.15 The lower edges of freeing ports are to be as near to the deck as practicable, and should not be more than 100 mm above the deck.

5.3.16 Where freeing ports are more than 230 mm high, vertical bars spaced 230 mm apart may be accepted as an alternative to a horizontal rail to limit the height of the freeing port.

5.3.17 Where shutters are fitted, the pins or bearings are to be of a non-corrodible material, with ample clearance to prevent jamming. The hinges are to be within the upper third of the port. Shutters are not to be fitted with securing appliances.

5.3.18 Ships of Type 'A' and Type 'B-100' are to have open rails for at least half the length of the exposed part of the weather deck. Alternatively, if a continuous bulwark is fitted, the minimum freeing area is to be at least 33 per cent of the total area of the bulwark. The freeing area is to be placed in the lower part of the bulwark.

5.3.19 Where superstructures are connected by trunks, open rails are to be fitted for the whole length of the exposed part of the freeboard deck.

5.3.20 Ships of Type 'B-60' are to have a minimum freeing area of at least 25 per cent of the total area of the bulwark. The freeing area is to be placed in the lower part of the bulwark.

5.3.21 Gutter bars greater than 300 mm in height fitted on the weather decks of tankers are to be treated as bulwarks and freeing ports arranged as required by this Section. Closures for use during loading and discharge operations are to be arranged in such a way that jamming cannot occur while at sea.

5.3.22 In ships having superstructures which are open at either or both ends to wells formed by bulwarks on the open deck, adequate provision for freeing the open spaces are to be provided as follows:

The freeing port area, A_w for the open well:

$$A_w = (0{,}07 l_w + A_c)\,(S_c)\left(\frac{0{,}5 h_s}{h_w}\right)$$

The freeing port area, A_s for the open superstructure:

$$A_s = (0{,}07 l_t)\,(S_c)\left(\frac{b_o}{l_t}\left(1-\left(\frac{l_w}{l_t}\right)^2\right)\left(\frac{0{,}5 h_s}{h_w}\right)\right)$$

where

l_w = the length of the open deck enclosed by bulwarks, in metres
l_s = the length of the common space within the open superstructure, in metres
l_t = $l_w + l_s$ but if 20 m or less then the freeing area is to be calculated in accordance with 5.3.3(a)
S_c = sheer correction factor, maximum 1,5 as defined in 5.3.8
b_o = breadth of openings in the end bulkhead of the enclosed superstructure, in metres
h_w = distance of the well deck above the freeboard deck, in metres
h_s = one standard superstructure height, *see 1.3.2*
h_b = actual height of the bulwark, in metres.
A_c = bulwark height correction factor taken as;
= 0 for bulwarks between 0,9 and 1,2 m in height
= $l_w\left(\frac{(h_b - 1{,}2)}{0{,}1}\right)(0{,}004)$ m^2 for bulwarks of height greater than 1,2 m, and
= $l_w\left(\frac{(h_b - 0{,}9)}{0{,}1}\right)(0{,}004)$ m^2 for bulwarks of height less than 0,9 m.

To adjust the freeing port area for the distance of the well deck above the freeboard deck, for decks located more than $0{,}5h_s$ above the freeboard deck, multiply by the factor 0,5 (h_s/h_w).

5.4 Free flow area

5.4.1 The effectiveness of the freeing port area in bulwarks of vessels not fitted with a continuous deck obstruction, depends on the free flow across the deck.

5.4.2 The free flow area is the net total longitudinal area of the transverse passageways or gaps between hatchways and superstructures or deckhouses, due account being made for any obstructions such as equipment or other fittings. The height of passageways or gaps used in the calculation of the area is the height of the bulwark.

5.4.3 The provision of freeing area in bulwarks should be related to the net free flow area as follows:

(a) If the free flow area is equal to, or greater than the freeing port area calculated from 5.3.11 when the hatchway coamings are continuous, then the minimum freeing area calculated from 5.3.3 is sufficient.
(b) If the free flow area is less than the freeing port area calculated from 5.3.3, then the minimum freeing area is to be that calculated from 5.3.11.
(c) If the free flow area is less than the freeing port area derived from (a) but greater than that derived from (b), the minimum freeing area, F, in the bulwark is to be obtained from the following formula:

$$F = F_1 + F_2 - f_p \quad \text{m}^2$$

where

f_p = total net area of passages and gaps between hatchways, superstructures and deckhouses (the free flow area)
F_1 = minimum area from 5.3.3
F_2 = minimum area from 5.3.11.

5.5 Special requirements for tugs and offshore supply ships

5.5.1 In tugs and offshore supply ships where there is a recess at the after end of the forecastle for the towing winch, the freeing port area in way of the recess is to be calculated as follows:

B = breadth of ship
b = breadth of recess
L = length of well
l = mean length of recess
a = freeing area for well length L

Freeing port area in way of recess:

$$A = a\,\frac{l}{L}$$

Reduction due to breadth of recess:

$$A_1 = A\,\frac{b}{B}$$

Reduce A_1 by 25 per cent for winch area:

A_2 = 0,75 A_1
= required freeing port area each side in way of the recess

Where the winch is enclosed in a non-weathertight compartment freeing ports are not required but adequate drainage by means of scuppers is to be provided.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are to be taken in conjunction with the Chapters of Parts 3 and 4 applicable to the particular ship type.

1.2 Symbols

1.2.1 The following symbols and definitions are applicable to this Chapter:

k = higher tensile steel factor, *see* Ch 2,1.2
l = overall length, of the stiffening member, in metres
l_e = effective length, in metres, of the stiffening member, measured between span points, *see* Ch 3,3.3
s = spacing, of stiffeners, in mm
B = moulded breadth of ship, in metres, *see* Ch 1,6.1
L = length of ship, in metres, *see* Ch 1,6.1
Z = section modulus of the stiffening member, in cm^3, *see* Ch 3,3.2.

1.2.2 Other symbols are defined in the appropriate Section.

■ *Section 2* Timber deck cargoes

2.1 Application

2.1.1 Where timber load lines are to be assigned, the full requirements of this Section are to be complied with, and the ship will be eligible to be assigned the notation ‘timber deck cargoes’.

2.1.2 In other cases, proposals to carry timber deck cargoes which will impose on the weather deck a mean cargo loading in excess of 8,5 kN/m^2 (0,865 tonne-f/m^2) will be considered on the basis of these requirements. In particular, the requirements of 2.9 to 2.12 are to be complied with.

2.2 Symbols and definitions

2.2.1 The term ‘timber deck cargo’ means a cargo of timber carried on an uncovered part of the freeboard or superstructure deck. The term does not include wood pulp or similar cargo.

2.2.2 The symbols used in this Section are defined as follows:

C = mean stowage rate, in m^3/tonne, of the timber deck cargo, making allowance for normal battens, etc.
h = the height, in metres, to which the timber deck cargo is to be stowed, measured vertically from the deck or hatch cover as applicable.

2.2.3 Other symbols are defined in 1.2.

2.3 General

2.3.1 Attention is drawn to the requirements of the *International Convention for the Safety of Life at Sea, 1974, Chapter VI*, as amended, the *International Load Line Convention, 1966*, concerning timber deck cargoes, and its 1988 Protocol, and to National Regulations. Attention is also drawn to IMO Resolution A.1048(27) *Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 2011*.

2.3.2 Timber deck cargoes are to be loaded, stowed and secured throughout the voyage, in accordance with the Cargo Securing Manual approved by the Flag Administration as required by SOLAS Chapter VI.

2.3.3 Each cargo securing arrangement for timber deck cargoes detailed in the ship’s Cargo Securing Manual is to be documented by a lashing plan that shows the following:

(a) maximum cargo weight for which the arrangement is designed;
(b) maximum stowage height;
(c) required number and strength of blocking devices and lashings, as applicable;
(d) required pre-tension in lashings;
(e) other cargo properties of importance for the securing arrangement, such as friction, rigidity of timber packages;
(f) illustrations of all securing items that might be used;
(g) any restrictions regarding maximum accelerations, weather criteria, restricted sea areas and for non-winter conditions only;
(h) the walkway/life-line arrangements; and
(j) stowage arrangement, which is to be in accordance with 2.7.

The Cargo Securing Manual is to be submitted for approval, and a copy placed on board the ship.

2.3.4 All timber deck cargoes must be compactly stowed, lashed and secured. Friction alone is not deemed sufficient and such methods are not endorsed by Lloyd's Register.

2.3.5 Timber freeboards cannot be used where wood pulp is being carried as the deck cargo. Packaged timber (timber which has been prelashed) may be carried on deck with the ship at its timber freeboards.

2.3.6 Type 'B–60' ships may have timber freeboards assigned based on ordinary Type 'B' freeboards.

2.3.7 Timber freeboards are not appropriate for ships which are assigned freeboards from a second deck. However, where the maximum geometric upper deck draught is restricted, a restricted timber draught may be assigned.

2.3.8 It is the Master's responsibility to ensure loose gear (e.g., uprights, wire lashings and life-lines) are supplied and fitted onboard in accordance with the approved timber deck cargo loading and lashing plan when the ship is carrying timber deck cargoes. However, it is not a requirement that loose gear remains permanently on board a ship assigned timber freeboards.

2.4 Arrangements

2.4.1 Double bottom tanks within the midship half-length are to have adequate longitudinal subdivision.

2.4.2 A forecastle of at least standard height of a superstructure, defined by Regulation 33 of the International Load Line Convention, as amended, and of length at least 0,07*L* is to be fitted. In addition, in ships of less than 100 m in length, a poop of at least standard height, or a raised quarterdeck with a deckhouse or strong steel hood of at least the same total height, is to be fitted.

2.5 Uprights

2.5.1 Uprights are to be of adequate strength but are not to exceed the strength of the bulwark. Where timber uprights are used, it is the responsibility of the Master to use timber which is of a type and grade which has proved satisfactory for the purpose. Where a timber load line is not assigned and uprights are not connected to the bulwark, uprights are to be of adequate strength but need not relate to that of the bulwark, *see* 2.1.2.

2.5.2 Uprights are to be used for all timber deck cargoes with the exception that, where only packaged timber is to be carried, uprights may be omitted, depending on racking strength and not including uprights or stoppers (low uprights) situated either side of hatch covers.

2.5.3 The spacing of the uprights is to be suitable for the length and character of the timber to be carried but is not to exceed 3 m.

2.5.4 Each upright is to extend above the top of the cargo and be fitted with a strap or bracket support at the top of the bulwark to hold it upright whilst loading.

2.5.5 Strong permanent bulwarks, or efficient rails of specially strong construction, are to be fitted. Steel bulwarks, along with guard rails and stanchions, are acceptable as supports for uprights, provided substantial sockets are built for each upright.

2.5.6 Deck sockets are to be of a size to suit the dimensions of the uprights and are to be not less than 100 mm in depth with drainage provided. They are to be efficiently connected to the hull structure. A locking pin or wedge is to be provided to prevent the upright lifting out of the socket.

2.6 Lashings

2.6.1 The timber deck cargo is to be secured along its length by independent top over lashings.

2.6.2 The spacing of top over lashings is to be determined by the height of the cargo above the deck or by the type of timber, *see* 2.6.3 and 2.6.4:

(a) For heights not more than 2,5 m, the spacing is to be not more than 3 m.
(b) For heights above 2,5 m, the spacing is to be not more than 1,5 m.

2.6.3 Where only packaged timber is to be carried, and uprights are omitted, *see* 2.5.2, lashings are to be spaced not more than 1,5 m apart.

2.6.4 Round wood timber deck cargo is to be secured throughout its length by top over lashings spaced not more than 1,5 m apart.

2.6.5 At the fore and aftermost ends of each continuous timber deck stow, the spacing of the lashings determined from 2.6.2, 2.6.3 or 2.6.4 is to be halved.

2.6.6 The spacing of lashings is to be such that lashings are positioned as close as practicable to the ends of each continuous timber deck stow.

2.6.7 Round wood timber deck cargo stowed over and above hatches, in addition to 2.6.4, is to be further secured by a system of athwartship lashings connecting respective port and starboard uprights at three quarters of the height of the stow. If the height of the hatch cover over which the cargo is stowed is less than 2 m, a further athwartship lashing is to be installed 1 m above the hatch cover.

2.6.8 Lashings and fittings must not:

(a) have a breaking strength of less than 133 kN;
(b) elongate more than 5 per cent at 80 per cent of the breaking strength;
(c) show any permanent deformation at less than 40 per cent of the breaking strength.

2.6.9 Where timber is in lengths of less than 3,6 m, the spacing of lashings is to be reduced, or other suitable provisions made to suit the length of the timber.

2.6.10 Open hooks, which may loosen if the lashing becomes slack, are not to be used in securing arrangements for timber deck cargoes and web lashing is not to be used in combination with chain or wire lashing.

2.6.11 Slip hooks or other appropriate methods may be used for quick and safe adjustment of lashings. Pelican hooks, when used, are to be moused.

2.6.12 Corner protectors are to be used to prevent lashings from cutting into the cargo and to protect lashings from damage at sharp corners.

2.6.13 Every lashing is to be provided with a tightening device or system, situated so that it can be safely and efficiently operated when required. The magnitude of the components of the resolved load produced by the tightening device or system is not to be less than:

(a) 27 kN in the horizontal; and
(b) 16 kN in the vertical.

2.6.14 Once the lashings are secured, the tightening device or system is to have not less than half the tightening capacity available for further use.

2.6.15 If wire rope clips are used to make a joint in a wire lashing, the following conditions are to be observed to avoid a significant reduction in strength:

(a) the number and size of rope clips utilised are to be in proportion to the diameter of the wire rope and no fewer than three, each spaced at intervals of not less than 150 mm.
(b) the saddle portion of the clip is to be applied to the live load segment; and
(c) rope clips are to be initially tightened so that they visibly compress the wire rope and are subsequently to be re-tightened after the lashing has been stressed.

2.6.16 Bulldog grips are only suitable for a standard wire rope of right-hand lay having six strands. Such grips are not to be used for wire rope of left-hand lay or different construction.

2.6.17 Rounded angle pieces of suitable material and design are to be used along the upper outboard edge of the stow to bear the stress and permit free reeving of the lashings.

2.6.18 Eye plates are to be of substantial construction, effectively connected to the hull structure, and placed at intervals determined from 2.6.2 to 2.6.5. The distance from a superstructure end bulkhead to the first eye plate and lashing is to be not more than 2 m.

2.7 Stowage

2.7.1 The stowage arrangements are to be detailed within the lashing plan, *see* 2.3.3.

2.7.2 Timber deck cargoes are to extend over at least the entire available length, which is the total length of the well or wells between superstructures. Where there is no limiting superstructure at the after end, the timber is to extend at least to the after end of the aftermost hatchway.

2.7.3 The timber deck cargo is to extend athwartships as close as possible to the ship's side, due allowance being made for obstructions, provided any gap thus created at the side of the ship does not exceed a mean of four per cent of the breadth.

2.7.4 The timber is to be stowed as solidly as possible to at least the standard height of a superstructure other than a raised quarter deck. It is not to interfere in any way with the safe navigation and necessary work of the ship.

2.7.5 On a ship within a seasonal winter zone in winter, the height of the deck cargo above the deck exposed to weather must not exceed one third of the extreme breadth of the ship.

2.7.6 Cargo which overhangs hatch coamings or other structures in the longitudinal direction by more than a third of their individual or packed length is to be supported at the outer end by other cargo stowed on deck or by structure of adequate strength.

2.8 Safety arrangements

2.8.1 If there is no convenient passage on or below the deck of the ship, a walkway is to be provided over the timber deck cargo. This walkway is either to be:

(a) At, or near, the centreline of the ship, consisting of two sets of guard wires, spaced 1 m apart, each with more than three courses of wire. The opening below the lowest course is not to exceed 230 mm; the remaining courses are to be spaced not more than 380 mm apart to a height of at least 1 m above the timber deck cargo. The guard wires are to be secured to stanchions. The stanchions are to be not more than 3 m apart, and these are to be secured to the timber cargo by spikes, or other equivalent means.
(b) Alternatively, where uprights are used, guard wires, spaced vertically not more than 330 mm apart, are to be secured to the uprights along the length of the timber deck cargo on both port and starboard sides to a height of not less than 1 m above the cargo. A wire life-line is also to be fitted at the centreline of the ship, adequately supported by stanchions spaced not more than 10 m apart.

A safe walking surface, not less than 600 mm in width, is to be fitted over the cargo and effectively secured to the top of it in line with the walkway or adjacent to the life-line. All lines are to be taut using tightening devices.

2.8.2 Safe access is to be provided to the top of the timber deck cargo by means of properly constructed ladders, steps or ramps fitted with guard lines or handrails.

2.8.3 All openings in the weather deck are to be capable of being properly closed and secured tight. Ventilators, air pipes and other fittings enclosing openings are to be efficiently protected against damage.

2.8.4 Access hatches, vents, air pipes, fire hydrants, hoses, valve operating positions, sounding pipes and other essential equipment are to be clearly marked and left accessible.

2.9 Longitudinal strength

2.9.1 The proposed timber deck loading conditions are to be taken into account in the longitudinal strength calculations, *see* Chapter 4, and details are to be included in the ship's Loading Manual.

2.10 Deck loading and scantlings

2.10.1 In general, the stowage rate, C, of timber deck cargoes is to be taken as:

(a) for round timber and logs:
C = 2,1 m^3/tonne

(b) for packaged sawn timber:
C = 1,45 m^3/tonne.

These values are based on the total volume occupied by the cargo, including normal battens, etc., measured from bulwark to bulwark, and deck, or hatch cover, to top of cargo.

2.10.2 Where it is proposed to store timber more densely than that corresponding to the above values, the appropriate value of C is to be used.

2.10.3 The load height, h, of the cargo at any position is to be determined from the overall heights of cargo stowage as supplied by the Shipbuilder. Where the height of cargo varies, a mean effective load height is to be adopted. Attention is drawn to the limitation on height of cargo contained in the Load Lines Conventions where these apply.

2.10.4 A scantling correction factor, K, is to be determined from $K = \dfrac{h}{1{,}08C}$ and the hull scantlings are to be increased as follows:

(a) **Deck longitudinals.** The section modulus is to be multiplied by the factor 0,5 (1 + K).
(b) **Deck beams.** The load head contained in the expression for section modulus is to be multiplied by K, and the section modulus determined using the increased value.
(c) **Deck girders and transverses.** The section modulus is to be multiplied by the factor K.
(d) **Pillars and deck supporting structure.** The design load is to be multiplied by the factor K, and scantlings determined using the increased value.
(e) **Side structure.** The arrangement and scantlings of side structure are to be considered, and increased scantlings of framing may be required.

2.11 Scantlings of hatch covers

2.11.1 The scantlings of primary supporting members and secondary stiffeners are to comply with Ch 11,2.3.4 for distributed cargo load p_L using $p_C = h/C$.

2.11.2 The hatch cover securing and support arrangements, stoppers, etc., and coamings are to be suitably reinforced to take account of increased loading from timber deck cargoes, *see* Ch 11,4.2.

2.12 Direct calculations

2.12.1 As an alternative to the above, the scantlings of the deck and side structure, and of hatch covers, may be assessed using direct calculations based on the proposed loading of the ship.

2.12.2 In the case of hatch covers, the stress and deflection criteria given in Ch 11,2.4 corresponding to a uniformly distributed weather load are not to be exceeded.

■ *Section 3*
Decks loaded by wheeled vehicles

3.1 General

3.1.1 Where it is proposed either to stow wheeled vehicles on the deck or to use wheeled vehicles for cargo handling, the deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, the hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required as a weather or cargo deck or hatch cover, as applicable.

3.1.2 The vehicles, types and axle loads, for which the vehicle carrying decks including, where applicable, hatch covers have been approved, are to be stated in the Loading Manual and be contained in a notice displayed on each deck.

3.2 Symbols

3.2.1 The symbols used in this Section are defined in 1.2 and in the appropriate sub-Section.

3.3 Loading

3.3.1 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Shipbuilder. These details are to include the wheel load, axle and wheel spacing, tyre print dimensions and type of tyre for the vehicles.

3.3.2 For design purposes, where wheeled vehicles are to be used for cargo handling, the deck is to be taken as loaded with a normal head cargo, except in way of the vehicle.

Table 9.3.1 Deck plate thickness calculation

Symbols	Expression
a, s, u, and *v* as defined in Fig. 9.3.1 n = tyre correction factor, *see* Table 9.3.3 P_W = load, in tonnes, on the tyre print. For closely spaced wheels the shaded area shown in Fig. 9.3.1 may be taken as the combined print P_1 = corrected patch load, in tonnes λ = dynamic magnification factor ϕ_1 = patch aspect ratio correction factor ϕ_2 = panel aspect ratio correction factor ϕ_3 = wide patch load factor	$P_1 = \phi_1 \phi_2 \phi_3 \lambda P_W$ $\phi_1 = \dfrac{2v_1 + 1{,}1s}{u_1 + 1{,}1s}$ $\quad v_1 = v$, but $\leq s$; $u_1 = u$, but $\leq a$ $\phi_2 = 1{,}0$ for $u \leq (a - s)$ $= \dfrac{1}{1{,}3 - \dfrac{0{,}3}{s}(a-u)}$ for $a \geq u > (a - s)$ $= 0{,}77 \dfrac{a}{u}$ for $u > a$ $\phi_3 = 1{,}0$ for $v < s$ $= 0{,}6 \dfrac{s}{v} + 0{,}4$ for $1{,}5 > \dfrac{v}{s} \geq 1{,}0$ $= 1{,}2 \dfrac{s}{v}$ for $\dfrac{v}{s} \geq 1{,}5$ λ = 1,25 for harbour conditions = $(1 + 0{,}7n)$ for sea-going conditions

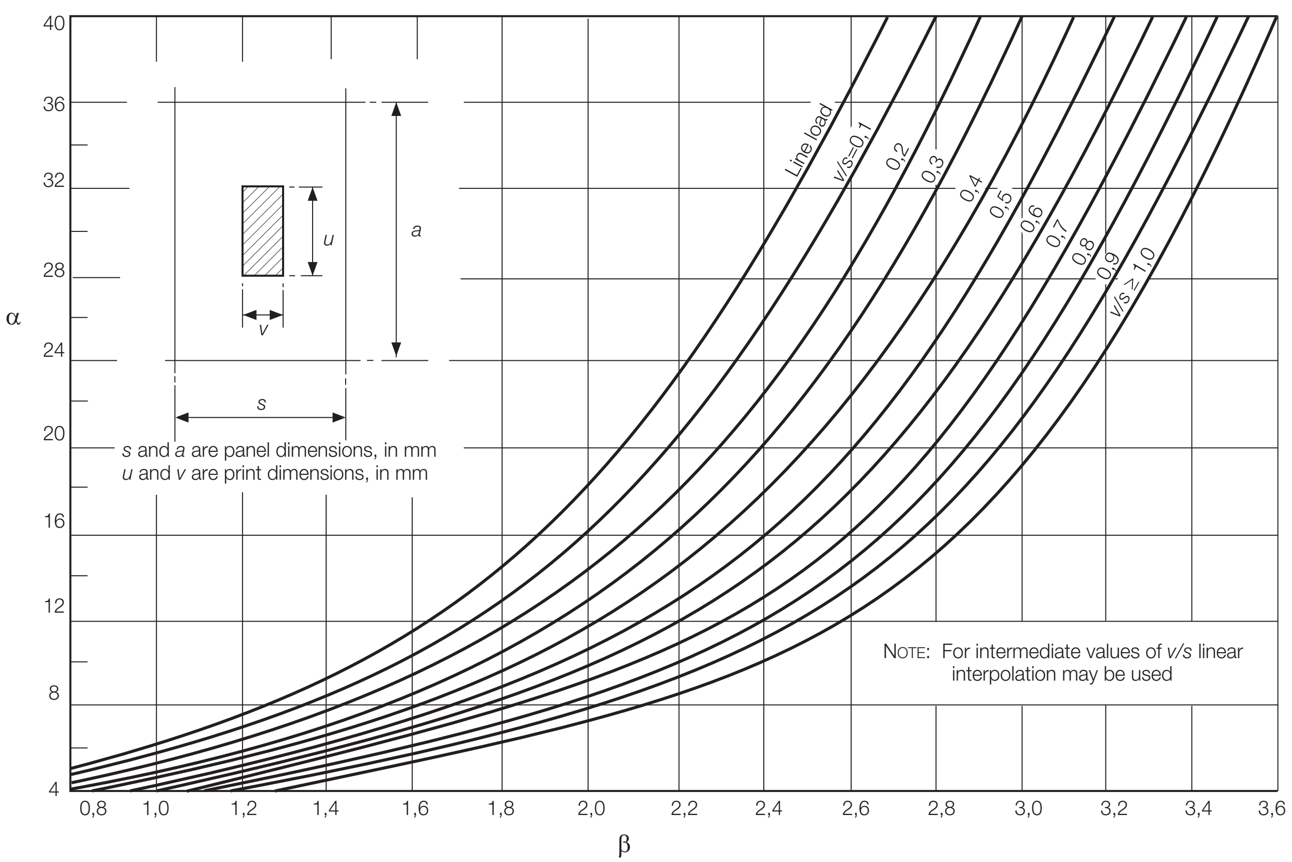


Fig. 9.3.1 Tyre print chart

3.4 Deck plating

3.4.1 The deck plate thickness, t, is to be not less than:

$t = t_1 + t_c$ mm

where

t_c = wear and wastage allowance determined from Table 9.3.2

$$t_1 = \frac{\alpha s}{1000\sqrt{k}} \text{ mm}$$

P_1 = corrected patch load obtained from Table 9.3.1

α = thickness coefficient obtained from Fig. 9.3.1

β = tyre print coefficient used in Fig. 9.3.1

$$= \log_{10}\left(\frac{P_1\,k^2}{s^2} \times 10^7\right)$$

3.4.2 Where transversely framed decks contribute to the hull girder strength, or where secondary stiffening is fitted perpendicular to the direction of vehicle lanes, the thickness, t, derived from 3.4.1 is to be increased by 1,0 mm.

3.4.3 Where decks are designed for the exclusive carriage of unladen wheeled vehicles, the deck plate thickness, t, may be reduced as follows:

$t = (t_1 - 0{,}75) + t_c$ mm.

3.4.4 Where it is proposed to carry tracked vehicles, the patch dimensions may be taken as the track print dimensions and P_w is to be taken as half the total weight of the vehicle. The wear and wastage allowance from Table 9.3.2 is to be increased by 0,5 mm. Deck fittings in way of vehicle lanes are to be recessed.

Table 9.3.2 Wear and wastage allowance

Location	t_c, in mm
Strength deck, weather decks, decks forming crown of tank, inner bottom	1,5
Internal decks elsewhere	0,75

Table 9.3.3 Tyre correction factor, n

Number of wheels in idealised patch	Pneumatic tyres	Solid rubber tyres	Steel or solid tyres
1 2 or more	0,6 0,75	0,8 0,9	1,0 1,0

3.4.5 If wheeled vehicles are to be used on insulated decks or tank tops, consideration will be given to the permissible loading in association with the insulation arrangements and the plating thickness.

3.5 Deck longitudinals and beams

3.5.1 The section modulus, Z, of deck longitudinals or beams is to be not less than that required for a weather or cargo deck as appropriate, nor less than the following:

(a) For general purpose cargo decks where fork lift trucks are to be used:

$Z = (0{,}375 K_1\, P\, l_e + 0{,}001\,25 K_2\, h\, s\, l_e^2)\, k$ cm^3.

(b) For permanent vehicle decks in association with a value of h which need not exceed 2,5 m:

h = normal load height on the deck, in metres

P = total weight, in tonnes, of the vehicle divided by the number of axles. Where distribution of weight is not uniform, P is to be taken as the maximum axle load. For fork lift trucks the total weight is to be applied to one axle

$Z = (0{,}536 K_1\, P\, l_e + 0{,}00125\, K_2\, h\, s\, l_e^2)\, k$ cm^3

where the values of K_1 and K_2 are given in Table 9.3.4.

(c) For decks designed for the carriage of wheeled vehicles only that required to satisfy the most severe arrangement of print wheel loads on the stiffener in association with a bending stress of $\frac{100}{k}$ N/mm^2 $\left(\frac{10{,}2}{k}\text{ kgf/mm}^2\right)$ assuming 100 per cent end fixity.

Table 9.3.4 Values of K_1 and K_2

Wheel spacing* / Beam span	K_1	K_2
0,1	15,4	1,89
0,2	14,6	1,845
0,3	13,35	1,730
0,4	11,8	1,55
0,5 and greater	10,1	1,30

* Outer wheel to outer wheel on axles with multiple wheel arrangements

3.6 Deck girders and transverses

3.6.1 Where the load on deck girders and transverses is uniformly distributed, the section modulus is to be not less than:

$Z = 4{,}75 b\, h\, l_e^2\, k$ cm^3

where

h is defined in 3.5.1

b = mean width of plating supported by a deck girder or transverse, in metres.

3.6.2 Where the member supports point loads, with or without the addition of uniformly distributed load, the section modulus is to be based on a stress of $\frac{123{,}6}{k}$ N/mm^2 $\left(\frac{12{,}6}{k}\text{ kgf/mm}^2\right)$, assuming 100 per cent end fixity.

3.6.3 Where it is proposed to carry tracked vehicles, the total weight of the vehicle is to be taken when determining the section modulus of the transverse at the top of a ramp or at other changes of gradient.

3.7 Direct calculations

3.7.1 As an alternative to the above, permissible deck loads may be determined by direct calculation. The assumed loadings in these calculations are to include suitable allowance for weather, generally 2,16 kN/m^2 (0,22 tonne-f/m^2), where applicable.

3.8 Hatch covers

3.8.1 Where wheeled vehicles are to be used, the hatch cover plating is to be not less in thickness than that required by 3.4, and the modulus of the stiffeners is to be not less than:

$$Z = (K_3 P l_e + 0{,}00167 K_4 h s l_e^2)\, k$$

where the values of K_3 and K_4 are given in Table 9.3.5 and P and h are defined in 3.5.1.
In no case, however, are the scantlings of plating and stiffeners to be less than would be required as a weather or cargo deck hatch cover, as applicable.

Table 9.3.5 Values of K_3 and K_4

Wheel spacing* / Stiffener span	K_3	K_4
0,1	11,96	2,32
0,2	10,69	1,89
0,3	9,58	1,55
0,4	8,46	1,28
0,5	7,46	1,07
0,6	6,51	0,91
0,7	5,55	0,73
0,8	4,23	0,36
0,9	2,38	0,11

* Outer wheel to outer wheel on axles with multiple wheel arrangements

3.8.2 Where unusual arrangements of hatch cover stiffening are proposed, the scantlings may be determined by direct calculations using a two-dimensional grillage idealisation, and the parameters given in Table 11.2.3 in Chapter 11.

3.9 Train decks

3.9.1 Decks for the transport of railway rolling stock on fixed rails will be specially considered.

3.10 Heavy and special loads

3.10.1 Where heavy or special loads, such as machinery transporters, are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered.

3.11 Securing arrangements

3.11.1 Details of the connections to the hull of vehicle securing arrangements are to be submitted for approval.

■ *Section 4* Movable decks

4.1 Classification

4.1.1 Movable vehicle decks hoisted by means of a hydraulic or electrical winch, or lifted by a mechanical lift on board the ship, are to comply with Chapter 6 of LR's *Code for Lifting Appliances in a Marine Environment*.

4.1.2 Movable decks other than described in 4.1.1, and which are subjected to general cargo loading, are to comply with the requirements of this Section.

4.2 Symbols

4.2.1 The symbols used in this Section are defined in 1.2 and in the appropriate sub-Section.

4.3 Arrangements and design

4.3.1 Movable decks are generally to be constructed as pontoons comprising a web structure with top decking. Other forms of construction will be individually considered.

4.3.2 These requirements assume that the pontoons are to be constructed of steel. Other materials will be considered on the basis of equivalent strength.

4.3.3 Positive means of control are to be provided to secure decks in the lowered position.

4.3.4 The decks are to be efficiently supported, and hinges, pillars, chains or other means (or a combination of these) are to be designed on the basis of the imposed loads. Where supporting chains and fittings are required, they are to have a factor of safety of at least two on the proof load.

4.3.5 Plans showing the proposed scantlings and arrangements of the system are to be submitted.

4.3.6 Where it is proposed to stow the pontoons on deck, when not in use, details of the proposals for racks, fittings, etc., are to be submitted for consideration.

4.4 Loading

4.4.1 Design loading for general cargo is to be specified on the plans, together with details of fork lift trucks where appropriate, and submitted for consideration.

4.5 Pontoon deck plating

4.5.1 Where the pontoon is constructed of steel decking with stiffening webs, the deck plate thickness, t, is to be not less than that required by 3.4.

4.5.2 The plate thickness, t, for aluminium pontoons is to be not less than:

$t = (1,4t_1 + 0,75)$ mm

where

t_1 is the mild steel thickness as determined from 3.4. For aluminium pontoons designed for the exclusive carriage of unladen wheeled vehicles:

$t = 1,4t_1$ mm

4.5.3 Where it is proposed to use plywood decking, the arrangement and thickness will be considered. Plywood alone, is not, generally, to be used for axle loads in excess of 7,8 kN (0,8 tonne-f).

4.5.4 Attention is drawn to National fire regulations which in certain cases may ban the use of plywood and certain other materials in 'special category spaces' on passenger ships.

4.6 Pontoon webs and stiffeners

4.6.1 The section modulus of webs and stiffening of steel pontoons is to be not less than:

$Z = (0,375K_1 \, P \, l_e + 0,00125K_2 \, h \, s \, l_e^2) \, k$ cm^3

for general-purpose cargo decks where fork lift trucks may be used

where the values of K_1 and K_2 are given in Table 9.4.1, and

h = load height of cargo on the deck, where this is proposed to be carried, in metres

P = the total fok lift truck load, in tonnes, is to be applied to one axle.

Table 9.4.1 Values of K_1 and K_2

Wheel spacing* / Beam span	K_1	K_2
0,1	15,4	1,89
0,2	14,6	1,845
0,3	13,35	1,730
0,4	11,8	1,55
0,5 and greater	10,1	1,30

* Outer wheel to outer wheel on axles with multiple wheel arrangements

4.6.2 The section modulus of webs and stiffening of aluminium pontoons is to be not less than that defined in 4.6.1 replacing k by k_a where k_a is defined in Ch 2,1.

4.6.3 Where plywood decking is proposed, or in other arrangements where the decking is not integral with the stiffening webs, the arrangement of the grillage of webs is to be such as to provide the required strength.

4.7 Deflection

4.7.1 Where wheeled vehicles are to be used, the supporting arrangements are to be such that the movement at the edge of one pontoon relative to the next does not exceed 50 mm during loading or unloading operations.

4.8 Direct calculations

4.8.1 As an alternative to 4.3 to 4.7, the structure may be designed on the basis of a direct calculation using a grillage idealisation. The method adopted and the stress levels proposed for the material of construction are to be submitted for consideration.

■ *Section 5* Helicopter landing areas

5.1 General

5.1.1 Where it is proposed to provide a helicopter landing area on the ship, the structure is to be designed to suit the largest helicopter type which it is intended to use.

5.1.2 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the ship. These include SOLAS Chapter II-2 Regulation 18 and Chapter III Regulation 28 as applicable. Guidance on the provision and operation of helicopter landing or winching facilities may be drawn from international standards such as the *International Chamber of Shipping (ICS) Guide to Helicopter/Ship Operations* and the *International Aeronautical Search and Rescue Manual (IAMSAR)*.

5.1.3 Plans are to be submitted showing the proposed scantlings and arrangements of the structure. The type, size and weight of helicopters to be used are also to be indicated. Details of the helicopter types to be used are to be included in the Loading Manual (*see* Ch 4,8.2) and be contained in a notice displayed on the helicopter landing deck.

5.1.4 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

5.2 Symbols

5.2.1 The symbols in this Section are defined in 1.2 and in the appropriate sub-Section.

5.3 Arrangements

5.3.1 The landing area is to be sufficiently large to allow for the landing and manoeuvring of the helicopter, and is to be approached by a clear landing and take-off sector complying in extent with the applicable Regulations, International Standards, or to the satisfaction of the National Authority.

5.3.2 The landing area is to be free of any projections above the level of the deck. Projections in the zone surrounding the landing area are to be kept below the heights permitted by the Regulations, International Standards, or to the satisfaction of the National Authority.

5.3.3 Suitable arrangements are to be made to minimise the risk of personnel or machinery sliding off the landing area. A non-slip surface and anchoring devices are to be provided.

5.3.4 Engine uptake arrangements are to be sited such that exhaust gases cannot be drawn into helicopter engine intakes during helicopter take off or landing operations.

5.4 Landing area plating

5.4.1 The deck plate thickness, t, within the landing area is to be not less than:

$t = t_1 + 1,5$ mm

where

$t_1 = \dfrac{\alpha s}{1000\sqrt{k}}$ mm

α = thickness coefficient obtained from Fig. 9.3.1

β = tyre print coefficient used in Fig. 9.3.1

$= \log_{10}\left(\dfrac{P_1 k^2}{s^2} \times 10^7\right)$

The plating is to be designed for the emergency landing case taking:

$P_1 = 2,5\,\phi_1\,\phi_2\,\phi_3\,f\,\gamma\,P_w$ tonnes

in which ϕ_1, ϕ_2, ϕ_3 are to be determined from Table 9.3.1

f = 1,15 for landing decks over manned spaces, e.g., deckhouses, bridges, control rooms, etc.

= 1,0 elsewhere

P_h = the maximum all-up weight of the helicopter, in tonnes

P_w = landing load, on the tyre print in tonnes; for helicopters with a single main rotor, P_w is to be taken as P_h divided equally between the two main undercarriage wheels, for helicopters with tandem main rotors, P_w is to be taken as P_h distributed between all main undercarriage wheels in proportion to the static loads they carry For helicopters fitted with landing gear consisting of skids, P_w is to be taken as P_h distributed in accordance with the actual load distribution given by the airframe manufacturer. If this is unknown, P_w is to be taken as $1/6P_h$ for each of the two forward contact points and $1/3P_h$ for each of the two aft contact points. The load may be assumed to act as a 300 mm x 10 mm line load at each end of each skid when applying Fig. 9.3.1.

γ = a location factor given in Table 9.5.1.

For wheeled undercarriages, the tyre print dimensions specified by the manufacturer are to be used for the calculation. Where these are unknown, it may be assumed that the print area is 300 x 300 mm and this assumption is to be indicated on the submitted plan.

For skids and tyres with an asymmetric print, the print is to be considered oriented both parallel and perpendicular to the longest edge of the plate panel and the greatest corresponding value of α, taken from Fig. 9.3.1.

Table 9.5.1 Location factor

Location	γ	
On decks forming part of the hull girder (a) within 0,4L amidships (b) at the F.P. or A.P.	 0,71 0,6	Values for intermediate locations are to be determined by interpolation
Elsewhere	0,6	

5.4.2 The plate thickness for aluminium decks is to be not less than:

$t = 1,4t_1 + 1,5$ mm

where

t_1 is the mild steel thickness as determined from 5.4.1.

5.5 Deck stiffening and supporting structure

5.5.1 The helicopter deck stiffening and the supporting structure for helicopter platforms are to be designed for the load cases given in Table 9.5.2 in association with the permissible stresses given in Table 9.5.3. The helicopter is to be positioned so as to produce the most severe loading condition for each structural member under consideration.

5.5.2 The minimum moment of inertia, I, of aluminium secondary structure stiffening is to be not less than:

$I = \dfrac{5,25}{k_a} Z\, l_e$ cm^4

where

Z is the required section modulus of the aluminium stiffener and attached plating and k_a as defined in 4.6.2.

5.5.3 Where a grillage arrangement is adopted for the platform stiffening, it is recommended that direct calculation procedures be used.

5.6 Bimetallic connections

5.6.1 Where aluminium alloy platforms are connected to steel structures, details of the arrangements in way of the bimetallic connections are to be submitted.

Table 9.5.2 Design load cases for deck stiffening and supporting structure

Loadcase	Loads			
	Landing area		Supporting structure (*See* Note 1)	
	UDL, in kN/m^2 (tonne-f/m^2)	Helicopter patch load (*See* Note 2)	Self weight	Horizontal load (*See* Note 2)
(1) Overall distributed loading	2 (0,2)	—	—	—
(2) Helicopter emergency landing	0,5 (0,05)	$2{,}5P_{w}f$	W_h	$0{,}5P_h$
(3) Normal usage	0,5 (0,05)	$1{,}5P_w$	W_h	$0{,}5P_h + 0{,}5W_h$

Symbols

P_h,P_w as defined in 5.4.1
UDL = Uniformly distributed vertical load over entire landing area
W_h = structural self-weight of helicopter platform

NOTES
1. For the design of the supporting structure for helicopter platforms, applicable self weight and horizontal loads are to be added to the landing area loads.
2. The helicopter is to be so positioned as to produce the most severe loading condition for each structural member under consideration.

Table 9.5.3 Permissible stresses for deck stiffening and supporting structure

Loadcase (*See* Table 9.5.2)	Permissible stresses, in N/mm^2 (kgf/mm^2)			
	Deck secondary structure (beams, longitudinals) (*See* Notes 1 and 2)	Primary structure (transverses, girders, pillars, trusses)		All structure
	Bending		Combined bending and axial	Shear
(1) Overall distributed loading	$\dfrac{147}{k}\ \left(\dfrac{15}{k}\right)$	$\dfrac{147}{k}\ \left(\dfrac{15}{k}\right)$	$0{,}6\sigma_c$	$\dfrac{\text{Bending}}{\sqrt{3}}$
(2) Helicopter emergency landing	$\dfrac{245}{k}\ \left(\dfrac{25}{k}\right)$	$\dfrac{220{,}5}{k}\ \left(\dfrac{22{,}5}{k}\right)$	$0{,}9\sigma_c$	
(3) Normal usage	$\dfrac{176}{k}\ \left(\dfrac{18}{k}\right)$	$\dfrac{147}{k}\ \left(\dfrac{15}{k}\right)$	$0{,}6\sigma_c$	

Symbols

k = a material factor:
= as defined in 1.2 for steel members
= k_a as defined in 4.6.2 for aluminium alloy members
σ_c = yield stress, 0,2% proof stress or compressive buckling stress, in N/mm^2 (kgf/mm^2), whichever is the lesser

NOTES
1. For strength deck longitudinals and girders, the permissible bending stresses are to be reduced as follows:
   (a) within 0,4*L* of amidships – by 30%
   (b) at the F.P. or A.P. – by 0%
   Values at intermediate locations are to be determined by interpolation between (a) and (b).
2. When determining bending stresses in secondary structure, for compliance with the above permissible stresses, 100% end fixity may be assumed.

Section 6 Lifting appliances and support arrangements

6.1 General

6.1.1 Masts, derrick posts, crane pedestals and similar supporting structures are classification items, and the scantlings and arrangements are to comply with LR's requirements whether or not LR is also requested to issue the Register of Ships' Cargo Gear and Lifting Appliances.

6.1.2 Where the lifting appliance is considered to be an essential feature of a classed ship, the special feature class notation **LA** will, in general, be mandatory.

6.1.3 Elsewhere, classification of lifting appliances is optional and may be assigned at the request of the Owner on compliance with the appropriate requirements.

6.1.4 Certain movable support structures and lifting appliances on special purpose vessels which are considered an essential feature of the vessel are to be included in the classification of the vessel.

6.1.5 Proposals to class lifting appliances on unclassed ships will be specially considered.

6.2 Masts, derrick posts and crane pedestals

6.2.1 The scantlings of masts and derrick posts, intended to support derrick booms, conveyor arms and similar loads, and of crane pedestals, are to comply with the requirements of LR's Code for *Lifting Appliances in a Marine Environment* (hereinafter referred to as LAME).

6.2.2 In addition to the information and plans requested in LR's LAME the following details are to be submitted:

(a) Details of masthouses or other supports for the masts, derrick posts or crane pedestals, together with details of the attachments to the hull structure.

(b) Details of any reinforcement or additional supporting material fitted to the hull structure in way of the mast, derrick post or crane pedestal.

6.3 Support structure for masts, derrick posts and crane pedestals

6.3.1 The requirements of 6.3.2 and 6.3.3 are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation, *see* Pt 1, Ch 2,2.3.

6.3.2 Masts, derrick posts and crane pedestals are to be efficiently supported and, in general, are to be carried through the deck and satisfactorily scarfed into a transverse hold or 'tween deck bulkhead. Alternatively, the masts, derrick posts or crane pedestals may be carried into a mast house, in which case the mast house is to be of substantial construction. Proposals for other support arrangements will be specially considered.

6.3.3 Deck plating and underdeck structure are to be reinforced under masts, derrick posts or crane pedestals and, where the deck is penetrated, the deck plating is to be suitably increased locally.

6.4 Lifting appliances

6.4.1 Ships or offshore units fitted with lifting appliances built in accordance with LR's LAME in respect of structural and machinery requirements will be eligible to be assigned Special Features class notations as listed in Table 9.6.1. This notation will be retained so long as the appliances are found upon examination at the prescribed surveys to be maintained in accordance with LR's requirements.

Table 9.6.1 Special features class notations associated with lifting appliances

Lifting appliance	Special features class notation	Remarks
Derricks, derrick cranes or cranes on ships	**CG**	Optional notation. Indicates that the ship's cargo gear is included in class.
Cranes on offshore installations	**PC**	Optional notation. Indicates that the installation's platform cranes are included in class.
Lifts and ramps on ships	**CL** **PL** **CR**	Optional notations. Indicate that the ship's cargo lifts (**CL**), passenger lifts (**PL**) or cargo ramps (**CR**) are included in class.
Lifting appliances forming an essential feature of the vessel, e.g., cranes on crane barges or pontoons, lifting arrangements for diving on diving support ships, etc.	**LA**	Mandatory notation. Indicates that the lifting appliance is included in class.

■ *Section 7*
Bottom strengthening for loading and unloading aground

7.1 Application

7.1.1 Where a ship of length, *L*, less than 90 m has the bottom structure additionally strengthened for loading and unloading aground in accordance with Table 9.7.1, it will be eligible for the special features notation 'bottom strengthened for loading and unloading aground'. Ships of length, *L*, 90 m or more intended for this service will receive individual consideration.

7.1.2 For dredgers intended to operate aground, the requirements of Pt 4, Ch 12 are to be applied.

Table 9.7.1 Bottom strengthening for loading and unloading aground

<table>
<tr><th>Item</th><th colspan="2">Requirement</th></tr>
<tr><td colspan="3">The following requirements are to be applied to the bottom structure upon which the ship is likely to be supported whilst aground</td></tr>
<tr><td>(1) Bottom shell and keel plating</td><td colspan="2">Thickness to be increased by 20% over the minimum requirements given in Part 4 for the particular type of ship with a minimum of 8 mm</td></tr>
<tr><td>(2) Bottom longitudinals in way of single bottoms</td><td colspan="2">For dry cargo ships, as required in way of double bottoms, see item (3)

For oil tankers, scantlings as required by Table 9.5.1 in Pt 4, Ch 9 in taking c_1 = 1,0</td></tr>
<tr><td>(3) Bottom longitudinals in way of double bottoms, see Note 1</td><td colspan="2">For dry cargo ships, scantlings as required by Table 1.6.1 in Pt 4, Ch 1 in taking c_1 = 1,0</td></tr>
<tr><td>(4) Bilge longitudinals (where fitted)</td><td colspan="2">Scantlings to be the same as bottom longitudinals</td></tr>
<tr><td rowspan="2">(5) Primary stiffening in way of single bottoms, see Notes 2 and 3</td><td>Transverse framing</td><td>Longitudinal framing</td></tr>
<tr><td>(a) Floors to be fitted at every frame with vertical stiffeners spaced, in general, not more than 1,25 m apart
(b) One side girder is to be fitted on each side of the centreline in addition to the requirements of Pt 4, Ch 1,7 and intermediate 150 x 10 bulb plate longitudinals or equivalent fitted</td><td>(a) The arrangements and scantlings will receive individual consideration depending on the structural arrangements of the particular ship type
(b) The spacing of transverse or floors is, in general, not to exceed 1,85 m</td></tr>
<tr><td>(6) Primary stiffening in way of double bottoms, see Notes 1, 2 and 3</td><td>(a) Plate floors are to be fitted at every frame and vertical stiffening arranged to give panel widths, in general, not exceeding 1,25 m
(b) One side girder is to be fitted on each side of the centreline in addition to the requirements of Pt 4, Ch 1,8 and intermediate 150 x 10 bulb plate longitudinals or equivalent fitted</td><td>(a) The spacing of floors is, in general, not to exceed 1,85 m
(b) One side girder is to be fitted on each side of the centreline in addition to the requirements of Pt 4, Ch 1,8</td></tr>
<tr><td colspan="3">NOTES
1. For oil tankers, to be specially considered.
2. The scantlings of floors, girders and transverses are to be determined from Part 4, for the particular ship type.
3. The number and sizes of holes in floors, girders and transverses are to be kept to a minimum; see Pt 4, Ch 1,8 and Pt 4, Ch 9,6.</td></tr>
</table>

■ *Section 8* Strengthening for regular discharge by heavy grabs

8.1 Application

8.1.1 For bulk carriers where cargoes are regularly discharged by heavy grabs and the thickness of the plating of the hold inner bottom, hopper and transverse bulkhead bottom stool is increased in accordance with the requirements of this Section, the ship will, at the Owner's option, be assigned the notation 'strengthened for regular discharge by heavy grabs'.

8.1.2 It should be noted that damage to the plating cannot be excluded even when complying with these requirements and can result from the mishandling of the grabs during the discharge of cargo.

8.1.3 The grab weight given in 9.2.1 does not preclude the use of heavier grabs. It is intended as an indication to the Builders, Owners and operators of the increased risk of local damage and the possibility of accelerated diminution of the plating thickness if grabs heavier than this are used regularly to discharge cargo.

8.1.4 The maximum unladen weight of the grab is to be recorded in the Loading Manual, *see also* Ch 4,8.2.4(e).

8.1.5 The requirements in this Section are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation. *See* Pt 1, Ch 2,2.3.

8.2 Inner bottom plating

8.2.1 The thickness of the inner bottom plating in the holds is to be not less than required by the greater of the following:

(a) $$t = \frac{\left(\log_{10}\left(1{,}775P\left(\frac{k}{s}\right)^2\right) + 5{,}7633\right)s - 344{,}5}{40{,}875\sqrt{k}} + 1{,}5 \text{ mm}$$

(b) t = the Rule required thickness, in mm in accordance with Pt 4, Ch 7,8 for the intended class notation.

where

P = specified unladen grab weight for the hold, in tonnes, and is not to be taken as less than 25 tonnes

s = spacing of inner bottom longitudinals, in mm

k = higher tensile steel factor as defined in Ch 2,1.2.

8.3 Hopper side tank sloped bulkhead plating

8.3.1 The thickness of the sloped bulkhead plating adjacent to the inner bottom knuckle is to be as required by 8.2.1 but based on the actual spacing of stiffeners. The plating of increased thickness is to extend for a minimum distance corresponding to a vertical height of 1,5 m above the line of the inner bottom. Outboard of the plating of increased thickness, the thickness of the adjacent strakes is to be tapered to the Rule thickness for plating, as required by Pt 4, Ch 1,8.4.1, at the top corner of the tank, *see also* Pt 4, Ch 7,9.2.3 where, in addition, the 'strengthened for heavy cargo' notation is desired.

8.4 Transverse bulkhead plating

8.4.1 The thickness of the bulkhead or stool plating adjacent to the inner bottom is to be as required by 8.2.1 but based on the actual spacing of the bulkhead or stool stiffeners. The plating of increased thickness is to extend for a minimum distance corresponding to a vertical height of 1,5 m above the line of the inner bottom.

Section

Section 1
General

1.1 Application

1.1.1 This Chapter is applicable to all ship types and components.

1.1.2 Requirements are given in this Chapter for the following:

(a) Welding-connection details, defined practices and sequence, consumables and equipment, procedures, workmanship and inspection.

(b) End connection scantlings and constructional details for longitudinals, beams, frames and bulkhead stiffeners.

(c) Primary member proportions, stiffening and construction details.

Additional requirements for primary structure of tankers and similar ships are given in Pt 4, Ch 9,6.

1.1.3 The requirements in this Chapter are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation (*see* Pt 1, Ch 2,2.3) with the exception of 2.5 to 2.9 which are to be complied with.

1.2 Symbols

1.2.1 Symbols are defined as necessary in each Section.

1.2.2 The Notation **ESP** serves to identify the ships as being subject to an Enhanced Survey Programme as detailed in Pt 1, Ch 3,3 and Ch 3,7, *see also* Pt 1, Ch 2,2.

Section 2
Welding

2.1 General

2.1.1 The plans to be submitted for approval are to indicate clearly details of the welded connections of main structural members, including the type and size of welds. This requirement includes welded connections to steel castings.

The information to be submitted should include the following:

(a) Whether weld sizes given are throat thicknesses or leg lengths.

(b) Grades and thicknesses of materials to be welded.

(c) Location, types of joints and angles of abutting members.

(d) Reference to welding procedures to be used.

(e) Sequence of welding of assemblies and joining up of assemblies.

2.1.2 Unless otherwise indicated, all welding is to be in accordance with the requirements of Chapter 13 of the Rules for Materials.

2.2 Fillet welds

2.2.1 The throat thickness of fillet welds is to be determined from:

$$\text{Throat thickness} = t_p \times \text{weld factor} \times \frac{d}{s}$$

where

d = the distance between start positions of successive weld fillet, in mm

s = the length, in mm, of correctly proportioned weld fillet, clear of end craters, and is to be not less than 75 mm

t_p = plate thickness, on which weld fillet size is based, in mm

see also Fig. 10.2.1

Weld factors are given in Tables 10.2.1, 10.2.3 and 10.2.4.

2.2.2 Where double continuous fillet welding is proposed, the throat thickness is to be determined taking $\left(\frac{d}{s}\right)$ equal to 1,0.

2.2.3 The leg length of the weld is to be not less than $\sqrt{2}$ times the specified throat thickness.

2.2.4 The plate thickness, t_p, to be used in the above calculation is generally to be that of the thinner of the two parts being joined. Where the difference in thickness is considerable, the size of fillet will be considered.

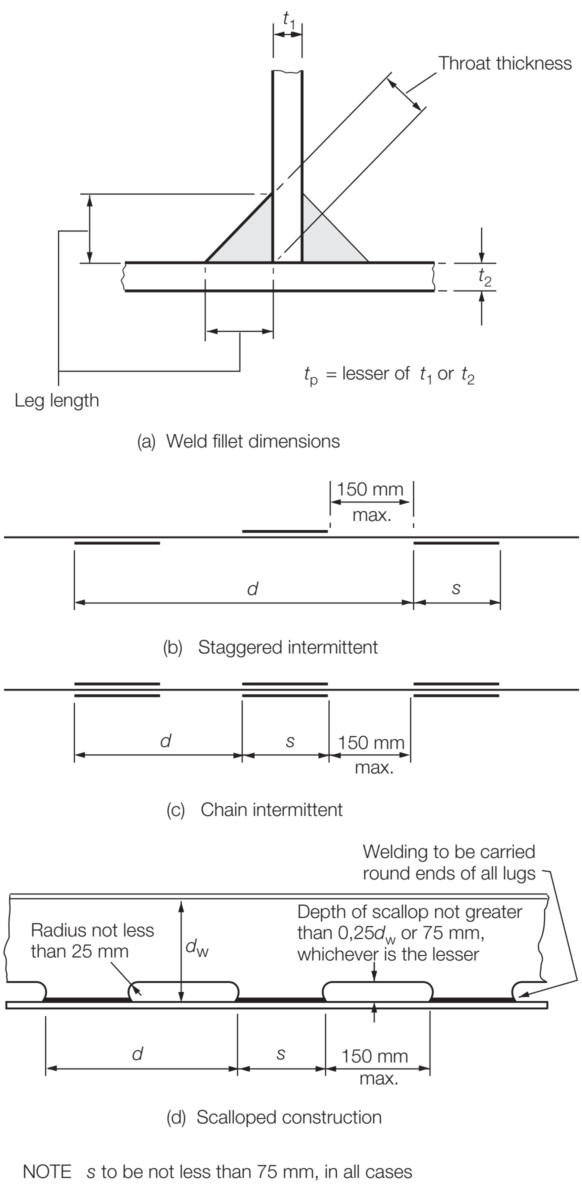


Fig. 10.2.1 Weld types

2.2.5 Where the thickness of the abutting member of the connection (e.g., the web of a stiffener) is greater than 15 mm and exceeds the thickness of the table member (e.g., plating), the welding is to be double continuous and the throat thickness of the weld is to be not less than the greatest of the following:

(a) 0,21 x thickness of the table member. The table member thickness used need not exceed 25 mm.
(b) 0,21 (0,27 in tanks) x half the thickness of the abutting member.
(c) As required by Table 10.2.2.

2.2.6 Except as permitted by 2.2.5, the throat thickness of the weld is not to be outside the limits specified in Table 10.2.2.

2.2.7 Double continuous fillet welding is to be adopted in the following locations, and may be used elsewhere if desired:

(a) Boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings.
(b) Boundaries of tanks and watertight compartments.
(c) All structure in the after peak and the after peak bulkhead stiffeners.
(d) All welding inside tanks intended for chemicals or edible liquid cargoes.
(e) All lap welds in tanks.
(f) Primary and secondary members to bottom shell in the 0,3*L* forward.
(g) Primary and secondary members to plating in way of end connections, and end brackets to plating in the case of lap connections.
(h) Where 2.2.5 applies.
(j) All water ballast tanks.
(k) Other connections or attachments, where considered necessary, and in particular the attachment of minor fittings to higher tensile steel plating.

2.2.8 Where intermittent welding is used, the welding is to be made double continuous in way of brackets, lugs and scallops and at the orthogonal connections with other members.

2.2.9 As an alternative to intermittent welding, single sided welding may be used. Only mechanised single sided welding is acceptable although manual single sided welding may be used at non-critical locations e.g., deck house stiffeners. Where single sided welding is used, the welding is to be made double continuous in way of brackets, lugs and scallops and at the orthogonal connections with other members.

2.2.10 Where structural members pass through the boundary of a tank, and leakage into the adjacent space could be hazardous or undesirable, full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively a small scallop of suitable shape may be cut in the member close to the boundary outside the compartment, and carefully welded all round.

2.3 Welding of primary structure

2.3.1 Weld factors for the connections of primary structure are given in Table 10.2.3.

2.3.2 The weld connection to shell, deck or bulkhead is to take account of the material lost in the notch where longitudinals or stiffeners pass through the member. Where the width of notch exceeds 15 per cent of the stiffener spacing, the weld factor is to be multiplied by:

$$\frac{0{,}85 \text{ x stiffener spacing}}{\text{length of web plating between notches}}$$

2.3.3 Where direct calculation procedures have been adopted, the weld factors for the 0,2 x overall length at the ends of the members will be considered in relation to the calculated loads.

Table 10.2.1 Weld factors (*see continuation*)

Item	Weld factor	Remarks
(1) General application:		except as required below
Watertight plate boundaries	0,34	
Non-tight plate boundaries	0,13	
Longitudinals, frames, beams, and other secondary members to shell, deck or bulkhead plating	0,10 0,13 0,21	 in tanks in way of end connections
Panel stiffeners, etc.	0,10	
Overlap welds generally	0,27	
Longitudinals of the flat-bar type to plating		*see* Note 5
(2) Bottom construction in way of holds or tanks:		
Non-tight centre girder: to keel to inner bottom	0,27 0,21	 no scallops
Non-tight boundaries of floors, girders and brackets	0,21 0,27	in way of 0,2 x span at ends in way of brackets at lower end of main frame
Inner bottom longitudinals or reverse frames	0,13	under holds strengthened for heavy cargoes
Connection of floors to inner bottom in way of plane bulkheads, bulkhead stools, or corrugated and double plate bulkheads supported on inner bottom. The supporting floors are to be continuously welded to the inner bottom	0,44	Weld size based on floor thickness Weld material compatible with floor material *see* Note 4
(3) Hull framing:		
Webs of web frames and stringers: to shell to face plate	 0,16 0,13	
Tank side brackets to shell and inner bottom	0,34	
(4) Decks and supporting structure:		
Strength deck plating to shell		as shown in Table 10.2.5 but alternative proposals will be considered
Other decks to shell and bulkheads (except where forming tank boundaries)	0,21	generally continuous
Webs of cantilevers to deck and to shell in way of root bracket	0,44	
Webs of cantilevers to face plate	0,21	
Pillars: fabricated end connections end connections (tubular)	0,10 0,34 full penetration	 *see* Note 1
Girder web connections and brackets in way of pillar heads and heels	0,21	continuous

2.3.4 The throat thickness limits given in Table 10.2.2 are to be complied with.

2.4 Welding of primary and secondary member end connections

2.4.1 Welding of end connections of primary members is to be such that the area of welding is not less than the cross-sectional area of the member, and the weld factor is to be not less than 0,34 in tanks or 0,27 elsewhere.

2.4.2 The welding of secondary member end connections is to be not less than as required by Table 10.2.4. Where two requirements are given the greater is to be complied with.

2.4.3 The area of weld, A_w, is to be applied to each arm of the bracket or lapped connection.

2.4.4 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the area of weld is to be not less than the cross-sectional area of the member.

Table 10.2.1 Weld factors (*continued*)

Item	Weld factor	Remarks
(5) Bulkheads and tank construction, *see also* Pt 4, Ch 7,10:		
Plane, double plate and corrugated watertight bulkhead boundary at bottom, bilge, inner bottom, deck and connection to shelf plate, where fitted	0,44	weld size to be based on thickness of bulkhead plating weld material to be compatible with bulkhead plating material
Shelf plate connection to stool	0,44	weld size to be based on thickness of stool at junction with shelf plate. Weld material to be compatible with stool material
Plane, double plate and corrugated bulkhead boundaries in way of deep tanks, holds in bulk carriers (*see* 1.1.3) which are floodable for the-sea going ballast condition or for the carriage of oil cargoes (Holds in bulk carriers (*see* 1.1.3) which are partially flooded for harbour conditions will be specially considered):		
– Boundary at bottom, bilge, inner bottom and deck	0,44	
– Connection of stool and bulkhead to lower stool shelf plating	full penetration	
– Connection of stool and bulkhead plating to upper stool shelf plate	0,44	
– Connection of bulkhead plating to hopper and topside tanks	0,44	
– Connection of bulkhead plating to side shell	0,34	
Secondary members where acting as pillars	0,13	
Non-watertight pillar bulkhead boundaries	0,13	
Perforated flats and wash bulkhead boundaries	0,10	
(6) Structure in cargo oil tanks of tankers, *see* 1.1.3:		
Bottom longitudinals to shell	0,21	for forward of 0,3*L*
Longitudinal of flat-bar type to plating		*see* 2.2.5
Connections between primary structural members	0,44 0,34	at bottom at deck
Oiltight bulkhead boundaries:		
longitudinal bulkhead	0,44	*see* Note 2
transverse bulkhead	0,44 0,34	at bottom, *see* Note 3 at deck, sides and longitudinal bulkhead
Vertical corrugations to an inner bottom	full penetration	
Non-tight bulkhead boundaries to plating	0,21	
(7) Structure in cargo tanks of chemical tankers:		
Tank boundary bulkheads:		
Type 1 ship	full penetration	
Type 2 ship		
longitudinal bulkheads	0,44	*see* Note 2
transverse bulkheads	0,44	
Type 3 ship		
longitudinal bulkheads	0,44	*see* Note 2
transverse bulkheads	0,44	at bottom *see* Note 3
transverse bulkheads at deck, sides and longitudinal bulkhead	0,34	
(8) Structure in hoppers of hopper dredgers, etc.:		
Bulkhead boundary connections	0,44 0,34	at bottom and bilge at deck and coamings
Cross members to bulkheads and keel	0,44	
Pillar end connections	0,34	
Hopper door hinges	full penetration	generally

Table 10.2.1 Weld factors (*continued*)

Item	Weld factor	Remarks
(9) Structure in machinery space:		
Centre girder to keel and inner bottom	0,27	
Floors to centre girder in way of engine, thrust and boiler bearers	0,27	
Floors and girders to shell and inner bottom	0,21	
Main engine foundation girders: to top plate to hull structure	deep penetration to depend on design	edge to be prepared with maximum root 0,33t_p deep penetration generally
Floors to main engine foundation girders	0,27	
Brackets, etc., to main engine foundation girders	0,21	
Transverse and longitudinal framing to shell	0,13	
(10) Construction in 0,25*L* forward:		
Floors and girders to shell and inner bottom	0,21	
Bottom longitudinals to shell	0,13	
Transverse and longitudinal side framing to shell	0,13	
Tank side brackets to frame and inner bottom	0,34	
Panting stringers to shell and frames	0,34	
Fore peak construction: all internal structure	0,13	unless a greater weld factor is required
(11) After peak construction:		
All internal structure and stiffeners on after peak bulkhead	0,21	unless a greater weld factor is required
(12) Superstructure and deckhouses:		
Connection of external bulkheads to deck	0,34 0,21	1st and 2nd tier erections elsewhere
Internal bulkheads	0,13	
(13) Hatchways and closing arrangements:		
Hatchways coamings to deck	0,34	0,44 at corners
Hatch cover rest bar	0,16	
Hatch coaming stays to coaming	0,13	
Hatch coaming stays to deck	0,21	
Cleats and fittings	0,44	full penetration welding may be required
Primary and secondary stiffening of hatch covers	0,10	0,13 for tank covers and where covers strengthened for loads over
(14) Steering control systems:		
Rudder: Fabricated mainpiece and mainpiece to side plates and webs	0,44	
Slot welds inside plates	0,44	
Remaining construction	0,21	
Fixed and steering nozzles: Main structure Elsewhere	0,44 0,21	
Fabricated housing and structure of thruster units, stabilisers, etc.: Main structure Elsewhere	0,44 0,21	

Table 10.2.1 Weld factors (*conclusion*)

Item	Weld factor	Remarks
(15) Miscellaneous fittings and equipment:		
Rings for manhole type covers, to deck or bulkhead	0,34	
Frames of shell and weathertight bulkhead doors	0,34	
Stiffening of doors	0,21	
Ventilator, air pipe, etc., coamings to deck	0,34 0,21	Load Line Positions 1 and 2 elsewhere
Ventilator, etc., fittings	0,21	
Scuppers and discharges, to deck	0,44	
Masts, derrick posts, crane pedestals, etc., to deck	0,44	full penetration welding may be required
Deck machinery seats to deck	0,21	generally
Mooring equipment seats	0,21	generally, but increased or full penetration welding may be required
Bulwark stays to deck	0,21	
Bulwark attachment to deck	0,34	
Guard rails, stanchions, etc., to deck	0,34	
Bilge keel ground bars to shell	0,34	Continuous fillet weld, minimum throat thickness 4 mm
Bilge keels to ground bars	0,21	Light continuous fillet weld, minimum throat thickness 3 mm
Fabricated anchors	full penetration	

NOTES

1. Where pillars are fitted inside tanks or under watertight flats, the end connection is to be such that the tensile stress in the weld does not exceed 108 N/mm^2 (11 kgf/mm^2).
2. t_p need not be taken greater than the thickness determined from item 1(a) or 1(b) and Notes, as appropriate, of Table 9.6.1 in Pt 4, Ch 9, but in no case is the weld throat thickness to be less than 0,34 x actual plate thickness.
3. t_p need not be taken greater than the Rule thickness determined from Table 9.7.1 of Pt 4, Ch 9 for stiffener spacing of 760 mm, but in no case is the weld throat thickness to be less than 0,34 x actual plate thickness.
4. In way of bulkhead stools in ballast holds of bulk carriers or in tanks at longitudinal girder/transverse floor intersection, cut-outs are to be omitted and full penetration welding is to be applied to both floor and girder for a distance of 150 mm on either side of intersection.
5. The throat thickness of the weld is to be determined by 2.2.5. For longitudinals within D/4 of the strength deck and with a thickness less than 100 mm, the throat thickness need not exceed 5,5 mm.

2.4.5 Where the secondary member passes through, and is supported by, the web of a primary member, the weld connection is to be in accordance with the following:

(a) In strengthening of bottom forward region: Comply with the requirements of Ch 5,1.5.

(b) Elsewhere: Comply with the requirements of 5.2.

2.4.6 The throat thickness limits given in Table 10.2.2 are to be complied with.

2.5 Welding equipment

2.5.1 Welding plant and equipment are to be in accordance with the requirements specified in Ch 13,1.8 of the Rules for Materials.

2.6 Welding consumables and equipment

2.6.1 Welding consumables used and associated equipment is to be in accordance with the requirements specified in Ch 13,1.8 of the Rules for Materials.

2.7 Welding procedures and welder qualifications

2.7.1 Welding procedures are to be established for the welding of all joints in accordance with the requirements specified in Ch 13,1.9 of the Rules for Materials.

2.7.2 All welding procedures are to be tested and qualified in accordance with the requirements of Chapter 12 of the Rules for Materials and are to be approved by the Surveyor prior to construction.

2.7.3 Welders and welding operators are to be proficient in the type of work to be undertaken and are to be qualified in accordance with the requirements specified in Chapter 12 of the Rules for Materials.

Table 10.2.2 Throat thickness limits

Item	Throat thickness, in mm	
	Minimum	Maximum
(1) Double continuous welding	$0{,}21t_p$	$0{,}44t_p$
(2) Intermittent welding	$0{,}27t_p$	$0{,}44t_p$ or 4,5
(3) All welds, overriding minimum:		
(a) Plate thickness $t_p \leq 7{,}5$ mm		
Hand or automatic welding	3,0	—
Automatic deep penetration welding	3,0	—
(b) Plate thickness $t_p > 7{,}5$ mm		
Hand or automatic welding	3,25	—
Automatic deep penetration welding	3,0	—

NOTES
1. In all cases, the limiting value is to be taken as the greatest of the applicable values given above.
2. Where t_p exceeds 25 mm, the limiting values may be calculated using a notional thickness equal to $0{,}4\,(t_p + 25)$ mm.
3. The maximum throat thicknesses shown are intended only as a design limit for the approval of fillet welded joints. Any welding in excess of these limits is to be to the Surveyor's satisfaction.

2.8 Workmanship and shipyard practice

2.8.1 A sufficient number of skilled supervisors is to be provided to ensure an effective and systematic control at all stages of welding operations.

2.9 Inspection of welds

2.9.1 Effective arrangements are to be provided by the Shipbuilder for the inspection of finished welds to ensure that all welding has been satisfactorily completed.

2.9.2 All finished welds are to be subjected to non-destructive examination by personnel designated by the Builder in accordance with the requirements specified in Ch 13,2.12 of the Rules for Materials.

2.9.3 In addition to the requirements of 2.9.2, a number of checkpoints are to be examined by volumetric examination as detailed in 2.9.4 to 2.9.9.

2.9.4 Typical locations and number of checkpoints to be taken are shown in Table 10.2.6. Critical locations as identified by *ShipRight FDA Procedure* (*see* Chapter 16) are also to be considered. A plan of the proposed checkpoint locations is to be submitted for approval.

2.9.5 Checkpoints are not to be identified on the ship's structural components prior to the welding taking place. Special treatment is not to be given at these locations except critical locations as identified by *ShipRight FDA Procedure*.

2.9.6 For ultrasonic examination the length of each checkpoint is to be 0,5 m and for radiographic examination the length is to be a minimum of 0,3 m. At weld intersections, examination is to be in both weld directions.

Table 10.2.3 Connections of primary structure

Primary member face area, in cm^2		Position(1)	Weld factor			
			In tanks		In dry spaces	
Exceeding	Not exceeding		To face plate	To plating	To face plate	To plating
	30,0	At ends Remainder	0,21 0,10	0,27 0,16	0,21 0,10	0,21 0,13
30,0	65,0	At ends Remainder	0,21 0,13	0,34 0,27	0,21 0,13	0,21 0,16
65,0	95,0	At ends Remainder	0,34 0,27(2)	0,44(3) 0,34	0,21 0,16	0,27 0,21
95,0	130,0	At ends Remainder	0,34 0,27(2)	0,44(3) 0,34	0,27 0,21	0,34 0,27
130,0		At ends Remainder	0,44 0,34	0,44(3) 0,34	0,34 0,27	0,44(3) 0,34

NOTES
1. The weld factors 'at ends' are to be applied for 0,2 x the overall length of the member from each end, but at least beyond the toes of the member end brackets. On vertical webs the increased welding may be omitted at the top, but is to extend at least 0,3 x overall length from the bottom.
2. Weld factor 0,34 in cargo oil tanks.
3. Where the web plate thickness is increased locally, the weld size may be based on the thickness clear of the increase, but is to be not less than 0,34 x the increased thickness.
4. In tankers over 122 m in length, the weld factor of the connection of bottom transverses to shell, and of side transverses to shell and vertical webs to longitudinal and transverse bulkheads all in the lower half depth, is to be not less than 0,34.
5. The final throat thickness of the weld fillet to be not less than $0{,}34t_p$ in cargo oil tanks.

Table 10.2.4 Secondary member end connection welds

Connection	Weld area, A_w, in cm^2	Weld factor
(1) Stiffener welded direct to plating	$0{,}25A_s$ or 6,5 cm^2 whichever is the greater	0,34
(2) Bracketless connection of stiffeners or stiffener lapped to bracket or bracket lapped to stiffener:		
(a) in dry space	$1{,}2\sqrt{Z}$	0,27
(b) in tank	$1{,}4\sqrt{Z}$	0,34
(c) main frame to tank side bracket in 0,15L forward	as (a) or (b)	0,34
(3) Bracket welded to face of stiffener and bracket connection to plating	—	0,34
(4) Stiffener to plating for 0,1 x span at ends, or in way of end bracket if that be greater	—	0,34

Symbols

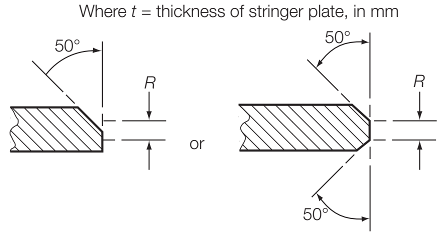
A_s = cross sectional area of the stiffener, in cm^2
A_w = the area of the weld, in cm^2, and is calculated as total length of weld, in cm, x throat thickness, in cm
Z = the section modulus, in cm^2, of the stiffener on which the scantlings of the bracket are based, *see* Section 3

NOTE
For maximum and minimum weld fillet sizes, *see* Table 10.2.2.

Table 10.2.5 Weld connection of strength deck plating to sheerstrake

Item	Stringer plate thickness, mm	Weld type
1	$t \leq 15$	Double continuous fillet weld with a weld factor of 0,44
2	$15 < t \leq 20$	Single vee preparation to provide included angle of 50° with root $R \leq {}^1/_3 t$ in conjunction with a continuous fillet weld having a weld factor of 0,39 or Double vee preparation to provide included angles of 50° with root $R \leq {}^1/_3 t$
3	$t > 20$	Double vee preparation to provide included angles of 50° with root $R \leq {}^1/_3 t$ but not to exceed 10 mm

Where t = thickness of stringer plate, in mm



Single vee preparation Double vee preparation

NOTES
1 Welding procedure, including joint preparation, is to be specified. Procedure is to be qualified and approved for individual Builders.
2. *See also* 2.2.10.
3. For thickness t in excess of 20 mm the stringer plate may be bevelled to achieve a reduced thickness at the weld connection. The length of the bevel is in general to be based on a taper not exceeding 1 in 3 and the reduced thickness is in general to be not less than 0,65 times the thickness of stringer plate or 20 mm, whichever is the greater.
4. Alternative connections will be considered.

2.9.7 The Builder is to provide the Surveyor with all the NDE reports of the checkpoints. These reports are to be available for the Surveyor to review within a short time after inspection, normally considered to be within 10 working days of the examination being carried out. Where welds are repaired the NDE report is to include details of examination of both the defective weld and of the re-weld.

2.9.8 Where the Surveyor notes that a checkpoint has been repaired without record of the original defect, the shipyard is to carry out additional examinations on additional lengths of weld. These lengths are to be adjacent to and on both sides of the defective checkpoint. These additional examinations are to be carried out in the presence of the Surveyor and reported in accordance with 2.9.7.

2.9.9 Where checkpoints are found to contain continuous or semi-continuous defects, additional lengths of weld adjacent to and on both sides of the defective length are to be subject to further volumetric examination. The NDE reports are to be submitted in accordance with 2.9.7.

2.9.10 The following non-destructive examination is to be carried out on ships to be assigned the class notation '**Chemical tanker**':

(a) All crossings of butts and seams of cargo tank bulkhead plating which are welded in assembly areas or on the berth.
(b) Where cargo tank boundary welding is completed in assembly areas or on the berth, a minimum of 10 per cent of the total weld length is to be crack detected.
(c) Where side and bottom longitudinal framing and longitudinal stiffeners terminate at transverse bulkheads, a minimum of 10 per cent of the bulkhead boundary connections is to be crack detected in addition to the requirement given in (b).

Table 10.2.6 Checkpoint locations

Item	Location	Checkpoints
Intersections of butts and seams of fabrication and section welds	Throughout: (a) hull envelope, shell envelope and deck structure plating: • at highly stressed areas, *see* Note 1 • remainder (b) longitudinal and transverse bulkheads (c) inner bottom and hopper plating	 all 1 in 2 1 in 2 1 in 2
SDA/FDA	At critical locations identified by SDA or FDA, *see* Note 2	all
Butt welds in plating	Throughout	1 m in 25 m, *see* Notes 3 and 4
Seam welds in plating	Throughout	1 m in 100 m
Butt welds in longitudinals	Hull envelope within 0,4*L* amidships Hull envelope outside 0,4*L* amidships	1 in 10 welds, *see* Note 5 1 in 20 welds
Bilge keel butt welds	Within 0,4*L* amidships Remainder	all 1 in 3
Structural items when made with full penetration welding as follows: • connection of stool and bulkhead to lower stool shelf plating • vertical corrugations to an inner bottom • hopper knuckles • sheerstrake to deck stringer • hatchways coaming to deck	Throughout Hatchway ends within 0,4*L* amidships Hatchway ends outside 0,4*L* amidships Remainder	 1 m in 20 m 1 m in 20 m 1 m in 10 m 1 m in 20 m 1 m in 40 m all 1 in 2 1 in 40 m

NOTES
1. Typically those at sheerstrake, deck stringer, keel strake and turn of bilge.
2. SDA signifies the *ShipRight Structural Design Assessment Procedure*, FDA signifies the *ShipRight Fatigue Design Assessment Procedure*.
3. Checkpoints in butt welds and seam welds are in addition to those at intersections.
4. Welds at inserts used to close openings in hull envelope plating are to be checked by non-destructive examination.
5. Particular attention is to be given to repair rates in butt welds in longitudinals. Additional welds are to be tested if defects such as lack of fusion or incomplete penetration are observed in more than 10 per cent of the welds examined.

(d) Where longitudinal framing and longitudinal bulkhead stiffeners are continuous through transverse bulkheads, 30 per cent each of the bottom and shipside boundaries and 20 per cent of the longitudinal bulkhead boundaries are to be crack detected in addition to the requirement given in (b).

(e) Where transverse framing members are continuous through the cargo tank boundary, a minimum of 10 per cent of boundary connections is to be crack detected.

■ *Section 3* Secondary member end connections

3.1 General

3.1.1 Secondary members, that is longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are generally to be connected at their ends in accordance with the requirements of this Section. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered.

3.1.2 Where end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

3.1.3 Where the section modulus of the secondary member on which the bracket is based (*see* 3.3.2) exceeds 2000 cm^3, the scantlings of the connection will be considered.

3.2 Symbols

3.2.1 The symbols used in this Section are defined as follows:

a, b = the actual lengths of the two arms of the bracket, in mm, measured from the plating to the toe of the bracket
b_f = the breadth of the flange, in mm
t = the thickness of the bracket, in mm
Z = the section modulus of the secondary member, in cm^3.

3.3 Basis for calculation

3.3.1 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the scantlings of the brackets are to be such that their section modulus and effective cross-sectional area are not less than those of the member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member.

3.3.2 In other cases the scantlings of the bracket are to be based on the modulus as follows:

(a) Bracket connecting stiffener to primary member: modulus of the stiffener.
(b) Bracket at the head of a main transverse frame where frame terminates: modulus of the frame.
(c) Brackets connecting lower deck beams or longitudinals to the main frame in the forward 0,15L: modulus of the frame.
(d) Elsewhere: the lesser modulus of the members being connected by the bracket.

3.3.3 Typical arrangements of stiffener end brackets are shown diagrammatically in Fig. 10.3.1.

3.4 Scantlings of end brackets

3.4.1 The lengths, a and b, of the arms are to be measured from the plating to the toe of the bracket and are to be such that:

(a) $a + b \geq 2{,}0l$
(b) $a \geq 0{,}8l$
(c) $b \geq 0{,}8l$

where

$$l = 90\left(2\sqrt{\frac{Z}{14+\sqrt{Z}}} - 1\right) \text{ mm}$$

but in no case is l to be taken as less than twice the web depth of the stiffener on which the bracket scantlings are to be based.

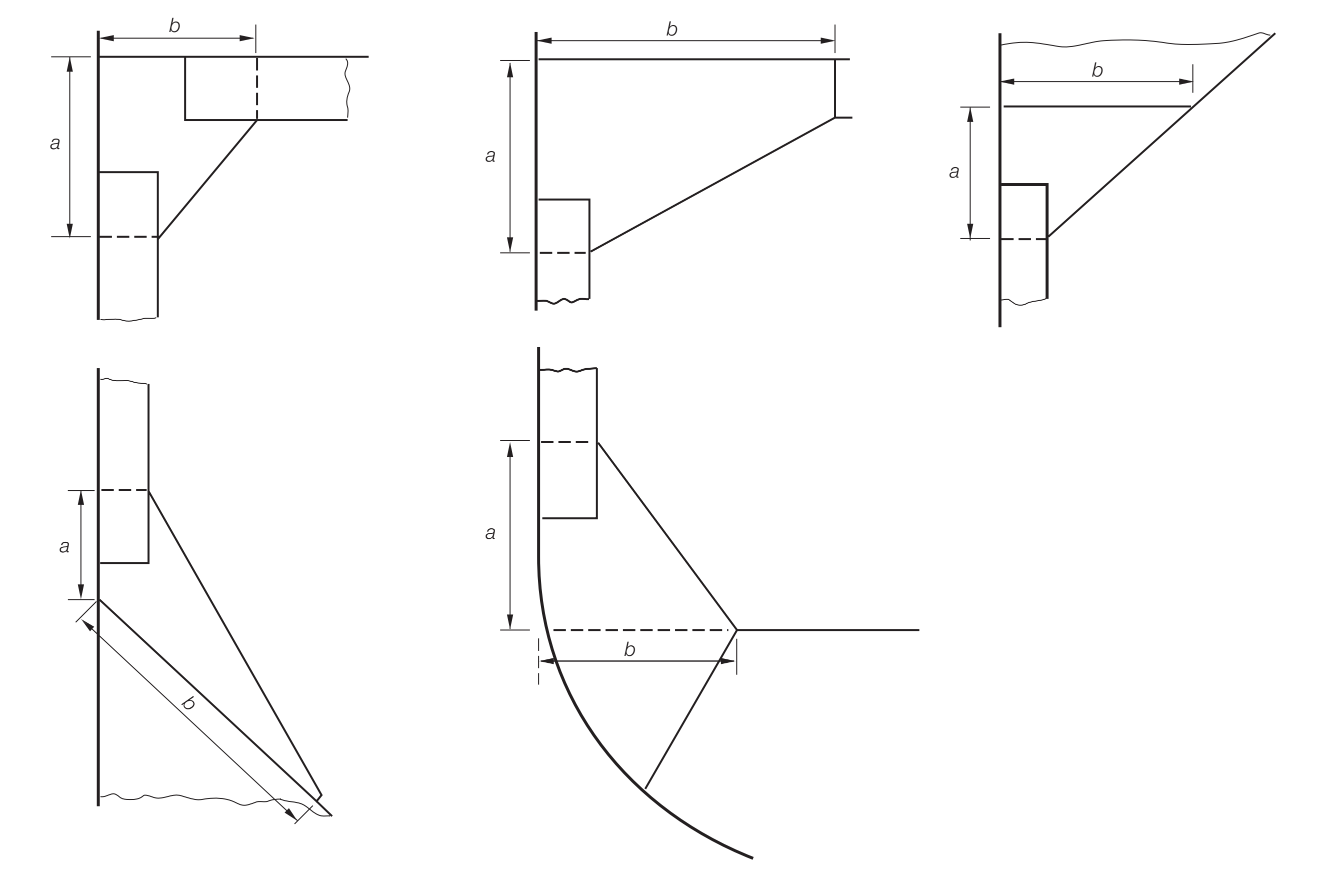


Fig. 10.3.1 Diagrammatic arrangements of stiffener end brackets

Table 10.3.1 Thickness of brackets

Bracket	Thickness, in mm	Limits	
		Minimum	Maximum
With edge stiffened:			
(a) in dry spaces	$3,5 + 0,25\sqrt{Z}$		6,5 12,5
(b) in tanks	$4,5 + 0,25\sqrt{Z}$	*See* Note	7,5 13,5
Unstiffened brackets:			
(a) in dry spaces	$5,5 + \dfrac{Z}{55} - \left(\dfrac{Z}{168}\right)^{1,3}$	7,5	—
(b) in tanks	$6,5 + \dfrac{Z}{55} - \left(\dfrac{Z}{168}\right)^{1,3}$	8,5 *See* Note	—

NOTE
In the cargo tank region of tankers, the minimum thickness is to be not less than the compartment minimum thickness, *see* Pt 4, Ch 9,10.

The scantlings of main frames are normally to be based on these standard brackets at top and bottom, while the scantlings of 'tween deck frames are normally to be based on a standard bracket at the top only. Where the actual arm lengths fitted, a_1 and b_1 (in mm) are smaller than Rule size, or bracket is omitted, an equivalent arm length, l_a, for the calculation of end connection factor, *see* Table 1.6.2 in Pt 4, Ch 1, is to be derived from:

(d) $l_a = \dfrac{(a_1 + b_1)}{2}$

(e) $a_1 \geq 0,8 l_a$
(f) $b_1 \geq 0,8 l_a$
(g) $l_a = 0$, where:
  (i) bracket is omitted from the upper or lower ends of the frame, or
  (ii) lower frame bracket at bilge is at same level as the inner bottom, or
  (iii) lower frame is welded directly to the inner bottom.

3.4.2 The length of arm of tank side and hopper side brackets is to be not less than 20 per cent greater than that required above.

3.4.3 The thickness of the bracket is to be not less than as required by Table 10.3.1.

3.4.4 The free edge of the bracket is to be stiffened where any of the following apply:
(a) The section modulus, Z, exceeds 2000 cm^3.
(b) The length of free edge exceeds $50t$ mm.
(c) The bracket is fitted at the lower end of main transverse side framing.

3.4.5 Where a flange is fitted, its breadth is to be not less than:

$$b_f = 40\left(1 + \frac{Z}{1000}\right) \text{ mm}$$

but not less than 50 mm

3.4.6 Where the edge is stiffened by a welded face flat, the cross-sectional area of the face flat is to be not less than:
(a) $0,009 b_f t$ cm^2 for offset edge stiffening.
(b) $0,014 b_f t$ cm^2 for symmetrically placed stiffening.

3.4.7 Where the stiffening member is lapped on to the bracket, the length of overlap is to be adequate to provide for the required area of welding. In general, the length of overlap should be not less than $10\sqrt{Z}$ mm, or the depth of stiffener, whichever is the greater.

3.4.8 Where the free edge of the bracket is hollowed out, it is to be stiffened or increased in size to ensure that the modulus of the bracket through the throat is not less than that of the required straight edged bracket.

3.5 Arrangements and details

3.5.1 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the modulus reduced to less than that of the stiffener with associated plating.

3.5.2 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

3.5.3 For arrangements where end brackets are not perpendicular to the adjacent plating the strength of the brackets, in terms of lateral stability, may need to be specially considered.

Section 4
Construction details for primary members

4.1 General

4.1.1 The requirements for section modulus and inertia (if applicable) of primary members are given in the appropriate Chapter. This Section includes the requirements for proportions, stiffening and construction details for primary members in dry spaces and in tanks of all ship types other than tankers.

4.1.2 The requirements for construction details for the primary structure of tankers are given in Pt 4, Ch 9,10.

4.1.3 The requirements of this Section may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

4.2 Symbols

4.2.1 The symbols used in this Section are defined as follows:

d_w = depth of member web, in mm
k_L, k = higher tensile steel factor, *see* Ch 2,1.2
t_w = thickness of member web, in mm
A_f = area of member face plate or flange, in cm^2
F_D = local scantlings reduction factor as defined in Ch 4,5.6
S_w = spacing of stiffeners on member web, or depth of unstiffened web, in mm.

4.3 Arrangements

4.3.1 Primary members are to be so arranged as to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring system.

4.3.2 The members are to have adequate lateral stability and web stiffening and the structure is to be arranged to minimise hard spots and other sources of stress concentration. Openings are to have well rounded corners and smooth edges and are to be located having regard to the stress distribution and buckling strength of the panel.

4.3.3 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

4.3.4 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended for at least two frame spaces, or equivalent, beyond the point of support before being tapered.

4.3.5 Where primary members are subject to concentrated loads, particularly if these are out of line with the member web, additional strengthening may be required.

4.4 Geometric properties and proportions

4.4.1 The geometric properties of the members are to be calculated in association with an effective width of attached plating determined in accordance with Ch 3,3.2.

4.4.2 The minimum thickness or area of material in each component part of the primary member is given in Table 10.4.1.

Table 10.4.1 Minimum thickness of primary members

Item	Requirement
(1) Member web plate *see* Note	$t_w = 0{,}01S_w$ but not less than 7 mm in dry spaces and not less than 8 mm in tanks
(2) Member face plate	A_f not to exceed $\dfrac{d_w\, t_w}{150}$ cm^2
(3) Deck plating forming the upper flange of underdeck girders	Plate thickness not less than $\sqrt{\dfrac{A_f}{1{,}8k}}$ mm, and 10 per cent greater for hatch side girders Width of plate not less than 700 mm
(4) Primary members in cargo oil tanks in tankers	As required by Pt 4, Ch 9,10

NOTE
For primary members having a web depth exceeding 1500 mm, the arrangement of stiffeners will be individually considered, and stiffening parallel to the member face plate may be required.

4.4.3 Primary members constructed of higher tensile steel are to comply with Table 10.4.1.

4.5 Web stability

4.5.1 Primary members of asymmetrical section are to be supported by tripping brackets at alternate secondary members. If the section is symmetrical, the tripping brackets may be four spaces apart.

4.5.2 Tripping brackets are also to be fitted at the toes of end brackets and in way of heavy or concentrated loads such as the heels of pillars.

4.5.3 Where the ratio of unsupported width of face plate (or flange) to its thickness exceeds 16:1, the tripping brackets are to be connected to the face plate and on members of symmetrical section, the brackets are to be fitted on both sides of the web.

4.5.4 Intermediate secondary members may be welded directly to the web or connected by lugs.

4.5.5 Where the depth of web of a longitudinal girder at the strength deck within 0,4L amidships exceeds:

(a) $55t_w$ for mild steel members

(b) $55t_w \sqrt{\frac{k_L}{F_D}}$ for higher tensile steel members

additional longitudinal web stiffeners are to be fitted at a spacing not exceeding the value given in (a) or (b) as appropriate, with a maximum of $65t_w \sqrt{k_L}$ for higher tensile steel members. In cases where this spacing is exceeded, the web thickness is, in general, to be suitably increased.

4.5.6 The arm length of unstiffened end brackets is not to exceed $100t_w$. Stiffeners parallel to the bracket face plate are to be fitted where necessary to ensure that this limit is not exceeded.

4.5.7 Web stiffeners may be flat bars of thickness t_w and depth $0{,}1d_w$, or 50 mm, whichever is the greater. Alternative sections of equivalent moment of inertia may be adopted.

4.6 Openings in the web

4.6.1 Where openings are cut in the web, the depth of opening is not to exceed 25 per cent of the web depth, and the opening is to be so located that the edges are not less than 40 per cent of the web depth from the face plate. The length of opening is not to exceed the web depth or 60 per cent of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be considered.

4.6.2 Openings are to have smooth edges and well rounded corners.

4.6.3 Cut-outs for the passage of secondary members are to be designed to minimise the creation of stress concentrations. The breadth of cut-out is to be kept as small as practicable and the top edge is to be rounded, or the corner radii made as large as practicable. The extent of direct connection of the web plating, or the scantlings of lugs or collars, is to be sufficient for the load to be transmitted from the secondary member.

4.7 End connections

4.7.1 End connections of primary members are generally to comply with the requirements of Section 3, taking Z as the section modulus of the primary member.

4.7.2 The thickness of the bracket is to be not less than that of the primary member web. The free edge of the bracket is to be stiffened.

4.7.3 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

4.7.4 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support. Proposals to fit brackets of reduced scantlings, or alternative arrangements, will be considered.

4.7.5 Connections between primary members forming a ring system are to minimise stress concentrations at the junctions. Integral brackets are generally to be radiused or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

■ *Section 5* Structural details

5.1 Continuity and alignment

5.1.1 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

5.1.2 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment.

5.1.3 Pillars and pillar bulkheads are to be fitted in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

5.1.4 Continuity is to be maintained where primary members intersect and where the members are of the same depth, a suitable gusset plate is to be fitted.

5.1.5 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

5.1.6 The toes of brackets, etc., should not land on unstiffened panels of plating. Special care should be taken to avoid notch effects at the toes of brackets, by making the toe concave or otherwise tapering it off.

5.1.7 Where primary and/or secondary members are constructed of higher tensile steel, particular attention is to be paid to the design of the end bracket toes in order to minimise stress concentrations. Sniped face plates which are welded onto the edge of primary member brackets are to be carried well around the radiused bracket toe and are to incorporate a taper not exceeding 1 in 3. Where sniped face plates are welded adjacent to the edge of primary member brackets, adequate cross sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area measured perpendicular to the face plate, is to be not less than 60 per cent of the full cross-sectional area of the face plate, *see* Fig. 10.5.1. *See also* Pt 4, Ch 1,4.3, Pt 4, Ch 1,6.1, Pt 4, Ch 9,5.7 and Pt 4, Ch 9,10.13.

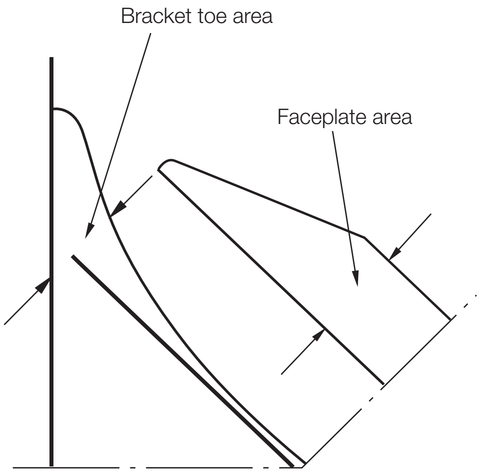


Fig. 10.5.1 Bracket toe construction

5.2 Arrangements at intersections of continuous secondary and primary members

5.2.1 Cut-outs for the passage of secondary members through the web of primary members, and the related collaring arrangements, are to be designed to minimise stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating. The critical shear buckling stress of the panel in which the cut-out is made is to be investigated. Cut-outs for longitudinals will be required to have double lugs in areas of high stress, e.g., in way of cross tie ends and floors under bulkhead stools in ore and ballast holds.

5.2.2 Cut-outs are to have smooth edges, and the corner radii are to be as large as practicable, with a minimum of 20 per cent of the breadth of the cut-out or 25 mm, whichever is the greater. It is recommended that the web plate connection to the hull envelope or bulkhead should end in a smooth tapered 'soft toe'. Recommended shapes of cut-out are shown in Fig. 10.5.3, but consideration will be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration. Consideration is to be given to the provision of adequate drainage and unimpeded flow of air and water when designing the cut-outs and connection details.

5.2.3 Asymmetrical secondary members are to be connected on the heel side to the primary member web plate. Additional connection by lugs on the opposite side may be required.

5.2.4 Symmetrical secondary members are to be connected by lugs on one or both sides, as necessary.

5.2.5 The cross-sectional areas of the connections are to be determined from the proportion of load transmitted through each component in association with its appropriate permissible stress.

5.2.6 The total load, P, transmitted to the primary member is to be derived in accordance with Table 10.5.1.

5.2.7 This load is to be apportioned between the connections as follows:

(a) Transmitted through the collar arrangement:

$$P_1 = P\left(\frac{s_1}{S_w} + \frac{A_1}{4C_f A_f + A_1}\right)$$

where A_1 is derived in accordance with 5.2.8 and $\dfrac{s_1}{S_w}$ is not to be taken as greater than 0,25

The collar load factor, C_f, is to be derived as follows:

Symmetrical secondary members

$C_f = 1{,}85$ for $A_f \leq 18$

$C_f = 1{,}85 - 0{,}0341\,(A_f - 18)$ for $18 < A_f \leq 40$

$C_f = 1{,}1 - 0{,}01\,(A_f - 40)$ for $A_f > 40$

Asymmetrical secondary members

$$C_f = 0{,}68 + 0{,}0224\,\frac{b_l}{A_f}$$

where

A_f = the area, in cm^2, of the primary member web stiffener in way of the connection including backing bracket, where fitted, *see* 5.2.10

b_l = the length of lug or direct connection, in mm, as shown in Fig. 10.5.3. Where the lug or direct connections differ in length, a mean value of b_l is to be used.

(b) Transmitted through the primary member web stiffener:

$P_2 = P - P_1$ kN (tonne-f)

(c) Where the web stiffener is not connected to the secondary member, P_1 is to be taken equal to P.

5.2.8 The effective cross-sectional area A_1 of the collar arrangements is to be taken as the sum of cross-sectional areas of the components of the connection as follows:

(a) Direct connection:

$A_1 = 0{,}01 b_l\, t_w$ cm^2

(b) Lug connection:

$A_1 = 0{,}01 f_1\, b_l\, t_l$ cm^2

where

f_1 = 1,0 for symmetrical secondary member connections

$\dfrac{140}{W_l}$ but not greater than 1,0, for asymmetrical secondary member connections

t_w = thickness of primary member web, in mm

t_2 = thickness, in mm, of lug connection, and is to be taken not greater than the thickness of the adjacent primary member web plate

Table 10.5.1 Total load transmitted to connection of secondary members (*see continuation*)

Ship type	Head, h_1, in metres	Total load, P, transmitted to connection
(1) Oil tankers, bulk chemical tankers and combination carriers, *see* 1.1.3	h_1 = load height, in metres, derived in accordance with the following provisions, but to be taken as not less than $\frac{L_1}{56}$ or $(0{,}01L_1 + 0{,}7)$ m whichever is the greater For shell framing members: (a) With mid-point of span at base line, $h_1 = 0{,}8D_2$ (b) With mid-point of span at a distance $0{,}6D_2$ above base line, $h_1 = f\,D_2\,B_f$ (c) With mid-point of span intermediate between (a) and (b). The value of h_1 is to be obtained by linear interpolation between values from (a) and (b). (d) With mid-point of span higher than $0{,}6D_2$ above base line. The value of h_1 is to be obtained by linear interpolation between the values from (b) and the values at the following points: (i) For framing members located at and abaft $0{,}2L$ from the forward perpendicular (*see* Fig. 10.5.2(a)) — Zero value at the level of the deck edge amidships (ii) For framing members forward of cargo tank region (*see* Fig. 10.5.2(b)) — Value of $f\,D_2\,(B_f - 1)$ at the level 3 m above the minimum bow height determined from the Load Lines Conventions (iii) Intermediate values between locations (i) and (ii) are to be determined by linear interpolation For secondary stiffening members of transverse and longitudinal bulkheads, and inner hull and inner bottom of double hull tankers, *see* 1.1.3: h_1 = distance from mid-point of span to top of tank but need not exceed $0{,}8D_2$	(a) In general $P = 10{,}06\,(S_w - s_1/2)\,s_1\,h_1$ kN $(P = 1{,}025\,(S_w - s_1/2)\,s_1\,h_1$ tonne-f) (b) For wash bulkheads $P = 11{,}77\,(S_w - s_1/2)\,s_1\,h_1$ kN $(P = 1{,}2\,(S_w - s_1/2)\,s_1\,h_1$ tonne-f)
(2) Other ship types for which oil tanker, (*see* 1.1.3) requirements are not applicable	Side and bottom shell longitudinals As for (1) except as follows: (a) h_1 to be derived in accordance with (1) above but to be taken as not less than $\frac{L_1}{56}$ m for type 'B – 60' and the greater of $\frac{L_1}{70}$, or 1,20 m for Type 'B' ships (b) h_1 for item (1)(d)(ii) above to extend forward of $0{,}15L$ from the forward perpendicular	$P = 10{,}06\,(S_w - s_1/2)\,s_1\,h_1$ kN $(P = 1{,}025\,(S_w - s_1/2)\,s_1\,h_1$ tonne-f)

W = overall width of the cut-out, in mm
W_2 = width for cut-out asymmetrical to secondary member web, in mm
see Fig. 10.5.3

5.2.9 The values of A_f and A_1 are to be such that the stresses given in Table 10.5.3 are not exceeded.

5.2.10 Where a bracket is fitted to the primary member web plate in addition to a connected stiffener it is to be arranged on the opposite side to, and in alignment with the stiffener. The arm length of the bracket is to be not less than the depth of the stiffener, and its cross-sectional area through the throat of the bracket is to be included in the calculation of A_f.

Table 10.5.1 Total load transmitted to connection of secondary members (*conclusion*)

Ship type	Head, h_1, in metres	Total load, P, transmitted to connection
(3) Other ship types for which oil tanker (*see* 1.1.3) requirements are not applicable (continued)	Internal tank boundaries (a) Topside tank longitudinals h_1 = distance from the longitudinal under consideration to the highest point of the tank with the ship inclined 30° either way, or = the greater of the distance from the longitudinal under consideration to the top of the tank, or half the distance to the top of the overflow, or = 1,5 m whichever is the greatest	$P = 10,06\ (S_w - s_1/2)\ s_1\ h_1$ kN ($P = 1,025\ (S_w - s_1/2)\ s_1\ h_1$ tonne-f)
	(b) Inner bottom and hopper longitudinals (i) For cargo ships and bulk carriers (*see* 1.1.3) without the notation 'strengthened for heavy cargoes' h_1 = 1,39T (ii) For cargo ships and bulk carriers (*see* 1.1.3) with the notation 'strengthened for heavy cargoes' $h_1 = H$ (iii) For longitudinal bulkheads of ore carriers $h_1 = H\ K_c$	$P = 9,81\ (S_w - s_1/2)\ s_1\ h_1/C$ kN $P = (S_w - s_1/2)\ s_1\ h_1/C$ tonne-f but not to be taken less than the load derived from (b)(iv), (b)(v), (b)(vi) or (c) where applicable
	(iv) For bulk carriers (*see* 1.1.3) where the topside wing tank is interconnected with hopper side and double bottom tanks h_1 = the distance from the longitudinal under consideration to the top of the topside tank with the ship inclined 25° either way	$P = 10,06\ (S_w - s_1/2)\ s_1\ h_1$ kN ($P = 1,025\ (S_w - s_1/2)\ s_1\ h_1$ tonne-f)
	(v) For bulk carriers (*see* 1.1.3) in way of ballast hold h_1 = the distance from the longitudinal under consideration to the top of the hatchway coaming	$P = 10,06\ (S_w - s_1/2)\ s_1\ h_1$ kN ($P = 1,025\ (S_w - s_1/2)\ s_1\ h_1$ tonne-f)
	(vi) For cargo ships and bulk carriers (*see* 1.1.3) with double hull where tank at side interconnected with double bottom $h_1 = H$	$P = 10,06\ (S_w - s_1/2)\ s_1\ h_1$ kN ($P = 1,025\ (S_w - s_1/2)\ s_1\ h_1$ tonne-f)
	(c) Longitudinals of inner hull of double hull cargo ships and bulk carriers (*see* 1.1.3) h_1 = the distance from the longitudinal under consideration to the top of the tank, or half the distance to the top of the overflow, whichever is the greater	$P = 10,06\ (S_w - s_1/2)\ s_1\ h_1$ kN ($P = 1,025\ (S_w - s_1/2)\ s_1\ h_1$ tonne-f)

B_f = bow fullness factor determined from Fig. 5.4.3 in Chapter 5 to be considered. To be taken as 1 for framing members located at and abaft 0,2L from the forward perpendicular
f = load height factor at level 0,6D above base line, *see* Table 10.5.2
h_1 = load height, in metres, *see also* Fig. 10.5.2
C = stowage rate, in m^3/tonne, as defined in Ch 3,5.2. For cargo ships without the notation 'strengthened for heavy cargoes', the value to be used is 1,39 m^3/tonne. For cargo ships and bulk carriers (*see* 1.1.3) with the notation 'strengthened for heavy cargoes', the actual stowage rate is to be used, but the value is not to be taken greater than 0,865 m^3/tonne
H = height from inner bottom at position under consideration, to deck at side amidships, in metres, for inner bottom longitudinals
= height from the longitudinal under consideration to the underside of the topside tank sloped bulkhead, in metres, for hopper longitudinals
S_w = spacing of primary members, in metres
s_1 = spacing of secondary members, in metres
T = the summer draught, in metres, measured from top of keel
D_2 = D in metres, but need not be taken greater than 1,6T
L_1 = L but need not be taken as greater than 190 m
K_c = as defined in Table 11.7.1 in Pt 4, Ch 11

5.2.11 In general where the primary member stiffener is connected to the secondary member it is to be aligned with the web of the secondary member, except where the face plate of the latter is offset and abutted to the web, in which case the stiffener connection is to be lapped. Lapped connections of primary member stiffeners to mild steel bulb plate or rolled angle secondary members may also be permitted. Where such lapped connections are fitted, particular care is to be taken to ensure that the primary member stiffener wrap around weld connection is free from undercut and notches, *see also* 2.9.

5.2.12 Fabricated longitudinals having the face plate welded to the underside of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where it is proposed to fit such sections, a symmetrical arrangement of connection to transverse members is to be incorporated. This can be achieved by fitting backing brackets on the opposite side of the transverse web or bulkhead. The primary member stiffener and backing brackets are to be lapped to the longitudinal web, *see* 5.2.11.

Table 10.5.2 Load height factor, *f*

	Ship depth, *D* metres					
	≤17,5	20	22,5	25	27,5	30
(1) (a) For oil tankers, bulk chemical tankers and combination carriers (*see* 1.1.3), tank boundaries wholly within parallel mid-body (b) For other ship types, at and abaft 0,2*L* from the forward perpendicular	0,6	0,6	0,582	0,556	0,535	0,517
(2) (a) For oil tankers, bulk chemical tankers and combination carriers (*see* 1.1.3), tank boundaries wholly or partially outside parallel mid-body (b) For other ship types, forward of 0,15*L* from the forward perpendicular	0,7	0,685	0,685	0,628	0,6	0,577

NOTE
Intermediate values to be obtained by linear interpolation.

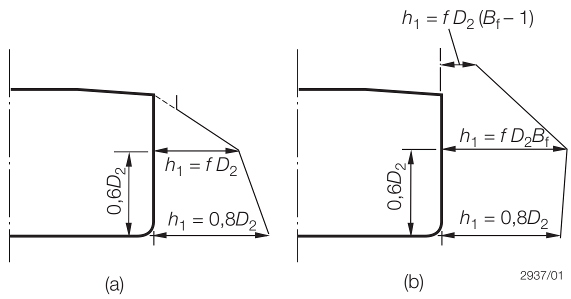


Fig. 10.5.2
Load height diagrams for framing members (a) at and abaft 0,2*L* from the forward perpendicular and (b) forward of cargo tank region for oil tankers, bulk chemical tankers and combination carriers (*see* 1.1.3) and forward of 0,15*L* from the forward perpendicular for other ship types

5.2.13 For ship types for which oil tanker (*see* 1.1.3) requirements are not applicable, the collar arrangement is to satisfy the requirements of 5.2.1 to 5.2.12 inclusive. In addition the weld area of the connections is to be not less than the following:

(a) Connection of primary member stiffener to the secondary member:
A_w = $0,25A_f$ or 6,5 cm^2, whichever is the greater, corresponding to a weld factor of 0,34 for the throat thickness

(b) Connection of secondary member to the web of the primary member:
A_w = $0,5\sqrt{Z}$ corresponding to a weld factor of 0,34 in tanks or 0,27 in dry spaces for the throat thickness

where
A_w = weld area, in cm^2, and is calculated as total length of weld, in cm, multiplied by throat thickness, in cm
A_f = cross-sectional area of the primary member web stiffener, in cm^2, in way of connection
Z = the section modulus, in cm^3, of the secondary member.

5.2.14 Where the stiffeners of the double bottom floors, and the hopper primary members are unconnected to the secondary members and offset from them (*see* Fig. 10.5.4) the collar arrangement is to satisfy the requirements of 5.2.1 to 5.2.13 inclusive. In addition, the fillet welds attaching the lugs to the secondary members are to be based on a weld factor of 0,44 for the throat thickness. To facilitate access for welding the offset, stiffeners are to be located 50 mm from the slot edge furthest from the web of the secondary member. The ends of the offset stiffeners are to be suitably tapered and softened.

5.2.15 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

5.3 Openings

5.3.1 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or double plate bulkheads within one-third of their length from either end, nor in floors or double bottom girders close to their span ends, or below the heels of pillars, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

5.3.2 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

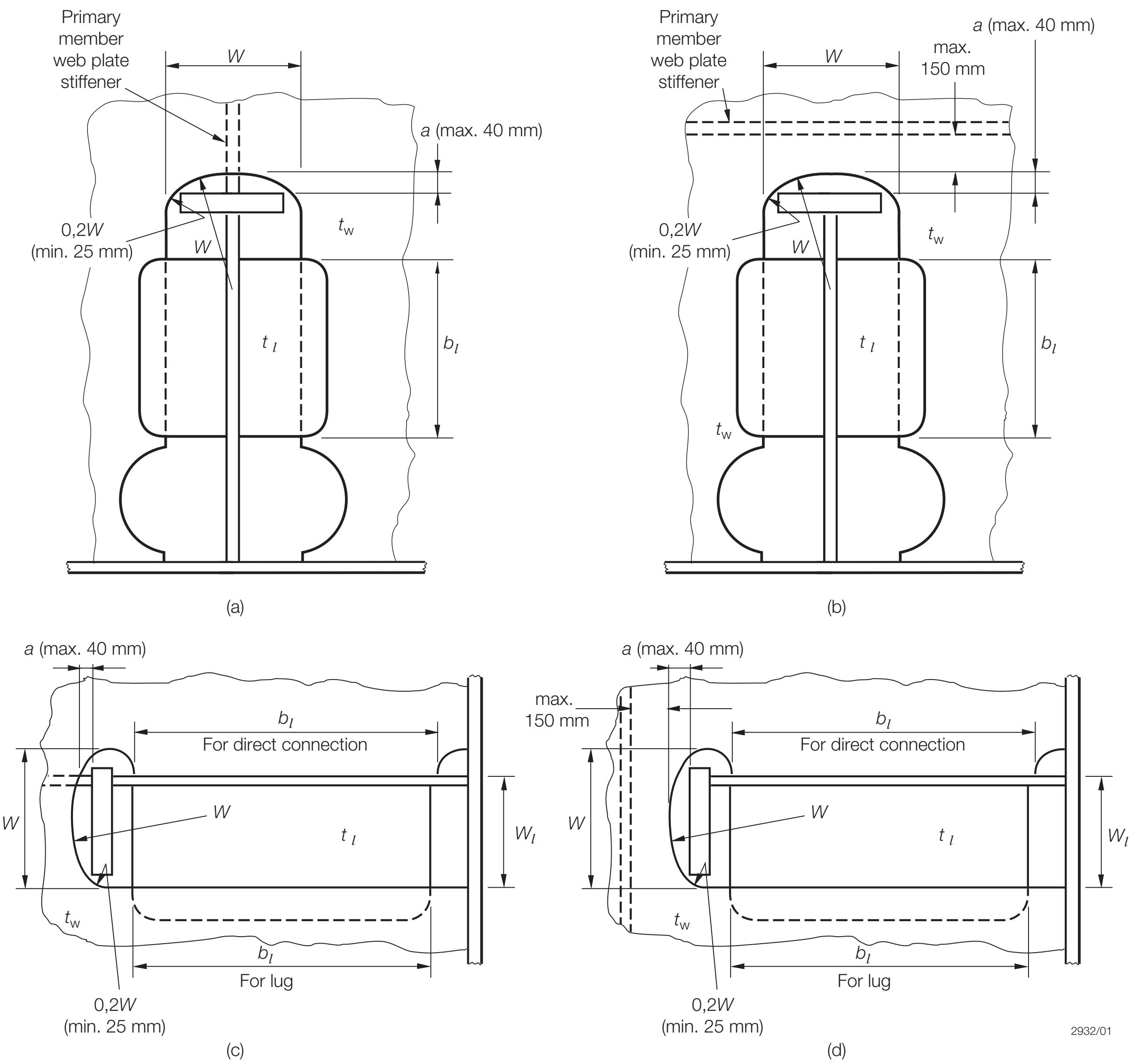


Fig. 10.5.3 Cut-outs and connections

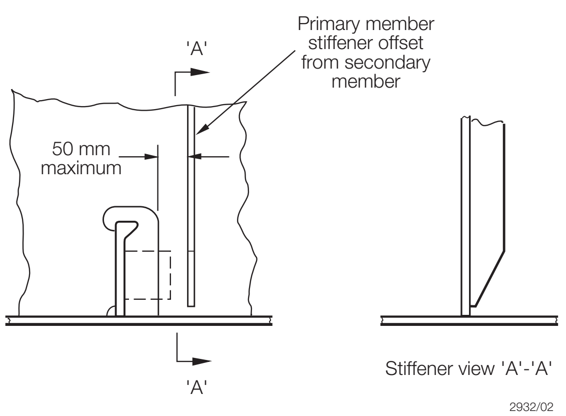


Fig. 10.5.4 Arrangement with offset stiffener

5.3.3 Air and drain holes, notches and scallops are to be kept at least 200 mm clear of the toes of end brackets and other areas of high stress. Openings are to be well rounded with smooth edges. Details of scalloped construction are shown in Fig. 10.2.1. Closely spaced scallops are not permitted in higher tensile steel members. Widely spaced air or drain holes may be accepted, provided that they are of elliptical shape, or equivalent, to minimise stress concentration and are, in general, cut clear of the weld connection.

5.4 Sheerstrake and bulwarks

5.4.1 Where an angled gunwale is fitted, the top edge of the sheerstrake is to be kept free of all notches and isolated welded fittings. Bulwarks are not to be welded to the top of the sheerstrake within the 0,5*L* amidships.

Table 10.5.3 Permissible stresses

Item		Direct stress, in N/mm^2 (kgf/mm^2) (*see* Notes 1 and 2)		Shear stress, in N/mm^2 (kgf/mm^2) (*see* Note 1)	
		Oil tankers	Other ship types for which oil tanker requirements are not applicable	Oil tankers and ship types where primary member stiffener unconnected	Other ship types for which oil tanker requirements are not applicable
Primary member web plate stiffener within distance *a* of end, *see* Fig. 10.5.3		147,2 (15,0)	157 (16,0)	—	—
Welding of primary member web plate stiffener to secondary member	Butted	98,1 (10,0) (double continuous fillet)	117,7 (12,0) (double continuous fillet)	—	—
		147,2 (15,0) (automatic deep penetration)	157 (16,0) (automatic deep penetration)	—	—
	Lapped	—	—	83,4 (8,5) *See* Note 2	98,1 (10,0) *See* Note 2
Lug or collar plate and weld	Single	—	—	68,6 (7,0)	98,1 (10,0)
	Double	—	—	83,4 (8,5)	

NOTES
1. The welding requirements of Section 2 and, where applicable 5.2.13 are also to be complied with, *see* 1.1.3.
2. Where longitudinals are of higher tensile steel having a yield stress of 32 kg/mm^2 or more, these stresses are to be divided by the factor 1,2 for application to side longitudinals above 0,3D_2 from the base-line. For definition of D_2 *see* Table 10.5.1.

5.4.2 Where a rounded gunwale is adopted, the welding of fairlead stools and other fittings to this plate is to be kept to the minimum, and the design of the fittings is to be such as to minimise stress concentration.

5.4.3 Arrangements are to ensure a smooth transition from rounded gunwale to angled gunwale towards the ends of the ship.

5.4.4 At the ends of superstructures where the side plating is extended and tapered to align with the bulwark plating, the transition plating is to be suitably stiffened and supported. Where freeing ports or other openings are essential in this plate, they are to be suitably framed and kept well clear of the free edge.

5.5 Fittings and attachments – General

5.5.1 The quality of welding and general workmanship of fittings and attachments as given in 5.6 and 5.7 are to be equivalent to that of the main hull structure. Visual examination of all welds is to be supplemented by non-destructive testing as considered necessary by the Surveyor.

5.6 Bilge keels and ground bars

5.6.1 It is recommended that bilge keels should not be fitted in the forward 0,3*L* region on ships intended to navigate in severe ice conditions.

5.6.2 Bilge keels are to be attached to a continuous ground bar as shown in Fig. 10.5.5. Butt welds in shell plating, ground bar and bilge keels are to be staggered.

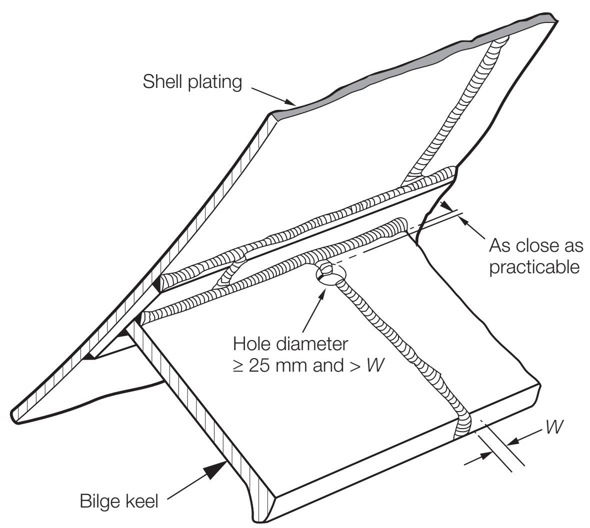


Fig. 10.5.5 Bilge keel construction

5.6.3 The minimum thickness of the ground bar is to be equal to the thickness of the bilge strake or 14 mm, whichever is the lesser.

5.6.4 The material class, grade and quality of the ground bar are to be in accordance with Table 2.2.1, Note 9 in Chapter 2.

5.6.5 The ground bar is to be connected to the shell with a continuous fillet weld and the bilge keel to the ground bar with a light continuous fillet weld.

5.6.6 Direct connection between ground bar butt welds and shell plating, and between bilge keel butt welds and ground bar is to be avoided.

5.6.7 The design of single web bilge keels is to ensure that failure to the web occurs before failure of the ground bar. In general, this may be achieved by ensuring the web thickness of bilge keels does not exceed that of the ground bar.

5.6.8 The end details of bilge keels and intermittent bilge keels, where adopted, are to be as shown in Fig. 10.5.6.

5.6.9 The ground bar and bilge keel ends are to be tapered or rounded. Where the ends are tapered, the tapers are to be gradual with ratios of at least 3:1, *see* Figs. 10.5.6(a) and (b). Where the ends are rounded, details are to be as shown in Fig. 10.5.6(c). Cut-outs on the bilge keel web within zone 'A' (*see* Fig. 10.5.6(b)) are not permitted.

5.6.10 The end of the bilge keel web is to be between 50 mm and 100 mm from the end of the ground bar, *see* Fig. 10.5.6(a).

5.6.11 An internal transverse support is to be positioned as close as possible to halfway between the end of the bilge keel web and the end of the ground bar, *see* Fig. 10.5.6(b).

5.6.12 Where an internal longitudinal stiffener is fitted in line with the bilge keel web, the longitudinal stiffener is to extend to at least the nearest transverse member outside zone 'A', *see* Fig. 10.5.6(b). In this case, the requirement of 5.6.10 does not apply.

5.6.13 For ships over 65 m in length, holes are to be drilled in the bilge keel butt welds. The size and position of these holes are to be as illustrated in Fig. 10.5.5. Where the butt weld has been subject to non-destructive examination the stop hole may be omitted.

5.6.14 Bilge keels of a different design from that shown in Fig.10.5.5 and Fig. 10.5.6 will be specially considered.

5.6.15 Within zone 'B' (*see* Fig. 10.5.6(a)) welds at the end of the ground bar and bilge plating, and at the end of the bilge keel web and ground bar, are to have weld factors of 0,44 and 0,34 respectively. These welds are to be ground and to blend smoothly with the base materials.

5.6.16 A plan of the bilge keels is to be submitted for approval of material grades, welded connections and detail design.

5.7 Other fittings and attachments

5.7.1 Gutterway bars at the upper deck are to be so arranged that the effect of main hull stresses on them is minimised.

5.7.2 Minor attachments, such as pipe clips, staging lugs and supports, are generally to be kept clear of toes of end brackets, corners of openings and similar areas of high stress. Where connected to asymmetrical stiffeners, the attachments may be in line with the web providing the fillet weld leg length is clear of the offset face plate or flange edge. Where this cannot be achieved the attachments are to be connected to the web, and in the case of flanged stiffeners they are to be kept at least 25 mm clear of the flange edge. On symmetrical stiffeners, they may be connected to the web or to the centreline of the face plate in line with the web.

5.7.3 Where necessary in the construction of the ship, lifting lugs may be welded to the hull plating but they are not to be slotted through. Where they are subsequently removed, this is to be done by flame or mechanical cutting close to the plate surface, and the remaining material and welding ground off. After removal the area is to be carefully examined to ensure freedom from cracks or other defects in the plate surface.

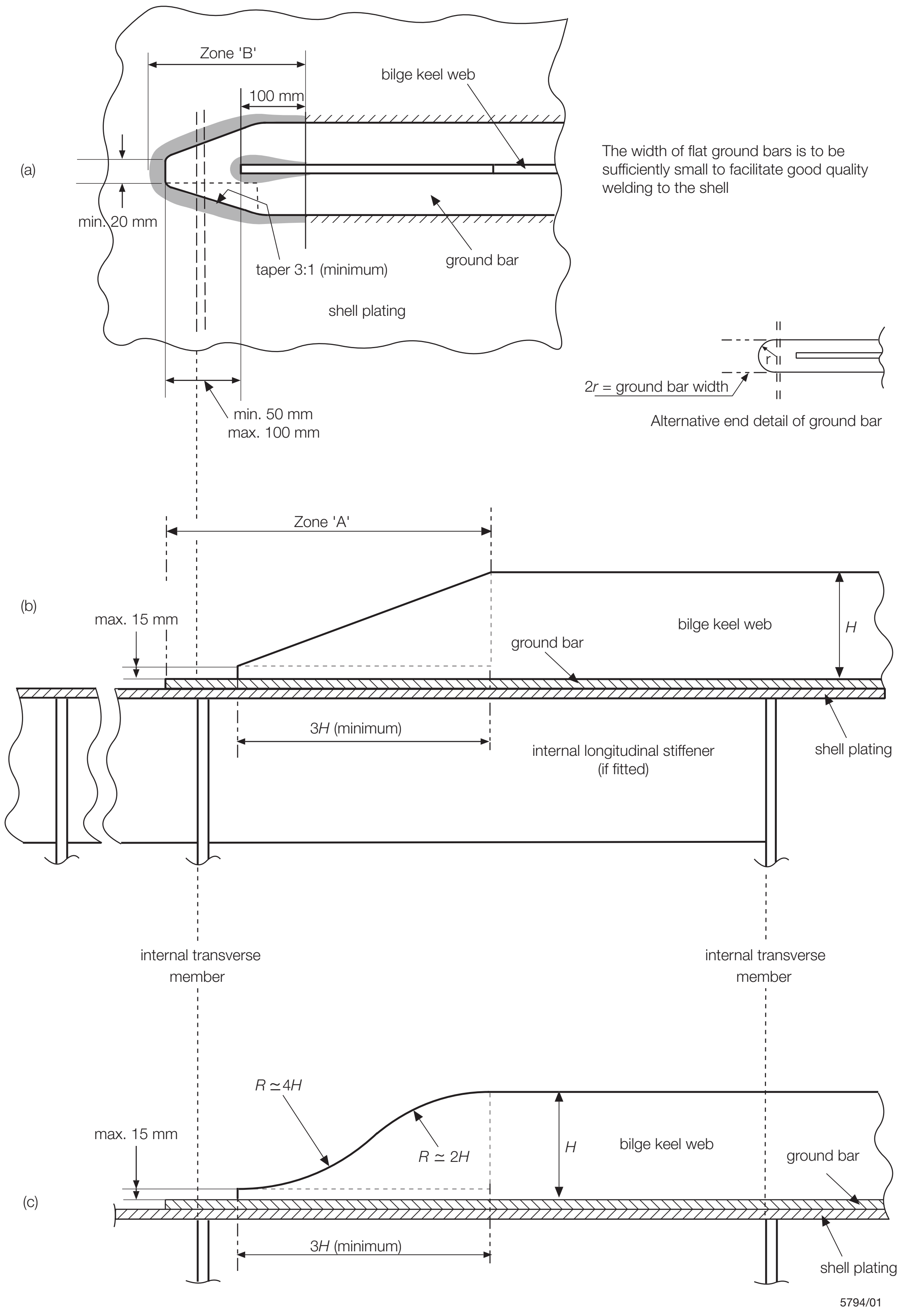


Fig. 10.5.6 Bilge keel end design

■ *Section 6*
Access arrangements for oil tankers and bulk carriers

6.1 Application

6.1.1 Access arrangements are to be provided as required by SOLAS.

6.2 Information for approval

6.2.1 Details of the attachment of the access arrangements to the ship's structure are to be submitted for approval and suitable designs are to take into account proper location, strength, detail and reinforcement of all attachments to hull structural members.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all ship types detailed in Part 4, unless otherwise stated, with the exception of Sections 1 to 5 which are not applicable to Bulk Carriers with a **CSR** notation, *see* Pt 1, Ch 2,2.3. Additional provisions regarding access arrangements for oil tankers and chemical carriers are contained in Pt 4, Ch 9, Ch 10 and the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquid Chemicals in Bulk* (hereinafter referred to as the Rules for Ships for Liquid Chemicals), respectively.

1.1.2 Requirements are given for steel and wooden hatch covers, securing arrangements, tarpaulins, coamings and side shell doors for main openings, also closing arrangements for other miscellaneous openings.

1.1.3 Where relevant, the contents of this Chapter conform with the requirements of the *International Convention on Load Lines, 1966*. Attention should, however, be given to any additional Statutory Requirements of the National Authority of the country in which the ship is to be registered and to the relevant regulations of the *International Convention for the Safety of Life at Sea, 1974* and applicable amendments.

1.1.4 For the purpose of this Chapter the basic types of ships are those defined in the *International Convention on Load Lines, 1966,* namely:

Type 'A' Ships designed solely for the carriage of liquid cargoes.
Type 'B' Cargo ships, other than Type 'A', with steel weathertight hatch covers.
Type 'B-100'
Type 'B-60' } Cargo ships of type 'B' with reduced freeboards on account of their ability to survive a stipulated damage.
Type 'B +' Cargo ships with increased freeboard on account of hatch cover arrangements.

1.1.5 The type of hatch covers on the weather decks of the basic ship types defined in 1.1.4 are detailed below and may be used in the types of ships as indicated in Table 11.1.1:

(a) Steel plated cargo hatch covers stiffened by webs or stiffeners and secured by clamping devices. Weathertightness to be achieved by means of gaskets. Hatch covers used for holds containing liquid cargoes are included in this category.
(b) Steel plated cargo hatch pontoon covers having interior webs and stiffeners extending for the full width of the hatchway. A pontoon cover is defined as a portable cover, secured weathertight by tarpaulins and battening devices.
(c) Hatch covers of wood or steel used in conjunction with portable beams. Weathertightness to be obtained by tarpaulins.
(d) Access hatch covers for cargo oil tanks and adjacent spaces. The hatch covers are to be of steel and gasketed.
(e) Access hatch covers other than (d). For Type 'A', Type 'B-100' and Type 'B-60' ships, the covers are to be of steel, and weathertightness is to be achieved by means of gaskets.

Table 11.1.1 Covers associated with ship types

Type of cover	Type of ship				
	'A'	'B-100'	'B-60'	'B'	'B +'
(a)	–	X	X	X	X
(b)	–	–	–	X	X
(c)	–	–	–	–	X
(d)	X	X	X	Not applicable	
(e)	X	X	X	X	X

1.1.6 The positions of hatches on weather decks are defined in Ch 1,6.5.

1.1.7 'Tween deck hatch covers may be any of the types defined in 1.1.5, but need not be weathertight unless fitted to deep tanks or water ballast holds or compartments, in which case the covers are to be of type (a) and oiltight or watertight as appropriate.

1.1.8 The scantlings specified in the following Sections are applicable to covers of mild steel or higher tensile steel. Where other materials are used, equivalent scantlings are to be provided. The scantlings apply basically to rectangular covers, with the stiffening members arranged primarily in one direction and carrying a uniformly distributed load. The covers are assumed to be simply supported. Where covers are stiffened by a grillage formation, and also where point loads are applied to any type of cover, the scantlings are to be determined from direct calculations.

1.1.9 In the case of flush hatch covers or of covers on coamings of lesser height than required by 5.1.1, their scantlings, the securing and sealing arrangements and the drainage of gutterways will be specially considered.

1.1.10 The scantlings of hatch covers need to be increased only if the loading exceeds that given in 2.3. The scantlings of the surrounding deck structure are to be sufficient to support this loading. Heavier loading may be permitted only if the scantlings of the cover are capable of withstanding this increased loading, satisfying the stress and deflection criteria given in this Chapter. The deck structure is also to be capable of withstanding this increased loading.

1.1.11 Where timber cargo is to be carried on the hatch covers the requirements of Ch 9,2.11 are to be satisfied in addition to the requirements of this Chapter.

1.1.12 Where hatchways are trunked through one or more ‘tween decks, and hatchway beams and covers are dispensed with at the intermediate decks, the hatchway beams, coamings and covers immediately below the trunk are to be adequately strengthened. Plans are to be submitted for approval.

1.1.13 The net plate thickness, t_{net}, is the calculated minimum thickness of the plating and stiffeners. The required thickness is the net thickness plus a corrosion addition, t_c, given in Table 11.1.2.

Table 11.1.2 Corrosion addition t_c

Application	Structure	t_c, in mm
Weather deck hatches of container ships, car carriers, paper carriers, passenger vessels	Hatch covers	1,0
	Hatch coamings	1,0
Weather deck hatches of all other ship types except bulk carriers, ore carriers and combination carriers, *see* Pt 4, Ch 7,12.1.2	Hatch covers in general	2,0
	Weather exposed plating and bottom plating of double skin hatch covers	1,5
	Internal structure of double skin hatch covers and closed box girders	1,0
	Hatch coamings	1,5
	Coaming stays and stiffeners	1,5
‘Tween deck hatches	Hatch covers in general	1,0

Section 2 Steel hatch covers

2.1 General

2.1.1 The requirements of Section 2 are not applicable to hatch covers of bulk carriers, ore carriers and combination carriers.

2.1.2 The strength requirements in 2.1 to 2.16 are applicable to hatch covers and closing arrangements of stiffened plate construction. The strength requirements are applicable to exposed weather deck hatch covers and 'tween deck hatch covers, unless otherwise stated.

2.1.3 Sub-Sections 2.1 to 2.16 are not applicable to portable covers secured weathertight by tarpaulins and battening devices, or pontoon covers, *see* 2.17.

2.1.4 Unless otherwise stated, the thicknesses referred to in the following Sections are net thicknesses. The net thicknesses are the member thicknesses necessary to obtain the minimum net scantlings required in this Section. The required gross thicknesses are obtained by adding corrosion additions, t_c, given in Table 11.1.2. Strength calculations using beam theory, grillage analysis or FEM are to be performed with net scantlings.

2.1.5 Material class I is to be applied for hatch covers.

2.1.6 The strength and closing arrangements of hatch covers are to comply with Pt 4, Ch 7,12 in addition to the requirements in this Chapter when hatch covers are subjected to internal ballast or oil cargo pressure.

2.1.7 Hatch covers are to comply with Pt 4, Ch 8,11 in addition to the requirements in this Chapter when containers are carried on covers.

2.2 Stiffener arrangement

2.2.1 The primary supporting members and secondary stiffeners of hatch covers are to be continuous over the breadth and length of hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to ensure sufficient load-carrying capacity.

2.2.2 The spacing of primary supporting members parallel to the direction of secondary stiffeners is not to exceed one-third of the span of primary supporting members. When strength calculation is carried out by FE analysis using plane strain or shell elements, this requirement can be waived.

2.3 Load model

2.3.1 The structural assessment of hatch covers is to be carried out using the design loads defined in this Section. The following symbols and definitions are applicable to this Section:

x = longitudinal co-ordinate measured from the AP to mid point of assessed structural member

T_{fb} = draught, in metres, corresponding to the assigned summer load line

h_N = standard superstructure height in metres
= $1,05 + 0,01L_L$, $1,8 \leq h_N \leq 2,3$

where

L_L = load line length, as defined in Pt 3, Ch 1,6.1.8.

2.3.2 The vertical weather design pressure, p_H, in kN/m^2, on the hatch cover panels is to be taken from Table 11.2.1. When cargo is carried on the cover, cargo loads according to 2.3.4, 2.3.5 and Pt 4, Ch 8,11.2 are to be considered. The vertical weather design load needs not to be combined with the cargo load. For 'tween deck hatch covers not exposed to weather load, the structural assessment is to be carried out using the cargo loads defined in 2.3.4 and 2.3.5. Covers carrying wheeled vehicles are also to comply with Ch 9,3 and where it is proposed to provide a helicopter landing area, covers are also to comply with Ch 9,5. Where an increased freeboard is assigned, the design load for hatch covers according to Table 11.2.1 on the actual freeboard deck may be as required for a superstructure deck, provided the summer freeboard is such that the resulting draught will not be greater than that corresponding to the minimum freeboard calculated from an assumed freeboard deck situated at a distance at least equal to the standard superstructure height, h_N, below the actual freeboard deck, *see* Fig. 11.2.2.

2.3.3 The horizontal weather design pressure, in kN/m^2, for determining the scantlings of outer edge girders (skirt plates) of weather deck hatch covers is:

$p_A = a\,c\,(b\,c_L\,f - z)$ kN/m^2

$f = \dfrac{L}{25} + 4,1$ for $L < 90$ m

$= 10,75 - \left(\dfrac{300 - L}{100}\right)^{1,5}$ for 90 m $\leq L <$ 300 m

$= 10,75$ for 300 m $\leq L <$ 350 m

$= 10,75 - \left(\dfrac{L - 350}{150}\right)^{1,5}$ for 350 m $\leq L \leq$ 500 m

$c_L = \sqrt{\dfrac{L}{90}}$ for $L < 90$ m

$= 1$ for $L \geq$ 90 m

$a = 20 + \dfrac{L_1}{12}$ for unprotected front coamings and hatch cover skirt plates

$a = 10 + \dfrac{L_1}{12}$ for unprotected front coamings and hatch cover skirt plates where the distance from the actual freeboard deck to the summer load line exceeds the minimum non-corrected tabular freeboard according to ICLL by at least one standard superstructure height, h_N

$a = 5 + \dfrac{L_1}{15}$ for side and protected front coamings and hatch cover skirt plates

$a = 7 + \dfrac{L_1}{100} - 8\dfrac{x'}{L}$ for aft ends of coamings and aft hatch cover skirt plates abaft amidships

$a = 5 + \dfrac{L_1}{100} - 4\dfrac{x'}{L}$ for aft ends of coamings and aft hatch cover skirt plates forward of amidships

L_1 = L, need not be taken greater than 300 m

$$b = 1,0 + \left(\frac{\frac{x'}{L} - 0,45}{C_b + 0,2}\right)^2 \quad \text{for } \left(\frac{x'}{L}\right) < 0,45$$

$$b = 1,0 + 1,5\left(\frac{\frac{x'}{L} - 0,45}{C_b + 0,2}\right)^2 \quad \text{for } \left(\frac{x'}{L}\right) \geq 0,45$$

$0,6 \leq C_b \leq 0,8$, when determining scantlings of aft ends of coamings and aft hatch cover skirt plates forward of amidships, C_b need not be taken less than 0,8

C_b = block coefficient, as defined in Pt 3, Ch 1,6.1.6

x' = distance, in metres, between the transverse coaming or hatch cover skirt plate considered and aft end of the length L. When determining side coamings or side hatch cover skirt plates, the side is to be subdivided into parts of approximately equal length, not exceeding $0,15L$ each, and x' is to be taken as the distance between aft end of the length L and the centre of each part considered

z = vertical distance in metres from the summer load line to the mid point of stiffener span, or to the middle of the plate field

$c = 0,3 + 0,7\,\dfrac{b'}{B'}$

b' = breadth of coaming in metres at the position considered

B' = actual maximum breadth of ship in metres on the exposed weather deck at the position considered

b'/B' is not to be taken less than 0,25

The design pressure p_A is not to be taken less than the minimum values given in Table 11.2.2.

Table 11.2.1 Design pressure p_H of weather deck hatches

Position (*see* Note)	p_H, in kN/m^2	
1	$\frac{x}{L_L} \le 0{,}75$	$0{,}75 < \frac{x}{L_L} \le 1{,}0$
	For 24 m ≤ L_L ≤ 100 m	
	$\frac{g}{76}\,(1{,}5L_L + 116)$	on freeboard deck $\frac{g}{76}\left[(4{,}28L_L + 28)\,\frac{x}{L_L} - 1{,}71L_L + 95\right]$
		upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck $\frac{g}{76}\,(1{,}15L_L + 116)$
	For L_L > 100 m	
	3,5*g*	on freeboard deck for type B ships according to ICLL $g\left[(0{,}0296L_1 + 3{,}04)\,\frac{x}{L_L} - 0{,}0222L_1 + 1{,}22\right]$
		on freeboard deck for ships with less freeboard than type B according to ICLL $g\left[(0{,}1452L_1 - 8{,}52)\,\frac{x}{L_L} - 0{,}1089L_1 + 9{,}89\right]$ $L_1 = L_L$ but not more than 340 m
		upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck 3,5*g*
2	For 24 m ≤ L_L ≤ 100 m	
	$\frac{g}{76}\,(1{,}1L_L + 87{,}6)$	
	For L_L > 100 m	
	2,6*g*	
	upon exposed superstructure decks located at least one superstructure standard height above the lowest Position 2 deck 2,1*g*	

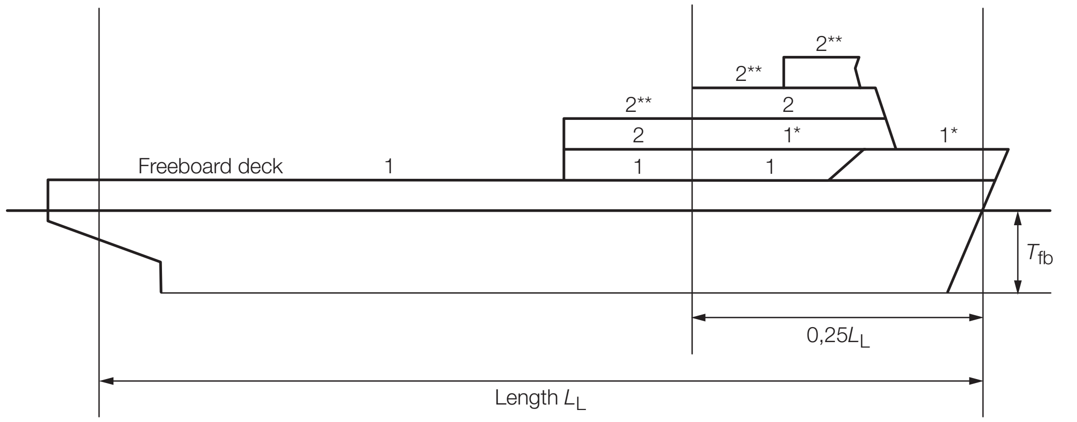
Symbols

L_L = load line length, as defined in Pt 3, Ch 1,6.1.8
g = acceleration due to gravity, 9,81 m/s^2

NOTE
The positions 1 and 2 are illustrated for example ships in Fig. 11.2.1 and Fig. 11.2.2.

Table 11.2.2 Minimum design load, p_{Amin}

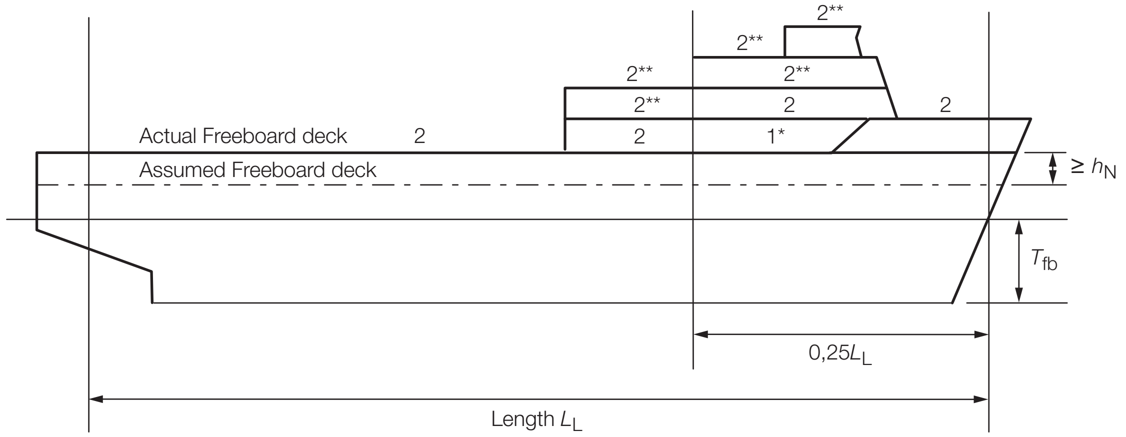
L	p_{Amin}, kN/m^2	
	For unprotected fronts	Elsewhere
≤ 50	30	15
> 50 < 250	$25 + \frac{L}{10}$	$12{,}5 + \frac{L}{20}$
≥ 250	50	25



* reduced load upon exposed superstructure decks located at least one standard height of superstructure above the freeboard deck

** reduced load upon exposed superstructure decks of vessels with L_L > 100 m located at least one superstructure standard height of superstructure above the lowest Position 2 deck

Fig. 11.2.1 Positions 1 and 2



* reduced load upon exposed superstructure decks located at least one standard height of superstructure above the freeboard deck

** reduced load upon exposed superstructure decks of vessels with L_L > 100 m located at least one superstructure standard height of superstructure above the lowest Position 2 deck

Fig. 11.2.2 Positions 1 and 2 for an increased freeboard

2.3.4 The pressure on hatch covers due to distributed cargo loads p_L, in kN/m^2, resulting from heave and pitch, is to be determined according to the following formula:

$p_L = p_c (1 + a_v)$ kN/m^2

where

p_c = uniform cargo load, in kN/m^2

NOTE

For 'tween deck hatch covers, p_c is not to be taken less than 7,07 H_{td} kN/m^2, *see* Ch 3,5.2.1, Table 3.5.1 and Fig. 3.5.1. A design load less than this will be specially considered.

a_v = acceleration addition as follows:

$a_v = F\,m$

$$F = 0{,}11 \frac{v_0}{\sqrt{L}}$$

$$m = m_0 - 5 (m_0 - 1) \frac{x}{L} \quad \text{for } 0 \le \frac{x}{L} \le 0{,}2$$

$$= 1{,}0 \text{ for } 0{,}2 < \frac{x}{L} \le 0{,}7$$

$$= 1 + \frac{m_0 + 1}{0{,}3} \left(\frac{x}{L} - 0{,}7\right) \quad \text{for } 0{,}7 < \frac{x}{L} \le 1{,}0$$

$m_0 = 1{,}5 + F$

v_0 = Maximum speed at summer load line draught, v_0 is not to be taken less than $\sqrt{L}$, in knots.

2.3.5 Point loads due to single forces, P, in kN, resulting from heave and pitch are to be determined as follows:

$P = P_s (1 + a_v)$ kN

P_s = single force, in kN.

2.3.6 In addition to the loads defined in this Section, hatch covers are loaded in the ship's transverse direction by forces due to elastic deformations of the ship's hull. Hatch covers are to be designed such that the sum of stresses does not exceed the permissible values given in 2.4.1.

2.4 Allowable stress and deflection

2.4.1 The equivalent stress, σ_v, in steel hatch cover structures related to the net thickness shall not exceed 0,8σ_o, where σ_o is the minimum yield stress, in N/mm^2, of the material. For design loads according to 2.3.3 to 2.3.6 and Pt 4, Ch 8,11.2, the equivalent stress, σ_v, related to the net thickness shall not exceed 0,9σ_o when the stresses are assessed by means of FEM using plane stress or shell elements.

For beam element calculations and grillage analysis, the equivalent stress may be taken as follows:

$$\sigma_v = \sqrt{\sigma^2 + 3\tau^2}\text{ , in N/mm}^2$$

σ = normal stress in N/mm^2

τ = shear stress in N/mm^2

For FEM calculations, the equivalent stress may be taken as follows:

$$\sigma_v = \sqrt{\sigma_x{}^2 - \sigma_x\sigma_y + \sigma_y{}^2 + 3\tau^2}\text{ , in N/mm}^2$$

σ_x = normal stress, in N/mm^2, in x-direction

σ_y = normal stress, in N/mm^2, in y-direction

τ = shear stress, in N/mm^2, in the x-y plane

Indices x and y are coordinates of a two-dimensional Cartesian system in the plane of the considered structural element.

In the case of FEM calculations using shell or plane strain elements, the stresses are to be read from the centre of the individual element. Where shell elements are used, the stresses are to be evaluated at the mid plane of the element. Stress concentrations are to be considered. FEM calculations are to be carried out in accordance with the ShipRight procedure *Assessment of Steel Hatch Covers using Finite Element Analysis*.

2.4.2 The vertical deflection of primary supporting members due to the vertical weather design load according to 2.3.2 is to be not more than 0,0056l_g where l_g is the greatest span of primary supporting members.

For 'tween deck hatch covers not exposed to the vertical weather design load according to 2.3.2, the vertical deflection of primary supporting members due to the cargo loads according to 2.3.4, 2.3.5 and Pt 4, Ch 8,11.2 is to be not more than 0,007l_g where l_g is the greatest span of primary supporting members.

2.5 Local net plate thickness

2.5.1 The local net plate thickness, t, in mm, of the hatch cover top plating is not to be less than:

$$t = F_p\, 0{,}0158 s \sqrt{\frac{p}{0{,}95\sigma_o}}$$

and to be not less than 1 per cent of the spacing of the stiffener or 6 mm, whichever is greater

F_p = factor for combined membrane and bending response

= 1,5 in general

$$= 1{,}9\,\frac{\sigma}{\sigma_a}, \quad \text{for } \frac{\sigma}{\sigma_a} \ge 0{,}8$$

for the attached plate flange of primary supporting members

s = stiffener spacing, in mm

p = pressure p_H and p_L, in kN/m^2, as defined in 2.3

σ = normal stress, in N/mm^2, of hatch cover top plating

σ_a = 0,8σ_o, in N/mm^2

For flange plates under compression, sufficient buckling strength according to 2.11 is to be demonstrated.

The normal stress σ of the hatch cover plating may be determined in a distance s from webs of adjacent primary supporting members perpendicular to secondary stiffeners, and in a distance s/2 from the web of an adjacent primary supporting member parallel to secondary stiffeners, *see* Fig. 11.2.3. The greater of both stresses is to be taken. For the distribution of normal stress σ between two parallel girders, *see* 2.14.1.

2.6 Local plate thickness of hatch covers for wheel loading and helicopter landing

2.6.1 The local gross plate thickness of hatch covers for wheel loading is to comply with Ch 9,3.

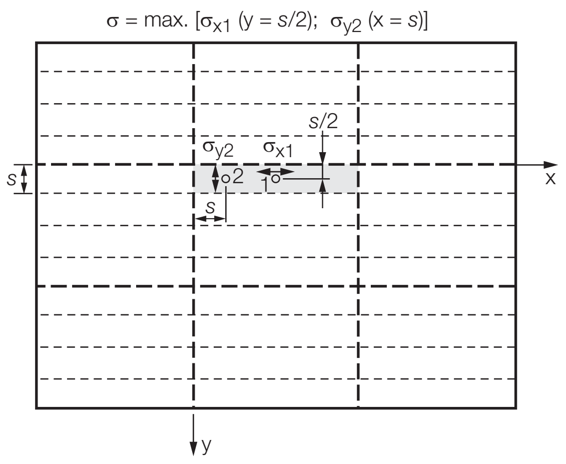


Fig. 11.2.3
Determination of normal stress of the hatch cover plating

2.6.2 The local gross plate thickness of hatch covers for helicopter landing is to comply with Ch 9,5.

2.7 Lower plating of double skin hatch covers and box girders

2.7.1 The thickness to fulfil the strength requirements is to be obtained from the calculation according to 2.10 under consideration of permissible stresses according to 2.4.1. The net thickness must not be less than the larger of the following values when the lower plating is taken into account as a strength member of the hatch cover:

t = 0,0065s, in mm
t_{min} = 5 mm
s = stiffener spacing, in mm.

2.8 Net scantling of secondary stiffeners

2.8.1 The net section modulus, Z, and net shear area, A_s, of uniformly loaded hatch cover stiffeners constrained at both ends is not to be less than:

$$Z = \frac{0{,}104}{\sigma_o} s\, l^2\, p, \text{ in cm}^3$$

$$A_s = \frac{0{,}01}{\sigma_o} s\, l\, p, \text{ in cm}^2$$

where

l = secondary stiffener span, in metres, to be taken as the spacing, in metres, of primary supporting members or the distance between a primary supporting member and the edge support, as applicable
s = secondary stiffener spacing, in mm
p = pressure p_H and p_L, in kN/m^2, as defined in 2.3.

2.8.2 The net section modulus of the secondary stiffeners is to be determined, based on an attached plate width assumed equal to the stiffener spacing.

2.8.3 For flat bar secondary stiffeners and buckling stiffeners, the ratio h/t_w is to be not greater than $15k^{0,5}$

where

h = height of the stiffener
t_w = net thickness of the stiffener
k = $235/\sigma_o$.

2.8.4 Stiffeners parallel to primary supporting members and arranged within the effective breadth according to 2.10 must be continuous when crossing primary supporting members and may be considered when calculating the cross-sectional properties of primary supporting members. It is to be verified that the combined stress of those stiffeners, induced by the bending of primary supporting members and lateral pressures, does not exceed the permissible stresses according to 2.4.1.

2.8.5 For hatch cover stiffeners under compression, sufficient safety against lateral and torsional buckling according to 2.15 and 2.16 is to be verified.

2.8.6 For hatch covers subject to wheel loading, stiffener gross scantlings are to comply with Ch 9,3.

2.8.7 For hatch covers subject to helicopter landing, stiffener gross scantlings are to comply with Ch 9,5.

2.9 Net scantling of primary supporting members

2.9.1 Scantlings of primary supporting members are obtained from calculations according to 2.10, under consideration of permissible stresses according to 2.4.1.

2.9.2 For all components of primary supporting members, sufficient safety against buckling must be verified according to 2.11 to 2.16. For biaxial compressed flange plates, this is to be verified within the effective widths according to 2.14.1.

2.9.3 The net thickness, t, in mm, of webs of primary supporting members is not to be less than:

(a) 0,0065s, in mm
(b) 5 mm

where

s = stiffener spacing, in mm.

2.9.4 Scantlings of edge girders (skirt plates) are obtained from the calculations according to 2.10, under consideration of permissible stresses according to 2.4.1.

2.9.5 The net thickness, t, in mm, of the outer edge girders exposed to wash of sea is not to be less than the largest of the following values:

(a) $0{,}0158s\sqrt{\dfrac{p_A}{0{,}95\sigma_o}}$
(b) 0,0085s mm
(c) 5 mm

where

p_A = horizontal pressure, as defined in 2.3.3
s = stiffener spacing, in mm.

2.9.6 The stiffness of edge girders is to be sufficient to maintain adequate sealing pressure between securing devices. The moment of inertia, in cm^4, of edge girders is not to be less than:

$I = 6q\, s_{SD}^4$

q = packing line pressure, in N/mm, minimum 5 N/mm

s_{SD} = spacing, in metres, of securing devices.

2.10 Strength calculations

2.10.1 Strength calculation for hatch covers may be carried out by using either beam theory, grillage analysis or FEM.

2.10.2 The effective cross-sectional properties for calculation by beam theory or grillage analysis are to be determined considering the effective breadth. Cross-sectional areas of secondary stiffeners parallel to the primary supporting member under consideration within the effective breadth can be included, *see* Fig. 11.2.5. The effective breadth of plating, e_m, of primary supporting members is to be determined according to Table 11.2.3, considering the type of loading. Special calculations may be required for determining the effective breadth of one-sided or non-symmetrical flanges. The effective cross-sectional area of plates is not to be less than the cross-sectional area of the face-plate. For flange plates under compression with secondary stiffeners perpendicular to the web of the primary supporting member, the effective width is to be determined according to 2.14.1.

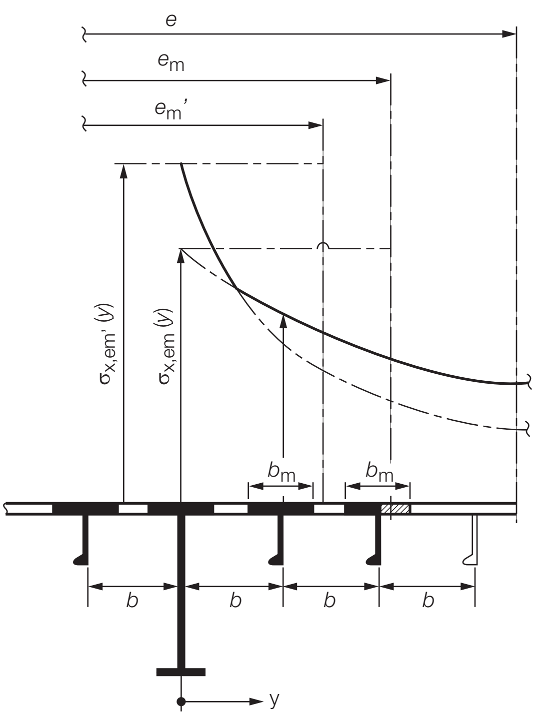


Fig. 11.2.5
Stiffening parallel to web of primary supporting member

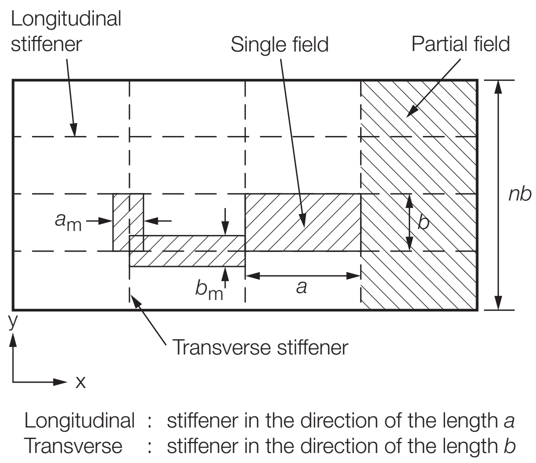


Fig. 11.2.4
General arrangement of panel

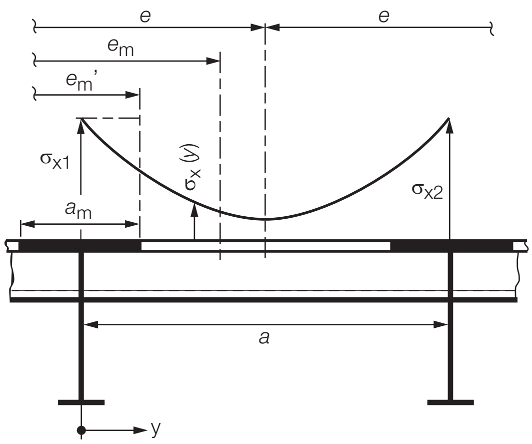


Fig. 11.2.6
Stiffening perpendicular to web of primary supporting member

Table 11.2.3 Effective breadth e_m of plating of primary supporting members

l/e	0	1	2	3	4	5	6	7	≥8
e_{m1}/e	0	0,36	0,64	0,82	0,91	0,96	0,98	1,00	1,00
e_{m2}/e	0	0,20	0,37	0,52	0,65	0,75	0,84	0,89	0,90
Symbols									
e_{m1} is to be applied where primary supporting members are loaded by uniformly distributed loads or else by no fewer than six equally spaced single loads e_{m2} is to be applied where primary supporting members are loaded by three or fewer single loads. Intermediate values may be obtained by direct interpolation l length of zero-points of bending moment curve: $l = l_0$ for simply supported primary supporting members $l = 0{,}6 l_0$ for primary supporting members with both ends constrained where l_0 is the unsupported length of the primary supporting member e width of plating supported, measured from centre to centre of the adjacent unsupported fields									

2.11 Buckling strength of hatch cover structures

2.11.1 For hatch cover structures, sufficient buckling strength is to be demonstrated.

a = length of the longer side of a single plate field, in mm
b = breadth of the shorter side of a single plate field, in mm
α = aspect ratio of single plate field
= a/b
n = number of single plate field breadths within the partial or total plate field
t = net plate thickness, in mm
σ_x = membrane stress, in N/mm^2, in x-direction
σ_y = membrane stress, in N/mm^2, in y-direction
τ = shear stress, in N/mm^2, in the x-y plane
E = modulus of elasticity, in N/mm^2, of the material
= $2{,}06 \times 10^5$ N/mm^2 for steel
σ_F = minimum yield stress, in N/mm^2, of the material.

Compressive and shear stresses are to be taken positive, tension stresses are to be taken negative.

If stresses in the x- and y-direction already contain the Poisson effect (calculated using FEM), the following modified stress values may be used. Both stresses σ_x^* and σ_y^* are to be compressive stresses, in order to apply the stress reduction according to the following formulae.

$$\sigma_x = \frac{(\sigma_x^* - 0{,}3\sigma_y^*)}{0{,}91}$$

$$\sigma_y = \frac{(\sigma_y^* - 0{,}3\sigma_x^*)}{0{,}91}$$

σ_x^*, σ_y^* = stresses containing the Poisson effect where compressive stress fulfils the condition
$\sigma_y^* < 0{,}3\sigma_x^*$, then $\sigma_y = 0$ and $\sigma_x = \sigma_x^*$
where compressive stress fulfils the condition
$\sigma_x^* < 0{,}3\sigma_y^*$, then $\sigma_x = 0$ and $\sigma_y = \sigma_y^*$
F_1 = correction factor for boundary condition at the longitudinal stiffeners according to Table 11.2.4
σ_e = reference stress, in N/mm^2, taken equal to
$= 0{,}9E\left(\frac{t}{b}\right)^2$

ψ = edge stress ratio taken equal to
$= \frac{\sigma_2}{\sigma_1}$

where
σ_1 = maximum compressive stress
σ_2 = minimum compressive stress or tension stress
S = safety factor (based on net scantling approach), taken equal to
= 1,25 for hatch covers when subjected to the vertical weather design load according to 2.3.2
= 1,10 for hatch covers when subjected to loads according to 2.3.3 to 2.3.6 and Pt 4, Ch 8,11,2
λ = reference degree of slenderness, taken equal to:
$= \sqrt{\frac{\sigma_o}{K\sigma_e}}$
K = buckling factor according to Table 11.2.6.

Table 11.2.4 Correction factor F_1

Stiffeners sniped at both ends	1,00	
Guidance values, *see* Note 1, where both ends are effectively connected to adjacent structures	1,05 1,10 1,21 1,30	for flat bars for bulb sections for angle and tee-sections for u-type sections, *see* Note 2, and girders of high rigidity
An average value of F, *see* Note 1, is to be used for plate panels having different edge stiffeners		
NOTES 1. Exact values may be determined by direct calculations. 2. A higher value, but not greater than 2,0, may be taken if it is verified by a buckling strength check of the partial plate field using non-linear FEA. The calculations are to be submitted to LR for approval.		

2.11.2 Proof is to be provided that the following condition is complied with for the single plate field *a b*:

$$\left(\frac{|\sigma_x|\,S}{\kappa_x\,\sigma_o}\right)^{e1}+\left(\frac{|\sigma_y|\,S}{\kappa_y\,\sigma_o}\right)^{e2}-B\left(\frac{\sigma_x\,\sigma_y\,S^2}{\sigma_o^{\,2}}\right)+\left(\frac{|\tau|S\sqrt{3}}{\kappa_\tau\,\sigma_o}\right)^{e3}\leq 1{,}0$$

The first two terms and the last term of the above condition shall not exceed 1,0.

The reduction factors κ_x, κ_y and κ_τ are given in Table 11.2.6.

Where $\sigma_x \leq 0$ (tension stress), $\kappa_x = 1{,}0$.

Where $\sigma_y \leq 0$ (tension stress), $\kappa_y = 1{,}0$.

The exponents e_1, e_2 and e_3 as well as the factor *B* are to be taken as given by Table 11.2.5.

Table 11.2.5 Coefficients e_1, e_2, e_3 and factor B

Exponents e_1 to e_3 and factor B	Plate panel
e_1	$1 + \kappa_x^{\,4}$
e_2	$1 + \kappa_y^{\,4}$
e_3	$1 + \kappa_x\,\kappa_y\,\kappa_\tau^{\,2}$
B σ_x and σ_y positive (compression stress)	$(\kappa_x\,\kappa_y)^5$
B σ_x or σ_y negative (tension stress)	1

2.12 Webs and flanges of primary supporting members

2.12.1 For non-stiffened webs and flanges of primary supporting members, sufficient buckling strength, as for the hatch cover top and lower plating, is to be demonstrated according to 2.11.2.

2.13 Longitudinal and transverse secondary stiffeners

2.13.1 It is to be demonstrated that the continuous longitudinal and transverse stiffeners of partial and total plate fields comply with the conditions set out in 2.15 and 2.16.

2.14 Effective width of top and lower hatch cover plating

2.14.1 For demonstration of buckling strength according to 2.15 and 2.16, the effective width of plating may be determined by the following formulae:

$b_m = \kappa_x\, b$ for longitudinal stiffeners

$a_m = \kappa_y\, a$ for transverse stiffeners

see also Fig. 11.2.4.

The effective width of plating is not to be taken greater than the value obtained from 2.10.2.

The effective width e'_m of stiffened flange plates of primary supporting members may be determined as follows:

(a) Stiffening parallel to web of primary supporting member:

$b < e_m$

$e'_m = n\, b_m$

n = integer number of stiffener spacings b inside the effective breadth e_m according to 2.10.2

$= \text{int}\left(\frac{e_m}{b}\right)$

(b) Stiffening perpendicular to web of primary supporting member:

$a \geq e_m$

$e'_m = n\, a_m < e_m$

$n = 2{,}7\,\frac{e_m}{a} \leq l$

e = width of plating supported according to 2.10.2

For $b \geq e_m$ or $a < e_m$, respectively, b and a are to be exchanged.

a_m and b_m for flange plates are in general to be determined for $\psi = 1$.

Scantlings of plates and stiffeners are in general to be determined according to the maximum stresses σ_x (*y*) at webs of primary supporting member and stiffeners, respectively. For stiffeners with spacing *b* under compression arranged parallel to primary supporting members, no value less than $0{,}25\sigma_o$ shall be inserted for σ_x (y=b).

The stress distribution between two primary supporting members can be obtained by the following formula:

$$\sigma_x(y) = \sigma_{x1}\left\{1-\frac{y}{e}\left[3+c_1-4c_2-2\,\frac{y}{e}\,(1+c_1-2c_2)\right]\right\}$$

where

$c_1 = \dfrac{\sigma_{x2}}{\sigma_{x1}}$ $\quad 0 \leq c_1 \leq 1$

$c_2 = \dfrac{1{,}5}{e}\,(e_{m1}'' + e_{m2}'') - 0{,}5$

e_{m1}'' = proportionate effective breadth e_{m1} or proportionate effective width e_{m1}' of primary supporting member 1 within the distance e, as appropriate

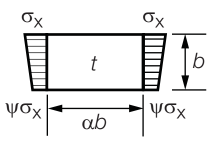
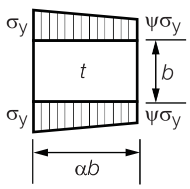
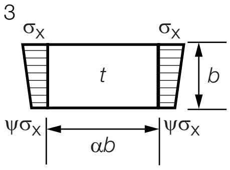
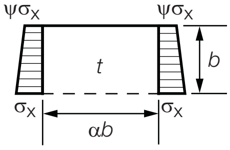
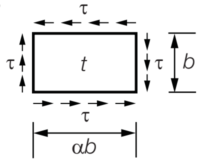
e_{m2}'' = proportionate effective breadth e_{m2} or proportionate effective width e_{m2}' of primary supporting member 2 within the distance e, as appropriate

σ_{x1}, σ_{x2} = normal stresses in flange plates of adjacent primary supporting member 1 and 2 with spacing e, based on cross-sectional properties considering the effective breadth or effective width, as appropriate

y = distance of considered location from primary supporting member 1

Shear stress distribution in the flange plates may be assumed linearly.

Table 11.2.6 Buckling and reduction factors for plane elementary plate panels

Buckling load case	Edge stress ratio ψ	Asp. ratio $\alpha = \frac{a}{b}$	Buckling factor K	Reduction factor κ
1 	$1 \geq \psi \geq 0$	$\alpha \geq 1$	$K = \dfrac{8,4}{\psi + 1,1}$	$\kappa_x = 1 \quad$ for $\lambda \leq \lambda_c$ $\kappa_x = c\left(\dfrac{1}{\lambda} - \dfrac{0,22}{\lambda^2}\right)$ for $\lambda > \lambda_c$ $c = (1,25 - 0,12\psi) \leq 1,25$ $\lambda_c = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0,88}{c}}\right)$
	$0 > \psi > -1$		$K = 7,63 - \psi\,(6,26 - 10\psi)$	
	$\psi \leq -1$		$K = 5,975\,(1 - \psi)^2$	
2 	$1 \geq \psi \geq 0$	$\alpha \geq 1$	$K = F_1\left(1 + \dfrac{1}{\alpha^2}\right)^2 \dfrac{2,1}{(\psi + 1,1)}$	$\kappa_y = c\left(\dfrac{1}{\lambda} - \dfrac{R + F^2\,(H - R)}{\lambda^2}\right)$ $c = (1,25 - 0,12\psi) \leq 1,25$ $R = \lambda\left(1 - \dfrac{\lambda}{c}\right)$ for $\lambda < \lambda_c$ $R = 0,22$ for $\lambda \geq \lambda_c$ $\lambda_c = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0,88}{c}}\right)$ $F = \left(1 - \dfrac{\dfrac{K}{0,91} - 1}{\lambda_p^2}\right) c_1 \geq 0$ $\lambda_p^2 = \lambda^2 - 0,5$ for $1 \leq \lambda_p^2 \leq 3$ $c_1 = \left(1 - \dfrac{F_1}{\alpha}\right) \geq 0$ $H = \lambda - \dfrac{2\lambda}{c\,(T + \sqrt{T^2 - 4})} \geq R$ $T = \lambda + \dfrac{14}{15\lambda} + \dfrac{1}{3}$
	$0 > \psi > -1$	$1 \leq \alpha \leq 1,5$	$K = F_1\left[\left(1 + \dfrac{1}{\alpha^2}\right)^2 \dfrac{2,1\,(1 + \psi)}{1,1} - \dfrac{\psi}{\alpha^2}\,(13,9 - 10\psi)\right]$	
		$\alpha > 1,5$	$K = F_1\left[\left(1 + \dfrac{1}{\alpha^2}\right)^2 \dfrac{2,1\,(1 + \psi)}{1,1} - \dfrac{\psi}{\alpha^2}\left(5,87 + 1,87\alpha^2 + \dfrac{8,6}{\alpha^2} - 10\psi\right)\right]$	
	$\psi \leq -1$	$1 \leq \alpha \leq \dfrac{3\,(1 - \psi)}{4}$	$K = 5,975F_1\left(\dfrac{1 - \psi}{\alpha}\right)^2$	
		$\alpha > \dfrac{3\,(1 - \psi)}{4}$	$K = F_1\left[3,9675\left(\dfrac{1 - \psi}{\alpha}\right)^2 + 0,5375\left(\dfrac{1 - \psi}{\alpha}\right)^4 + 1,87\right]$	
3 	$1 \geq \psi \geq 0$	$\alpha > 0$	$K = \dfrac{4\left(0,425 + \dfrac{1}{\alpha^2}\right)}{3\psi + 1}$	$\kappa_x = 1$ for $\lambda \leq 0,7$ $\kappa_x = \dfrac{1}{\lambda^2 + 0,51}$ for $\lambda > 0,7$
	$0 > \psi \geq -1$		$K = 4\left(0,425 + \dfrac{1}{\alpha^2}\right)(1 + \psi) - 5\psi\,(1 - 3,42\psi)$	
4 	$1 \geq \psi \geq -1$	$\alpha > 0$	$K = \left(0,425 + \dfrac{1}{\alpha^2}\right)\dfrac{3 - \psi}{2}$	
5 	—		$K = K_\tau\sqrt{3}$	$\kappa_\tau = 1$ for $\lambda \leq 0,84$ $\kappa_\tau = \dfrac{0,84}{\lambda}$ for $\lambda > 0,84$
		$\alpha \geq 1$	$K_\tau = \left(5,34 + \dfrac{4}{\alpha^2}\right)$	
		$0 < \alpha < 1$	$K_\tau = \left(4 + \dfrac{5,34}{\alpha^2}\right)$	
Explanations for boundary conditions	- - - - - - - - plate edge free ———— plate edge simply supported			

2.15 Lateral buckling of secondary stiffeners

2.15.1 The secondary stiffeners are to comply with the following criteria:

$$\frac{\sigma_a + \sigma_b}{\sigma_o} S \le 1$$

where

σ_a = uniformly distributed compressive stress, in N/mm^2, in the direction of the stiffener axis

σ_a = σ_x for longitudinal stiffeners

σ_a = σ_y for transverse stiffeners

σ_b = bending stress, in N/mm^2, in the stiffener

$= \dfrac{M_0 + M_1}{Z_{st} \times 10^3}$

M_0 = bending moment, in Nmm, due to the deformation w of stiffener, taken equal to:

$$M_0 = F_{Ki} \frac{p_z w}{c_f - p_z} \quad \text{with } (c_f - p_z) > 0$$

M_1 = bending moment, in Nmm, due to the lateral load p equal to:

$$M_1 = \frac{p\, b\, a^2}{24 \times 10^3} \quad \text{for longitudinal stiffeners}$$

$$M_1 = \frac{p\, a\, (n\, b)^2}{8 c_s \times 10^3} \quad \text{for transverse stiffeners}$$

n is to be taken equal to 1 for ordinary transverse stiffeners

p = lateral load, in kN/m^2

F_{Ki} = ideal buckling force, in N, of the stiffener

$$F_{Kix} = \frac{\pi^2}{a^2} E\, I_x \times 10^4 \quad \text{for longitudinal stiffeners}$$

$$F_{Kiy} = \frac{\pi^2}{(n\, b)^2} E\, I_y \times 10^4 \quad \text{for transverse stiffeners}$$

I_x, I_y = net moments of inertia, in cm^4, of the longitudinal or transverse stiffener, including effective width of attached plating according to 2.14.1. I_x and I_y are to comply with the following criteria:

$$I_x \ge \frac{b\, t^3}{12 \times 10^4}$$

$$I_y \ge \frac{a\, t^3}{12 \times 10^4}$$

p_z = nominal lateral load, in N/mm^2, of the stiffener due to σ_x, σ_y and τ

$$p_{zx} = \frac{t}{b}\left(\sigma_{xl}\left(\frac{\pi\, b}{a}\right)^2 + 2 c_y \sigma_y + \sqrt{2}\, \tau_1\right)$$

for longitudinal stiffeners

$$p_{zy} = \frac{t}{a}\left(2 c_x \sigma_{xl} + \sigma_y \left(\frac{\pi\, a}{n\, b}\right)^2 \left(1 + \frac{A_y}{a\, t}\right) + \sqrt{2}\, \tau_1\right)$$

for transverse stiffeners

$$\sigma_{xl} = \sigma_x\left(1 + \frac{A_x}{b\, t}\right)$$

c_x, c_y = factor taking into account the stresses perpendicular to the stiffener's axis and distributed variably along the stiffener's length

$= 0{,}5\,(1 + \psi)$ for $0 \le \psi \le 1$

$= \dfrac{0{,}5}{1 - \psi}$ for $\psi < 0$

A_x, A_y = net sectional area, in mm^2, of the longitudinal or transverse stiffener, respectively, without attached plating

$$\tau_1 = \left[\tau - t\sqrt{\sigma_o E\left(\frac{m_1}{a^2} + \frac{m_2}{b^2}\right)}\right] \ge 0$$

for longitudinal stiffeners:

$\dfrac{a}{b} \ge 2{,}0$: $m_1 = 1{,}47$ $m_2 = 0{,}49$

$\dfrac{a}{b} < 2{,}0$: $m_1 = 1{,}96$ $m_2 = 0{,}37$

for transverse stiffeners:

$\dfrac{a}{n\, b} \ge 0{,}5$: $m_1 = 0{,}37$ $m_2 = \dfrac{1{,}96}{n^2}$

$\dfrac{a}{n\, b} < 0{,}5$: $m_1 = 0{,}49$ $m_2 = \dfrac{1{,}47}{n^2}$

w = $w_0 + w_1$

w_0 = assumed imperfection, in mm

$$w_{0x} = \le \min\left(\frac{a}{250}, \frac{b}{250}, 10\right) \quad \text{for longitudinal stiffeners}$$

$$w_{0y} = \le \min\left(\frac{a}{250}, \frac{n\, b}{250}, 10\right) \quad \text{for transverse stiffeners}$$

NOTE

For stiffeners sniped at both ends, w_0 must not be taken less than the distance from the mid point of plating to the neutral axis of the profile, including effective width of plating

w_1 = deformation of stiffener, in mm, at mid point of stiffener span due to lateral load p

In the case of uniformly distributed load, the following values for w_1 may be used:

$$w_1 = \frac{p\, b\, a^4}{384 \times 10^7 E\, I_x} \quad \text{for longitudinal stiffeners}$$

$$w_1 = \frac{5a\, p\, (n\, b)^4}{384 \times 10^7 E\, I_y\, c_s^2} \quad \text{for transverse stiffeners}$$

c_f = elastic support provided by the stiffener, in N/mm^2

(i) For longitudinal stiffeners:

$$c_{fx} = F_{Kix} \frac{\pi^2}{a^2} (1 + c_{px})$$

$$c_{px} = \frac{1}{1 + \dfrac{0{,}91\left(\dfrac{12 \times 10^4 I_x}{t^3 b} - 1\right)}{c_{xa}}}$$

$$c_{xa} = \left(\frac{a}{2b} + \frac{2b}{a}\right)^2 \quad \text{for } a \ge 2b$$

$$c_{xa} = \left(1 + \left(\frac{a}{2b}\right)^2\right)^2 \quad \text{for } a < 2b$$

(ii) For transverse stiffeners:

$$c_{fy} = c_S F_{Kiy} \frac{\pi^2}{(n\, b)^2} (1 + c_{py})$$

$$c_{py} = \frac{1}{1 + \dfrac{0{,}91\left(\dfrac{12 \times 10^4\, I_y}{t^3\, a} - 1\right)}{c_{ya}}}$$

$$c_{ya} = \left(\frac{n\,b}{2a} + \frac{2a}{n\,b}\right)^2 \quad \text{for } n\,b \geq 2a$$

$$c_{ya} = \left(1 + \left(\frac{n\,b}{2a}\right)^2\right)^2 \quad \text{for } n\,b < 2a$$

c_s = factor accounting for the boundary conditions of the transverse stiffener
= 1,0 for simply supported stiffeners
= 2,0 for partially constrained stiffeners

Z_{st} = net section modulus of stiffener (longitudinal or transverse), in cm^3, including effective width of plating according to 2.14.1.

If no lateral load p is acting, the bending stress σ_b is to be calculated at the mid point of the stiffener span for that fibre which results in the largest stress value. If a lateral load p is acting, the stress calculation is to be carried out for both fibres of the stiffener's cross-sectional area (if necessary for the biaxial stress field at the plating side).

2.16 Torsional buckling of secondary stiffeners

2.16.1 The longitudinal secondary stiffeners are to comply with the following criteria:

$$\frac{\sigma_x\, S}{\kappa_T\, \sigma_o} \leq 1{,}0$$

where

κ_T = coefficient taken equal to:

κ_T = 1,0 for $\lambda_T \leq 0{,}2$

$$\kappa_T = \frac{1}{\phi + \sqrt{\phi^2 - \lambda_T^2}} \quad \text{for } \lambda_T > 0{,}2$$

ϕ = $0{,}5\,(1 + 0{,}21\,(\lambda_T - 0{,}2) + \lambda_T^2)$

λ_T = reference degree of slenderness taken equal to:

$$\lambda_T = \sqrt{\frac{\sigma_F}{\sigma_{KiT}}}$$

$$\sigma_{KiT} = \frac{E}{I_p}\left(\frac{\pi^2\, I_\omega 10^2}{a^2}\,\varepsilon + 0{,}385 I_T\right), \text{ in N/mm}^2$$

For I_P, I_T, I_ω, *see* Fig. 11.2.7 and Table 11.2.7

I_P = net polar moment of inertia of the stiffener, in cm^4, related to the point C

I_T = net St.Venant's moment of inertia of the stiffener, in cm^4

I_ω = net sectorial moment of inertia of the stiffener, in cm^6, related to the point C

ε = degree of fixation taken equal to:

$$\varepsilon = 1 + 10^{-3}\sqrt{\frac{a^4}{\dfrac{3}{4}\,\pi^4\, I_\omega\left(\dfrac{b}{t^3} + \dfrac{4h_w}{3t_w^3}\right)}}$$

h_w = web height, in mm
t_w = net web thickness, in mm
b_f = flange breadth, in mm
t_f = net flange thickness, in mm
A_w = net web area equal to: $A_w = h_w\, t_w$
A_f = net flange area equal to: $A_f = b_f\, t_f$
e_f = $h_w + \dfrac{t_f}{2}$, in mm
b = stiffener spacing, in mm
t = local net plate thickness of the attached plate, in mm.

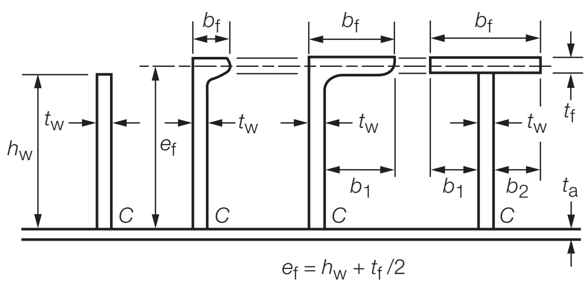


Fig. 11.2.7 Dimensions of stiffener

Table 11.2.7 Moments of inertia

Section	I_P	I_T	I_ω
Flat bar	$\dfrac{h_w^3\, t_w}{3 \times 10^4}$	$\dfrac{h_w\, t_w^3}{3 \times 10^4}\left(1 - 0{,}63\,\dfrac{t_w}{h_w}\right)$	$\dfrac{h_w^3\, t_w^3}{36 \times 10^6}$
Sections with bulb or flange	$\left(\dfrac{A_w\, h_w^2}{3} + A_f\, e_f^2\right) 10^{-4}$	$\dfrac{h_w\, t_w^3}{3 \times 10^4}\left(1 - 0{,}63\,\dfrac{t_w}{h_w}\right) + \dfrac{b_f\, t_f^3}{3 \times 10^4}\left(1 - 0{,}63\,\dfrac{t_f}{b_f}\right)$	for bulb and angle sections: $\dfrac{A_f\, e_f^2\, b_f^2}{12 \times 10^6}\left(\dfrac{A_f + 2{,}6A_W}{A_f + A_W}\right)$ for tee sections: $\dfrac{b_f^3\, t_f\, e_f^2}{12 \times 10^6}$

2.16.2 For transverse secondary stiffeners loaded by compressive stresses and which are not supported by longitudinal stiffeners, sufficient torsional buckling strength is to be demonstrated analogously in accordance with this sub-Section.

2.17 Pontoon covers

2.17.1 The structural assessment of pontoon covers, as defined in 1.1.5(b), is to be carried out by direct calculations, which are to be submitted for approval, using the minimum design pressures acting on the hatch covers defined in Table 11.2.8. The permissible stress, deflection and buckling criteria are given in Table 11.2.10.

2.17.2 The gross thickness of the plating of steel pontoon covers is to be not less than the greater of:

(a) t = 0,01s mm

(b) t = 6,0 mm as required by Table 11.2.8

where

s = stiffener spacing in mm

t = thickness as required by 2.17.1.

2.17.3 The gross scantlings of steel pontoon cover primary and secondary webs or stiffeners are to be not less than would be required to satisfy the requirements of Table 11.2.11. Alternatively, scantlings may be determined by direct calculations, which are to be submitted for approval. In no case are the stresses and deflections given in Table 11.2.10 to be exceeded.

Table 11.2.8 Pontoon cover minimum design pressures

For ships of 100 m in length and above:
(a) Position 1 hatch covers located in the forward quarter of the ship's length shall be designed for wave pressures at the forward perpendicular, calculated from the following equation: Minimum design pressure, p = 49,05 + 9,81 (L_H –100) a in kN/m^2 where L_H is L for ships of not more than 340 m but not less than 100 m in length and equal to 340 m for ships of more than 340 m in length: a = 0,0074 for Type B freeboard ships = 0,0363 ships assigned reduced freeboard The pressure, p, is to be reduced linearly to 34,3 kN/m^2 at the end of the forward quarter's length, as shown in Table 11.2.9 The design pressure used for each hatch cover panel shall be that determined at its mid point location: (b) All other position 1 hatch covers shall be designed to 34,3 kN/m^2 (c) Position 2 hatch covers shall be designed to 25,5 kN/m^2 (d) Where a position 1 hatchway is located at least one superstructure standard height higher than the freeboard deck, it may be designed to 34,3 kN/m^2
For ships 24 m in length:
(a) Position 1 hatch covers located in the forward quarter of the ship's length shall be designed for wave pressures of 23,8 kN/m^2 at the forward perpendicular and reduced linearly to 19,6 kN/m^2 at the end of the forward quarter's length, as shown in Table 11.2.9 The design pressure used for each hatch cover panel shall be that determined at its mid point location (b) All other position 1 hatch covers shall be designed to 19,6 kN/m^2 (c) Position 2 hatch covers shall be designed to 14,7 kN/m^2 (d) Where a position 1 hatchway is located at least one superstructure standard height higher than the freeboard deck, it may be designed to 19,6 t/m^2
For ships between 24 m and 100 m in length, and for positions between FP and 0,25L, wave pressures shall be obtained by linear interpolation of the values shown in Table 11.2.9

Table 11.2.9 Summary of pontoon cover minimum design pressures

Deck location	Longitudinal position		
	FP	0,25L	Aft of 0,25L
L>100 m			
Freeboard deck	Equation given in Table 11.2.8(a)	34,3 kN/m^2	34,3 kN/m^2
Superstructure deck	34,3 kN/m^2		25,5 kN/m^2
L = 100 m			
Freeboard deck	49,05 kN/m^2	34,3 kN/m^2	34,3 kN/m^2
Superstructure deck	34,3 kN/m^2		25,5 kN/m^2
L = 24 m			
Freeboard deck	23,84 kN/m^2	19,6 kN/m^2	19,6 kN/m^2
Superstructure deck	19,6 kN/m^2		14,7 kN/m^2

Table 11.2.10 Steel pontoon cover permissible stress, deflection and buckling criteria

Location	Permissible bending stress, N/mm^2	Permissible shear stress, N/mm^2	Permissible deflection, metres
Weather deck – Positions 1 and 2	$0{,}68\sigma_o$	$0{,}39\sigma_o$	$0{,}0044l_0$
Buckling requirements			
Symbols			
b = length of panel (longer panel dimension), in mm, in transverse direction, *see* Fig. 11.2.8 s = spacing of webs and stiffeners (shorter panel dimension), in mm t = thickness of plating, in mm σ_{ac} = corrected critical buckling stress, in N/mm^2 σ_b = the compressive bending stress, in N/mm^2, in the steel cover plating, calculated by taking the cover as a loaded beam simply supported at its ends σ_c = critical buckling stress of panel, in N/mm^2 σ_o = yield stress of cover plating material, in N/mm^2 $\sigma_c = 18{,}6R_c\left(\frac{t}{b}\right)^2 \times 10^4$ N/mm^2 $\sigma_{ac} = \sigma_o\left(1 - \frac{\sigma_o}{4\sigma_c}\right)$ N/mm^2 (a) Where primary bending stress acts on longer panel edge b, *see* Fig. 11.2.8: $\frac{\sigma_c}{\sigma_b}\left(\text{or } \frac{\sigma_{ac}}{\sigma_b}\right) \geq 1{,}3$ where $R_c = \left(\frac{s}{b} + \frac{b}{s}\right)^2$ Where primary bending stress acts on shorter panel edge s: $\frac{\sigma_c}{\sigma_b}\left(\text{or } \frac{\sigma_{ac}}{\sigma_b}\right) \geq 1{,}2$ where $R_c = 4\left(\frac{b^2}{s^2}\right)$ If $\sigma_c > 0{,}5\ \sigma_o$, then corrected value σ_{ac} is used It is recommended that $\frac{b}{s} < 5{,}0$ (b) Where covers are stiffened in two directions by a grillage formation, buckling checks are to be carried out as per (a) above for bending stresses acting on both the longer and shorter edges of the panel For the derivation of the section modulus for primary members, an effective width of plating to achieve a balanced section is to be adopted However, a greater width of plating in accordance with Ch 3,3.2 may be adopted where this is suitably stiffened in the directions being considered from the buckling aspect			

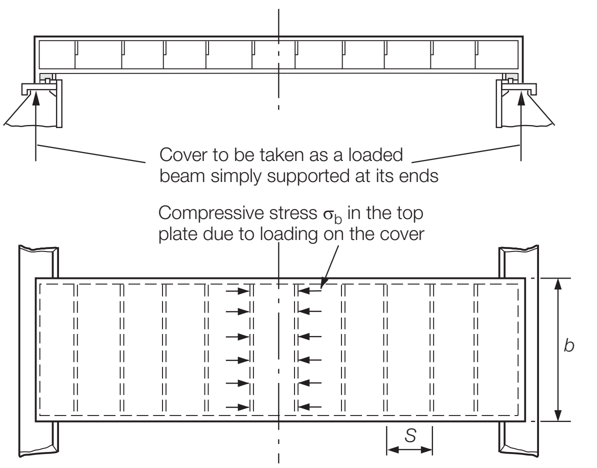


Fig. 11.2.8
Cover with stiffening fitted normal to the axis of primary bending

Table 11.2.11 Steel pontoon cover webs and stiffeners

Symbols	Primary and secondary stiffening requirements
A_S = shear area, in cm^2 K = higher tensile steel factor, *see* Ch 2,1.2 K_1 = 1281 C_1 = 696 I_0 = moment of inertia at mid-span, in cm^4 I_1 = moment of inertia at supports, in cm^4 where I_1 > 0,05 I_0 l_0 = unsupported span, in metres, measured as shown in Fig. 11.2.9 l_1 = proportion of the span, in metres, measured as shown in Fig. 11.2.9. The depth and face area over the remainder of the span is assumed to be constant p = minimum design pressure, in kN/m^2, acting on the hatch covers as defined in Table 11.2.8 Z_0 = section modulus at mid-span, in cm^3 Z_1 = section modulus at supports, in cm^3 $C_H = 1 + \dfrac{8\alpha_H{}^3(1-\beta_H)}{0,2 + 3\sqrt{\beta_H}}$ $K_H = 1 + \dfrac{3,2\alpha_H - \gamma_H - 0,8}{7,0\gamma_H + 0,4}$ but not less than 1,0. To be specially considered when discontinuities in area of face material occur $\alpha_H = \dfrac{l_1}{l_0}$ $\beta_H = \dfrac{I_1}{I_0}$ $\gamma_H = \dfrac{Z_1}{Z_0}$	$Z_0 = \dfrac{p\,s\,l_0{}^2 K_H k}{K_1}$ cm^3 $I_0 = \dfrac{p\,s\,l_0{}^3 C_H}{C_1}$ cm^4 $A_S = \dfrac{0,01282 p\,s\,l_0}{\sigma_o}$ cm^2 NOTE Where the ends of the secondary panel stiffeners are effectively bracketed or continuous, the values of modulus and inertia of the secondary panel stiffeners may be reduced respectively by 33% and 80%.

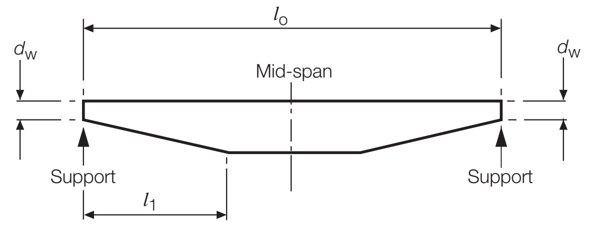


Fig. 11.2.9
Diagrammatic profile of web or stiffener or portable beam

Section 3
Hatch beams and wood covers

3.1 Portable hatch beams

3.1.1 The section modulus and moment of inertia of portable web plate beams stiffened at their upper and lower edges by continuous flat bars are to satisfy the requirements of 2.17 for pontoon covers. Alternatively, direct calculations may be used, provided the requirements of 2.17 for pontoon covers are complied with.

3.1.2 The ends of web plates are to be doubled, or inserts fitted for at least 180 mm along length of web.

3.1.3 At beams which carry the ends of wood or steel hatch covers, a vertical 50 mm flat is to be arranged on the upper face plate. The width of bearing surface for hatch covers is to be not less than 65 mm.

3.1.4 Carriers or sockets, or other suitable arrangements, of suitable construction are to provide means for the efficient fitting and securing of portable hatch beams. The width of bearing surface is to be not less than 75 mm.

3.1.5 Sliding hatch beams are to be provided with an efficient device for locking them in their correct fore and aft positions when the hatchway is closed.

3.2 Wood covers

3.2.1 Wood covers are to have a finished thickness of not less than 60 mm in association with an unsupported span of not more than 1,5 m. Where the ‘tween deck height, measured vertically on the centreline of the ship from ‘tween deck to underside of the hatch cover stiffeners on deck above, exceeds 2,6 m, the thickness of the wood covers is to be increased at the rate of 16,5 per cent per metre excess in ‘tween deck height.

3.2.2 The ends of all wood hatch covers are to be protected by encircling galvanised steel bands, about 65 mm wide and 33 mm thick, efficiently secured.

Section 4 Hatch cover securing arrangements and tarpaulins

4.1 Cargo oil tank and adjacent spaces

4.1.1 For access hatchways to cargo oil tanks and adjacent spaces, *see* Section 7.

4.2 Steel covers – Clamped and gasketed

4.2.1 These requirements, unless stated otherwise, apply to steel hatch covers in Positions 1 and 2 fitted with gaskets and securing devices and situated above dry cargo holds.

4.2.2 Where steel hatch covers are fitted to hatch openings on weather decks, the arrangements are to be such that weathertightness can be maintained. A sufficient number of securing devices is to be provided at each side of the hatch cover, considering the requirements of 2.9.4 to 2.9.6. This applies also to hatch covers consisting of several parts.

4.2.3 The weight of the covers and weather loading may be transmitted to the ship's structure by means of continuous steel to steel contact of the cover skirt plate with the ship's structure in association with a maximum bearing pressure of 200 kgf/cm^2. Alternatively the weight may be transmitted by means of defined bearing pads. For covers loaded by containers or other cargo, the total load together with inertial forces generated by the ship's motion, are to be transmitted by means of defined bearing pads only.

4.2.4 For the design of the securing devices against shifting, the horizontal mass forces $F_h = m\,a$ are to be calculated with the following accelerations:

a_x = 0,2 g in longitudinal direction
a_y = 0,5 g in transverse direction
m = sum of mass of cargo lashed on the hatch cover and mass of hatch cover.

4.2.5 For the transmission of the support forces resulting from the load cases specified in 2.3 and of the horizontal mass forces specified in 4.2.4, hatch cover supports are to be provided, which are to be designed such that the nominal surface pressures do not, in general, exceed the following values:

$p_{n\ max}$ = dp_n, in N/mm^2
d = 3,75 – 0,015L
d_{max} = 3,0
d_{min} = 1,0 in general
= 2,0 for partial loading conditions, *see* Pt 4, Ch 8, 11.2.4
p_n = *see* Table 11.4.1

For metallic supporting surfaces not subjected to relative displacements, the nominal surface pressure applies:

$p_{n\ max}$ = $3p_n$, in N/mm^2

The supports are to be designed such that the permissible stresses according to 2.4.1 are not exceeded.

Table 11.4.1 Permissible nominal surface pressure p_n

Support material	p_n in N/mm^2 when loaded by	
	Vertical force	Horizontal force (on stoppers)
Hull structural steel	25	40
Hardened steel	35	50
Plastics materials on steel	50	—

4.2.6 Drawings of hatch cover supports which specify the permitted maximum pressure related to long-term stress, given by the material manufacturer, must be submitted.

4.2.7 Where large relative displacements of the supporting surfaces of hatch cover supports are to be expected, the use of material having low wear and frictional properties is recommended. If necessary, sufficient abrasive strength may be shown by tests demonstrating an abrasion of support surfaces of not more than 0,3 mm per year in service, at a total distance of shifting of 15 000 m/year.

4.2.8 The substructures of the hatch cover supports must be of such a design that a uniform pressure distribution is achieved. Irrespective of the arrangement of stoppers, the supports must be able to transmit the following force P_h in the longitudinal and transverse direction:

$$P_h = \mu \frac{P_v}{\sqrt{d}}$$

where
P_v = vertical supporting force
μ = frictional coefficient
= 0,5 in general

For non-metallic, low-friction support materials on steel, the friction coefficient may be reduced, but is not to be less than 0,35. The substructures are to be designed such that the permissible stresses according to 2.4.1 are not exceeded.

4.2.9 For substructures and adjacent structures of supports subjected to horizontal forces P_h, as defined in 4.2.8, a fatigue strength analysis is to be carried out.

4.2.10 Hatch covers are to be sufficiently secured against horizontal shifting. Stoppers are to be provided for hatch covers on which cargo is carried. The greater of the loads resulting from 2.3.3 and 4.2.4 is to be applied for the dimensioning of the stoppers and their substructures. The permissible stress in stoppers and their substructures in the cover and in the coamings is to be determined according to 2.4.1. In addition, the provisions in 4.2.5 are to be observed.

4.2.11 The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness. Similar sealing is to be arranged between cross-joint elements. Where fitted, compression flat bars or angles are to be well rounded where in contact with the gasket and are to be made of a corrosion-restraint material or suitably protected against corrosion.

4.2.12 Special consideration is to be given to the gasket and securing arrangements in ships with large relative movements between cover and ship structure or between cover elements. The relative horizontal and vertical deflections are to be calculated and submitted with the hatch cover plans. Where applicable, deflections due to thermal effects and internal pressure loads are also to be included.

4.2.13 The suitability of the gasket material and the securing adhesive is the responsibility of the Builder and Owner. When selecting such material, consideration is to be given to its suitability for the environmental conditions likely to be experienced by the ship and its compatibility with the cargo carried. The material and form of gasket selected are to be considered in conjunction with the type of cover, the securing arrangement and the expected relative movement between cover and ship structure. The gasket is to be effectively secured to the cover.

4.2.14 Drainage is to be arranged inside the line of gasket by means of a gutter bar or vertical extension of the hatch side and end coaming; drain openings are to be provided at appropriate positions on the drain channels. This requirement need not be complied with for special ships carrying container cargoes when the requirements of Pt 4, Ch 8,11 are satisfied.

4.2.15 Where the arrangement includes continuous steel to steel contact between hatch cover and coaming or between hatch cover and ship structure or at cross-joints, drainage on both sides of the gasket is to be provided.

4.2.16 Drain openings are to be arranged at the ends of drain channels and are to be provided with non-return valves for preventing ingress of water from outside.
The following requirements are to be complied with:

(a) If manufactured from steel, the minimum drain pipe wall thickness is to be not less than 4,5 mm.
(b) If not manufactured from steel, details of the drain, including the material specification, method of manufacture and details of any tests carried out, are to be submitted for consideration.
(c) The drains are to be securely attached to the hatch coaming and adequately protected if in an exposed position.
(d) When the drain is fitted to a hold also designed to carry liquids, a shut-off valve is to be incorporated into the assembly.
(e) Drain openings in hatch coamings are to be arranged with sufficient distance to areas of stress concentration (e.g., hatch corners, transitions to crane posts).

4.2.17 Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced alongside the coamings. The securing devices are not to have a vertical clearance but are to be pre-tensioned when the cover is in the closed position. The devices are also to be arranged in close proximity horizontally to the gasket. Arrangement and spacing are to be determined with due attention to the effectiveness for weathertightness, depending upon the type and the size of the hatch cover, as well as on the stiffness of the cover edges between the securing devices. A minimum of two securing devices for each side of a panel are to be fitted. The securing devices should be arranged as close to the panel corners as is practicable.

4.2.18 Between cover and coaming and at cross-joints, a gasket pressure sufficient to obtain weathertightness is to be maintained by the securing devices. This pressure is to be specified. Securing devices of a design other than rod or bolts will be specially considered, *see* 4.2.26.

4.2.19 The net sectional area of each securing device is to be not less than:

$$A = \frac{1{,}4 S_1 W_1}{50f} \text{ cm}^2 \quad \left(\frac{1{,}4 S_1 W_1}{5{,}1 f} \text{ cm}^2 \right)$$

where

$$f = \left(\frac{\sigma_c}{235} \right)^e$$

S_1 = spacing between securing devices, in metres, not to exceed 6 m and not to be taken less than 2 m
W_1 = the gasket loading per unit length, in N/cm (kgf/cm), but not less than 50 N/cm (5,1 kgf/cm)
σ_c = specified minimum upper yield stress in N/mm^2 (kgf/mm^2) of the steel used for cleats or securing devices, to be taken not greater than 70 per cent of the ultimate tensile strength
e = 0,75 for $\sigma_c \geq 235$ (24)
= 1,0 for $\sigma_c < 235$ (24).

4.2.20 Rods or bolts are to have a gross diameter not less than 19 mm for hatchways exceeding 5 m^2 in area.

4.2.21 In order to ensure compression between gasket and compression bar along the full length, the cover edge stiffness is to be examined. The inertia of the cover edge is to be not less than:

$$I_E = 0{,}6 W_1 S_1^4 \quad \text{cm}^4$$
$$(I_E = 5{,}89 W_1 S_1^4 \quad \text{cm}^4)$$

where
W_1 and S_1 are as defined in 4.2.12.

4.2.22 Securing devices are to be constructed of reliable design and securely attached to the hatchway coamings, decks or covers. Individual securing devices on each cover are to have approximately the same stiffness characteristics.

4.2.23 Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

4.2.24 Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

4.2.25 The cross-joints of multi-panel covers are to be arranged with wedges, or locators (male and female) to retain the hatch covers in the correct sealing position, the number and spacing are to be arranged to suit the size and type of cover, gasket arrangements and stiffness of cover edges at cross-joints. Means are also to be provided to prevent excessive relative vertical deflections between loaded and unloaded panels. The arrangement of the gasket retaining angle and the compression bar at the cross-joints is to be such that the gasket compression is maintained between loaded and unloaded panels.

4.2.26 In addition to the requirements given above, all hatch covers, especially those carrying deck cargo are to be effectively secured against horizontal shifting due to the horizontal forces arising from the ship motions.

4.2.27 To prevent damage to hatch covers and ship structure, the location of stoppers is to be compatible with the relative movements between hatch covers and ship structure. The number should be as small as practically possible.

4.2.28 Towards the ends of the ship, vertical acceleration forces may exceed gravity forces. The resulting lifting forces must therefore be also considered when dimensioning the securing devices. Also lifting forces from cargo secured on the hatch cover during rolling are to be taken into account.

4.2.29 Hatch coamings and supporting structure are to be adequately stiffened to accommodate the loading from hatch covers and cargo carried thereon.

4.2.30 Upon completion of installation of hatch covers, a hose test with a pressure of water as specified in Table 1.9.1 in Chapter 1 is to be carried out. Alternative methods of tightness testing will be considered. This does not apply to covers with reduced securing arrangements as specified in Pt 4, Ch 8,11.

4.2.31 All hatch covers are to be tested to prove satisfactory operation.

4.2.32 It is recommended that ships with steel hatch covers are supplied with an operation and maintenance manual including:

(a) opening and closing instructions;
(b) maintenance requirements and specifications for packings, securing devices and operating items;
(c) cleaning instructions for the drainage system;
(d) corrosion prevention instructions;
(e) list of spare parts.

4.2.33 The spacing and size of securing devices in hatch covers for holds which may be flooded and used for ballast tanks and holds in OBO, ore or oil and similar types of ship are to correspond to the reaction forces at the cover edges found by calculation. The loading is to be as required by Pt 4, Ch 7,12.4.1(c)

The permissible stress in the securing devices is not to exceed the following:

$\sigma_e = 0,9 \times 235\, f$ N/mm^2

where

f = material factor as defined in 4.2.19
σ = bending stress in N/mm^2
σ_e = equivalent stress, in N/mm^2
$= \sqrt{(\sigma^2 + 3\tau^2)}$
τ = shear stress in N/mm^2.

4.2.34 On tank hatch covers in 'tween decks the maximum spacing of cleats is to be 600 mm, but cleats are to be arranged as close to the corners as practicable.

4.2.35 Steel hatch covers with special sealing arrangements, insulated covers, flush hatch covers, and covers having coamings less than required by 5.1, will be specially considered.

4.2.36 The material and weld specifications of stoppers and securing devices are to be shown in the drawings of the hatch covers.

4.2.37 Securing devices of special design in which significant bending or shear stresses occur may be designed as anti-lifting devices according to Pt 4, Ch 8,11.2.5. The packing line pressure, as defined in 4.2.12, multiplied by the spacing between securing devices, as defined in 4.2.12, is to be applied as design load.

4.3 Portable covers – Tarpaulins and battening devices

4.3.1 At least two layers of tarpaulin in good condition are to be provided for each hatchway in Positions 1 and 2.

4.3.2 Tarpaulins are to be free from jute, waterproof and of ample strength. The minimum mass of the material before treatment is to be 0,65 kg/m^2 if the material is to be tarred, 0,60 kg/m^2 if to be chemically dressed, or 0,55 kg/m^2 if to be dressed with black oil. A certificate to this effect is to be supplied by the makers of the tarpaulins. Special consideration will be given to the use of synthetic materials for tarpaulins.

4.3.3 Cleats are to be of an approved pattern, at least 65 mm wide, with edges so rounded as to minimise damage to the wedges, and are to be spaced not more than 600 mm from centre to centre: the first and last cleats along each side or end are to be not more than 150 mm from the hatch corners. Cleats should be so set as to fit the taper of the wedges.

4.3.4 Battens and wedges shall be efficient and in good condition. Wedges are to be of tough wood, generally not more than 200 mm in length and 50 mm in width. They should have a taper of not more than 1 in 6 and should not be less than 13 mm at the point.

4.3.5 For all hatchways in Positions 1 and 2, steel bars or other equivalent means are to be provided in order to secure each section of hatch covers efficiently and independently after the tarpaulins are battened down. Hatch covers of more than 1,5 m in length are to be secured by at least two such securing appliances. Where hatchway covers extend over intermediate supports, steel bars or their equivalent are to be fitted at each end of each section of covers. At all other hatchways in exposed positions on weather decks, ring bolts or other fittings suitable for lashings are to be provided.

4.4 Packing material

4.4.1 Packing material is to be suitable for all expected service conditions of the ship and is to be compatible with the cargoes to be transported. The packing material is to be selected with regard to dimensions and elasticity in such a way that expected deformations can be carried. Forces are to be carried by the steel structure only.

4.4.2 Packing material is to be compressed so as to give the necessary tightness effect for all expected operating conditions. Special consideration will be given to the packing arrangement in ships with large relative movements between hatch covers and coamings or between hatch cover sections.

■ *Section 5* **Hatch coamings**

5.1 General

5.1.1 The height of coamings above the upper surface of the deck, measured above sheathing if fitted, for hatchways closed by portable covers secured weathertight by tarpaulins and battening devices, is to be not less than:

600 mm at Position 1,
450 mm at Position 2.

5.1.2 The height of coamings of hatchways situated in Positions 1 and 2 closed by steel covers fitted with gaskets and clamping devices is to be as specified in 5.1.1, but may be reduced, or the coamings may be omitted entirely, if the safety of the ship is not thereby impaired in any sea condition. Special attention will be given in such cases to the scantlings of the covers, to their gasketing and securing arrangements and to the drainage of recesses in the deck. The agreement of the National Authority concerned will also be required.

5.1.3 The height of coamings may be required to be increased on ships of Type 'B-100' or Type 'B-60' where this is shown to be necessary by the floatability calculations required by the *International Convention on Load Lines, 1966.*

5.2 Construction

5.2.1 Vertical cargo hatch coamings 600 mm or more in height are to be stiffened on their upper edges by a horizontal bulb flat or equivalent which is to be not less than 180 mm in width for ships where L is greater than 75 m. Additional support is to be afforded by fitting brackets or stays from the bulb flat to the deck at intervals of not more than 3 m. Each bracket or stay is to be aligned with suitable underdeck stiffeners and is to have a softened nose.

5.2.2 Vertical coamings less than 600 mm in height are to be stiffened at their upper edge by a substantial rolled or fabricated section. Additional support is to be arranged as required by 5.2.2.

5.2.3 Cargo hatchways on other decks, in positions not specified in Ch 1,6.5, are to be suitably framed.

5.2.4 The scantlings and arrangements of hatch coamings acting as girders will be specially considered. The coamings are to be arranged with intermediate continuous horizontal stiffeners supported by the bracket stays.

5.2.5 Sloped cargo hatch coamings will be specially considered. In general, the sloped coaming arrangement is to be restricted to the hatch side coamings with vertical coamings at the ends. The sloped coaming is not to have a knuckle and the angle to the vertical is not to exceed 30°. The scantlings are to be in accordance with 5.2.1, 5.2.2 and 5.3, except that the end coamings are to be increased by 20 per cent for a distance of 0,15b from the side coamings where b is the width of the hatchway at the deck. Particular care is to be taken where the proposed loadings exceed those given in 2.3 and Ch 3,5, and where the coamings are not in alignment with the topside tank vertical strake in bulk carriers.

5.2.6 A radiused coaming plate at the corner junction of the longitudinal and transverse cargo hatch coamings is acceptable for ships where $L \leq 90$ m and the heights of coamings are not in excess of that specified in 5.1.1. Where $L > 90$ m the corner junctions are to be rectangular and arranged with continuation brackets as required by 5.2.8.

5.2.7 The deck plating is to extend inside the coamings and the side coamings are to be extended in the form of tapered brackets. A recommended arrangement is shown in Fig. 11.5.1. Continuation brackets are also to be arranged athwartships in line with the hatch end coamings and the under deck transverse. In bulk carriers the athwartship brackets, in conjunction with the hatch end beams should be arranged to achieve a satisfactory overlap with the top side tank transverses. In cases where the hatch end beam is formed by the transverse bulkhead top stool the horizontal knuckle of the stool should be arranged well clear of the topside tank knuckle line.

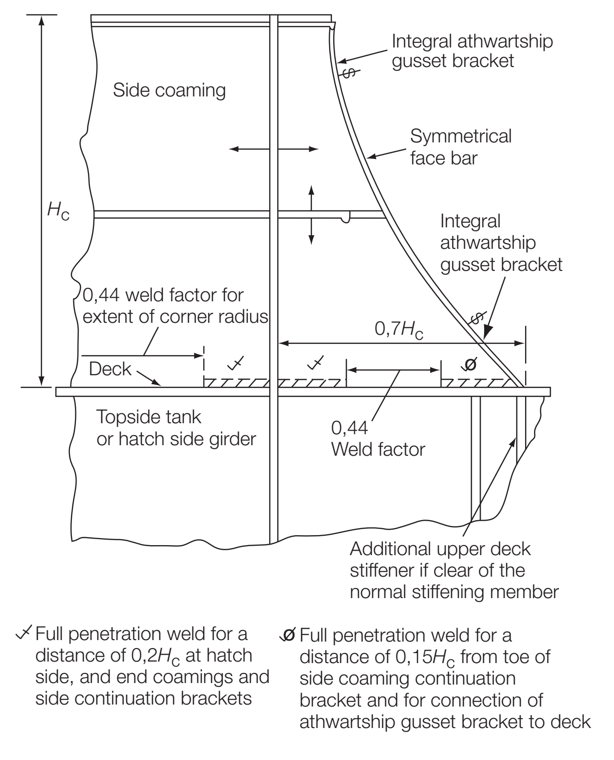


Fig. 11.5.1
Coaming continuation bracket – Recommended arrangement

5.2.8 In bulk carriers where the hatch side coaming does not align with the topside tank vertical strake the arrangement and scantlings will be specially considered. In general, suitable underdeck girders and cantilever brackets are to be arranged taking into consideration the hatch cover loading. The underdeck girders are to continue beyond the hatch end for a distance of $2H_c$ mm. Alternative arrangements incorporating bulkhead top stool structure or cross-deck structure will be considered.

5.2.9 Extension brackets or rails arranged approximately in line with the cargo hatch side coamings and intended for the stowage of steel covers are not to be welded to a deckhouse, masthouse or to each other unless they form part of the longitudinal strength members.

5.2.10 The arrangement and scantlings of continuous hatchway coamings on the strength deck will be specially considered. The material of the coamings is to comply with Tables 2.2.1 and 2.2.2 in Chapter 2 and is to be of the same strength level as the deck plating. Discontinuous coamings of length greater than 0,09*L* are also to satisfy this requirement.

5.2.11 Where containers are carried on multi-panel hatch covers, the hatch coaming in way of the loaded panel will be required to be reinforced to resist the lateral loads imposed on the coaming due to rolling of the ship. Thrust blocks are to be fitted on the coaming rest bar to prevent the covers from moving. Where one-piece hatch covers are fitted with locating devices, the coamings are to be reinforced in way of the locators.

5.2.12 Cut outs in the top of hatch coamings are to be avoided. Where these are necessary for the securing devices they are to be circular or elliptical in shape. Also any local reinforcements should be given a tapered transition in the longitudinal direction with a taper the rate of which should not exceed 1 in 3. Cut-outs and drain holes are to be avoided in the hatch side coaming continuation brackets. Where these are necessary the size, shape and position will be specially considered.

5.2.13 Material for hatch coamings is to be steel, according to the requirements for ship's hull. Alternative materials will be subject to special consideration.

5.2.14 Secondary stiffeners of hatch coamings are to be continuous over the breadth and length of hatch coamings.

5.2.15 Longitudinal hatch coamings with a length exceeding 0,1*L* m are to be provided with tapered brackets or equivalent transitions and a corresponding substructure at both ends. At the end of the brackets they are to be connected to the deck by full penetration welds of minimum 300 mm in length.

5.2.16 Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions. Structures under deck are to be checked against the load transmitted by coaming stays.

5.2.17 On ships carrying cargo on deck, such as timber, coal or coke, coaming stays are to be spaced not more than 1,5 m apart.

5.2.18 Coaming plates are to extend to the lower edge of the deck beams; they are to be flanged or fitted with face bars or half-round bars. Fig.11.5.2 gives an example.

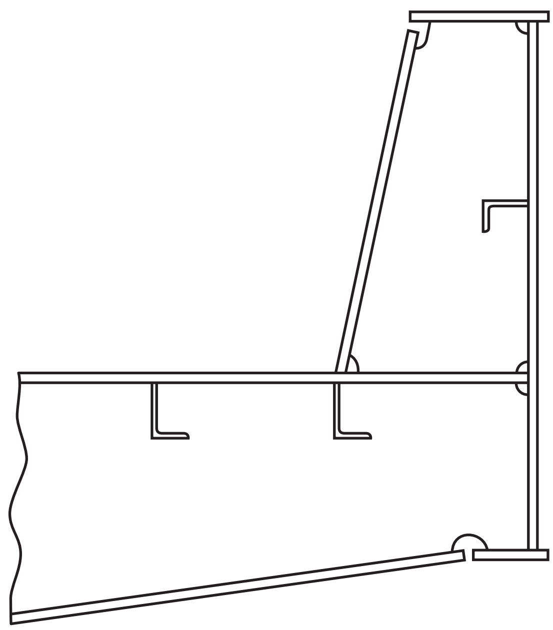


Fig. 11.5.2
Example for the extent of coaming plates

5.3 Strength criteria

5.3.1 The strength requirements in this Section are applicable to hatch coamings of stiffened plate construction.

5.3.2 The local net plate thickness of weather deck hatch coamings is not to be less than the larger of the following values:

$$t = 0{,}0142s\sqrt{\frac{p_A}{0{,}95\,\sigma_o}} \text{ in mm}$$

$$t_{min} = 6 + \frac{L_1}{100} \text{ in mm}$$

where

s = stiffener spacing, in mm
L_1 = L need not be taken greater than 300 metres
p_A = pressure, in kN/m^2, as defined in 2.3.3

Longitudinal strength aspects are to be observed.

5.3.3 Secondary stiffeners of coamings must be continuous at the coaming stays. For stiffeners with both ends constrained, the elastic net section modulus Z in cm^3 and net shear area A_S in cm^2, calculated on the basis of net thickness, are not to be less than:

$$Z = \frac{0{,}083}{\sigma_o} s\, l^2 p_A \text{ cm}^3$$

$$A_s = \frac{0{,}01 s\, l\, p_A}{\sigma_o} \text{ cm}^2$$

where

l = secondary stiffener span, in metres, to be taken as the spacing of coaming stays

s = stiffener spacing in mm

p_A = pressure, in kN/m^2, as defined in 2.3.3.

5.3.4 For sniped stiffeners at coaming corners, section modulus and shear area at the fixed support are to be increased by 35 per cent. The gross thickness of the coaming plate at the sniped stiffener end is not to be less than:

$$t = 19{,}6 \sqrt{\frac{0{,}001 s\, p_A (l - 0{,}0005\, s)}{\sigma_o}} \quad \text{N mm}$$

where

p_A = pressure, in kN/m^2, as defined in 2.3.3.

5.3.5 Coaming stays are to be designed for the loads transmitted through them, and permissible stresses according to 2.4.1.

5.3.6 The net section modulus Z of coaming stays, with a height of h_s < 1,6 m and which are to be designed for the load p_A, is not to be less than:

$$Z = \frac{526}{\sigma_o} e\, h_s^2\, p_A \quad \text{in cm}^3$$

where

e = spacing of coaming stays, in metres

p_A = pressure, in kN/m^2, as defined in 2.3.3.

5.3.7 Coaming stays of coamings having a height of 1,6 m or more are to be designed using direct calculations under consideration of the permissible stresses according to 2.4.1. The effective breadth of the coaming plate is not to be larger than the effective plate breadth according to 2.10.2.

5.3.8 Coaming stays are to be supported by appropriate substructures. Face-plates may be included in the calculation only if an appropriate substructure is provided and welding ensures an adequate joint.

5.3.9 The web gross thickness of coaming stays at the root point is not to be less than:

$$t_w = \frac{2\, e\, h_s\, p_A}{\sigma_o\, h_w} + t_c$$

where

h_w = web height of coaming stay at its lower end, in metres

t_c = corrosion addition, in mm, according to 1.1.13

p_A = pressure, in kN/m^2, as defined in 2.3.3.

5.3.10 Webs of coaming stays are to be connected to the deck by fillet welds on both sides with a throat thickness of $a = 0{,}44 t_w$.

5.3.11 For coaming stays which transfer friction forces at hatch cover supports, sufficient fatigue strength is to be verified, *see* 4.2.5 to 4.2.8.

5.3.12 Hatch coamings which are part of the longitudinal hull structure are to be designed according to the requirements for longitudinal strength in Pt 3, Ch 4.

5.3.13 For structural members welded to coamings and for cut-outs in the top of coamings, sufficient fatigue strength is to be verified.

5.4 Rest bars in hatchways

5.4.1 Rest bars are to provide at least 65 mm bearing surface and are to be aligned if required to suit the slope of the hatches.

5.5 Loading in excess of Rule requirements

5.5.1 For weather deck hatch side coamings forming part of a hatch side girder subjected to loading exceeding that defined in 2.3, *see* Pt 4, Ch 1,4.

■ *Section 6* Miscellaneous openings

6.1 Small hatchways on exposed decks

6.1.1 Hatches which:

- are designed for access to spaces below the deck;
- are capable of being closed weathertight or watertight, as applicable;
- have an opening 2,5 m^2 or less;
- are located on the exposed deck over the forward 0,25L of the ship's rule length;
- are on a ship of sea-going service of length 80 m or more, where the height of the exposed deck in way of the hatch is less than 0,1L or 22 m above the summer load waterline, whichever is the lesser;

are to comply with the requirements of 6.6. All other small hatchways or access openings in the positions defined in 1.1.6 are to comply with the following requirements.

6.1.2 The number and size of hatchways and other access openings are to be kept to the minimum consistent with the satisfactory operation of the ship.

6.1.3 The height of coamings is to be in accordance with 5.1.1. Lower heights may be considered in relation to operational requirements and the nature of the spaces to which access is given.

6.1.4 Rope hatches may be accepted with reduced coamings, but generally not less than 380 mm, provided they are well secured and closed before the ship leaves port. A suitable notice is to be displayed at the hatch stating that it is to be closed whilst the ship is at sea.

6.1.5 The thickness of the coamings is to be not less than the Rule minimum thickness for the deck inside line of openings for that position, or 11 mm, whichever is the lesser. Stiffening of the coaming is to be appropriate to its length and height.

6.1.6 Hatch covers are to be of steel, weathertight and generally hinged. The means of securing are to be such that weathertightness can be maintained in any sea condition. Where toggles are fitted, their diameter and spacing are to be in accordance with ISO Standard or equivalent.

6.1.7 Hinges are not to be used as securing devices unless specially considered.

6.1.8 The thickness of covers is to be not less than the Rule minimum thickness inside the line of openings for the deck at that point, or 8 mm, whichever is the lesser.

6.1.9 The covers are to be adequately stiffened.

6.1.10 To facilitate a swift and safe means of escape to the lifeboat and life raft embarkation deck, the following provisions apply to overhead hatches fitted along the escape routes addressed by SOLAS Reg. II-2/13:

(a) escape hatches and their securing devices shall be of a type which can be opened from both sides;
(b) the maximum force needed to open the hatch cover should not exceed 150 N; and
(c) the use of a spring equalising, counterbalance or other suitable device on the hinge side to reduce the force needed for opening is acceptable.

6.1.11 Small hatches, including escape hatches, are to be situated clear of cargo containment areas, particularly in the case of offshore supply ships.

6.1.12 Where portable plates are required in decks for unshipping machinery, or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced deck and are secured by gaskets and closely spaced bolts at a pitch not exceeding five diameters.

6.1.13 Satisfactory means are to be provided to prevent inadvertent flooding of chain lockers. *See* Ch 13,8.10.5 and 8.10.7.

6.1.14 Where permitted by the National Authority, access hatch coaming heights may be reduced on ships engaged on protected or extended protected water service. Coaming heights are to be as high as practicable with a minimum height of 230 mm.

6.2 Manholes and flush scuttles

6.2.1 Manholes and flush scuttles fitted in Positions 1 and 2, or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

6.3 Hatchways within enclosed superstructures or ‘tween decks

6.3.1 The requirements of 6.1 are to be complied with where applicable.

6.3.2 Access hatches within a superstructure or deckhouse in Positions 1 or 2 need not be provided with means for closing if all openings in the surrounding bulkheads have weathertight closing appliances.

6.4 Companionways, doors and accesses on weather decks

6.4.1 Companionways on exposed decks are to be of equivalent construction, weathertightness and strength to a deckhouse in the same position and effectively secured to the deck.

6.4.2 Access openings in:

(a) bulkheads at ends of enclosed superstructures;
(b) deckhouses or companionways protecting openings leading into enclosed superstructures or to spaces below the freeboard deck; and
(c) deckhouse on a deckhouse protecting an opening leading to a space below the freeboard deck;

are to be fitted with doors of steel or other equivalent material, permanently and strongly attached to the bulkhead and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead, and weathertight when closed. The doors are to be gasketed and secured weathertight by means of clamping devices or equivalent arrangements, permanently attached to the bulkhead or to the door. Doors are generally to open outwards and are to be capable of being operated and secured from both sides. The sill heights are to be as required by 6.4.5. *See also* Section 7 and Pt 4, Ch 9,13 and Ch 11,1 and the Rules for Ships for Liquid Chemicals, Chapter 3 concerning access openings in tankers, chemical tankers and ore or oil ships. Double doors are to be equivalent in strength to the unpierced bulkhead, and in Position 1, a centre pillar is to be provided which may be portable.

6.4.3 Elsewhere doors may be of hardwood not less than 50 mm in thickness or of equivalent material and strength.

6.4.4 Fixed lights in doors in Positions 1 and 2 are to comply with the requirements for side scuttles as given in 6.5.1 and 6.5.2. Hinged steel deadlights may be external.

6.4.5 The height of doorway sills above deck sheathing, if fitted, is to be not less than 600 mm in Position 1, and not less than 380 mm in Position 2.

6.4.6 Where access is provided from the deck above as an alternative to access from the freeboard deck, the height of sill into a bridge or a poop is to be not less than 380 mm. The same requirement applies to deckhouses on the freeboard deck. The sill height for doorways in a forecastle, if protecting a companionway, is to be 600 mm regardless of whether or not access is provided from above. If not protecting a companionway, the sill height may be 380 mm.

6.4.7 When the closing appliances of openings in superstructures and deckhouses do not comply with 6.4.2, interior deck openings are to be treated as if exposed on the weather deck.

6.4.8 Where an access opening, in the top of a deckhouse situated on a raised quarterdeck, gives access below the freeboard deck or to an enclosed superstructure, the closing appliances in the surrounding bulkheads are not required to be gasketed, provided the raised quarterdeck is at least standard height, and the deckhouse is at least standard superstructure height.

6.4.9 The height of door sills may be required to be increased on ships of Type ‘A’, Type ‘B-100’ or Type ‘B-60’ where this is shown to be necessary by the floatability calculations required by the *International Convention on Load Lines, 1966.*

6.4.10 Direct access from the freeboard deck to the machinery space through exposed casings is not permitted on ships of Type ‘A’, Type ‘B-100’ or Type ‘B-60’. A door complying with 6.4.2 may, however, be fitted in an exposed machinery casing on these ships, provided that it leads to a space or passageway which is of equivalent strength to the casing and is separated from the machinery space by a second weathertight door complying with 6.4.2. The outer and inner weathertight doors are to have sill heights of not less than 600 mm and 230 mm, respectively and the space between is to be adequately drained by means of a screw plug or equivalent.

6.4.11 For a Type ‘A’ ship with freeboards assigned greater than, or equal to, Type ‘B’, inner doors are not required for direct access to the engine-room.

6.4.12 If internal access is provided from a wheelhouse in Position 2, or below, to spaces below the weather deck either directly or through other spaces, the opening should be protected by a hinged weathertight cover adequately secured, fitted on a coaming appropriate to its position, or by an equivalent arrangement, and the space adequately drained.

6.4.13 In way of a moonpool, where a working or platform deck is provided below the weather deck, openings in the surrounding bulkheads are to be kept to a minimum. Access or companionway openings are to be provided with weathertight closing appliances as for an exposed superstructure bulkhead, with 600 mm high coamings.

6.4.14 Where portable plates are required in casings for unshipping machinery, or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced bulkhead and are secured by gaskets and close spaced bolts at a pitch not exceeding five diameters.

6.4.15 The sill heights of accesses closed by covers which are secured by closely spaced bolts or otherwise kept permanently closed at sea will be specially considered.

6.4.16 Where permitted by the National Authority, companionway coaming heights may be reduced on ships engaged on protected or extended protected water service. Coaming heights are to be as high as practicable with a minimum height of 230 mm. Where the wheelhouse is on the freeboard deck, or located in the forward quarter of the ship’s length, with internal access below, a weathertight cover, fitted to a coaming not less than 230 mm high, is to be provided for the access. Alternatively, storm covers are to be provided for windows in exposed positions. The wheelhouse is to be adequately drained.

6.5 Side scuttles, windows and skylights

6.5.1 Side scuttles are defined as being round or oval openings with an area not exceeding 0,16 m^2.

6.5.2 Windows are defined as being rectangular openings generally, and round or oval openings with an area exceeding 0,16 m^2.

6.5.3 A plan showing the location of side scuttles and windows is to be submitted. Attention is to be given to any relevant Statutory Requirements of the National Authority of the country in which the ship is to be registered.

6.5.4 Side scuttles and windows together with their glasses and deadlights if fitted, are to be of an approved design or in accordance with a recognised National or International Standard, *see also* Pt 4, Ch 4,6.3 for offshore supply ships.

6.5.5 Side scuttles to spaces below the freeboard deck, or to spaces within the first tier of enclosed superstructures, or to first tier deckhouses on the freeboard deck protecting openings leading below or considered buoyant in stability calculations, are to be fitted with efficient, hinged, inside deadlights and capable of being effectively closed and secured watertight.

6.5.6 Deadlights are to be capable of being closed and secured watertight if fitted below the freeboard deck or weathertight if fitted above.

6.5.7 No side scuttle is to be fitted in such a position that its sill is below a line drawn parallel to the freeboard deck at side and having its lowest point 2,5 per cent of the breadth B above the load waterline corresponding to the summer freeboard (or timber summer freeboard if assigned), or 500 mm, whichever is the greater distance, *see* Fig. 11.6.1.

6.5.8 If the required damage stability or floatability calculations indicate that the side scuttles would become immersed at any intermediate stages of flooding or the final equilibrium waterline, these are to be of the non-opening type. Windows are not to be fitted in such locations.

6.5.9 Windows are not to be fitted in machinery space boundaries. However this does not preclude the use of glass in control rooms within the machinery space.

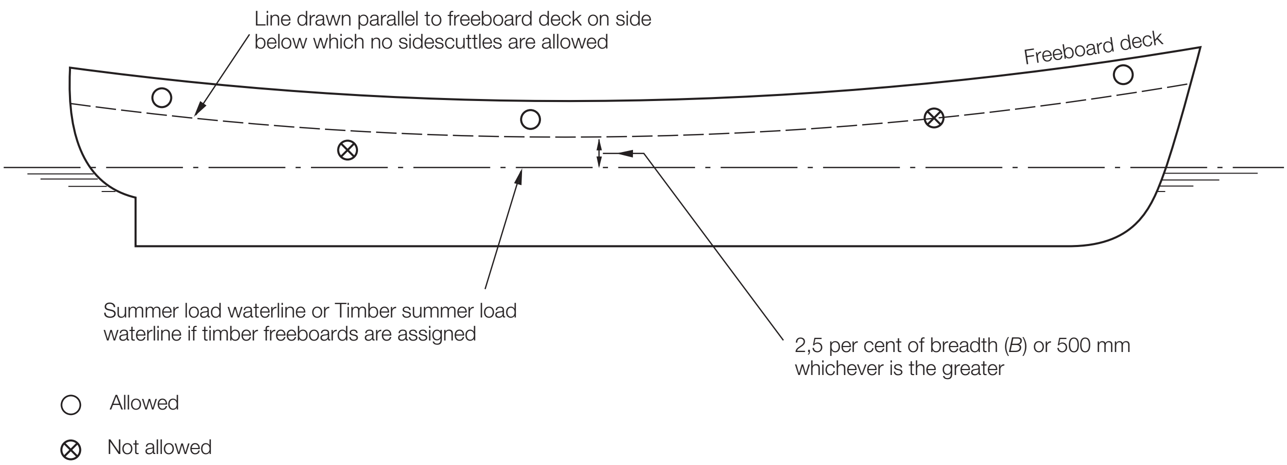


Fig. 11.6.1 Side scuttle positioning

6.5.10 If fitted in a deckhouse in Position 1, windows are to be provided with strong, hinged, steel, weathertight storm covers. However, if there is an opening leading below deck in this deckhouse, this opening is to be treated as being on an exposed deck and is to be protected as required by 6.4.2.

6.5.11 Windows are not to be fitted below the freeboard deck, in first tier end bulkheads or sides of enclosed superstructures, or in first tier deckhouses that are considered buoyant in stability calculations.

6.5.12 Side scuttles and windows at the shell in Position 2, protecting direct access below, are to be provided with strong permanently attached deadlights.

6.5.13 Side scuttles and windows at the shell in Position 2, not protecting direct access below, are to be provided with strong portable steel covers for 50 per cent of each size, with means for securing at each side scuttle and window.

6.5.14 Side scuttles and windows set inboard from the shell in Position 2, protecting direct access below, are either to be provided with strong permanently attached deadlights or, where they are accessible, strong permanently attached external steel storm covers instead of internal deadlights.

6.5.15 Side scuttles and windows set inboard from the shell in Position 2, not protecting direct access below, do not require deadlights or storm covers.

6.5.16 In Position 2, cabin bulkheads and doors are considered effective between side scuttles or windows and access below.

6.5.17 Windows in the shell, located at least one standard height of superstructure above the lowest Position 2 deck, are to be provided with strong portable internal storm covers for 25 per cent of each size of window, with means of securing being provided at each window.

6.5.18 Where windows are permitted in an exposed bulkhead on the weather deck in the forward $0,25L_L$, strong external storm covers which may be portable and stored adjacent are to be provided.

6.5.19 Where the wheelhouse is in Position 2, in lieu of storm covers being provided for the wheelhouse windows, a weathertight cover, fitted to a coaming of not less than 230 mm in height around the internal stairway opening within the wheelhouse, may be accepted. If this arrangement is accepted, adequate means of draining the wheelhouse are to be provided.

6.5.20 If necessary, for practical considerations, the storm covers may be in two parts.

6.5.21 Deckhouses situated on a raised quarter deck may be treated as being in Position 2 as far as the provision of deadlights is concerned, provided the height of the raised quarter deck is equal to, or greater than, the standard height.

6.5.22 Skylights, where fitted, are to be of substantial construction and securely attached to their coamings. The height of the lower edge of opening is to be as required by 5.1.1. The scantlings of the coaming are to be as required by this Section or Section 5, as appropriate. The thickness of glasses in fixed or opening skylights is to be appropriate to their size and position as required for side scuttles or windows. Glasses in any position are to be protected from mechanical damage, and where fitted in Positions 1 or 2 are to be provided with robust deadlights or storm covers permanently attached. Cargo pump room and machinery space skylights are not to contain glass.

6.5.23 Skylights to cargo pump rooms are to be capable of being closed from outside the pump room.

6.5.24 Laminated toughened safety glass may also be used for windows but the total thickness will need to be greater than that required for the equivalent sized window using toughened safety glass. The equivalent thickness of laminated toughened safety glass is to be determined from the following formula:

$$T_{L1}^2 + T_{L2}^2 + \ldots.T_{Ln}^2 = T_S^2$$

where:

n = number of laminates
T_L = thickness of glass laminate
T_S = thickness of toughened safety glass.

Alternative arrangements that do not meet the above thickness requirement will be specially considered, provided that equivalent strength and bending stiffness to that of a single, thermally toughened pane of thickness, t_s, can be demonstrated in a four-point bending test in accordance with EN-ISO 1288-3 or an equivalent recognised National or International Standard, using not less than ten samples. The lower limit of the 90 per cent confidence level interval for the laminated pane shall not be less than the same for monolithic toughened safety glass. Small scale punch test or ring-in-ring test methods shall not be used.

6.5.25 Rubber frames are not acceptable for windows in Positions 1 and 2, and are not generally acceptable in any other position in external casings. Any proposals to fit rubber frames are to be submitted for consideration, and are to be acceptable to the administration. The proposed locations, frame dimensions, glass thicknesses and the results of any tests carried out, are to be forwarded.

6.6 Small hatchways on exposed fore decks

6.6.1 For the application of the following requirements, *see* 6.1.1.

6.6.2 The number and size of hatchways and other access openings are to be kept to the minimum consistent with the satisfactory operation of the ship.

6.6.3 The height of coamings is to be in accordance with 5.1.1. Lower heights may be considered in relation to operational requirements and the nature of the spaces to which access is given.

6.6.4 Rope hatches may be accepted with reduced coamings, but generally not less than 380 mm, provided they are well secured and closed before the ship leaves port. A suitable notice is to be displayed at the hatch stating that it is to be closed whilst the ship is at sea.

6.6.5 Where permitted by the National Authority, access hatch coaming heights may be reduced on ships engaged on protected or extended protected water service. Coaming heights are to be as high as practicable with a minimum height of 230 mm.

6.6.6 The thickness of the coamings is to be not less than the Rule minimum thickness for the deck inside line of openings for that position, or 11 mm, whichever is the lesser.

6.6.7 The upper edge of the hatchway coamings is to be suitably reinforced by a horizontal section, normally not more than 170 to 190 mm from the upper edge of the coamings.

6.6.8 Hatches are to be fitted with primary securing devices such that their hatch covers can be secured in place and weather-tight by means of a mechanism employing any one of the following methods:

(a) Butterfly nuts tightening onto forks (clamps),
(b) Quick acting cleats, or
(c) Central locking device.

Emergency escape hatches are excluded from options (a) and (b).

6.6.9 Dogs (twist tightening handles) with wedges are not acceptable as primary securing devices.

6.6.10 Escape hatches are to be capable of being opened from either side and are to have a quick-acting type securing device, e.g., one action wheel handle central locking device for latching/unlatching the hatch cover.

6.6.11 For a primary securing method using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed to minimise the risk of butterfly nuts being dislodged while in use; by means of curving the forks upward, a raised surface on the free end, or a similar method. The plate thickness of unstiffened steel forks is not to be less than 16 mm. An example arrangement is shown in Fig. 11.6.3.

6.6.12 The hatch cover is to be fitted with a gasket of elastic material. This is to be designed to allow a metal to metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged. The metal-to-metal contacts are to be arranged close to each securing device in accordance with Fig. 11.6.2, and of sufficient capacity to withstand the bearing force.

6.6.13 The primary securing method is to be designed and manufactured such that the designed compression pressure can be achieved by one person without the need of any tools.

6.6.14 For small rectangular steel hatch covers, the plate thickness, stiffener arrangement and scantlings are to be in accordance with Table 11.6.1 and Fig. 11.6.2. Stiffeners, where fitted, are to be aligned with the metal-to-metal contact points required in 6.6.11, *see* Fig. 11.6.2. Primary stiffeners are to be continuous. All stiffeners are to be welded to the inner edge stiffener, *see* Fig. 11.6.3.

6.6.15 For hatch covers constructed of materials other than steel, the required scantlings are to provide equivalent strength.

6.6.16 For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement are to be of equivalent strength to that of the small rectangular steel hatch covers described in 2.2.1.

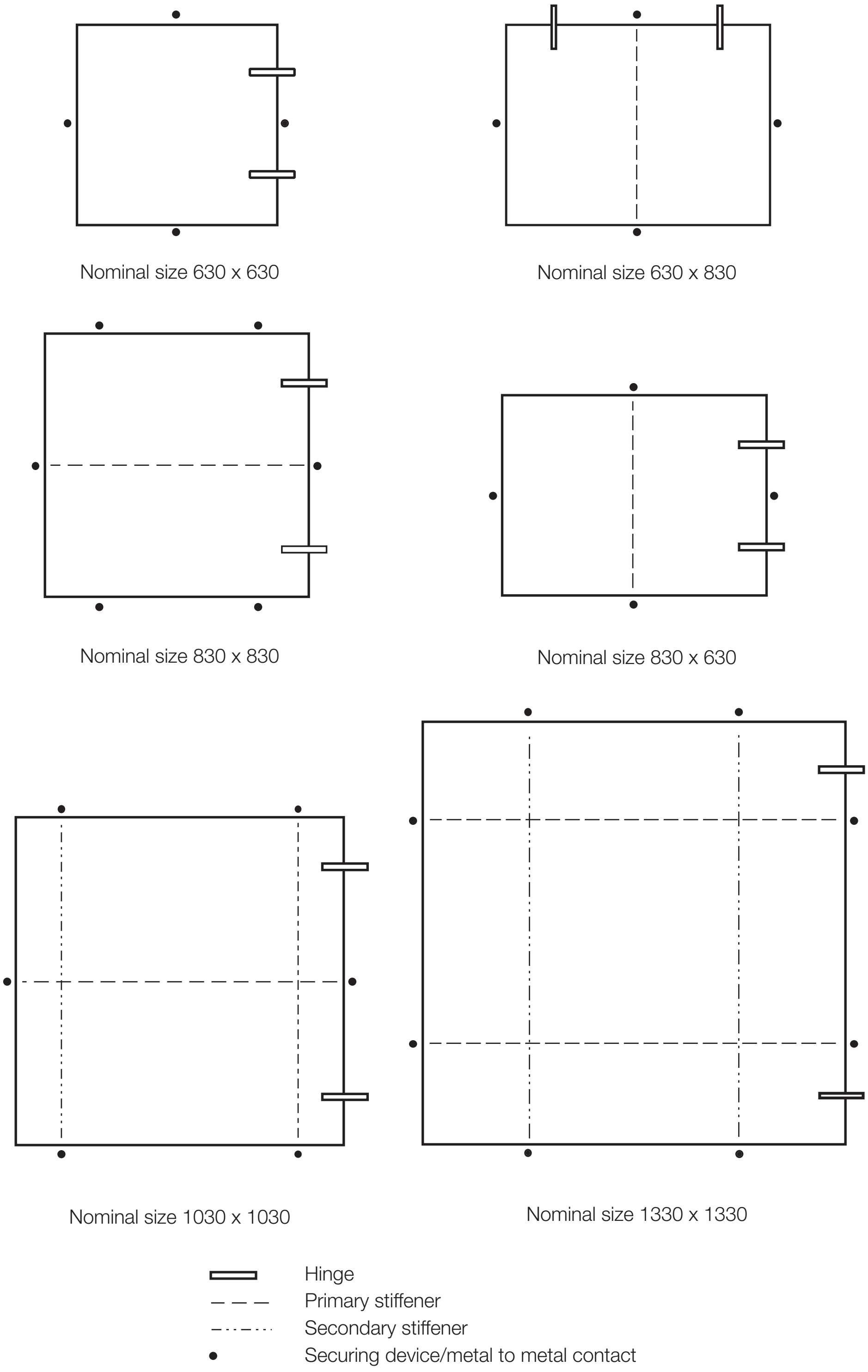
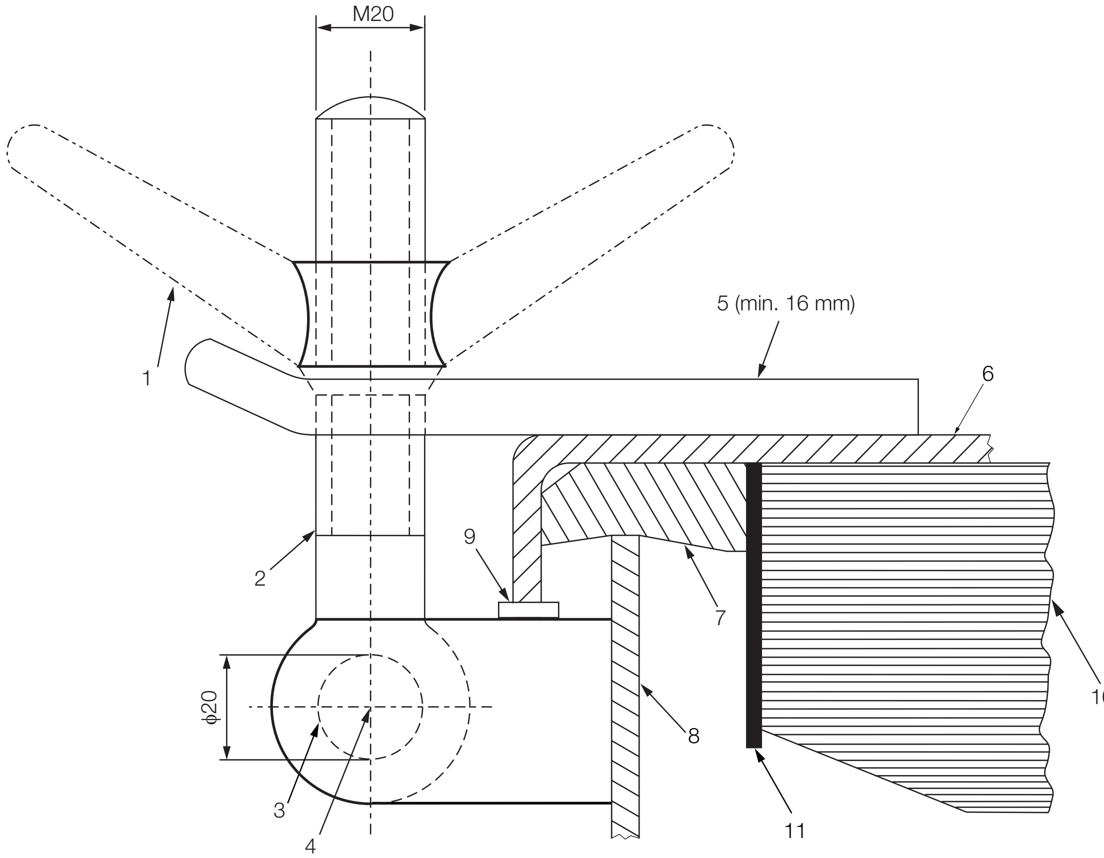


Fig. 11.6.2 Arrangement of stiffeners

6.6.17 For hatch covers located on the deck forward of the fore-most cargo hatch, the hinges are to be fitted such that the predominant direction of green sea will cause the cover to close. The hinges are normally to be located on the fore edge.

6.6.18 On small hatches located between the main hatches, for example between Numbers 1 and 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green water in beam sea and bow quartering conditions.



1. butterfly nut
2. bolt
3. pin
4. centre of pin
5. fork (clamp) plate
6. hatch cover
7. gasket
8. hatch coaming
9. bearing pad welded on the bracket of a toggle bolt for metal to metal contact
10. stiffener
11. inner edge stiffener

(Note: Dimensions in millimeters)

Fig. 11.6.3 Example of a primary securing method

Table 11.6.1 Scantlings for small steel hatch covers on exposed deck

Nominal size (mm x mm)	Cover plate thickness (mm)	Primary stiffeners	Secondary stiffeners
		Flat bar (mm x mm); number	
630 x 630	8	–	–
630 x 830	8	100 x 8,1	–
830 x 630	8	100 x 8,1	–
830 x 830	8	100 x 10,1	–
1030 x 1030	8	120 x 12,1	80 x 8,2
1330 x 1330	8	150 x 12,2	100 x 10,2

6.6.19 Hatches, excluding emergency escape hatches, are to be fitted with an independent secondary securing device, e.g., by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

6.6.20 Small hatches, including escape hatches, are to be situated clear of cargo containment areas, particularly in the case of offshore supply ships.

6.6.21 Where portable plates are required in decks for unshipping machinery, or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced deck and are secured by gaskets and closely spaced bolts at a pitch not exceeding five diameters.

6.6.22 Satisfactory means are to be provided to prevent inadvertent flooding of chain lockers, *see* Ch 13,8.10.5 and 8.10.7.

■ *Section 7* Tanker access arrangements and closing appliances

7.1 Materials

7.1.1 Covers for access hatches, tank cleaning and other openings to cargo tanks and adjacent spaces are to be manufactured from steel complying with the Rules for Materials.

7.1.2 Consideration will be given to the use of bronze, brass or other materials; however, aluminium alloy is not to be used for the covers of any openings to tanks.

7.1.3 Synthetic materials will be considered, taking into account their fire resistance and physical and chemical properties in relation to the intended operating conditions. Details of the properties of the material, the design of the cover and the method of manufacture are to be submitted for approval.

7.1.4 The hatch cover packing material is to be compatible with the cargoes to be carried and is to be efficiently held in place.

7.2 Cargo tank access hatchways

7.2.1 Attention is drawn to IMO Resolutions concerning safe access to, and working in, large tanks.

7.2.2 Oiltight hatchways are to be kept to the minimum size required to provide reasonable access and ventilation. Where tanks are large or subdivided by wash bulkheads, additional hatchways may be required. In determining the size and location of hatchways, consideration should be given to the handling of materials and staging for maintenance in the tank.

7.2.3 The size and location of hatchways should also take into account access for personnel wearing breathing apparatus, and removal of injured personnel (possibly on a stretcher) from the bottom of the tank.

7.2.4 The height of hatch coaming is to be not less than 600 mm, measured above the upper surface of the freeboard deck, unless a lower height is permitted by the Administration of the country in which the ship is to be registered.

7.2.5 Taking account of sheer and camber, the height of any cargo tank hatch coaming is to be such as to ensure that the top of the hatch coaming is above the highest point of the tank over which it is fitted.

7.2.6 The height of the coaming may be required to be increased if this is shown to be necessary by the floatability calculations required by the *International Convention on Load Lines, 1966.*

7.2.7 The thickness of the coaming plate is to be not less than 10 mm, but may be required to be increased, and edge stiffening fitted, where the coaming height exceeds 600 mm.

7.2.8 Unstiffened plate covers are to be not less than 12,5 mm in thickness, but if the area of the cover exceeds 1,2 m^2 this thickness may be required to be increased or stiffening fitted.

7.2.9 Unstiffened covers are to be secured by fastenings spaced not more than 600 mm apart on circular hatchways. On rectangular hatchways the spacing of fastenings is generally not to exceed 450 mm, and the distance between hatch corners and adjacent fastenings is to be not more than 230 mm.

7.2.10 The arrangement of fastenings on stiffened hatchway covers and covers of special design will be specially considered.

7.2.11 Where the cover is hinged, adequate stiffening of the coaming and cover in way of the hinge is to be provided. In general, hinges are not to be used as securing devices for the cover.

7.3 Enlarged cargo tank access openings

7.3.1 Proposals to fit enlarged cargo tank accesses closed by bolted plate covers will be considered. Such openings may be of extended dimensions for ease of access and evacuation of personnel, *see* 7.2.3, and may incorporate a smaller access hatch for normal use constructed as required by 7.2.

7.3.2 The plate cover is to be not less than 15 mm in thickness and is to be secured by closely spaced studs to a ring of suitable dimensions, welded to the deck. The studs are not to penetrate the deck plating.

7.4 Miscellaneous openings

7.4.1 Small openings for tank cleaning, ullage and similar purposes may be closed by flush covers which are to be not less than 12,5 mm in thickness and secured by studs not more than 100 mm apart. Studs are to be arranged in a ring of suitable width and thickness attached to the deck, and are not to penetrate the deck plating.

7.4.2 Small diameter holes provided for staging wires are to be closed by plugs of an approved pattern. The plugs are to be provided with a thick washer of suitable material which is also compatible with the intended cargoes. Spare plugs equal to at least 10 per cent of the number of holes are to be provided and maintained on board, *see also* Pt 4, Ch 9,4. If these openings are threaded they are to be protected while in use with a protective sleeve of suitable material.

7.5 Access to spaces other than cargo tanks

7.5.1 Access to clean ballast or dry tanks and to cofferdams may be either by access hatch or by manhole generally complying with the preceding requirements.

7.6 Equivalents

7.6.1 Alternative access cover designs and securing arrangements will be considered on the basis of equivalence to the above requirements and taking into account any relevant National Requirements.

7.7 Other openings

7.7.1 For access to structure within cargo tanks, *see* Pt 4, Ch 9,13.

■ *Section 8* Side and stern doors and other shell openings

8.1 Symbols

8.1.1 The symbols used in this Section are defined as follows:

d = distance between closing devices, in metres

k = material factor, *see* Ch 2,1.2, but is not to be taken less than 0,72 unless demonstrated otherwise by a direct strength analysis with regard to relevant modes of failure

I = moment of inertia, in cm^4, of the stiffener or girder, in association with an effective width of attached plating determined in accordance with Ch 3,3

σ = bending stress, in N/mm^2 (kgf/mm^2)

σ_e = equivalent stress, in N/mm^2 (kgf/mm^2)

$= \sqrt{(\sigma^2 + 3\tau^2)}$

σ_o = minimum yield stress of the bearing material, in N/mm^2 (kgf/mm^2)

τ = shear stress, in N/mm^2 (kgf/mm^2).

8.2 General

8.2.1 These requirements cover cargo and service doors in the ship side (abaft the collision bulkhead) and stern area, below the freeboard deck and in enclosed superstructures.

8.2.2 For the requirements of bow doors, *see* Pt 4, Ch 2,8.

8.2.3 Side and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure, *see also* Ch 1,6.3.2 and 6.4.2.

8.2.4 In general, and for passenger ships in particular, the lower edge of door openings is not to be below a line drawn parallel to the freeboard deck at side, which has at its lowest point at least 230 mm above the upper edge of the uppermost Load Line.

8.2.5 When the lower edge is below the line specified in 8.2.4, the arrangement will be specially considered. Special consideration is to be given to preventing the spread of leakage water over the deck. The reference to the uppermost Load Line is to be taken as the tropical fresh waterline or, if timber freeboards are assigned, the timber tropical fresh waterline.

8.2.6 Watertight doors below the freeboard deck, with the exception of pilot doors which are to open inwards, are to open outwards. Weathertight doors are generally to be arranged to open outwards, however inward opening doors will be considered provided these satisfy the requirements of 8.2.7.

8.2.7 Inward opening doors situated in the first two 'tween decks above the summer load waterline are to be fitted with a second independent securing device, such as a strongback or equivalent arrangement, capable of providing weathertight integrity. Where the consequences of water ingress due to failure of the door are minimal, such as a small pilot door giving access to a watertight trunk leading to the bulkhead deck, the required enhancements will be specially considered.

8.2.8 For passenger ships the following are also applicable:

(a) Gangway, cargo and service ports fitted below the margin line, *see* Ch 3,4.3, are to satisfy the strength requirements given for side doors in this Section. They are to be effectively closed and secured watertight before the ship leaves port, and are to be kept closed during navigation. Such ports are not to have their lowest point below the deepest subdivision Load Line.

(b) Where the inboard end of a rubbish chute is below the margin line in a passenger ship, the inboard end cover is to be watertight and, in addition to the discharge flap interlock, a screwdown automatic non-return valve is to be fitted in an easily accessible position above the deepest subdivision. The valve is to be controlled from a position above the bulkhead deck and provided with an open/shut indicator, and kept closed when not in use. A suitable notice is to be displayed at the valve position.

8.2.9 For ships complying with the requirements of this Section, the securing, supporting and locking devices are defined as follows:

(a) A securing device is used to keep the door closed by preventing it from rotating about its hinges or other pivoted attachments to the ship.

(b) A supporting device is used to transmit external and internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the ship's structure.

(c) A locking device locks a securing device in the closed position.

8.2.10 Ro-ro cargo spaces are spaces not normally subdivided in any way and extending to either a substantial length or the entire length of the ship, in which motor vehicles with fuel in their tanks for their own propulsion and/or goods (packaged or in bulk, in or on rail or road cars, vehicles (including road or rail tankers), trailers, containers, pallets, demountable tanks in or on similar stowage units or other receptacles) can be loaded and unloaded normally in a horizontal direction.

8.2.11 Special category spaces are those enclosed spaces above and below the bulkhead deck, into and from which vehicles can be driven and to which passengers have access, and which may be accommodated on more than one deck where total overall clear height for vehicles does not exceed 10 m.

8.3 Scantlings

8.3.1 In general the strength of side and stern doors is to be equivalent to the strength of the surrounding structure.

8.3.2 Door openings in the side shell are to have well rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below, *see* Pt 4, Ch 1,5.

8.3.3 Doors are to be adequately stiffened, and means are to be provided to prevent movement of the doors when closed. Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the ship structure.

8.3.4 The thickness of the door plating is to be not less than the shell plating calculated with the door stiffener spacing, and in no case to be less than the minimum adjacent shell thickness.

8.3.5 Where stern doors are protected against direct wave impact by a permanent external ramp, the thickness of the stern door plating may be reduced by 20 per cent relative to the requirements of 8.3.4. Those parts of the stern door which are not protected by the ramp are to have the thickness of plating in full compliance with 8.3.4.

8.3.6 Where higher tensile steel is proposed, the plating thickness required in 8.3.4 and 8.3.5 may be reduced by $\sqrt{k}$.

8.3.7 The section modulus of horizontal or vertical stiffeners is to be not less than required for the adjacent shell framing using the actual stiffener spacing. Consideration is to be given, where necessary, to differences in fixity between ship's frames and door stiffeners.

8.3.8 Where necessary, door secondary stiffeners are to be supported by primary members constituting the main stiffening elements of the door.

8.3.9 The scantlings of such primary members are to be based on direct strength calculations. Normally, formulae for simple beam theory may be applied to determine the bending stress. Members are to be considered to have simply supported end connections. The design load is the uniformly distributed external sea pressure, p_e, as defined in 8.8.1. For minimum scantlings, p_e, is to be taken as 25 kN/m^2 (2,55 tonne-f/m^2) and the permissible stresses as follows:

$$\tau = \frac{80}{k} \text{ N/mm}^2 \quad \left(\frac{8,2}{k} \text{ kgf/mm}^2\right)$$

$$\sigma = \frac{120}{k} \text{ N/mm}^2 \quad \left(\frac{12,2}{k} \text{ kgf/mm}^2\right)$$

$$\sigma_e = \frac{150}{k} \text{ N/mm}^2 \quad \left(\frac{15,3}{k} \text{ kgf/mm}^2\right)$$

8.3.10 The webs of primary members are to be adequately stiffened, preferably in a direction perpendicular to the shell plating.

8.3.11 The stiffness of the edges of the doors and the hull structure in way are to be sufficient to ensure weathertight integrity. Edge stiffeners/girders are to be adequately stiffened against rotation and are to have a moment of inertia not less than:

$$I = 0{,}8 p_I d^4 \quad \text{cm}^4$$

$$(I = 8 p_I d^4 \quad \text{cm}^4)$$

where

p_I = packing line pressure along edges, not to be taken less than 50 N/cm (5,1 kgf/cm).

For edge girders supporting main door girders between securing devices, the moment of inertia is to be increased in relation to the additional force.

8.3.12 The buckling strength of primary members is to be specially considered.

8.3.13 All load transmitting elements in the design load path from door through securing and supporting devices into the ship structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices. These elements include pins, supporting brackets and back-up brackets. Where cut-outs are made in the supporting structure, the strength and stiffness will be specially considered.

8.4 Doors serving as ramps

8.4.1 Where doors also serve as vehicle ramps, the plating and stiffeners are to be not less than required for vehicle decks, *see* Ch 9,3.

8.4.2 The design of the hinges for these doors should take into account the ship angle of trim or heel which may result in uneven loading of the hinges.

8.5 Arrangements for the closing, securing and supporting of doors

8.5.1 Doors are to be fitted with adequate means of closing, securing and support so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

8.5.2 Devices are to be simple to operate and easily accessible. They are to be of a design approved by Lloyd's Register for the intended purpose.

8.5.3 Securing devices are to be equipped with positive locking arrangements. Arrangements are to be such that the securing devices are retained in the closed position within design limits of inclination, vibration and other motion-induced loads and in the event of loss of any actuating power supply.

8.5.4 Systems for door opening/closing and securing/locking are to be interlocked in such a way that they can only operate in a proper sequence. Hydraulic systems are to comply with Pt 5, Ch 14,9.

8.5.5 Means are to be provided to enable the doors to be mechanically fixed in the open position taking into account the self weight of the door and a minimum wind pressure of 1,5 kN/m^2 (0,153 tonne-f/m^2) acting on the maximum projected area in the open position.

8.5.6 The spacing for cleats or closing devices should not exceed 2,5 m and there should be cleats or closing devices positioned as close to the corners as practicable. Alternative arrangements for ensuring weathertight sealing will be specially considered.

8.5.7 Control and monitoring arrangements are to comply with the applicable requirements of Pt 6, Ch 2,19.

8.6 Design loads

8.6.1 The design force considered for the scantlings of primary members, securing and supporting devices of side shell doors and stern doors are to be taken not less than:

(a) Design forces for securing or supporting devices of doors opening inwards:

External force:

$P_e = Ap_e + P_p$ kN (tonne-f)

Internal force:

$P_i = P_o + 10W$ kN

($P_i = P_o + 1{,}02W$ tonne-f)

(b) Design forces for securing or supporting devices of doors opening outwards:

External force:

$P_e = Ap_e$ kN (tonne-f)

Internal force:

$P_i = P_o + 10W + P_p$ kN

($P_i = P_o + 1{,}02W + P_p$ tonne-f)

(c) Design forces for primary members:

External force:

$P_e = Ap_e$ kN (tonne-f)

Internal force:

$P_i = P_o + 10W$ kN

($P_i = P_o + 1{,}02W$ tonne-f)

whichever is the greater.

The symbols used are defined as follows:

p_e = external sea pressure, in kN/m^2 (tonne-f/m^2), determined at the centre of gravity of the door opening and is not to be taken less than:

for $Z_G < T$ $10\,(T - Z_G) + 25$ kN/m^2
($1{,}02\,(T - Z_G) + 2{,}55$ tonne-f/m^2)

for $Z_G \geq T$ 25 kN/m^2
(2,55 tonne-f/m^2)

For stern doors of ships fitted with bow doors, p_e is not to be taken less than:

$p_{emin} = 0{,}6\lambda C_H\,(0{,}8 + 0{,}6L^{0{,}5})^2$ kN/m^2

($p_{emin} = 0{,}061\lambda C_H\,(0{,}8 + 0{,}6L^{0{,}5})^2$ tonne-f/m^2)

T = summer draught, in metres

Z_G = height of the centre of area of the door, in m, above the base line

L = length of ship, but need not be taken greater than 200 m

λ = coefficient depending on the area where the ship is intended to be operated:
= 1 for sea-going ships
= 0,8 for ships operated in coastal waters
= 0,5 for ships operated in sheltered waters

C_H = $0{,}0125L$ for $L < 80$ m
= 1 for $L \geq 80$ m

A = area, in m^2, of the door opening

W = weight of the door, in tonnes

P_p = total packing force, kN (tonne-f). When packing is fitted, the packing line force per unit length is to be specified, normally not to be taken less than:
5 kN/m (0,51 tonne-f/m)

P_o = the greater of P_c and $5A$ kN ($0{,}5A$ tonne-f)

P_c = accidental force, in kN (tonne-f), due to loose cargo, etc., to be uniformly distributed over the area A and not to be taken less than 300 kN (30,6 tonne-f). For small doors such as bunker doors and pilot doors, the value of P_c may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental force due to loose cargoes.

8.7 Design of securing and supporting devices

8.7.1 Securing devices and supporting devices are to be designed to withstand the forces given above using the following permissible stresses:

$$\tau = \frac{80}{k} \text{ N/mm}^2 \quad \left(\frac{8{,}2}{k} \text{ kgf/mm}^2\right)$$

$$\sigma = \frac{120}{k} \text{ N/mm}^2 \quad \left(\frac{12{,}2}{k} \text{ kgf/mm}^2\right)$$

$$\sigma_e = \frac{150}{k} \text{ N/mm}^2 \quad \left(\frac{15{,}3}{k} \text{ kgf/mm}^2\right)$$

The terms ‘securing device’ and ‘supporting device’ are defined in Pt 4, Ch 2,8.2.8.

8.7.2 The arrangement of securing and supporting devices is to be such that threaded bolts are not to carry support forces. The maximum tensile stress in way of threads of bolts, not carrying support forces, is not to exceed:

$$\frac{125}{k} \text{ N/mm}^2 \quad \left(\frac{12{,}7}{k} \text{ kgf/mm}^2\right)$$

8.7.3 For steel to steel bearings in securing and supporting devices, the normal bearing pressure is not to exceed 0,8σ_o, *see* 8.1.1. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer’s specification. The normal bearing pressure is to be calculated by dividing the design force by the projected bearing area.

8.7.4 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports. Small and/or flexible devices, such as cleats, intended to provide load compression of the packing material are not generally to be included in these calculations.

8.7.5 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be considered in the calculation of the reaction forces acting on the devices.

8.7.6 The number of securing and supporting devices is generally to be the minimum practicable whilst complying with 8.5.3 and taking account of the available space in the hull for adequate support.

8.7.7 The arrangement of securing devices and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces, without exceeding, by more than 20 per cent, the permissible stresses as defined in 8.7.1.

8.8 Operating and Maintenance Manual

8.8.1 An Operating and Maintenance Manual for the doors is to be provided on board and is to contain necessary information on:

(a) main particulars and design drawings,
(b) service conditions, e.g., service area restrictions, acceptable clearances for supports,
(c) maintenance and function testing,
(d) register of inspections, repairs and renewals.

8.8.2 For passenger/vehicle ferries and roll on-roll off cargo ships, *see* Pt 4, Ch 2,1.1.1, an Operating and Maintenance Manual for the doors, as defined in Pt 4, Ch 2,8.7.1, is to be provided on board instead of that required by 8.8.1.

8.8.3 The Manual is to be submitted for approval, and is to contain a note recommending that recorded inspections of the door supporting and securing devices be carried out by the ship’s staff at monthly intervals or following incidents that could result in damage, including heavy weather or contact in the region of the doors. Any damages recorded during such inspections are to be reported to LR.

8.8.4 Documented operating procedures for closing and securing the doors are to be kept on board and posted at an appropriate place.

■ *Section 9*
Watertight doors in bulkheads below the freeboard deck

9.1 Openings in bulkheads

9.1.1 Certain openings below the freeboard deck are permitted, but these must be kept to a minimum and provided with means of closing to watertight standards. All such openings are to be to the satisfaction of the Surveyor.

9.2 Watertight doors

9.2.1 Watertight doors are to be of equivalent strength to the unpierced bulkhead, efficiently constructed and fitted, and are to be capable of being closed watertight when the ship is listed up to 15° either way. They are to be operated under working conditions and hose tested in place, *see* Table 1.9.1 in Chapter 1.

9.2.2 The scantlings of the watertight doors are to comply with Pt 4, Ch 1,9 using the actual stiffener spacing of the door.

9.2.3 The scantlings of the frames of the watertight doors are to satisfy the requirements of watertight bulkheads given in Table 1.9.1(5) in Pt 4, Ch 1,9 taking into account the arrangement of door stiffeners and securing arrangements.

9.2.4 Watertight doors of the sliding type are to be capable of being operated both at the door itself and from an accessible position above the bulkhead deck. Means are to be provided at all the remote operating positions to indicate whether the door is open or closed. Doors are to be capable of being remotely closed from the bridge. The relevant regulations regarding openings in watertight bulkheads, contained in the *International Convention for the Safety of Life at Sea, 1974* and applicable amendments, are also to be complied with.

9.2.5 Hinged watertight doors of approved pattern may be fitted in 'tween decks in approved positions. The hinges of these doors are to be fitted with gunmetal pins or gunmetal bushes.

9.2.6 The frames of vertical watertight doors shall have no groove at the bottom in which dirt might lodge and prevent the door closing properly.

9.2.7 Means are to be provided on the navigating bridge to indicate whether the watertight doors are open or closed. A notice is to be affixed to both sides of each such door or hatch cover to the effect that it is not to be left open.

9.2.8 In passenger ships the number and construction of the watertight doors in bulkheads will be specially considered. Each watertight door is to be tested, *see* Table 1.9.1 in Chapter 1. The test may be carried out either before or after the door is fitted. The relevant regulations regarding openings in watertight bulkheads in passenger ships, contained in the *International Convention for the Safety of Life at Sea, 1974* and applicable amendments, are also to be complied with.

■ *Section 10*
External openings and openings in watertight bulkheads and internal decks in cargo ships

10.1 Shell and watertight subdivision openings

10.1.1 In addition to the requirements of Sections 8 and 9, for cargo ships of 80 m in length and above, the relevant regulations concerning shell and watertight subdivision openings contained in the *International Convention for the Safety of Life at Sea*, 1974, and amendments thereto are also to be complied with.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all ship types detailed in Part 4, and provides requirements for ventilators, air and sounding pipes and overboard discharges.

1.1.2 The requirements conform, where relevant, with those of the *International Convention on Load Lines, 1966*. Reference should also be made to any additional requirements of the National Authority of the country in which the ship is to be registered and to the relevant regulations of the *International Convention for the Safety of Life at Sea, 1974* and applicable amendments.

1.2 Protection

1.2.1 In all cargo spaces and other areas where mechanical damage is likely, all air and sounding pipes, scuppers and discharges, including their valves, controls and indicators, are to be well protected. This protection is to be of steel or other equivalent material.

■ *Section 2* Ventilators

2.1 General

2.1.1 Ventilators located on the exposed deck over the forward 0,25*L* of the rule length, of ships of sea-going service of length 80 m or more, where the height of the exposed deck in way of the item is less than 0,1*L* or 22 m above the summer load waterline, whichever is the lesser, are to comply with the requirements of Section 5. All other ventilators are to comply with the following requirements.

2.1.2 Special care is to be taken in the design and positioning of ventilator openings and coamings, particularly in the region of the forward end of superstructures and other points of high stress. The deck plating in way of the coamings is to be efficiently stiffened.

2.1.3 Ventilators from deep tanks and tunnels passing through 'tween decks are to have scantlings suitable for withstanding the pressures to which they may be subjected, and are to be made watertight.

2.1.4 For height and location of cargo tank vent outlets, *see* Pt 5, Ch 15,4 and *see also* Ch 8,8.2.9 and 8.2.10 of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk* (hereinafter referred to as the Rules for Ships for Liquefied Gases), or Ch 8,8.2.2, of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquid Chemicals in Bulk* (hereinafter referred to as the Rules for Ships for Liquid Chemicals), where applicable.

2.2 Coamings

2.2.1 The scantlings and height of ventilator coamings exposed to the weather are to be not less than required by Table 12.2.1 but the thickness need not exceed that of the adjacent deck or bulkhead plating. In particularly exposed positions, the height of coamings and scantlings may be required to be increased.

Table 12.2.1 Ventilator coaming requirements

Feature	Requirements
Height (measured above sheathing if fitted)	(1) z_C = 900 mm at Position 1 (*see* Ch 1,6.5) z_C = 760 mm at Position 2 (*see* Ch 1,6.5)
Thickness	(2) $t_C = 5{,}5 + 0{,}01\delta_V$ mm where 7,5 mm $\le t_C \le$ 10,0 mm
Support	(3) If z_C > 900 mm the coaming is to be specially supported
Symbols	
t_C = thickness of coaming, in mm z_C = height of coaming, in mm δ_V = internal diameter of coaming, in mm	
NOTE Where the height of the ventilator exceeds that given in Item (1), the thickness given by (2) may be gradually reduced, above that height, to a minimum of 6,5 mm. The ventilator is to be adequately stayed.	

2.2.2 The height of ventilator coamings may be required to be increased on ships of Type 'A', Type 'B-100' and Type 'B-60' where this is shown to be necessary by the floatability calculations required by the *International Convention on Load Lines, 1966.*

2.2.3 For gooseneck ventilators, the coaming height is to be measured to the underside of the bend, this being the lowest point through which water on deck could pass freely to spaces below.

2.2.4 Where wall vents are fitted with an internal baffle which rises above the lower edge of the exterior opening, the coaming height is measured to the top of the baffle.

2.2.5 Where permitted by the National Authority, ventilator coaming heights may be reduced on ships engaged on protected or extended protected water service. Coaming heights are to be as high as practicable, with a minimum height of 450 mm in Position 1 and 300 mm in Position 2.

2.3 Closing appliances

2.3.1 All ventilator openings are to be provided with efficient weathertight closing appliances of steel or other equivalent material unless:
(a) the height of the coaming is greater than 4,5 m where Table 12.2.1 requires a minimum height of 900 mm; or
(b) the height of the coaming is greater than 2,3 m where Table 12.2.1 requires a minimum height of 760 mm.

2.3.2 In ships where the load line length, L_L (*see* Ch 1,6.1), is not more than 100 m, the closing appliances are to be permanently attached to the ventilator coaming. Where not so provided in other ships, they are to be conveniently stowed near the ventilator to which they are to be fitted.

2.3.3 Where, in ferries, ventilators are proposed to be led overboard in an enclosed 'tween deck, the closing arrangements are to be submitted for approval. If such ventilators are led overboard more than 4,5 m above the main vehicle deck, closing appliances may be omitted, provided that satisfactory baffles and drainage arrangements are provided, as in the case of air intakes or exhaust openings for machinery spaces, which may be arranged in the sides of the ship.

2.3.4 On offshore supply ships, to ensure satisfactory operation in all weather conditions, machinery space ventilation inlets and outlets are to be located in such positions that closing appliances will not be necessary.

2.3.5 Mushroom ventilators closed by a head revolving on a centre spindle (screw down head) are acceptable in Position 2, and also in sheltered positions in Position 1, excluding those described in 2.1.1, but the diameter is not to exceed 300 mm if situated within the forward $0,25L_L$.

2.3.6 Mushroom ventilators with a fixed head and closed by a screw down plate (screw down cover) may be accepted in exposed positions within the forward $0,25L_L$, excluding those described in 2.1.1, up to a diameter of 750 mm.

2.3.7 Wall ventilators (jalousies) may be accepted provided they are capable of being closed weathertight by hinged steel gasketed covers secured by bolts or toggles.

2.3.8 A ventilator head not forming part of the closing arrangements is to be not less than 6,5 mm thick.

2.3.9 In order to limit the fire growth potential in every space of the ship, the main inlets and outlets of all ventilation systems shall be capable of being closed from outside the spaces being ventilated. The means of closing shall be easily accessible as well as prominently and permanently marked and shall indicate whether the inlet or outlet is open or closed. Battery room ventilators are only to be fitted with a means of closing, whenever:
(a) the battery room does not open directly on to an exposed deck; or
(b) the ventilation opening for the battery room is required to be fitted with a closing device according to the Load Line Convention; or
(c) the battery room is fitted with a fixed gas fire extinguishing system.
Where a battery room ventilator is fitted with a closing device *see* Pt 6, Ch 2,12.5.2.

2.4 Machinery spaces

2.4.1 In general, ventilators necessary to continuously supply the machinery space are to have coamings of sufficient height to comply with 2.3.1 without having to fit weathertight closing appliances. Ventilators to emergency generator rooms are to be so positioned that closing appliances are not required.

2.4.2 Where due to ship size and arrangement this is not practicable, lesser heights for machinery space ventilator coamings fitted with weathertight closing appliances may be permitted by the administration in combination with other suitable arrangements to ensure uninterrupted, adequate supply of ventilation to these spaces.

■ *Section 3* Air and sounding pipes

3.1 General

3.1.1 Air pipes located on the exposed deck over the forward $0,25L$ of the rule length, of ships of sea-going service of length 80 m or more, where the height of the exposed deck in way of the item is less than $0,1L$ or 22 m above the summer load waterline, whichever is the lesser, are to comply with the requirements of Section 5. All other air and sounding pipes are to comply with the following requirements in addition to the applicable requirements of Pt 5, Ch 13,12 and Ch 13,15.2.

3.1.2 Striking plates of suitable thickness, or their equivalent, are to be fitted under all sounding pipes.

3.1.3 On offshore supply ships, air pipes are to be situated clear of the cargo containment areas.

3.2 Height of air pipes

3.2.1 The height of air pipes from the upper surface of decks exposed to the weather, to the point where water may have access below, is normally to be not less than:

- 760 mm on the freeboard deck;
- 450 mm on the superstructure deck;

these heights being measured above deck sheathing, where fitted.

3.2.2 Lower heights may be approved in cases where these are essential for the working of the ship, provided that the design and arrangements are otherwise satisfactory. In such cases, efficient, permanently attached closing appliances of an approved automatic type will generally be required.

3.2.3 The height of air pipes may be required to be increased on ships of Type 'A', Type 'B-100' and Type 'B-60' where this is shown to be necessary by the floatability calculations required by the *International Convention on Load Lines, 1966.* An increase in height may also be required or recommended by individual Administrations when air pipes to oil fuel and settling tanks are situated in positions where sea-water could be temporarily entrapped, e.g., in recesses in the sides and ends of superstructures or deckhouses, between hatch ends, behind high sections of bulwark, etc. This may entail an increase in tank scantlings, *see also* Chapter 3.

3.2.4 Air pipes are generally to be led to an exposed deck. For alternative arrangements in an enclosed space on a main vehicle deck, *see* Pt 4, Ch 2,9.

3.2.5 Where air pipes are led through the side of superstructures, the opening is to be at least 2,3 m above the summer load waterline.

3.2.6 The minimum wall thickness of air pipes in positions indicated in 3.2.1 is to be:

- 6,0 mm for pipes of 80 mm external diameter or smaller;
- 8,5 mm for pipes of 165 mm external diameter or greater.

Intermediate minimum thicknesses are to be determined by linear interpolation.

3.2.7 Where permitted by the National Authority, air pipe coaming heights may be reduced on ships engaged on protected or extended protected water service. Coaming heights are to be as high as practicable, with a minimum height of 450 mm on the freeboard deck and 300 mm on a superstructure deck.

3.3 Closing appliances

3.3.1 All openings of air and sounding pipes are to be provided with permanently attached, satisfactory means of closing to prevent the free entry of water, *see also* 3.2.2.

3.3.2 Closing appliances are to be of an approved automatic type.

3.3.3 Pressure/vacuum valves as required by Pt 5, Ch 15,4 may be accepted as closing appliances for cargo tanks.

■ *Section 4* Scuppers and sanitary discharges

4.1 General

4.1.1 Scuppers sufficient in number and size to provide effective drainage are to be fitted in all decks.

4.1.2 Scuppers draining weather decks and spaces within superstructures or deckhouses not fitted with efficient weathertight doors are to be led overboard.

4.1.3 Where the freeboard is such that the freeboard deck edge is immersed when the ship heels 5° or less, scuppers and discharges which drain spaces below the freeboard deck, or spaces within intact superstructures or deckhouses on the freeboard deck fitted with efficient weathertight doors, are to be led to the bilges in the case of scuppers or to suitable sanitary tanks in the case of sanitary discharges. Where the freeboard is such that the freeboard deck edge is immersed when the ship heels greater than 5° then they may be led overboard and fitted with means of preventing water from passing inboard in accordance with 4.2.

4.1.4 In ships where an approved fixed pressure water spray fire-extinguishing system is fitted in vehicle or cargo spaces, deck scuppers of not less than 150 mm diameter are to be provided port and starboard, spaced about 9,0 m apart. The scupper area will require to be increased if the design capacity of the drencher system exceeds the Rule required capacity by 10 per cent or more. After installation, the two adjacent sections with the greatest aggregate drencher capacity are to be tested in operation to ensure that there is no build up of water on the deck, *see also* Pt 4, Ch 2,11.2.2. The mouth of the scupper is to be protected by bars.

4.1.5 Where a sewage system is fitted, the shipside valves on the discharge pipe from the effluent tank(s) and the by-pass system are to comply with 4.2.

4.1.6 The minimum wall thickness of pipes not indicated in 4.2.6 is to be:

- 4,5 mm for pipes of 155 mm external diameter or smaller;
- 6,0 mm for pipes of 230 mm external diameter or greater.

Intermediate minimum thicknesses are to be determined by linear interpolation.

4.1.7 For the use of non-metallic pipe, *see* Pt 5, Ch 12,5.

4.1.8 Scuppers and discharge pipes should not normally pass through fuel oil or cargo oil tanks. Where scuppers and discharge pipes pass, unavoidably, through fuel oil or cargo oil tanks, and are led through the shell within the tanks, the thickness of the piping should be at least the same thickness as Rule shell plating in way, derived from the appropriate Chapters, but need not exceed 19 mm.

4.1.9 Piping within tanks is to be tested in accordance with Ch 1,8.

4.1.10 All piping is to be adequately supported.

4.1.11 *See also* the Rules for Ships for Liquefied Gases or *the* Rules for Ships for Liquid Chemicals, where applicable.

4.1.12 For additional requirements for scuppers and sanitary discharges on dredging and reclamation craft, *see* Pt 4, Ch 12,15.

4.2 Closing appliances

4.2.1 In general, each separate overboard discharge is to be fitted with a screw-down non-return valve capable of being operated from a position always accessible and above the freeboard deck. An indicator is to be fitted at the control position showing whether the valve is open or closed. A machinery space, whether manned or unattended (i.e., with **UMS** notation), is considered accessible. Cargo holds or spaces with access only by hatches or bolted manholes are not considered accessible.

4.2.2 Where a drencher fire-extinguishing system is provided in an enclosed vehicle space of a ferry, the scupper controls are to be operated from a position above the bulkhead deck, and outside the vehicle space protected by the drencher system, and are to be protected from mechanical damage.

4.2.3 Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds $0{,}01L_L$ the discharge may be fitted with two automatic non-return valves without positive means of closing, instead of the screw-down non-return valve, provided that the inboard valve is always accessible for examination under service conditions.

4.2.4 Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds $0{,}02L_L$, a single automatic non-return valve without positive means of closing may be fitted, *see* Fig. 12.4.1.

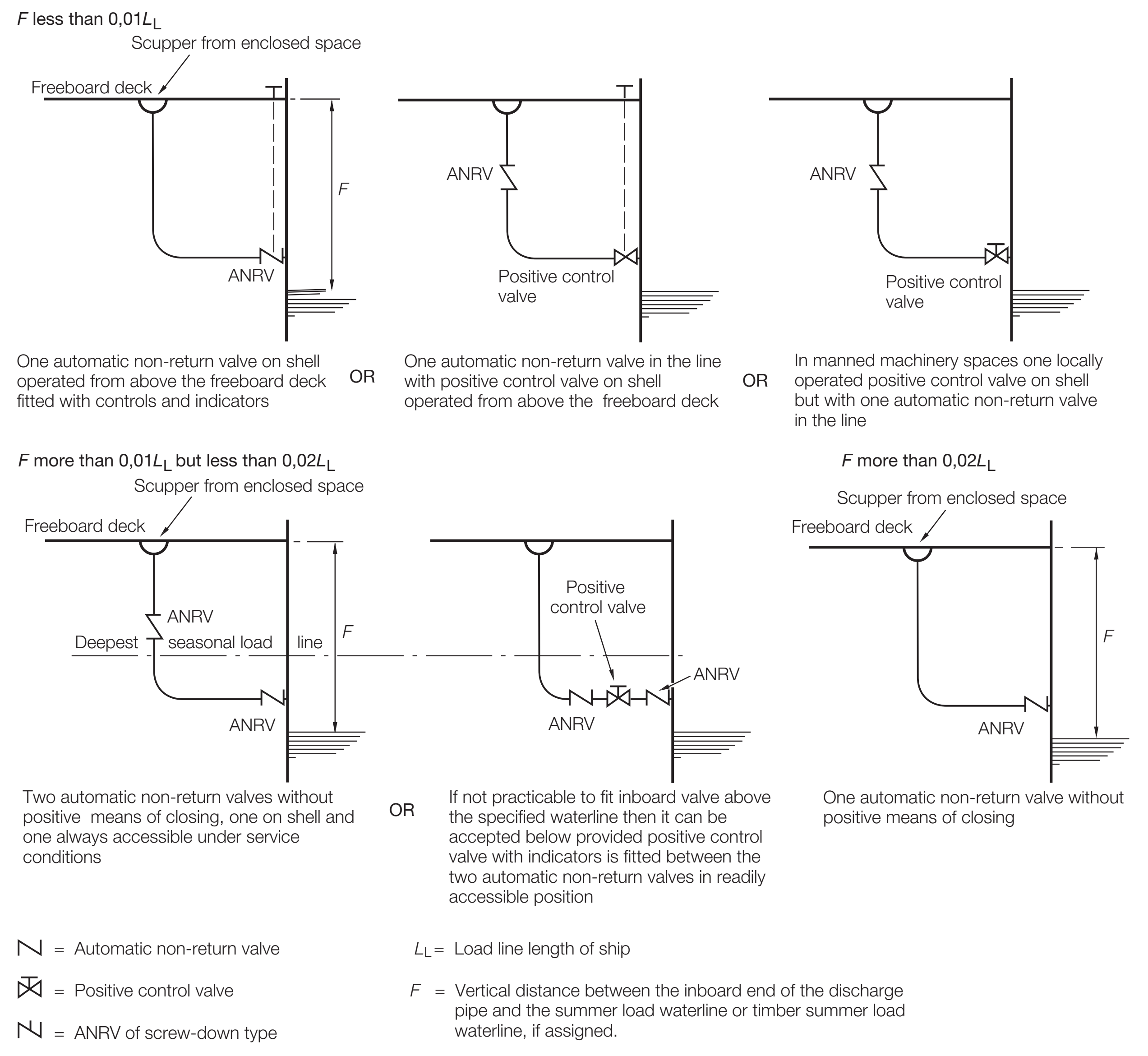


Fig. 12.4.1 Diagrammatic arrangement of discharge valves

4.2.5 The requirements for non-return valves are applicable only to those discharges which remain open during the normal operation of the ship. For discharges which are closed at sea, such as gravity drains from topside ballast tanks, a single screw down valve operated from the freeboard deck is considered to provide sufficient protection.

4.2.6 Scuppers and discharge pipes originating at any level which penetrate the shell either more than 450 mm below the freeboard deck or less than 600 mm above the summer load waterline, are to be fitted with an automatic non-return valve at the shell. This valve, unless required by 4.1.3, may be omitted provided the piping has a minimum wall thickness of:

- 7,0 mm for pipes of 80 mm external diameter or smaller;
- 10,0 mm for pipes of 180 mm external diameter;
- 12,5 mm for pipes of 220 mm external diameter or greater.

Intermediate minimum thicknesses are to be determined by linear interpolation. Unless required by 4.1.8, the maximum thickness need not exceed 12,5 mm.

4.2.7 The outboard valve is to be mounted directly on the shell and secured in accordance with Pt 5, Ch 13,2.5.1. If this is impracticable, a short distance piece of rigid construction may be introduced between the valve and the shell. Valves should not be fitted in cargo tanks.

4.2.8 If a valve is required by 4.1.3, this valve should preferably be fitted as close as possible to the point of entry of the pipe into the tank. If fitted below the freeboard deck, the valve is to be capable of being controlled from an easily accessible position above the freeboard deck. Local control is also to be arranged, unless the valve is inaccessible. An indicator is to be fitted at the control position showing whether the valve is open or closed.

4.2.9 In a ship to which timber freeboards are assigned, the summer load waterline is to be regarded as that corresponding to the timber summer freeboard.

4.2.10 For ship side valves and fittings (other than those on scuppers and sanitary discharges), *see* Pt 5, Ch 13,2 and Pt 6, Ch 1,2.

4.3 Rubbish chutes, offal and similar discharges

4.3.1 Rubbish chutes, offal and similar discharges should be constructed of mild steel piping or plating of shell thickness. Other materials will be specially considered. Openings are to be kept clear of the sheerstrake and areas of high stress concentration.

4.3.2 Rubbish chute hoppers are to be provided with a hinged weathertight cover at the inboard end with an inter-lock so that the discharge flap and hopper cover cannot be open at the same time. The hopper cover is to be secured closed when not in use, and a suitable notice displayed at the control position.

4.3.3 Where the inboard end of the hopper is less than $0,01L_L$ above the summer load waterline, a suitable valve with positive means for closing is to be provided in addition to the cover and flap in an easily accessible position above the deepest seasonal waterline. The valve is to be controlled from a position adjacent to the hopper and provided with an open/shut indicator. The valve is to be kept closed when not in use, and a suitable notice displayed at the valve operating position.

4.3.4 Where damage stability requirements apply and the inboard end of the chute is below the equilibrium waterlines, or in passenger ships, where the inboard end of a rubbish chute is below the margin line; *see* Ch 11,8.2.8(b).

4.3.5 In trawlers or fish factory ships, offal discharges in the fish working spaces are to be provided with either a non-return flap, preferably fitted at the shell which can be positively secured weathertight, or a separate positively controlled valve kept closed when not in use. A suitable notice is to be displayed at the flap or valve operating position.

4.4 Materials for valves, fittings and pipes

4.4.1 All shell fittings and valves required by 4.2 are to be of steel, bronze or other approved ductile material; ordinary cast iron or similar material is not acceptable. Materials are to satisfy the requirements of the *Rules for the Manufacture, Testing and Certification of Materials*.

4.4.2 All these items, if made of steel or other approved material with low corrosion resistance, are to be suitably protected against wastage.

4.4.3 The lengths of pipe attached to the shell fittings, elbow pieces or valves are to be of galvanised steel or other equivalent approved material.

■ *Section 5*
Air pipes, ventilator pipes and their securing devices located on the exposed fore deck

5.1 General

5.1.1 For the application of the following requirements relating to ventilators, *see* 2.1.1. For the application of the following requirements relating to air pipes, *see* 3.1.1. Air pipes complying with the following requirements are also to comply with the applicable requirements of Pt 5, Ch 13,12 and Pt 5, Ch 15,2.5.

5.1.2 Special care is to be taken in the design and positioning of ventilator openings and coamings, particularly in the region of the forward end of superstructures and other points of high stress. The deck plating in way of the coamings is to be efficiently stiffened.

5.1.3 Ventilators from deep tanks and tunnels passing through 'tween decks are to have scantlings suitable for withstanding the pressures to which they may be subjected, and are to be made watertight.

5.1.4 For height and location of cargo tank vent outlets, *see* Pt 5, Ch 15,4 and *see also* Ch 8,8.2.9 and 8.2.10 of the Rules for Ships for Liquefied Gases, or Ch 8,8.2.2, of the Rules for Ships for Liquid Chemicals, where applicable.

5.1.5 On offshore supply ships, air pipes are to be situated clear of the cargo containment areas.

5.2 Loading

5.2.1 The design pressure acting on air pipes, ventilator pipes and their closing devices is to be taken as not less than:

p = $0,5\rho\, V^2\, C_d\, C_s\, C_p$ kN/m^2

where

ρ = density of sea-water (1,025 t/m^3)

V = velocity of water over the fore deck
= 13,5 m/sec for $d \leq 0,5d_1$
= $13,5\sqrt{2\left(1-\dfrac{d}{d_1}\right)}$ for $d > 0,5d_1$

d = distance from summer load waterline to exposed deck

d_1 = $0,1L$ but need not be taken as greater than 22 m

C_d = shape coefficient (0,5 for pipes,1,3 for air pipe or ventilator heads in general and 0,8 for an air pipe or ventilator head of cylindrical form with its axis in the vertical direction)

C_s = slamming coefficient (3,2)

C_p = protection coefficient (0,7 for pipes and ventilator heads located immediately behind a breakwater or forecastle and 1,0 elsewhere and immediately behind a bulwark).

5.2.2 Forces acting in the horizontal direction on the pipe and its closing device are to be not less than those calculated from 5.2.1 using the largest projected area of each component.

5.3 Strength requirements

5.3.1 Bending moments and stresses in air and ventilator pipes are to be calculated at critical positions:

- at penetration pieces;
- at weld or flange connections; and
- at toes of supporting brackets.

5.3.2 Bending stresses in the net section are not to exceed $0,8\sigma_y$, where σ_y is the specified minimum yield stress or 0,2 per cent proof stress of the steel at room temperature. Irrespective of corrosion protection, a corrosion addition to the net section of 2,0 mm is then to be applied.

Table 12.5.1 Air pipe thickness and bracket standards

Nominal pipe diameter, in mm	Minimum fitted gross thickness, in mm	Maximum projected area of head, in cm^2	Height (1) of brackets, in mm
65A	6,0	–	480
80A	6,3	–	460
100A	7,0	–	380
125A	7,8	–	300
150A	8,5	–	300
175A	8,5	–	300
200A	8,5 (2)	1900	300 (2)
250A	8,5 (2)	2500	300 (2)
300A	8,5 (2)	3200	300 (2)
350A	8,5 (2)	3800	300 (2)
400A	8,5 (2)	4500	300 (2)

(1) Brackets (*see* 5.3.3) need not extend over the joint flange for the head.
(2) Brackets are required where the as fitted (gross) thickness is less than 10,5 mm, or where the tabulated projected head area is exceeded.

NOTE
For other pipe heights, the relevant requirements of 5.3 are to be applied.

5.3.3 For standard air pipes of 760 mm coaming height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in Table 12.5.1. Where brackets are required, three or more radial brackets are to be fitted. Brackets are to be of gross thickness 8 mm or more, of minimum length 100 mm, and height according to Table 12.5.1 but need not extend over the joint flange for the head. Bracket toes at the deck are to be suitably supported.

5.3.4 For other configurations, loads according to 5.2 are to be applied, and means of support determined in order to comply with the requirements of 5.3.1 and 5.3.2. Brackets, where fitted, are to be of suitable thickness and length according to their height. Pipe thickness is not to be taken less than as indicated in Pt 5, Ch 12.

5.3.5 For standard ventilators of 900 mm coaming height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in Table 12.5.2. Brackets, where required, are to be as specified in 5.3.3.

5.3.6 For ventilators of coaming height greater than 900 mm, the coaming support will be specially considered. Pipe thickness is not to be taken less than as indicated in Pt 5, Ch 12.

5.3.7 All component parts and connections of the air pipe or ventilator are to be capable of withstanding the loads defined in 5.2.

Table 12.5.2 900 mm ventilator pipe thickness and bracket standards

Nominal pipe diameter, in mm	Minimum fitted gross thickness, in mm	Maximum projected area of head, in cm^2	Height of brackets, in mm
80A	6,3	—	460
100A	7,0	—	380
150A	8,5	—	300
200A	8,5	550	—
250A	8,5	880	—
300A	8,5	1200	—
350A	8,5	2000	—
400A	8,5	2700	—
450A	8,5	3300	—
500A	8,5	4000	—

NOTE
For ventilator heights other than 900 mm, the relevant requirements of 5.3 are to be applied.

5.4 Ventilator coamings

5.4.1 The heights of ventilator coamings is to be not less than 900 mm, this height being measured above deck sheathing, where fitted. In particularly exposed positions, the heights of coamings and scantlings may be required to be increased.

5.4.2 The height of ventilator coamings may be required to be increased on ships of Type ‘A’, Type ‘B-100’ and Type ‘B-60’ where this is shown to be necessary by the floatability calculations required by the *International Convention on Load Lines, 1966.*

5.4.3 For gooseneck ventilators, the coaming height is to be measured to the underside of the bend, this being the lowest point through which water on deck could pass freely to spaces below.

5.4.4 Where wall vents are fitted with an internal baffle which rises above the lower edge of the exterior opening, the coaming height is measured to the top of the baffle.

5.4.5 Where permitted by the National Authority, ventilator coaming heights may be reduced on ships engaged on protected or extended protected water service. Coaming heights are to be as high as practicable, with a minimum height of 450 mm.

5.5 Height of air pipes

5.5.1 The height of air pipes from the upper surface of decks exposed to the weather, to the point where water may have access below is normally to be not less than 760 mm, this height being measured above deck sheathing, where fitted.

5.5.2 Lower heights may be approved in cases where these are essential for the working of the ship, provided that the design and arrangements are otherwise satisfactory. In such cases, efficient, permanently attached closing appliances of an approved automatic type will generally be required.

5.5.3 The height of air pipes may be required to be increased on ships of Type ‘A’, Type ‘B-100’ and Type ‘B-60’ where this is shown to be necessary by the floatability calculations required by the *International Convention on Load Lines, 1966.* An increase in height may also be required or recommended by individual Administrations when air pipes to oil fuel and settling tanks are situated in positions where sea-water could be temporarily entrapped, e.g., in recesses in the sides and ends of superstructures or deckhouses, between hatch ends, behind high sections of bulwark, etc. This may entail an increase in tank scantlings, *see also* Chapter 3.

5.5.4 Air pipes are generally to be led to an exposed deck. For alternative arrangements in an enclosed space on a main vehicle deck, *see* Pt 4, Ch 2,9.

5.5.5 Where air pipes are led through the side of super-structures, the opening is to be at least 2,3 m above the summer load waterline.

5.5.6 Where permitted by the National Authority, air pipe coaming heights may be reduced on ships engaged on protected or extended protected water service. Coaming heights are to be as high as practicable, with a minimum height of 450 mm.

5.6 Closing appliances for ventilators

5.6.1 All ventilator openings are to be provided with efficient weathertight closing appliances unless the height of the coaming is greater than 4,5 m.

5.6.2 In ships where the load line length, L_L (*see* Ch 1,6.1), is not more than 100 m, the closing appliances are to be permanently attached to the ventilator coaming. Where not so provided in other ships, they are to be conveniently stowed near the ventilator to which they are to be fitted.

5.6.3 Where, in ferries, ventilators are proposed to be led overboard in an enclosed ‘tween deck, the closing arrangements are to be submitted for approval. If such ventilators are led overboard more than 4,5 m above the main vehicle deck, closing appliances may be omitted, provided that satisfactory baffles and drainage arrangements are provided, as in the case of air intakes or exhaust openings for machinery spaces, which may be arranged in the sides of the ship.

5.6.4 On offshore supply ships, to ensure satisfactory operation in all weather conditions, machinery space ventilation inlets and outlets are to be located in such positions that closing appliances will not be necessary.

5.6.5 Rotating type mushroom ventilator heads are unsuitable for application on the exposed fore deck.

5.6.6 Wall ventilators (jalousies) may be accepted provided they are capable of being closed weathertight by hinged steel gasketed covers secured by bolts or toggles.

5.6.7 A ventilator head not forming part of the closing arrangements is to be not less than 6,5 mm thick.

5.7 Closing appliances for air pipes

5.7.1 All openings of air pipes are to be provided with permanently attached, satisfactory means of closing to prevent the free entry of water, *see also* 5.5.2.

5.7.2 Closing appliances are to be of an approved automatic type where, with the ship at its summer load waterline, the openings are immersed at an angle of heel of 40° or, the angle of down flooding if this is less than 40°, *see also* Ch 3,7.

5.7.3 Where the closing appliances are not of an automatic type, provision is to be made for relieving vacuum when the tanks are being pumped out.

5.7.4 In a ship to which timber freeboards are assigned, air pipes which will be inaccessible when the deck cargo is carried are to be provided with approved automatic closing appliances.

5.7.5 Pressure/vacuum valves as required by Pt 5, Ch 15,4 may be accepted as closing appliances for cargo tanks.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all the ship types detailed in Part 4, and requirements are given for rudders, nozzles, steering gear, bow and stern thrust unit structure, stabiliser structure, anchoring and mooring equipment, and emergency towing arrangements.

1.1.2 The requirements in this Chapter are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation (*see* Pt 1, Ch 2,2.3) with the exception of the following:

- For Double Hull Oil Tankers; Sections 2 to 6 and Section 9 are to be complied with as applicable.
- For Bulk Carriers; Sections 3 to 6, 9 and 10 are to be complied with as applicable.

1.2 General symbols

1.2.1 The following symbols and definitions are applicable to this Chapter, unless otherwise stated:

L, B and C_b as defined in Ch 1,6.1

σ_o = minimum yield stress or 0,5 per cent proof stress of the material, in N/mm^2 (kgf/mm^2)

k = higher tensile steel factor, *see* Ch 2,1.2.

1.3 Navigation in ice

1.3.1 Where an ice class notation is included in the class of a ship, additional requirements are applicable as detailed in Part 8.

1.4 Podded propulsion

1.4.1 Where podded propulsion is included in the class of a ship, additional requirements as detailed in Pt 5, Ch 9 are to be complied with, as applicable.

1.5 Materials

1.5.1 The requirements for materials are contained in the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.5.2 Stern frames, rudder horns, shaft brackets, rudder stocks, pintles, coupling bolts, keys, and other rudder members are to be made of rolled, forged or cast carbon-manganese steel in accordance with Chapters 3, 4 and 5 of the Rules for Materials. Cast steel stern frames, rudder horns, shaft brackets and sole pieces are to be manufactured from special grade material as specified in Ch 4,2 of the Rules for Materials.

■ *Section 2* Rudders

2.1 Design considerations

2.1.1 Effective means are to be provided for supporting the weight of the rudder without excessive bearing pressure, e.g., by a rudder carrier attached to the upper part of the rudder stock. The hull structure in way of the rudder carrier is to be suitably strengthened.

2.1.2 Suitable arrangements are to be provided to prevent the rudder from lifting.

2.1.3 In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline, two separate stuffing boxes are to be provided. Rudder trunk boundaries, where exposed to the sea, are to have a corrosion protection coating applied in accordance with the manufacturer's instructions.

2.2 Lateral force on rudder blade

2.2.1 The lateral rudder force at the centre of pressure is to be determined for both ahead and stern conditions from the following formula:

$$P_L = 132 c_1 c_2 c_3 C_{TH} A_R V^2 \quad \text{N}$$

where

A_R = rudder blade area, in m^2

A_T = sum of rudder blade area A_R and area of rudder post or rudder horn, if any, within the rudder mean height h_R, in m^2

c_1 = factor depending on the aspect ratio λ of the rudder area

$= \dfrac{\lambda + 2}{3}$

c_2 = rudder profile coefficient, *see* Table 13.2.1

c_3 = 1,0 in general
= 0,8 for rudders outside the propeller jet
= 1,15 for rudders behind a fixed propeller nozzle

C_{TH} = thrust coefficient, is generally to be taken as 1

P_L = lateral force acting on the rudder, in N, is to be calculated for both ahead and astern conditions. The greater of these two values is to be used throughout Section 2

V = maximum service speed, in knots, which the ship is designed to maintain, at the summer load waterline. Maximum ahead service speed means the maximum service speed which the ship is designed to maintain, at the summer load waterline at maximum propeller RPM and corresponding engine MCR. When the speed is less than 10 knots, V is to be replaced by the expression $V_{min} = \dfrac{V + 20}{3}$. For the astern condition the actual astern speed, in knots, or 0,5V, whichever is the greater is to be used (for bow rudders $V = V_A$)

λ = $\dfrac{h_R^2}{A_T}$, but not to be taken greater than 2

h_R = mean height, in metres, of the rudder area, *see* Fig. 13.2.2.

Table 13.2.1 Rudder profile coefficient, c_2

Profile type (*see* Fig. 13.2.1)	Ahead	Astern
NACA-00	1,1	0,8
Hollow profiles	1,35	0,9
Flat side profiles	1,1	0,9
High lift profile	1,7	to be specially considered

NOTE
For rudder profiles not defined above, the value of c_2 may be determined on the basis of experimental results. These results are to be submitted for consideration.

2.3 Rudder torque calculation for rudders without cut-outs

2.3.1 The rudder torque, M_T, is to be determined for both the ahead and astern conditions according to the following formula:

$M_T = P_L x_P$ Nm

where

P_L = lateral force acting on rudder, as calculated in 2.2

x_P = $b_R (\alpha - k)$, in metres, but not less than $0{,}1 b_R$

M_T = the rudder torque, in Nm, to be calculated for both ahead and astern conditions. The greater of these two values are to be used throughout Section 2

b_R = mean breadth of rudder, in metres, *see* Fig. 13.2.2

α = as given in Table 13.2.2

$k = \dfrac{A_f}{A_R}$

A_f = portion of the rudder blade area, situated in front of the centreline of the rudder stock, in m^2, *see* Fig. 13.2.2.

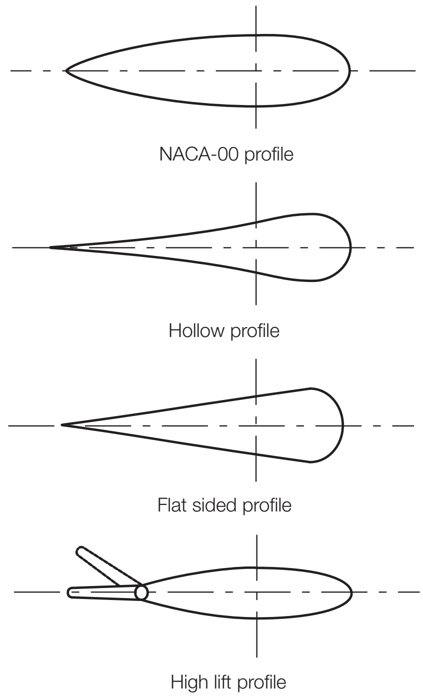


Fig. 13.2.1 Rudder profiles

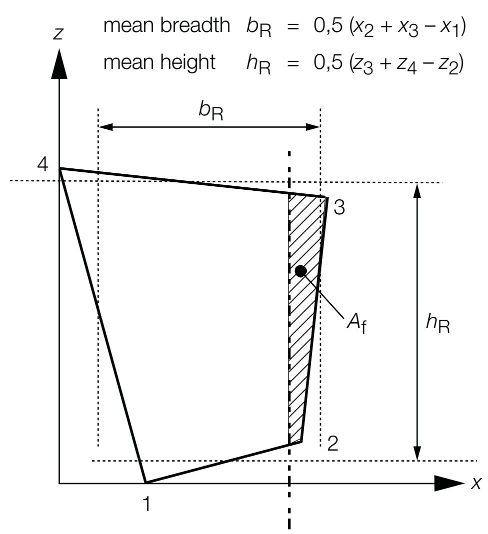


Fig. 13.2.2 Rudder co-ordinate system

Table 13.2.2 Coefficient, α

Condition	Behind fixed structure (*see* Note)	Not behind a fixed structure
Ahead	0,25	0,33
Astern	0,55	0,66
NOTE For rudder parts behind a fixed structure such as a rudder horn.		

2.4 Rudder torque calculation for rudders with cut-outs

2.4.1 The rudder torque, M_T, is to be determined for both the ahead and astern conditions as follows. The rudder area, A_R, used in the derivation of the rudder torque may be divided into two rectangular or trapezoidal parts with areas A_1 and A_2, so that $A_R = A_1 + A_2$, *see* Fig. 13.2.3.

$$M_T = M_1 + M_2 \quad \text{Nm}$$

where

$M_1 = P_{L1}\, x_{P1}$ Nm

$M_2 = P_{L2}\, x_{P2}$ Nm

M_T = the rudder torque, in Nm, to be calculated for both ahead and astern conditions. The greater of these two values are to be used throughout Section 2

P_L = lateral force acting on the rudder, in N, as calculated in 2.2.1

$$P_{L1} = \frac{A_1}{A_R} P_L \quad \text{N}$$

$$P_{L2} = \frac{A_2}{A_R} P_L \quad \text{N}$$

$x_{P1} = b_{R1}(\alpha - k_1)$, in metres

$x_{P2} = b_{R2}(\alpha - k_2)$, in metres

$A_1 = A_{1a} + A_{1f}$, in m^2, *see* Fig. 13.2.3

$A_2 = A_{2a} + A_{2f}$, in m^2, *see* Fig. 13.2.3

b_{R1} = mean breadth, in metres, of partial area A_1

b_{R2} = mean breadth, in metres, of partial area A_2

α = as given in Table 13.2.2

$$k_1 = \frac{A_{1f}}{A_1}$$

$$k_2 = \frac{A_{2f}}{A_2}$$

For ahead condition M_T is not to be taken less than

$$M_{T,min} = 0{,}1 P_L \frac{A_1\, b_{R1} + A_2\, b_{R2}}{A_R} \quad \text{Nm}$$

2.5 Rudder stock and bearings

2.5.1 The scantlings of the stock are to be not less than required by Table 13.2.3.

2.5.2 For the purpose of this Section, the material factor, k_o, applicable to rudder stocks, pintles, coupling flanges, bolts, keys, etc., is defined in Table 13.2.4. For higher tensile steel rudder stocks, welding, including cladding, is not generally permitted.

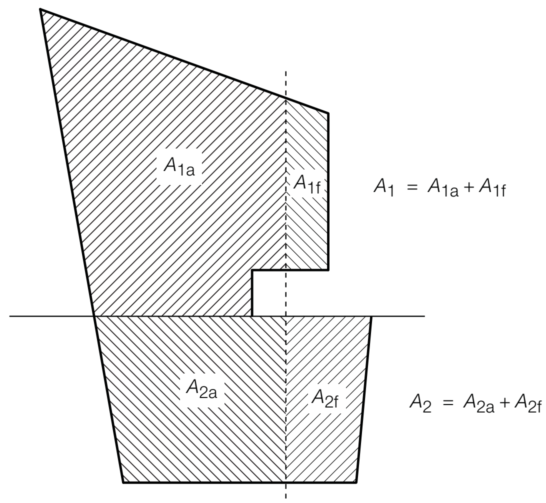


Fig. 13.2.3 Rudder areas

Table 13.2.3 Rudder stock diameter

Item	Requirement
(1) Basic stock diameter, δ_S, at and below lowest bearing	$\delta_S = \delta_t \sqrt[6]{1 + \frac{4}{3}\left(\frac{M_B}{M_T}\right)^2}$ mm
(2) Diameter, δ_t, in way of tiller	$\delta_t = 4{,}2 \sqrt[3]{M_T\, k_o}$ mm
Symbols	
M_T = Total rudder torque, in Nm, as calculated in 2.3 or 2.4 M_B = bending moment, in Nm, at section considered. If direct calculations of bending moment distribution are not carried out, then M_B at the lowest main bearing or rudder coupling may be taken as: $M_B = \frac{h_R}{10 C_r} P_L$, for rudders with heel support $M_B = b P_L$, for spade rudders $M_B = \frac{h_R}{10(1 + C_r)} P_L$, for semi-spade rudders $C_r = \frac{b_R^2}{A_R}$ b = distance, in metres, from centroid of rudder area to the centre of lowest bearing, *see* Fig. 13.2.4 b_R = mean breadth of rudder, in metres, *see* Fig. 13.2.2 h_R = mean depth of rudder, in metres, *see* Fig. 13.2.2 P_L = rudder force, as defined in 2.2.1 k_o = as defined in Table 13.2.4	

2.5.3 The rudder stock diameter is to be dimensioned such that the stresses do not exceed the permissible stresses given in Table 13.2.5.

Table 13.2.4 Material factor k_o

σ_o	k_o
For $\sigma_o > 235$ (24)	$\left(\dfrac{235}{\sigma_o}\right)^{0,75}$ $\left(\dfrac{24}{\sigma_o}\right)^{0,75}$
For $\sigma_o \le 235$ (24)	$\left(\dfrac{235}{\sigma_o}\right)$ $\left(\dfrac{24}{\sigma_o}\right)$
Symbols	
σ_o = minimum yield stress in N/mm^2 (kgf/mm^2) k_o = higher tensile steel correction factor	
NOTE σ_o is to be taken not greater than 70 per cent of the ultimate tensile strength or 450 N/mm^2 (45,9 kgf/mm^2), whichever is the lesser. σ_o is not to be less than 200 N/mm^2, *see* Ch 5,2.4.6 of the Rules for Materials.	

2.5.4 Where reductions in rudder stock diameter due to the application of steels with yield stresses exceeding 235 N/mm^2 are requested, evaluation of the rudder stock deformations may be required. Large deformations are to be avoided in order to avoid excessive edge pressures in way of bearings.

2.5.5 For spade rudders the stock diameter corrected for higher tensile steel is to be greater than 90 per cent of the uncorrected stock diameter unless direct calculations are submitted showing that the slope of the stock at the lowest main bearing does not exceed 0,0035 when the rudder blade is loaded by a lateral force of P_L, acting at the centre of pressure.

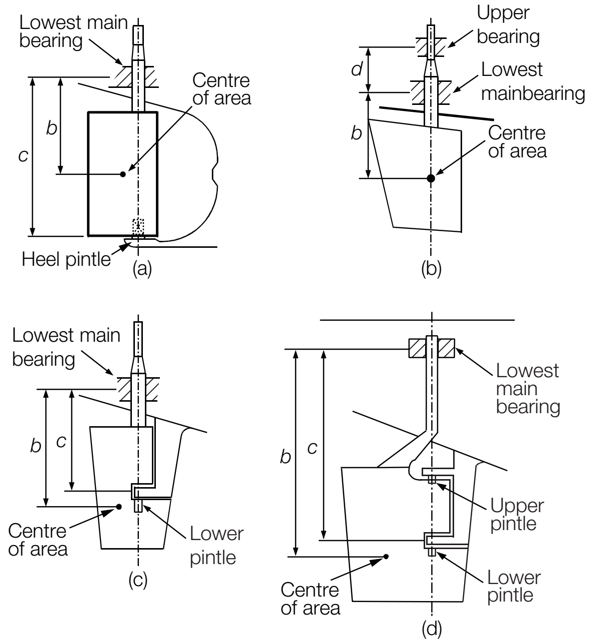


Fig. 13.2.4
Centroid of rudder area for common rudder types

2.5.6 For rudders having an increased diameter of the rudder stock in way of the rudder, the increased diameter is to be maintained to a point as far as practicable above the top of the lowest bearing. The diameter may then be tapered to the diameter required in way of the tiller. The length of the taper is to be at least three times the reduction in diameter. Particular care is to be taken to avoid the formation of a notch at the upper end of the taper, *see* Fig. 13.2.5.

Table 13.2.5 Permissible stresses

Mode	Permissible stress, N/mm^2	(kgf/mm^2)
(1) Torsional shear stress, τ_T	$68/k_o$	$(6,9/k_o)$
(2) Equivalent stress, σ_e	$118/k_o$	$(12/k_o)$
Symbols and parameters		

σ_T = equivalent stress

$= \sqrt{\sigma_b^2 + 3\tau^2}$ N/mm^2 (kgf/mm^2)

σ_b = bending stress

$$= 10,2 \frac{M_B}{\delta_s^3} 10^3 \text{ N/mm}^2 \left(1,04 \frac{M_B}{\delta_s^3} 10^3 \text{ kgf/mm}^2\right)$$

τ_T = torsional shear stress

$$= 5,1 \frac{M_T}{\delta_s^3} 10^3 \text{ N/mm}^2 \left(0,52 \frac{M_T}{\delta_s^3} 10^3 \text{ kgf/mm}^2\right)$$

δ_S = actual stock diameter, as calculated in Table 13.2.3
M_B = bending moment, in Nm, at the section considered. If direct calculations of bending moment distribution are not carried out, then M_B at the lowest main bearing or rudder coupling may be taken as given in Table 13.2.3
M_T = total rudder torque, in Nm, as calculated in 2.2 or 2.3
k_o = as defined in Table 13.2.4

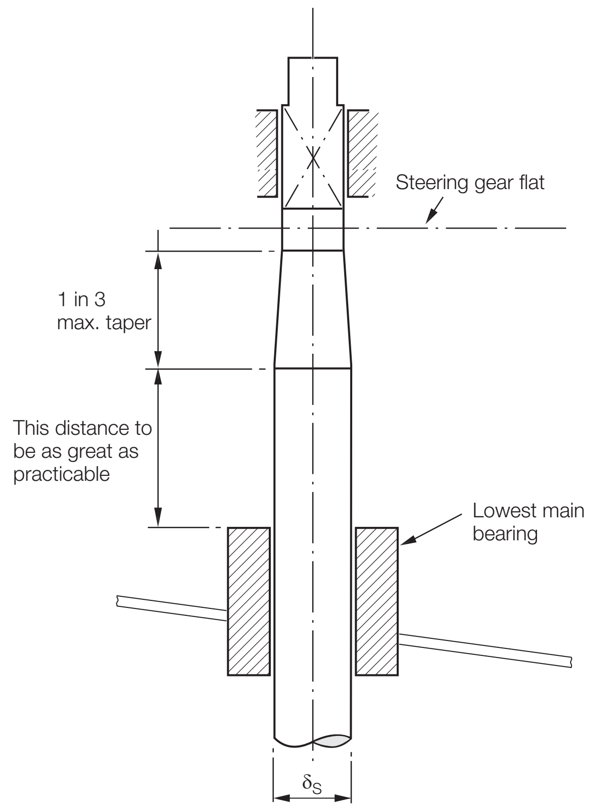


Fig. 13.2.5 Rudder stock taper

2.5.7 Sudden changes of section or sharp corners in way of the rudder coupling, jumping collars and shoulders for rudder carriers, are to be avoided. Jumping collars are not to be welded to the rudder stock. Keyways in the rudder stock are to have rounded ends and the corners at the base of the keyway are to be radiused. For stainless steel liners formed by weld deposit, *see* 2.9.3.

2.5.8 Bearings are to comply with the requirements of Table 13.2.6. The fitting of bearings is to be carried out in accordance with the manufacturer's recommendations to ensure that they remain secure under all foreseeable operating conditions.

2.5.9 On dredging and reclamation craft classed **A1 protected water service**, the rudder stock diameter may be 84 per cent of that required for ships classed **100A1**.

2.6 Rudder construction – Double plated

2.6.1 The scantlings of a double plated rudder are to be not less than required by Table 13.2.8.

2.6.2 The rudder is to be dimensioned such that the stresses do not exceed the permissible stresses given in Table 13.2.9.

2.6.3 In way of rudder couplings and heel pintles, the plating thickness is to be suitably increased.

2.6.4 On semi-spade/mariner type rudders the following items are to be complied with:

(a) The main vertical web forming the mainpiece is to be continuous over the full depth of the rudder.

(b) The thickness of the main vertical web is to be not less than two times the thickness required by Table 13.2.8(4) from the top of the rudder to the lower pintle. The thickness is to be not less than required by Table 13.2.8(4) from the lower pintle to approximately a point midway between the lower pintle and bottom of the rudder. Below this the thickness, t_2, is to be not less than the thickness required by Table 13.2.8(2). *See* Fig. 13.2.6.

(c) Where an additional continuous main vertical web is arranged to form an efficient box mainpiece structure, the thickness of each web is to be not less than that required by Table 13.2.8(4) from the top of the rudder to approximately a point midway between the lower pintle and bottom of the rudder. Below this the thickness, t_2, is not to be less than that required by Table 13.2.8(2).

(d) The internal radius, *r*, of the cut-out for the rudder pintle is to be as large as practicable. *See* Fig. 13.2.6.

(e) To reduce the notch effect at the corners of the cut-out for the lower pintle, an insert plate 1,6 times the Rule thickness of the side plating is to be fitted. The insert plate is to extend aft of the main vertical web and to have well rounded corners.

2.6.5 Adequate hand or access holes are to be arranged in the rudder plating in way of pintles as required, and the rudder plating is to be reinforced locally in way of these openings. Continuity of the modulus of the rudder mainpiece is to be maintained in way of the openings.

2.6.6 Connection of rudder side plating to vertical and horizontal webs, where internal access for welding is not practicable, is to be by means of slot welds on to flat bars on the webs. The slots are to have a minimum length of 75 mm and, in general, a minimum width of twice the side plating thickness. The ends of the slots are to be rounded. The space between the slots is not to exceed 150 mm and welding is to be based on a weld factor of 0,44.

2.6.7 For testing of rudders, *see* Table 1.9.1 in Chapter 1.

2.6.8 Where the fabricated mainpiece of a spade rudder is connected to the horizontal coupling flange by welding, a full penetration weld is required.

2.7 Rudder construction – Single plated

2.7.1 The scantlings of a single plated rudder are to be not less than required by Table 13.2.8.

2.7.2 Rudder arms are to be efficiently attached to the mainpiece.

2.8 Rudder couplings

2.8.1 Rudder coupling design is to be in accordance with Table 13.2.10.

Table 13.2.6 Bearing requirements for rudder stock and pintles

Item	Requirement	
(1) Bearing surface area	$A_B = \dfrac{B}{q_a}$ mm^2	
(2) Bearing length	The length/diameter ratio of the actual bearing surface is not to be greater than 1,2	
(3) Clearance	Bearing material	Minimum clearance (on diameter)
	Metal	$0{,}001\delta + 1{,}0$
	Synthetic	*See* Notes 1, 3, 4 and 5
(4) Rudder stock main bearing wall thickness	Lesser of $0{,}2\delta$ or 100	*See* Note 2
(5) Gudgeon thickness in way of pintle (measured outside bush if fitted)	$b_G \geq 0{,}25\delta$ but need not normally exceed 125 mm	

Symbols

A_B = bearing surface area, in mm^2, defined as the projected area (length x diameter) of liner
b = distance, in metres, from centre of rudder area to the centre of lowest bearing
b_G = thickness of gudgeon material in way of pintle, in mm
c = distance, in metres, from centre of lower pintle to the centre of lowest bearing
d = distance, in metres, from centre of lowest bearing to the centre of upper bearing. In the case of semi spade rudder with two pintles, d, is to be measured between the centre of upper pintle and centre of upper bearing
δ = diameter of stock, δ_S, given in Table 13.2.3, or pintle, δ_{PL}, given in Table 13.2.11, in mm
l_B = length of bearing, in mm
q_a = maximum surface pressure, *see* Table 13.2.7
B = bearing force, in N. If direct calculations are not carried out, the bearing force at various positions can be taken as:
$B_2 = \left(1 - \dfrac{b}{c}\right) P_L$, at lowest main bearing for single pintle rudders and semi-spade rudders, *see* Fig. 13.2.4(a), (c) and (d). B_2 is not to be less than $0{,}35 P_L$
$B_2 = P_L + B_3$, at lowest main bearing for spade rudders, *see* Fig. 13.2.4(b).
$B_3 = \dfrac{M_B}{d}$, at upper bearing for spade rudders, *see* Fig. 13.2.4(b). For bearing force at pintles, *see* Table 13.2.11.

NOTES
1. If non-metallic bearing material is applied, the bearing clearance is to be specially determined considering the material's swelling and thermal expansion properties. This clearance is not to be less than 1,5 mm on bearing diameter unless a smaller clearance is supported by the manufacturer's recommendation and there is documented evidence of satisfactory service history with a reduced clearance.
2. Where web stiffening is fitted on the bearing, a reduction in wall thickness will be considered.
3. For bearings which are pressure lubricated the clearance must be restricted to enable the pressure to be maintained.
4. The value of the proposed minimum clearance is to be indicated on plans submitted for approval.
5. Proposals for higher pressures or other materials will be specially considered on the basis of satisfactory test results.

Table 13.2.7 Maximum surface pressure

Bearing material	q_a (N/mm^2) (*see* Note 1)
Lignum vitae	2,5
White metal, oil lubricated	4,5
Synthetic material with hardness between 60 and 70 Shore D (*see* Note 2)	5,5
Steel (*see* Note 3) and bronze and hotpressed bronze-graphite materials	7,0

NOTES
1. Proposals for higher pressures will be specially considered on the basis of satisfactory test results.
2. Indentation hardness test at 23ºC and with 50% moisture, according to a Recognised Standard. Synthetic bearing materials are to be of an approved type.
3. Stainless and wear-resistant steel in an approved combination with stock liner.

2.8.2 Where coupling bolts are required they are to be fitted bolts. Suitable arrangements are to be made to lock the nuts.

2.8.3 For rudders with horizontal coupling arrangements the rudder stock should be forged when the stock diameter exceeds 350 mm. Where the stock diameter does not exceed 350 mm the rudder stock may be either forged or fabricated. Where the upper flange is welded to the rudder stock, a full penetration weld is required and its integrity is to be confirmed by non-destructive examination. The flange material is to be from the same welding materials group as the stock. Such rudder stocks are to be subjected to a furnace post-weld heat treatment (PWHT) after completion of all welding operations. For carbon or carbon manganese steels, the PWHT temperature is not to be less than 600°C.

Table 13.2.8 Single and double plated rudder construction

Type	Item	Requirement
Double plated rudder construction	(1) Rudder side, top and bottom plating	$t = 5{,}5 s_{min}\, s_e \sqrt{\left(T + \frac{P_L\, 10^{-4}}{A_R}\right) k} + 2{,}5$ mm
	(2) Webs vertical and horizontal	t_W = 0,7t from (1) but is not to be less than 8 mm
	(3) Nose plate	t_N = 1,25t from (1) but need not exceed 22 mm
	(4) Mainpiece fabricated rectangular, *see* Note 1	Breadth and width ≥ δ_S $t_M = 8{,}5 + 0{,}56\sqrt{\delta_S}\ \sqrt[3]{k}$ mm Minimum fore and aft extent of side plate = 0,2b_R Stress due to bending, *see* Table 13.2.9
	(5) Mainpiece tubular, *see* Note 1	Inside diameter ≥ δ_S t_M as for (4) Side plating as for (1) Bending stress as for (4)
	(6) Mainpiece semi-spade (Mariner) type rudders in way of lower pintle regions, *see* Note 2	Bending moment applied at section 'AA' (*see* Fig. 13.2.6) by the underhung position to result in stresses not greater than those given in Table 13.2.9
Single plated rudder construction	(7) Blade thickness	t_B = 0,0015$V\, y_W$ + 2,5 mm with a minimum of 10 mm
	(8) Arms	Spacing ≤ 1000 mm $Z_A = 0{,}0005\, V^2\, x_a^2\, y_W$ cm^3 thickness = t_B in mm with a minimum of 10 mm
	(9) Mainpiece	Diameter ≥ δ_S for spade rudders, the lower third may be tapered down to 0,75δ_S mm at the bottom end

Symbols

b_R = mean breadth of rudder at centreline of stock, in mm
k = *see* Note 3
$s_e = \sqrt{1{,}1 - 0{,}5\left(\frac{s_{min}}{s_{max}}\right)^2}$ but not more than 1,00 if $s_{max}/s_{min} \geq 2{,}5$
s_{max} = greatest unsupported width of plating, in metres
s_{min} = smallest unsupported width of plating, in metres
t = thickness, in mm
t_W = thickness of webs, in mm
t_M = thickness of side plating and vertical webs forming mainpiece, in mm
t_N = thickness of nose plate, in mm
x_a = horizontal distance from the aft edge of the rudder to the centre of the rudder stock, in metres
y_W = vertical spacing of rudder arms, in mm. Not to exceed 1000 mm
A_R = rudder area, in m^2
P_L = rudder force, as defined in 2.1.1
T = as given in Ch 1,6.1
V = as defined in 2.1.1
Z_A = section modulus of arm, in cm^3
δ_S = basic stock diameter, given by Table 13.2.3, in mm

NOTES
1. The value of the basic stock diameter δ_S, used in (4) and (5), is that for mild steel, as given in Table 13.2.3.
2. The effective breadth of the side plate may be taken as 0,16h_R.
3. For higher tensile steels, the material factor k = 0,78 for steels with δ_y = 315 N/mm^2 and k = 0,72 for steels with δ_y = 355 N/mm^2.

Table 13.2.9 Permissible stresses for rudder blade scantlings

Item	Permissible stresses, in N/mm^2 (kgf/mm^2)		
	Bending stress	Shear stress	Equivalent stress
Rudder blades clear of cut-outs, *see* Fig. 13.2.2	$\frac{110}{k}$ $\left(\frac{11,2}{k}\right)$	$\frac{50}{k}$ $\left(\frac{5,1}{k}\right)$	$\frac{120}{k}$ $\left(\frac{12,2}{k}\right)$
Rudder blades in way of cut-outs, *see* Fig. 13.2.2 and Note	$\frac{75}{k}$ $\left(\frac{7,6}{k}\right)$	$\frac{50}{k}$ $\left(\frac{5,1}{k}\right)$	$\frac{100}{k}$ $\left(\frac{10,2}{k}\right)$
Symbols			
k is as defined in 1.2.1			
NOTE Requirements in way of cut-outs apply to semi-spade/mariner type rudders.			

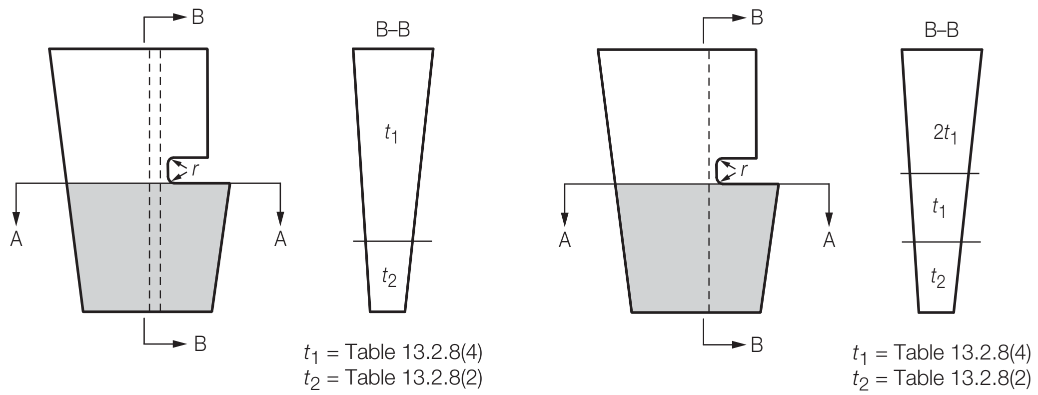


Fig. 13.2.6 Main vertical web thickness

2.8.4 For a spade rudder, the fillet radius between the rudder stock and the flange is to conform to the requirements of Fig. 13.2.7. Where space permits between the upper face of the flange and the lowest main bearing, it is preferable to use a compound fillet design of the parabolic or Morgenbrod form having similar dimensions to those of Fig. 13.2.7. Alternative arrangements will be specially considered.

2.8.5 The connecting bolts for coupling the rudder to the rudder stock are to be positioned with sufficient clearance to allow the fitting and removal of the bolts and nuts without contacting the palm radius, R, *see* Fig. 13.2.8(a). The surface forming the palm radius is to be free of hard and sharp corners and is to be machined smooth to the Surveyor's satisfaction. The surface in way of bolts and nuts is to be machined smooth to the Surveyor's satisfaction.

2.8.6 For spade rudders fitted with a fabricated rectangular mainpiece, the mainpiece is to be designed with its forward and aft transverse sections at equal distances forward and aft of the rudder stock transverse axis, *see* Fig. 13.2.8(b).

2.8.7 Where a rudder stock is connected to a rudder by a keyless fitting, the rudder is to be a good fit on the rudder stock cone. During the fit-up, and before the push-up load is applied, an area of contact of at least 80 per cent of the theoretical area of contact is to be achieved, and this is to be evenly distributed. The relationship of the rudder to stock at which this occurs is to be marked, and the push-up then measured from that point. The upper edge of the upper mainpiece bore is to have a slight radius. After final fitting of the stock to the rudder, positive means are to be used for locking the securing nut to the stock.

2.8.8 Where a keyed conical fitting of a rudder stock to a rudder is proposed, a securing nut is to be provided. Minimum dimensions for the securing nut are given in Table 13.2.10. After final fitting of the stock to the rudder, positive means are to be used for locking this nut.

2.8.9 Guidelines for keys and keyways are given in Table 13.2.10.

Table 13.2.10(a) Rudder couplings to stock – Bolted couplings

Item	Requirement: Horizontal coupling	Requirement: Vertical coupling
Number of bolts in coupling	$n \geq 6$	$n \geq 8$
Diameter of coupling bolts	$\delta_b = 0{,}62 \sqrt{\dfrac{\delta_S{}^3\, k_b}{l_a\, n\, k_S}}$	$\delta_b = 0{,}81\delta_S \sqrt{\dfrac{k_b}{n\, k_S}}$
First moment of area of bolts about centre of coupling	$m = 0{,}00071n\, \delta_S\, \delta_b{}^2 \sqrt{\dfrac{k_b}{k_S}}$	$m = 0{,}00043\delta_S{}^3 \sqrt{\dfrac{k_b}{k_S}}$
Thickness of coupling flange	$t_f = \delta_b \sqrt{\dfrac{k_b}{k_S}}$ (*see* Notes 1 and 2)	$t_f = \delta_b$
Stress concentration factor for as built scantlings	$\alpha_{as\ built} \leq \alpha_{max}$ (*see* Note 3)	—
Maximum allowable stress concentration factor	$\alpha_{max} = (53{,}82 - 35{,}29k_{max}) \dfrac{\delta_S{}^3}{hP_L\, 10^3} - \left(1{,}8 - 6{,}3\, \dfrac{R}{\delta_S}\right) \dfrac{t_f - t_{fa}}{t_{fa}}$ (*see* Note 3)	—
Width of flange material outside the bolt holes	$w_f = 0{,}67\delta_b$	$w_f = 0{,}67\delta_b$

Symbols

$\alpha_{as\ built}$ = stress concentration factor for as built scantlings

$$= \frac{0{,}73}{\sqrt{\dfrac{R}{\delta_S}}}$$

α_{max} = maximum allowable stress concentration factor
δ_b = diameter of coupling bolts, in mm
δ_S = basic stock diameter as defined in Table 13.2.3, in mm
b_f = breadth of the flange, in mm
h = vertical distance, in metres, between the centre of pressure and the centre point of the palm radius, *see* Fig. 13.2.8
k_b = coupling bolt material factor, *see* 2.5.2
k_{max} = the greater of k_s and k_f
k_f = upper coupling flange material factor, *see* 2.5.2
k_S = rudder stock material factor, *see* 2.5.2
l_a = the mean of the horizontal distances between the centres of the bolts and the centre of the coupling, in mm
m = first moment of area of bolts about a longitudinal axis through centre of coupling, in cm^3
n = number of bolts in coupling
P_L = lateral force on rudder as defined in 2.2.1, in N (tonne-f)
R = palm radius, in mm, between the rudder stock and connection flange, *see* 2.8.4 and 2.8.5.
t_f = minimum thickness of coupling flange, in mm
t_{fa} = as built flange thickness, in mm
w_f = width of flange material outside the bolt holes, in mm

NOTES
1. For spade rudders with horizontal couplings, t_f is not to be less than $0{,}33\delta_S \sqrt[3]{k_s}$. The mating plate on the rudder is to have the same thickness as the flange on the stock
2. For a twin spade rudder arrangement with single screw where the rudders are within the slipstream of the propeller:
   (a) the thickness of the palm is not to be less than $0{,}35\delta_S \sqrt[3]{k_s}$
   (b) where the stock is welded to the palm plate, the stock diameter, δ_S is to be increased by 14 %.
3. This requirement is applicable only for spade rudders with horizontal couplings, *see* Fig. 13.2.6.

Table 13.2.10(b) Rudder couplings to stock – Conical couplings (*see continuation*)

Item	Requirement
Taper of conical coupling on the diameter	$\theta_t \leq \dfrac{1}{K_1}$
Length of taper	$l_t \geq 1{,}5\delta_S$
Required mean grip stress – keyless connection	$p_M = \dfrac{P_R\,\theta_t\,\delta_{CTM} + 4M_T\,10^3\sqrt{K_2\left(\left[\dfrac{P_R\,\delta_{CTM}}{2000M_T}\right]^2 + 1\right) - \left(\dfrac{\theta_t}{2}\right)^2}}{5{,}03\delta_{CTM}^2\,l_t\left(K_2 - \left(\dfrac{\theta_t}{2}\right)^2\right)}$
Required mean grip stress – keyed connection	$p_M = 20$
Corresponding push-up of rudder stock	$w = \dfrac{9{,}6\;10^{-6}\,p_M\,\delta_{CTM}}{\theta_t\left(1 - f_M^2\right)}$ $\left(\dfrac{0{,}95\;10^{-4}\,p_M\,\delta_{CTM}}{\theta_t\left(1 - f_M^2\right)}\right)$
Corresponding push-up load	Approximately equal to $P_U = 0{,}8\pi\,p_M\,l_t\,\delta_{CTM}\left(K_3 + \dfrac{\theta_t}{2}\right)$
Corresponding pull-off load	Approximately equal to $P_O = 2{,}83p_M\,l_t\,\delta_{CTM}\left(K_3 - \dfrac{\theta_t}{2}\right)$
Minimum yield stress of stock and gudgeon	$\sigma_o = \dfrac{123\,500\,w\,\theta_t\sqrt{3 + f^4}}{\delta_{CT}}$ $\left(\dfrac{12600\,w\,\theta_t\sqrt{3 + f^4}}{\delta_{CT}}\right)$
Recommended minimum effective sectional area of the key in shear	$A_{key} = \dfrac{M_T\,k_{min}}{3{,}3\delta_{CTM}}$ (*see* Note)
Minimum thickness of key	$\delta_{key} = \dfrac{67A_{key}}{H}$
Minimum dimensions of securing nut	$\delta_g = 0{,}65\delta_S$ $\delta_n = 1{,}2\delta_{SU}$ or $1{,}5\delta_g$ whichever is the greater $h_n = 0{,}6\delta_g$

2.9 Pintles

2.9.1 Rudder pintles and their bearings are to comply with the requirements of Table 13.2.11.

2.9.2 The distance between the lowest rudder stock bearing and the upper pintle should be as short as possible.

2.9.3 Where liners are fitted to pintles, they are to be shrunk on or otherwise efficiently secured. If liners are to be shrunk on, the shrinkage allowance is to be indicated on the plans. Where liners are formed by stainless steel weld deposit, the pintles are to be of weldable quality steel and details of the procedure are to be submitted, *see also* 2.10.4.

2.9.4 The bottom pintle on semi-spade (Mariner) type rudders and all pintles over 500 mm in diameter are:

(a) if inserted into their sockets from below, to be keyed to the rudder or sternframe as appropriate or to be hydraulically assembled, with the nut adequately locked, or

(b) if inserted into their sockets from above, to be provided with an appropriate locking device, the nut being adequately secured.

2.9.5 Fitting of pintle bearings is to be carried out in accordance with the bearing manufacturer's recommendations to ensure that they remain secure under all foreseen operating conditions.

2.9.6 Where an ***IWS** (In-water Survey) notation is to be assigned (*see* Pt 1, Ch 2,2.3.11), means are to be provided for ascertaining the rudder pintle and bush clearances and for verifying the security of the pintles in their sockets with the vessel afloat.

Table 13.2.10(b) **Rudder couplings to stock – Conical couplings** (*conclusion*)

Symbols

h_n = minimum required length of securing nut, in mm, *see* Fig. 13.2.9

$f = \dfrac{\delta_{CT}}{\delta_{GH}}$

$f_M = \dfrac{\delta_{CTM}}{\delta_{GHM}}$

k_{min} = taken as k_0, where σ_0 is the minimum nominal upper yield point of the key, stock or coupling material, in N/mm^2, whichever is less

k_o = material factor as defined in Table 13.2.3, for the appropriate item

l_t = length of taper, in mm

p_M = required mean grip stress, in N/mm^2

w = corresponding push-up of rudder stock, in mm

A_{key} = recommended minimum effective sectional area of the key in shear, in cm^2

H = length of the key, in mm

M_T = rudder torque, in Nm, as given in Table 13.2.5

P_R = effective weight of rudder, in N (kgf)

P_U, P_O = corresponding push-up, pull-off loads respectively, in N (kgf)

δ_g = minimum external thread diameter, in mm, *see* Fig. 13.2.9

δ_n = minimum outer diameter of nut, in mm, *see* Fig. 13.2.9

δ_{CT} = diameter of coupling taper in any position, in mm

δ_{CTM} = mean diameter of coupling taper, in mm

$= \dfrac{\delta_S + \delta_{SU}}{2}$

δ_{GH} = external diameter of gudgeon housing at any position, in mm

δ_{GHM} = mean external diameter of gudgeon housing, in mm

δ_{key} = minimum thickness of key. *See* Fig. 13.2.9

δ_S = basic stock diameter as defined in Table 13.2.3, in mm

δ_{SU} = *see* Fig. 13.2.9, in mm

σ_o = minimum yield stress of stock and gudgeon material, in N/mm^2 (kgf/mm^2) σ_o is not to be taken greater than 70 % of the ultimate tensile strength or 450 N/mm^2 (45,9 kgf/mm^2) whichever is the lesser

θ_t = taper of conical coupling, on the diameter, e.g. $\dfrac{1}{15}$ = 0,067

K_1, K_2, K_3 = constants depending on the type of assembly adopted as follows:

Type of assembly		K_1	K_2	K_3
Oil injection	With key	12	–	0,025
	Without key	15	0,0036	0,025
Dry fit method	With key	8	–	0,170
	Without key	12	0,0072	0,170

NOTE
The keyway is to have a smooth fillet at the bottom of the keyway. The radius of the fillet is to be at least 0,0125 of the diameter of the rudder stock at the top of the cone.

2.9.7 For axle type rudder support used with Simplex rudders, *see* Ch 6,7.

2.10 Ancillary items

2.10.1 Internal surfaces of double plate rudders are to be efficiently coated. Alternatively, where it is intended to fill the rudder with plastic foam or use a corrosion inhibitor, details are to be submitted. Means for draining the rudder are to be provided.

2.10.2 Where a bow rudder is fitted for use when navigating astern, a locking device is to be arranged to ensure that the rudder is kept in the central position when the ship is navigating ahead.

2.10.3 Where the weight of the rudder is supported by a carrier bearing attached to the rudder head, the structure in way is to be adequately strengthened. The plating under all rudder head bearings or rudder carriers is to be increased in thickness.

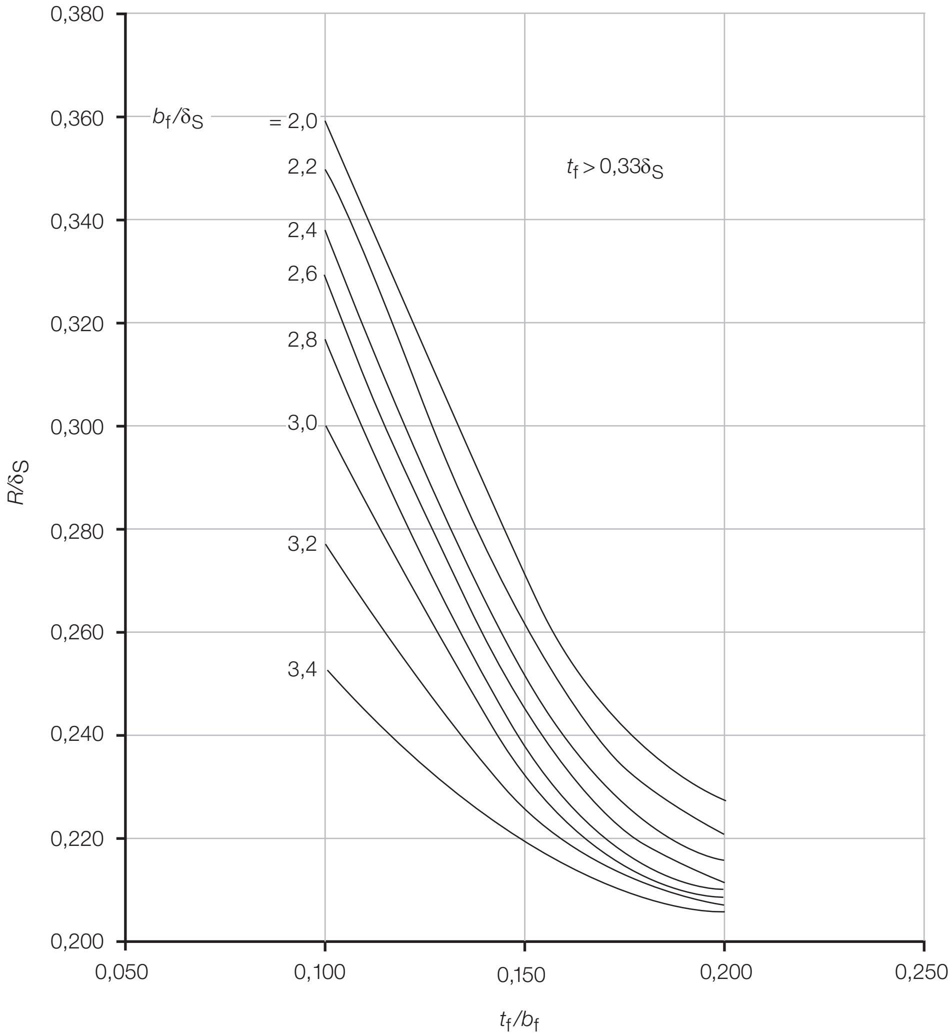


Fig. 13.2.7 Rudder stock horizontal flange fillet radius for spade rudders

2.10.4 Where it is proposed to use stainless steel for liners or bearings for rudder stocks and/or pintles, the chemical composition is to be submitted for approval. Synthetic rudder bearing materials are to be of a type approved by Lloyd's Register (hereinafter referred to as 'LR'). When this type of lining material is used, arrangements to ensure an adequate supply of sea-water to the bearing are to be provided.

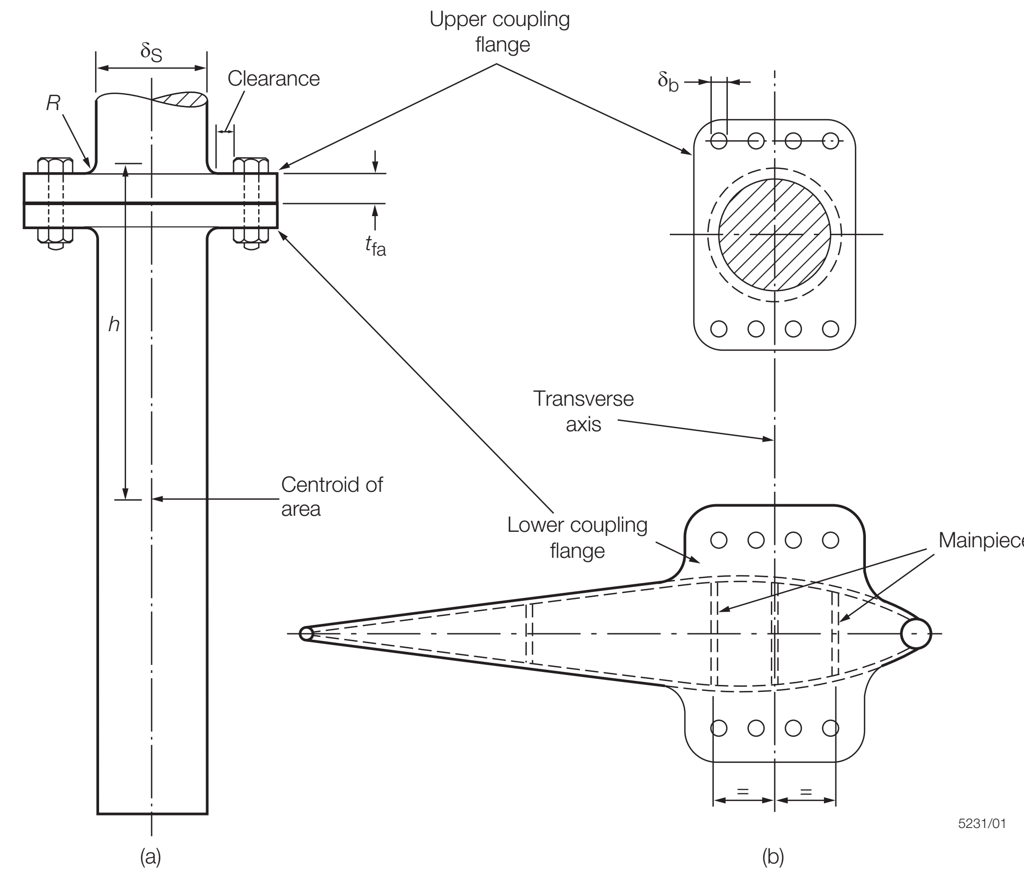


Fig. 13.2.8 Rudder stock connection

Table 13.2.11 Pintle requirements

Item	Requirement	
(1) Pintle diameter	$\delta_{PL} = 0{,}35\sqrt{B\,k_o}$ mm	
(2) Pintle taper	Method of assembly	Taper (on diameter)
	Keyed and other manually assembled pintles	1:8 – 1:12
	Pintles mounted with oil injection and hydraulic nut	1:12 – 1:20

Symbols

b = distance in metres, from centroid of rudder area to the centre of lowest main bearing, *see* Fig. 13.2.4
c = distance, in metres, from centre of bearing of lower pintle to the centre of lowest main bearing, *see* Fig. 13.2.4
k_o = as defined in Table 13.2.3 or 13.2.4
B = bearing force, in N. If direct calculations are not carried out, the bearing force at various positions can be taken as:

$B_{1L} = \frac{b}{c} P_L$ for single pintle rudders and lower pintle of semi-spade rudders

$B_{1U} = \left(1 - \frac{b}{c}\right) P_L$ at upper pintle on semi-spade rudder. B_{1U} is not to be less than $0{,}35P_L$

$B = \frac{1}{N_{PL}} P_L$ for rudders with two or more pintles (except semi-spade rudders)

N_{PL} = number of pintles on the rudder
P_L = rudder force, as defined in 2.2.1

NOTE
The length of the pintle housing in the gudgeon is not to be less than the maximum pintle diameter.

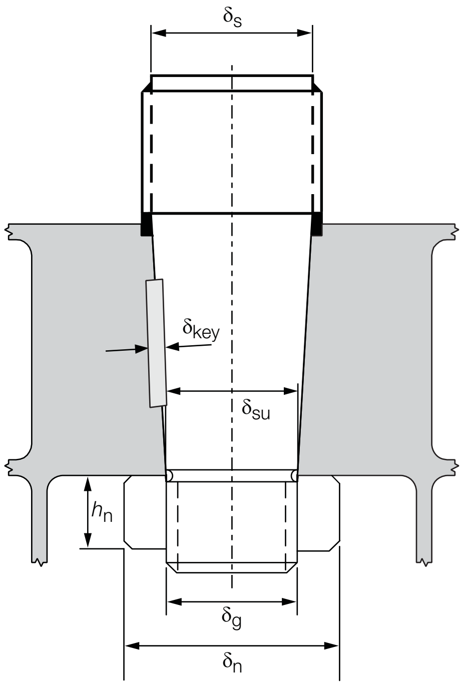


Fig. 13.2.9 Conical coupling

■ *Section 3* Fixed and steering nozzles

3.1 General

3.1.1 The requirements for scantlings for fixed and steering nozzles are given, for guidance only, in 3.2 to 3.4 and Table 13.3.1.

3.1.2 The requirements, in general, apply to nozzles with a numeral not greater than 200, *see* Table 13.3.1. Nozzles exceeding this value will be specially considered.

3.2 Nozzle structure

3.2.1 For basic scantlings of the structure, *see* Table 13.3.1, in association with Fig. 13.3.1.

3.2.2 The shroud plating in way of the propeller tips is to be carried well forward and aft of this position, due allowance being made on steering nozzles for the rotation of the nozzle in relation to the propeller.

3.2.3 Fore and aft webs are to be fitted between the inner and outer skins of the nozzle. Both sides of the headbox and pintle support structure are to be connected to fore and aft webs of increased thickness. For thicknesses, *see* Table 13.3.1.

Table 13.3.1 Nozzle construction requirements

Item	Requirement
(1) Nozzle numeral	$N_N = 0{,}01P\delta_p$ $(N_N = 0{,}00736H\delta_p)$
(2) Shroud plating in way of propeller blade tips	For $N_N \le 63$ $t_s = (11 + 0{,}1N_N)$ mm For $N_N > 63$ $t_s = (14 + 0{,}052N_N)$ mm
(3) Shroud plating clear of blade tips, flare and cone plating, wall thickness of leading and trailing edge members	$t_p = (t_s - 7)$ mm but not less than 8 mm
(4) Webs and ring webs	As item (3) except in way of headbox and pintle support where $t_W = (t_s + 4)$ mm
(5) Nozzle stock	Combined stresses in stock at lower bearing $\le 92{,}7$ N/mm^2 (9,45 kgf/mm^2) Torsional stress in upper stock $\le 62{,}0$ N/mm^2 (6,3 kgf/mm^2)
(6) Solepiece and strut	Bending stresses not to exceed 70,0 N/mm^2 (7,1 kgf/mm^2)

Symbols

N_N = a numeral dependent on the nozzle requirements
P = power transmitted to the propellers, in kW
(H = power transmitted to the propellers, in shp)
δ_p = diameter of the propeller, in metres
t_s = thickness of shroud plating in way of propeller tips, in mm
t_p = thickness of plating, in mm
t_W = thickness of webs and ring webs in way of headbox and pintle support, in mm

NOTE
Thicknesses given are for mild steel. Reductions in thickness will be considered for certain stainless steels.

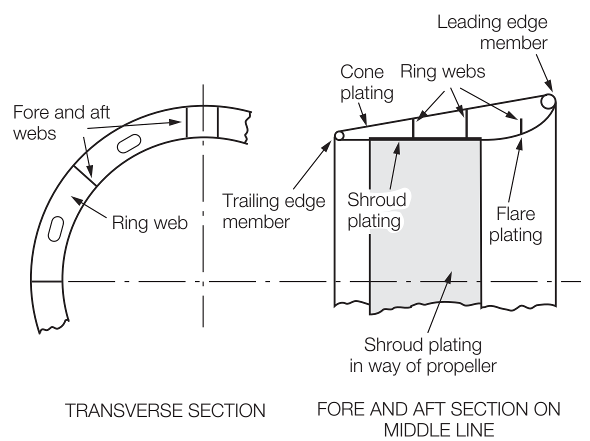


Fig. 13.3.1 Nozzle construction

3.2.4 The transverse strength of the nozzle is to be maintained by the fitting of ring webs. Two ring webs are to be fitted in nozzles not exceeding 2,5 m diameter. Nozzles between 2,5 and 3,0 m in diameter are generally to have two full ring webs and a half-depth web supporting the flare plating. The number of ring webs is to be increased as necessary on nozzles exceeding 3,0 m in diameter. Where ring webs are increased in thickness in way of the headbox and pintle support structure in accordance with Table 13.3.1, the increased thickness is to be maintained to the adjacent fore and aft web.

3.2.5 Local stiffening is to be fitted in way of the top and bottom supports which are to be integrated with the webs and ring webs. Continuity of bending strength is to be maintained in these regions.

3.2.6 Fin plating thickness should be not less than the cone plating, and the fin should be adequately reinforced. Solid fins should be not less than 25 mm thick.

3.2.7 Care is to be taken in the manufacture of the nozzle to ensure its internal preservation and watertightness. The preservation and testing are to be as required for rudders, *see* 2.7 and Table 1.9.1 in Chapter 1.

3.3 Nozzle stock and solepiece

3.3.1 Stresses, derived using the maximum side load on the nozzle and fin acting at the assumed centre of pressure, are not to exceed the values given in Table 13.3.1, in both the ahead and astern conditions.

3.4 Ancillary items

3.4.1 The diameter and first moment of area about the stock axis of coupling bolts and the diameter of pintles, are to be derived from 2.5 and 2.6.

3.4.2 Suitable arrangements are to be provided to prevent the steering nozzle from lifting.

■ *Section 4*
Steering gear and allied systems

4.1 General

4.1.1 For the requirements of steering gear, *see* Pt 5, Ch 19.

■ *Section 5*
Bow and stern thrust unit structure

5.1 Unit wall thickness

5.1.1 The wall thickness of the unit is, in general, to be in accordance with the manufacturer's practice, but is to be not less than either the thickness of the surrounding shell plating plus 10 per cent or 15 mm, whichever is greater.

5.2 Framing

5.2.1 The unit is to be framed to the same standard as the surrounding shell plating.

5.2.2 The unit is to be adequately supported and stiffened.

■ *Section 6*
Stabiliser structure

6.1 Fin stabilisers

6.1.1 The box into which the stabilisers retract is to have perimeter plating of the same thickness as the surrounding Rule shell plating plus 2 mm, but is to be not less than 12,5 mm, and is to be stiffened to the same standard as the shell.

6.1.2 The stabiliser machinery and surrounding structure are to be adequately supported and stiffened. Where bending stresses are induced in the structure under fatigue conditions the maximum stress is not to exceed 39,0 N/mm^2 (4 kgf/mm^2).

6.2 Stabiliser tanks

6.2.1 The general structure of the tank is to comply with the Rule requirements for deep tanks. Sloshing forces in the tank structure are to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculation.

■ *Section 7*
Equipment

7.1 General

7.1.1 To entitle a ship to the figure **1** in its character of classification, equipment in accordance with the requirements of Table 13.7.1 is to be provided. The regulations governing the assignment of the character figure **1** for equipment are given in Pt 1, Ch 2,2.

Table 13.7.1 **Equipment requirements** (*see continuation*)

Ship type	Service	Required equipment
Cargo ships, bulk carriers, tankers, ferries, dredgers, etc. (*see* 1.1.2)	Unrestricted service	(1) *See* Tables 13.7.2 and 13.7.3, using N_C
Ferries	Certain restricted Services, *see* Pt 1, Ch 2,2.3.9	(2) *See* Tables 13.7.2 and 13.7.3, using N_C and N_A as appropriate Mass of bower anchor, Chain cable length and diameter – N_A = one grade below N_C Stream anchor may be omitted
Ferries	Specified coastal service, *see* Pt 1, Ch 2,2.3.8	(3) As per item (2), also Anchor chains: Where L < 30 m, may be replaced with wire ropes of equal minimum breaking strength which should: (a) have a length 1,5 times that for chain cable required by Table 13.7.2 and (b) have a length of Grade U2/U1 chain cable not less than 12,5 m between anchor and wire rope. Where 30 m ≤ L ≤ 40 m one chain cable may be replaced with wire rope meeting the requirements of L > 40 m. The other may be replaced with wire rope meeting the requirements of L < 30 m. Where 40 m < L ≤ 90 m, both chain cables may be replaced with wire rope of equal minimum breaking strength which should (a) have a length 1,5 times that for chain cable required by Table 13.7.2 and (b) have a minimum mass per unit length of 30% that of Grade U2 chain cable required by Table 13.7.2 and (c) have a length of Grade U2/U1 chain cable not less than 12,5 m between anchor and wire rope.
Dredging and reclamation craft	Extended protected waters service, *see* Pt 1, Ch 2,2.3.7	(4) *See* Tables 13.7.2 and 13.7.3, using N_C and N_A as appropriate N_A = N_C reduced by two grades, except for stream anchors, or mooring lines Stream anchor – not required if ship fitted with positioning spuds
	Protected waters service, *see* Pt 1, Ch 2,2.3.6	(5) *See* Tables 13.7.2 and 13.7.3 using N_C and N_A as appropriate Mass of bower anchor, Chain cable diameter – $N_A = 0{,}5N_C$ Bower anchors – powered ships – two anchors; unpowered (manned) ships – one anchor Chain cable length – greater of $2L$ m or $10{,}0T_D$ m, but need not exceed requirements for an ordinary cargo ship with anchors of the same mass Mooring lines – as required for N_C Wire ropes – may be substituted for chain cable on bower anchors if breaking strength ≥1,5 times that of the chain cable

7.1.2 For ships intended to be operated only in suitable areas or conditions which have been agreed by the Committee, as defined in Pt 1, Ch 2,2.3.6 to 2.3.10, equipment differing from these requirements may be approved if considered suitable for the particular service on which the ship is to be engaged, *see also* Table 13.7.1.

7.1.3 Where the Committee has agreed that anchoring and mooring equipment need not be fitted in view of the particular service of the ship, the character letter **N** will be assigned, *see also* Pt 1, Ch 2,2.2.2.

7.1.4 Where the ship is intended to perform its primary designed service function only while it is anchored, moored, towed or linked, the character letter **T** will be assigned, *see also* Pt 1, Ch 2,2.2.2.

Table 13.7.1 Equipment requirements (*continued*)

Ship type	Service	Required equipment
Trawlers, stern trawlers, fishing vessels	Unrestricted service	(6) *See* Table 13.7.4, and Notes to Table 13.7.3 using N_C Anchor chains Where L < 30 m, may be replaced with wire ropes of equal strength. Where 30 m ≤ L ≤ 40 m, one chain cable may be replaced with wire rope of equal strength provided normal chain cable maintained for the second line. Wire ropes of trawl winches complying with above may be used as anchor cables. Wire ropes substituted for anchor chains should (a) have a length 1,5 times that for chain cable required by Table 13.7.4 and (b) have a length Grade U2/U1 of chain not less than 12,5 m between anchor and wire rope. Hawsers and warps – Sufficient in number and strength for proper working of the ship
For symbols, *see* continuation of Table		
Tugs	Unrestricted and restricted service	(7) *See* Table 13.7.2 and Table 13.7.3 using N_C except as stated below Stream anchor – not required Towlines – adequate for tug's maximum bollard pull with factor of safety ≥ 2,0
	Service restricted, *see* Pt 1, Ch 2,2.3.7 to 2.3.10	(8) *See* Table 13.7.2 and Table 13.7.3 using N_C Mass of bower anchor, Chain cable diameter } reduced to correspond to two Equipment Letters below that required for N_C Anchor chains As item (3) in this Table
	Protected waters service, *see* Pt 1, Ch 2,2.3.6	(9) *See* Table 13.7.2 and Table 13.7.3 using N_A Mass of bower anchor, Chain cable diameter } $N_A = 0{,}5N_C$ Chain cable length = 0,5 times length required by N_A Where N_C < 90, the requirements for anchors and chain cable will be specially considered Anchor chains As item (3) in this Table
Offshore supply ships	Unrestricted service	(10) *See* Tables 13.7.2 and 13.7.3, using N_C Chain cable length and diameter – increased to correspond to two Equipment Letters above that required for N_C. Need not be applied for ships with **DP(AAA)**, **DP(AA)** or **DP(AM)** notations
Manned barges and pontoons	Service restricted, *see* Pt 1, Ch 2,2.3.7 to 2.3.10	(11) As item (4) in this Table

7.1.5 For classification purposes, the character figure **1**, or either of the character letters **N** or **T**, is to be assigned.

7.2 Anchors

7.2.1 Anchors are to be of an approved design. The design of all anchor heads is to be such as to minimise stress concentrations, and in particular, the radii on all parts of cast anchor heads are to be as large as possible, especially where there is considerable change of section.

7.2.2 Anchors which must be specially laid the right way up, or which require the fluke angle or profile to be adjusted for varying types of sea bed, will not generally be approved for normal ship use, but may be accepted for offshore units, floating cranes, etc. In such cases suitable tests may be required.

7.2.3 The mass of each bower anchor given in Table 13.7.2 is for anchors of equal mass. The masses of individual anchors may vary by ±7 per cent of the masses given in the Table, provided that the total mass of the anchors is not less than would have been required for anchors of equal mass.

Table 13.7.1 Equipment requirements (*conclusion*)

Ship type	Service	Required equipment
Unmanned barges and pontoons	Unrestricted service, or service restricted, *see* Pt 1, Ch 2,2.3.7 to 2.3.10	(12) *See* Tables 13.7.2 and 13.7.3, using N_C and N_A as appropriate Anchors { L < 30 m, no anchor need be carried $L \geq$ 30 m, one anchor to be fitted Anchor cable length – greater of 40 m or 2L m (a) Unrestricted service: mass of anchors and chain cable diameters as for N_C (b) Protected water service, *see* Pt 1, Ch 2,2.3.6: mass of anchors and chain cable diameters, $N_A = 0,5N_C$ (c) Service restriction, *see* Pt 1, Ch 2,2.3.7 to 2.3.10: mass of anchor and chain cable diameter, N_A reduced to correspond to two Equipment Letters below N_C Mooring lines { L < 65 m, two mooring lines to be fitted $L \geq$ 65 m, three mooring lines to be fitted length of mooring lines to be the greater of 2L or 80 m, but need not exceed that for manned ships Strength of each line to be that required by N_C Consideration will be given to proposals to omit anchoring equipment in association with the assignment of the character figure **1**, *see* Pt 1, Ch 2,2.2. Where L < 65 m consideration will be given to the omission of anchoring and mooring equipment, in which case the character letter **N** will be assigned in the character of classification, *see* Pt 1, Ch 2,2.2
Symbols		
L = length of ship as defined in Ch 1,6.1 N_A = actual equipment number to be used, if different from N_C N_C = calculated equipment number for ship as required by Ch 1,7 T_D = maximum depth at which ship is designed to dredge, in metres		

7.2.4 The mass of the head, including pins and fittings, of an ordinary stockless anchor is to be not less than 60 per cent of the total mass of the anchor.

7.2.5 When stocked bower or stream anchors are to be used, the mass 'ex-stock' is to be not less than 80 per cent of the mass given in Table 13.7.2 for ordinary stockless bower anchors. The mass of the stock is to be 25 per cent of the total mass of the anchor, including the shackle, etc., but excluding the stock.

7.3 High holding power anchors

7.3.1 When high holding power anchors are used as bower anchors, the mass of each such anchor may be 75 per cent of the mass given in the Table for ordinary stockless bower anchors.

7.3.2 Anchor designs for which approval is sought as high holding power anchors are to be tested at sea to show that they have holding powers of at least twice those of approved standard stockless anchors of the same mass.

7.3.3 If approval is sought for a range of sizes, then at least two sizes are to be tested. The smaller of the two anchors is to have a mass not less than one-tenth of that of the larger anchor, and the larger of the two anchors tested is to have a mass not less than one-tenth of that of the largest anchor for which approval is sought.

7.3.4 High holding power anchors are to be of a design that will ensure that the anchors will take effective hold of the sea bed without undue delay and will remain stable, for holding forces up to those required by 7.3.2, irrespective of the angle or position at which they first settle on the sea bed when dropped from a normal type of hawse pipe. In case of doubt, a demonstration of these abilities may be required.

7.3.5 The test should normally be carried out from a tug or other suitable vessel, and the pull measured by dynamometer or derived from recently verified curves of tug rev/min against bollard pull. The tests are to be conducted on no fewer than three different types of bottom, which should normally be soft mud or silt, sand or gravel, and hard clay or similarly compacted material. A scope of 10 is recommended for the anchor cable, but in no case should a scope of less than six be used. The same scope is to be used for the anchor for which approval is sought and the anchor that is being used for comparison purposes.

7.4 Chain cables

7.4.1 Chain cables may be of mild steel, special quality steel or extra quality steel in accordance with the requirements of Chapter 10 of the Rules for Materials and are to be graded in accordance with Table 13.7.5.

7.4.2 Grade U1 material having a tensile stress of less than 400 N/mm^2 (41 kgf/cm^2) is not to be used in association with high holding power anchors. Grade U3 material is to be used only for chain 20,5 mm or more in diameter.

Table 13.7.2 Equipment – Bower anchors and chain cables

Equipment number		Equipment Letter	Stockless bower anchors		Stud link chain cables for bower anchors			
						Diameter, in mm		
Exceeding	Not exceeding		Number	Mass of anchor, in kg	Total length, in metres	Mild steel (Grade 1 or U1)	Special quality steel (Grade U2)	Extra special quality steel (Grade U3)
50	70	A	2	180	220	14	12,5	—
70	90	B	2	240	220	16	14	—
90	110	C	2	300	247,5	17,5	16	—
110	130	D	2	360	247,5	19	17,5	—
130	150	E	2	420	275	20,5	17,5	—
150	175	F	2	480	275	22	19	—
175	205	G	2	570	302,5	24	20,5	—
205	240	H	2	660	302,5	26	22	20,5
240	280	I	2	780	330	28	24	22
280	320	J	2	900	357,5	30	26	24
320	360	K	2	1020	357,5	32	28	24
360	400	L	2	1140	385	34	30	26
400	450	M	2	1290	385	36	32	28
450	500	N	2	1440	412,5	38	34	30
500	550	O	2	1590	412,5	40	34	30
550	600	P	2	1740	440	42	36	32
600	660	Q	2	1920	440	44	38	34
660	720	R	2	2100	440	46	40	36
720	780	S	2	2280	467,5	48	42	36
780	840	T	2	2460	467,5	50	44	38
840	910	U	2	2640	467,5	52	46	40
910	980	V	2	2850	495	54	48	42
980	1060	W	2	3060	495	56	50	44
1060	1140	X	2	3300	495	58	50	46
1140	1220	Y	2	3540	522,5	60	52	46
1220	1300	Z	2	3780	522,5	62	54	48
1300	1390	A†	2	4050	522,5	64	56	50
1390	1480	B†	2	4320	550	66	58	50
1480	1570	C†	2	4590	550	68	60	52
1570	1670	D†	2	4890	550	70	62	54
1670	1790	E†	2	5250	577,5	73	64	56
1790	1930	F†	2	5610	577,5	76	66	58
1930	2080	G†	2	6000	577,5	78	68	60
2080	2230	H†	2	6450	605	81	70	62
2230	2380	I†	2	6900	605	84	73	64
2380	2530	J†	2	7350	605	87	76	66
2530	2700	K†	2	7800	632,5	90	78	68
2700	2870	L†	2	8300	632,5	92	81	70
2870	3040	M†	2	8700	632,5	95	84	73
3040	3210	N†	2	9300	660	97	84	76
3210	3400	O†	2	9900	660	100	87	78
3400	3600	P†	2	10 500	660	102	90	78
3600	3800	Q†	2	11 100	687,5	105	92	81
3800	4000	R†	2	11 700	687,5	107	95	84
4000	4200	S†	2	12 300	687,5	111	97	87
4200	4400	T†	2	12 900	715	114	100	87
4400	4600	U†	2	13 500	715	117	102	90
4600	4800	V†	2	14 100	715	120	105	92
4800	5000	W†	2	14 700	742,5	122	107	95
5000	5200	X†	2	15 400	742,5	124	111	97
5200	5500	Y†	2	16 100	742,5	127	111	97
5500	5800	Z†	2	16 900	742,5	130	114	100
5800	6100	A*	2	17 800	742,5	132	117	102
6100	6500	B*	2	18 800	742,5	—	120	107
6500	6900	C*	2	20 000	770	—	124	111
6900	7400	D*	2	21 500	770	—	127	114
7400	7900	E*	2	23 000	770	—	132	117
7900	8400	F*	2	24 500	770	—	137	122
8400	8900	G*	2	26 000	770	—	142	127
8900	9400	H*	2	27 500	770	—	147	132
9400	10 000	I*	2	29 000	770	—	152	132
10 000	10 700	J*	2	31 000	770	—	157	137
10 700	11 500	K*	2	33 000	770	—	157	142
11 500	12 400	L*	2	35 500	770	—	162	147
12 400	13 400	M*	2	38 500	770	—	—	152
13 400	14 600	N*	2	42 000	770	—	—	157
14 600	16 000	O*	2	46 000	770	—	—	162

7.4.3 Where stream anchors are used in association with chain cable, this cable may be either stud link or short link.

7.4.4 The form and proportion of links and shackles are to be in accordance with Chapter 10 of the Rules for Materials.

7.4.5 Where Owners require equipment for anchoring at depths greater than 82,5 m, it is their responsibility to specify the appropriate total length of the chain cable required for this purpose. In such cases, consideration can be given to dividing the chain cable into two unequal lengths.

7.5 Towlines and mooring lines for ships under 90 m in length

7.5.1 **Ships under 90 m** require mooring lines as specified in Table 13.7.3. Towlines are not required for classification and the details given in the Table are for guidance purposes only. Mooring lines may be of wire, natural fibre or synthetic fibre. The diameter, construction and specification of wire or natural fibre mooring lines are to comply with the requirements of Chapter 10 of the Rules for Materials. Where it is proposed to use synthetic fibre ropes, the size and construction will be specially considered.

7.6 Towlines and mooring lines for ships over 90 m in length

7.6.1 **Ships 90 m and over** in length do not require towlines and mooring lines as a classification item. It is recommended, however, that the number, length and strength of mooring lines provided on board the ship not be less than that given in Table 13.7.3.

7.6.2 For ease of handling, fibre ropes are to be not less than 20 mm in diameter. All ropes having breaking strengths in excess of 736,0 kN (75,0 tonne-f) and used in normal mooring operations are to be handled by, and stored on, suitably designed winches. Alternative methods of storing should give due consideration to the difficulties experienced in manually handling ropes having breaking strengths in excess of 490,0 kN (50,0 tonne-f).

7.6.3 Mooring winches should be fitted with drum brakes, the strength of which is sufficient to prevent unreeling of the mooring line when the rope tension is equal to 80 per cent of the breaking strength of the rope as fitted on the first layer on the winch drum.

Table 13.7.3 Equipment – Stream anchors, stream wires, towlines and mooring lines (*see continuation*)

Equipment number		Equipment Letter	Mass of stockless stream anchor, in kg	Stream wire or chain		Towline (1)		Mooring lines		
Exceeding	Not exceeding			Minimum length in metres	Minimum breaking strength, in kN (tonne-f)	Minimum length in metres	Minimum breaking strength, in kN	Number	Minimum length of each line, in metres	Minimum breaking strength, in kN (tonne-f)
50	70	A	60	80	64,7 (6,60)	180	98	3	80	34
70	90	B	80	85	73,5 (7,50)	180	98	3	100	37
90	110	C	100	85	81,4 (8,30)	180	98	3	110	39
110	130	D	120	90	89,2 (9.10)	180	98	3	110	44
130	150	E	140	90	98,1 (10,00)	180	98	3	120	49
150	175	F	165	90	107,9 (11,00)	180	98	3	120	54
175	205	G	190	90	117,7 (12,00)	180	112	3	120	59
205	240	H	—	—	— —	180	129	4	120	64
240	280	I	—	—	— —	180	150	4	120	69
280	320	J	—	—	— —	180	174	4	140	74
320	360	K	—	—	— —	180	207	4	140	78
360	400	L	—	—	— —	180	224	4	140	88
400	450	M	—	—	— —	180	250	4	140	98
450	500	N	—	—	— —	180	277	4	140	108
500	550	O	—	—	— —	190	306	4	160	123
550	600	P	—	—	— —	190	338	4	160	132
600	660	Q	—	—	— —	190	370	4	160	147
660	720	R	—	—	— —	190	406	4	160	157
720	780	S	—	—	— —	190	441	4	170	172
780	840	T	—	—	— —	190	479	4	170	186
840	910	U	—	—	— —	190	518	4	170	201
910	980	V	—	—	— —	190	559	4	170	216
980	1060	W	—	—	— —	200	603	4	180	230
1060	1140	X	—	—	— —	200	647	4	180	250
1140	1220	Y	—	—	— —	200	691	4	180	270
1220	1300	Z	—	—	— —	200	738	4	180	284
1300	1390	A†	—	—	— —	200	786	4	180	309
1390	1480	B†	—	—	— —	200	836	4	180	324
1480	1570	C†	—	—	— —	220	888	5	190	324
1570	1670	D†	—	—	— —	220	941	5	190	333
1670	1790	E†	—	—	— —	220	1024	5	190	353
1790	1930	F†	—	—	— —	220	1109	5	190	378
1930	2080	G†	—	—	— —	220	1168	5	190	402
2080	2230	H†	—	—	— —	240	1259	5	200	422
2230	2380	I†	—	—	— —	240	1356	5	200	451
2380	2530	J†	—	—	— —	240	1453	5	200	480
2530	2700	K†	—	—	— —	260	1471	6	200	480
2700	2870	L†	—	—	— —	260	1471	6	200	490
2870	3040	M†	—	—	— —	260	1471	6	200	500
3040	3210	N†	—	—	— —	280	1471	6	200	520
3210	3400	O†	—	—	— —	280	1471	6	200	554
3400	3600	P†	—	—	— —	280	1471	6	200	588
3600	3800	Q†	—	—	— —	300	1471	6	200	618
3800	4000	R†	—	—	— —	300	1471	6	200	647
4000	4200	S†	—	—	— —	300	1471	7	200	647
4200	4400	T†	—	—	— —	300	1471	7	200	657
4400	4600	U†	—	—	— —	300	1471	7	200	667
4600	4800	V†	—	—	— —	300	1471	7	200	677
4800	5000	W†	—	—	— —	300	1471	7	200	686
5000	5200	X†	—	—	— —	300	1471	8	200	686
5200	5500	Y†	—	—	— —	300	1471	8	200	696
5500	5800	Z†	—	—	— —	300	1471	8	200	706
5800	6100	A*	—	—	— —	300	1471	9	200	706
6100	6500	B*	—	—	— —	—	—	9	200	716
6500	6900	C*	—	—	— —	—	—	9	200	726
6900	7400	D*	—	—	— —	—	—	10	200	726
7400	7900	E*	—	—	— —	—	—	11	200	726
7900	8400	F*	—	—	— —	—	—	11	200	736
8400	8900	G*	—	—	— —	—	—	12	200	736
8900	9400	H*	—	—	— —	—	—	13	200	736
9400	10000	I*	—	—	— —	—	—	14	200	736
10000	10700	J*	—	—	— —	—	—	15	200	736
10700	11500	K*	—	—	— —	—	—	16	200	736
11500	12400	L*	—	—	— —	—	—	17	200	736
12400	13400	M*	—	—	— —	—	—	18	200	736
13400	14600	N*	—	—	— —	—	—	19	200	736
14600	16000	O*	—	—	— —	—	—	21	200	736

Table 13.7.3 Equipment – Stream anchors, stream wires, towlines and mooring lines (*conclusion*)

NOTES

1. Towline specified for guidance only, *see* 7.5.1. For tugs *see* Table 13.7.1 item (6).
2. The rope used for stream wire is to be constructed of not less than 72 wires, made up into six strands.
3. Wire ropes used for towlines and mooring lines are generally to be of a flexible construction with not less than:
   144 wires in six strands with seven fibre cores for strengths up to 490 kN (50 tonne-f).
   222 wires in six strands with one fibre core for strengths exceeding 490 kN (50 tonne-f).
   The wires laid round the fibre centre of each strand are to be made up in not less than two layers.
4. Wire ropes for towlines and mooring lines used in association with mooring winches (on which the rope is stored on the winch drum) are to be of suitable construction.
5. The lengths of individual mooring lines may be reduced by up to seven per cent of the Table length, provided that the total length of mooring lines is not less than would have resulted had all lines been of equal length.
6. Tests. *See* Chapter 10 of the Rules for Materials for wire ropes and fibre ropes respectively.
7. For individual mooring lines with breaking strength above 490 kN the breaking strength may be reduced with corresponding increase of the number of the mooring lines and vice versa, provided that the total breaking strength of all lines aboard the ship is not less than the Rule value. In this case the number of lines is not to be less than 6 and no one line is to have a strength of less than 490 kN.
8. Where wire rope is used in lieu of chain cable for anchoring, *see* Table 13.7.1, galvanised wire rope with an independent wire core in accordance with Ch 10,6 of the Rules for Materials is to be used. Wire rope terminal fittings are to comply with an acceptable code or standard. The strength of terminations, connecting fittings, shackles or links is not to be less than that of the anchor line.

Table 13.7.4 Trawlers, stern trawlers and fishing vessels

Equipment number		Stockless bower anchors		Stud link chain cables for bower anchors		
					Diameter, in mm	
Exceeding	Not exceeding	Number	Mass of anchor in kg	Total length in metres	Mild steel (Grade 1 or U1)	Special quality steel (Grade U2)
50	60	2	120	192,5	12,5	–
60	70	2	140	192,5	12,5	–
70	80	2	160	220,0	14,0	12,5
80	90	2	180	220,0	14,0	12,5
90	100	2	210	220,0	16,0	14,0
100	110	2	240	220,0	16,0	14,0
110	120	2	270	247,5	17,5	16,0
120	130	2	300	247,5	17,5	16,0
130	140	2	340	275,0	19,0	17,5
140	150	2	390	275,0	19,0	17,5
150	175	2	480	275,0	22,0	19,0
175	205	2	570	302,5	24,0	20,5
205	240	2	660	302,5	26,0	22,0
240	280	2	780	330,0	28,0	24,0
280	320	2	900	357,5	30,0	26,0
320	360	2	1020	357,5	32,0	28,0
360	400	2	1140	385,0	34,0	30,0
400	450	2	1290	385,0	36,0	32,0
450	500	2	1440	412,5	38,0	34,0
500	550	2	1590	412,5	40,0	34,0
550	600	2	1740	440,0	42,0	36,0
600	660	2	1920	440,0	44,0	38,0
660	720	2	2100	440,0	46,0	40,0

Table 13.7.5 Chain cable steel grades

Grade	Material	Tensile strength	
		N/mm^2	(kgf/mm^2)
U1	Mild steel	300 – 490	(31 – 50)
U2 (a)	Special quality steel (wrought)	490 – 690	(50 – 70)
U2 (b)	Special quality steel (cast)	490 – 690	(50 – 70)
U3	Extra special quality steel	690 min.	(70 min.)

■ *Section 8* Windlass design and testing

8.1 Windlass design

8.1.1 A windlass of sufficient power and suitable for the size of chain is to be fitted to the ship. Where Owners require equipment significantly in excess of Rule requirements, it is their responsibility to specify increased windlass power.

8.1.2 The following performance criteria are to be used as a design basis for the windlass:

(a) The windlass is to have sufficient power to exert a continuous duty pull over a period of 30 minutes of:
  - for specified design anchorage depths up to 82,5 m:

Chain cable grade	Duty pull, P, in N (kgf)
U1	$37{,}5d_c^2$ $(3{,}82d_c^2)$
U2	$42{,}5d_c^2$ $(4{,}33d_c^2)$
U3	$47{,}5d_c^2$ $(4{,}84d_c^2)$

- for specified design anchorage depths greater than 82,5 m:
  $P_1 = P + (D_a - 82{,}5)\ 0{,}27 d_c^2$ N
  $[P_1 = P + (D_a - 82{,}5)\ 0{,}0275 d_c^2$ kgf]

where
d_c is the chain diameter, in mm
D_a is the specified design anchorage depth, in metres
P is the duty pull for anchorage depth up to 82,5 m
P_1 is the duty pull for anchorage depths greater than 82,5 m.

(b) The windlass is to have sufficient power to exert, over a period of at least two minutes, a pull equal to the greater of:
  (i) short term pull:
  1,5 times the continuous duty pull as defined in 8.1.2(a), or
  (ii) anchor breakout pull:

$$12{,}18 W_a + \frac{7{,}0 L_c\, d_c^2}{100}\ \text{N}$$

$$\left(1{,}24 W_a + \frac{7{,}1 L_c\, d_c^2}{1000}\ \text{kgf}\right)$$

  where
  L_c is the total length of chain cable on board, in metres, as given by Table 13.7.2
  W_a is the mass, in kilograms, of bower anchor as given in Table 13.7.2.

(c) The windlass, with its braking system in action and in conditions simulating those likely to occur in service, is to be able to withstand, without permanent deformation or brake slip, a load, applied to the cable, given by:
  $K_b d_c^2\ (44 - 0{,}08 d_c)$ N
  $(K_b d_c^2\ (44 - 0{,}08 d_c)$ kgf)
  where K_b is given in Table 13.8.1.

The performance criteria are to be verified by means of shop tests in the case of windlasses manufactured on an individual basis. Windlasses manufactured under LR's *Type Approval Scheme for Marine Engineering Equipment* will not require shop testing on an individual basis.

Table 13.8.1 Values of K_b

Cable grade	K_b			
	Windlass used in conjunction with chain stopper		Chain stopper not fitted	
	N	(kgf)	N	(kgf)
U1	4,41	(0,45)	7,85	(0,8)
U2	6,18	(0,63)	11,0	(1,12)
U3	8,83	(0,9)	15,7	(1,6)

8.1.3 Calculations for torque transmitting components are to be based on 1500 hours of operation with a nominal load spectrum factor of K_m = 1,0. Alternatively unlimited hours with K_m = 0,8 can be applied.

8.1.4 Where the available input torque exceeds the torque required for anchor breakout then torque overload protection is to be fitted.

8.1.5 An arrangement to release the anchor and chain in the event of windlass power failure is to be provided.

8.1.6 The design of the windlass is to be such that the following requirements or equivalent arrangements will minimise the probability of the chain locker or forecastle being flooded in bad weather:

(a) a weathertight connection can be made between the windlass bedplate, or its equivalent, and the upper end of the chain pipe, and
(b) access to the chain pipe is adequate to permit the fitting of a cover or seal, of sufficient strength and proper design, over the chain pipe while the ship is at sea.

8.2 Calculations

8.2.1 Where shop testing is not possible and Type Approval has not been obtained, calculations demonstrating compliance with 8.1.2 are to be submitted together with detailed plans and an arrangement plan showing the following components:

- Shafting
- Gearing
- Brakes
- Clutches.

8.2.2 The maximum stress from load cases stated in Table 13.8.2 are not to exceed the limits stated in Table 13.8.3.

Table 13.8.2 Design load cases for windlass and chainstopper

Load case	Condition	Note
1	Continuous pull	*See* 8.1.2(a)
2	Over load pull	*See* 8.1.2(b)
3	Brake holding load	*See* 8.1.2(c)

8.2.3 The following criteria are to be used for gearing design:

(a) Torque is to be based on the performance criteria specified in 8.1.2.
(b) The use of an equivalent torque, T_{eq}, for dynamic strength calculations is acceptable but the derivation is to be submitted to LR for consideration.
(c) The application factor for dynamic strength calculation, K_A, is to be 1,15.
(d) Calculations are to be based on 1500 hours of operation.
(e) The static torque is to be 1,5 x T_n where T_n is the nominal torque.
(f) The minimum factors of safety for load capacity of spur and helical gears, as derived using ISO 6336 or a relevant National or International standard acceptable to LR, are to be 1,5 for bending stress and 0,6 for contact stress.

8.2.4 Keyways are to be designed to a relevant National or International standard acceptable to LR.

8.2.5 The maximum stress in brake components is not to exceed the permissible stress stated in Table 13.8.3.

Table 13.8.3 Permissible stress for design load cases

Stress	Load case	
	1 and 2	3
	Permissible stress	
Tension	0,8Y	0,9Y
Compression or bending	0,8Y	0,9Y
Shear	0,7Y	0,7Y
Combined	0,85Y	0,9Y

NOTES
1. Where a component is subjected to axial tensile, axial compressive, bending or shear stress, F_c is to be calculated in the normal manner.
2. Where a component is subjected to a combination of co-existent stresses, F_c is the combined stress which is to be calculated as follows:

Combined bending and tension

$F_c = 1{,}25 f_c + f_{bt}$

Combined bending and compression

$F_c = f_c + f_{bc}$

Combined bending, tension and shear

$$F_c = \sqrt{(1{,}25 f_t + f_{bt})^2 + 3 f_q{}^2}$$

Combined bending, compression and shear

$$F_c = \sqrt{(f_c + f_{bc})^2 + 3 f_q{}^2}$$

where

f_t is the calculated axial tensile stress
f_c is the calculated axial compressive stress
f_{bt} is the calculated maximum tensile stress due to bending about both principal axes
f_{bc} is the calculated maximum compressive stress due to bending about both principal axes
f_q is the calculated shear stress
Y is the specified 0,2 per cent proof stress for the material

8.3 Control arrangements

8.3.1 All control devices are to be capable of being controlled from readily accessible positions and protected against unintentional operation.

8.3.2 The maximum travel of the levers is not to exceed 600 mm if movable in one direction only, or 300 mm to either side from a central position if movable in both directions. They are to move toward the right when hauling and toward the left when paying out. Alternatively, they are to move backward when hauling and forward when paying out.

8.3.3 Wherever practical, the lever is to move in the direction of the intended movement.

8.3.4 For lever-operated brakes, the brake is to engage when the lever is pulled and disengage when the lever is pushed. The physical effort on the brake for the operator is not to exceed 160 N.

8.3.5 For pedal-operated brakes the maximum travel is not to exceed 250 mm and the physical effort for the operator is not to exceed 320 N.

8.3.6 The handwheel or crankhandle is to actuate the brake when turned clockwise and release it when turned counterclockwise. The physical effort for the operator is not to exceed 250 N for speed regulation and 500 N at any moment.

8.3.7 When not provided with automatic sequential control, separate push-buttons are to be provided for each direction of operation.

8.3.8 The push-buttons are to actuate the machinery when depressed and stop and effectively brake the machinery when released.

8.3.9 The above mentioned individual push-buttons may be replaced by two 'start' and 'stop' push-buttons.

8.3.10 Control systems, whether electric, pneumatic or hydraulic, are to comply with the general requirements of Pt 6, Ch 1,2.

8.4 Maintenance arrangements

8.4.1 Access is to be provided for inspection of reduction gears, bearings, brakes, etc.

8.4.2 Accessible manual lubrication points, including nipples, are to be provided for both for oil and grease, as applicable.

8.4.3 Gear-boxes are to be provided with adequate access arrangements for monitoring and replacing oil.

8.5 Protection arrangements

8.5.1 Where applicable, moving parts of windlass machinery are to be provided with suitable railings and/or guards to prevent injury to personnel.

8.5.2 Protection is to be provided for preventing persons from coming into contact with surfaces having temperatures over 50°C.

8.5.3 Steel surfaces not protected by lubricant are to be protected by a coating in accordance with the requirements of a relevant National or International Standard acceptable to LR.

8.5.4 For arrangements of power transmission systems and relief requirements *see* Pt 5, Ch 14,9.1.

8.6 Marking and identification

8.6.1 Controls are to be permanently marked for identification, unless their functions are readily apparent. If required, instructions are to be permanently marked and readily visible.

8.7 Testing and acceptance

8.7.1 During trials on board ship, the windlass is to be shown to be capable of:

(a) for all specified design anchorage depths: raising the anchor from a depth of 82,5 m to a depth of 27,5 m at a mean speed of 9 m/min; and

(b) for specified design anchorage depths greater than 82,5 m: in addition to (a), raising the anchor from the specified design anchorage depth to a depth of 82,5 m at a mean speed of 3 m/min.

Where the depth of the water in the trial area is inadequate, suitable equivalent simulating conditions will be considered as an alternative. Following trials, the ship will be eligible to be assigned a descriptive note **specified design anchorage depth ... metres**, which will be entered in column 6 of the *Register Book*.

8.7.2 Windlass performance characteristics specified in 8.1.2 and 8.7.1 are based on the following assumptions:

(a) one cable lifter only is connected to the drive shaft;

(b) continuous duty and short term pulls are measured at the cable lifter;

(c) brake tests are carried out with the brakes fully applied and the cable lifter declutched;

(d) the probability of declutching a cable lifter from the motor with its brake in the off position is minimised;

(e) hawse pipe efficiency assumed to be 70 per cent.

8.8 Winch design and testing

8.8.1 A winch of sufficient power and suitable for the size of wire rope and chain cable is to be fitted to the ship. Where owners require equipment significantly in excess of Rule requirements, it is their responsibility to specify increased winching power.

8.8.2 The requirements of 8.1.2, 8.2.1 and 8.7.1 are to be applied as performance criteria for winches assuming an equivalent U2 Grade chain cable diameter and Rule length for the same equipment letter. When applying the requirements of 8.1.2(c) the factor K_b is to be taken as specified for when a chain stopper is not fitted.

8.9 Testing of equipment

8.9.1 All anchors and chain cables are to be tested at establishments and on machines recognised by the Committee and under the supervision of LR's Surveyors or other Officers recognised by the Committee, and in accordance with Chapter 10 of the Rules for Materials.

8.9.2 Test certificates showing particulars of weights of anchors, or size and weight of cable and of the test loads applied are to be furnished. These certificates are to be examined by the Surveyors when the anchors and cables are placed on board the ship.

8.9.3 Steel wire and fibre ropes are to be tested as required by Chapter 10 of the Rules for Materials.

8.9.4 For holding power testing requirements relating to high holding power anchors, *see* Ch 10,1.7 of the Rules for Materials

8.10 Structural requirements associated with anchoring

8.10.1 The windlass or winch is to be efficiently bedded and secured to the deck. The thickness of the deck in way of the windlass or winch is to be increased, and adequate stiffening is to be provided, to the Surveyor's satisfaction. The structural design integrity of the bedplate is the responsibility of the Shipbuilder and windlass or winch manufacturer.

8.10.2 An easy lead of the cables from the windlass to the anchors and chain lockers is to be arranged. Where cables pass over or through stoppers, these stoppers are to be manufactured from ductile material and be designed to minimise the probability of damage to, or snagging of, the cable. They are to be capable of withstanding without permanent deformation a load equal to 80 per cent of the Rule breaking load of the cable passing over them.

8.10.3 Hawse pipes and anchor pockets are to be of ample thickness and of a suitable size and form to house the anchors efficiently, preventing, as much as practicable, slackening of the cable or movements of the anchor being caused by wave action. The shell plating and framing in way of the hawse pipes are to be reinforced as necessary. Reinforcing is also to be arranged in way of those parts of bulbous bows liable to be damaged by anchors or cables. Substantial chafing lips are to be provided at shell and deck. These are to have sufficiently large, radiused faces to minimise the probability of cable links being subjected to high bending stresses. Alternatively, roller fairleads of suitable design may be fitted. Where unpocketed rollers are used, it is recommended that the roller diameter be not less than eleven times the chain diameter. Where hawse pipes are not fitted, alternative arrangements will be specially considered.

8.10.4 The chain locker is to be of a capacity and depth adequate to provide an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. Chain or spurling pipes are to be of suitable size and provided with chafing lips. The port and starboard cables are to be separated by a division in the locker.

8.10.5 Where means of access is provided to the chain locker it is to be closed by a substantial cover and secured by closely spaced bolts. Where a means of access to spurling pipes or cable lockers is located below the weather deck, the access cover and its securing arrangements are to be in accordance with ISO 5894-1999, or an equivalent National Standard acceptable to LR, recognised standards or equivalent for watertight manhole covers. Butterfly nuts and/or hinged bolts are prohibited as the securing mechanism for the access cover.

8.10.6 Chain lockers and spurling pipes are to be watertight up to the exposed weather deck and the space is to be efficiently drained. However, bulkheads between separate chain lockers, or which form a common boundary of chain lockers, need not be watertight.

8.10.7 Spurling pipes are to be provided with permanently attached closing appliances to minimise water ingress. Examples of acceptable arrangements are:

(a) steel plates with cutouts to accommodate chain links, or
(b) canvas hoods with a lashing arrangement that maintains the cover in the secured position.

8.10.8 Provision is to be made for securing the inboard ends of the cables to the structure. This attachment should have a working strength of not less than 63,7 kN (6,5 tonne-f) or 10 per cent of the breaking strength of the chain cable, whichever is the greater, and the structure to which it is attached is to be adequate for this load. Attention is drawn to the advantages of arranging that the cable may be slipped from an accessible position outside the chain cable locker. The proposed arrangement for slipping the chain cable, if constructed outside the chain locker, must be made watertight.

8.10.9 Satisfactory arrangements are to be made for the stowage and working of the stream anchor, if provided.

8.10.10 On dredging and reclamation craft the following are to be complied with:

(a) On unpowered ships, the windlass may be hand operated.
(b) On split type vessels, the arrangements are to be such that jamming of the anchor cable during opening and closing operations of the hull will not occur.

8.10.11 When wire rope instead of chain is used for the anchor cable, it is to be stored on a suitably designed drum or reel. Fairleads intended for use with wire rope cable are to be designed to minimise wear and to avoid kinking or other damage occurring to the rope. Fairleads should, in general, be fitted with rollers having a diameter not less than eleven times the diameter of the anchor cable or as specified/recommended by the rope manufacturer.

8.11 Structural requirements for windlasses on exposed fore decks

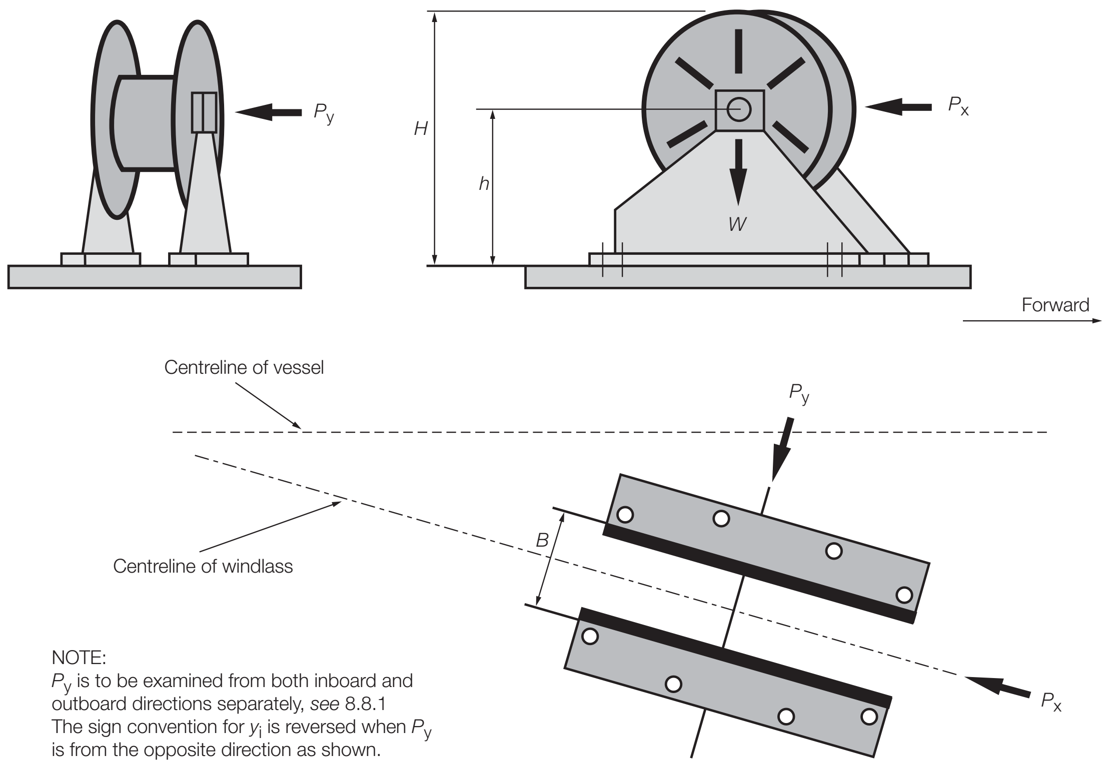
8.11.1 Windlasses located on the exposed deck over the forward 0,25*L* of the rule length, of ships of sea-going service of length 80 m or more, where the height of the exposed deck in way of the item is less than 0,1*L* or 22 m above the summer load waterline, whichever is the lesser, are to comply with the following requirements. Where mooring winches are integral with the anchor windlass, they are to be considered as part of the windlass.

8.11.2 The following pressures and associated areas are to be applied, *see* Fig. 13.8.1:

- 200 kN/m^2 normal to the shaft axis and away from the forward perpendicular, over the projected area in this direction;
- 150 kN/m^2 parallel to the shaft axis and acting both inboard and outboard separately, over the multiple of f times the projected area in this direction;

where

f = 1+ B/H, but not greater than 2,5



NOTE:
P_y is to be examined from both inboard and outboard directions separately, *see* 8.8.1
The sign convention for y_i is reversed when P_y is from the opposite direction as shown.

Fig. 13.8.1 Windlass loading

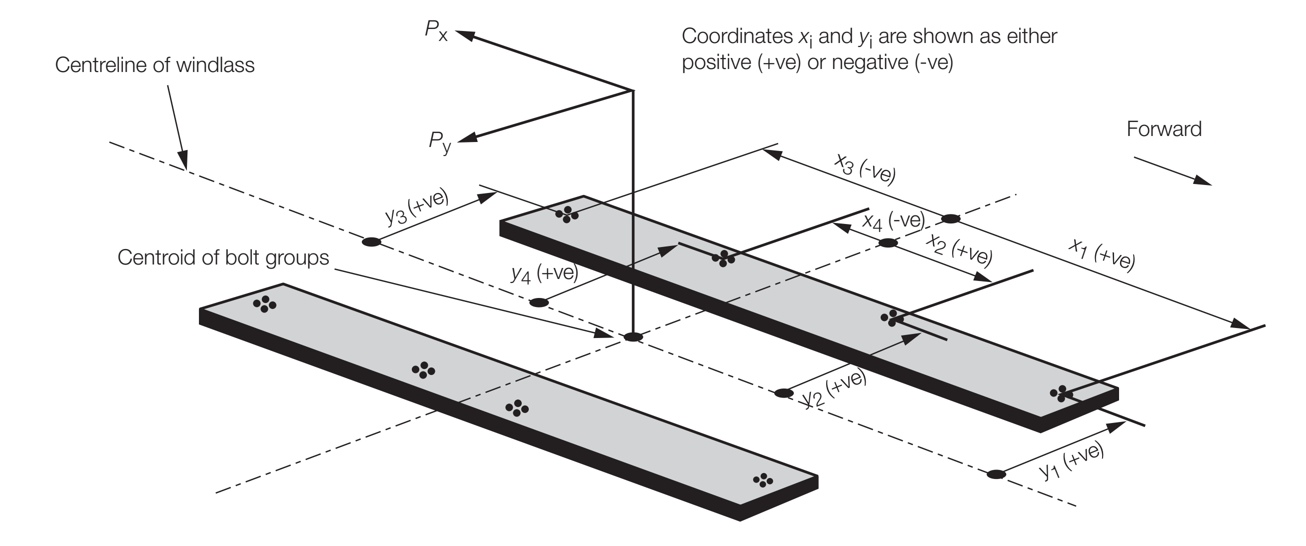


Fig. 13.8.2 Direction of forces and weight

B = width of windlass measured parallel to the shaft axis, in metres
H = overall height of windlass, in metres.

8.11.3 Forces in the bolts, chocks and stoppers securing the windlass to the deck are to be calculated. The windlass is supported by N bolt groups, each containing one or more bolts, *see* Fig. 13.8.2.

8.11.4 The axial force R_i in bolt group (or bolt) i, positive in tension, may be calculated from:

$R_{xi} = P_x\, h\, x_i\, A_i/I_x$ in kN
$R_{yi} = P_y\, h\, y_i\, A_i/I_y$ in kN

and

$R_i = R_{xi} + R_{yi} - R_{si}$ in kN

where

P_x = force acting normal to the shaft axis, in kN
P_y = force acting parallel to the shaft axis, either inboard or outboard whichever gives the greater force in bolt group i, in kN
h = shaft height above the windlass mounting, in cm
x_i, y_i = x and y coordinates of bolt group i from the centroid of all N bolt groups, positive in the direction opposite to that of the applied force, in cm
A_i = cross sectional area of all bolts in group i, in cm^2
I_x = $\Sigma A_i x_i^2$ for N bolt groups, in cm^4
I_y = $\Sigma A_i y_i^2$ for N bolt groups, in cm^4
R_{si} = static reaction at bolt group i, due to weight of windlass, in kN.

8.11.5 Shear forces F_{xi}, F_{yi} applied to the bolt group i, and the resultant combined force F_i may be calculated from:

$F_{xi} = (P_x - \alpha\, g\, M)/N$ in kN
$F_{yi} = (P_y - \alpha\, g\, M)/N$ in kN

and

$F_i = \sqrt{(F_{xi}^2 + F_{yi}^2)}$ kN

where

α = coefficient of friction (0,5)
M = mass of windlass, in tonnes
g = gravity acceleration (9,81 m/sec^2)
N = number of bolt groups.

8.11.6 Tensile axial stresses in the individual bolts in each bolt group i are to be calculated. The horizontal forces F_{xi} and F_{yi} are normally to be reacted by shear chocks. Where 'fitted' bolts are designed to support these shear forces in one or both directions, the von Mises equivalent stresses in the individual bolts are to be calculated, and compared to the stress under proof load. Where pourable resins are incorporated in the holding down arrangements, due account is to be taken in the calculations.

8.11.7 The safety factor against bolt proof strength is to be not less than 2,0.

8.11.8 Bolts are to be of ISO 898/1 material Grade 8.8, 10.9 or 12.9 or equivalent and are to be pretensioned by controlled means to 70 to 90 per cent of their yield stress. Pretensioning is to be in accordance with the manufacturer's instructions and, in general, pretensioning by bolt torqueing up to bolt size M30 may be used. Beyond this, pretensioning is to be carried out by an hydraulic tensioning device and the elongation of the bolts measured to determine pre-load. Where resin chocks are proposed plans and calculations are to be submitted for consideration.

8.11.9 The windlass is to be efficiently bedded and secured to the deck. The thickness of the deck in way of the windlass is to be increased. Adequate stiffening of the deck in way of the windlass is to be provided. The scantlings of the supporting structure and deck are to be determined by additional calculations applying the weight of the windlass combined with the resultant force on the seat due to the application of the following design loads:

- P_x (as defined in 8.11.4);
- P_y;
- P_x and P_y combined;
- a load no less than the maximum pull developed by the windlass under normal operating conditions;
- a load no less than the ultimate breaking strength of the chain stopper, but need not be taken greater than the maximum brake holding capacity of the windlass. Requirements for chain stoppers are described in Section 9.

The allowable stresses given in Table 13.8.4 are not to be exceeded.

Table 13.8.4 Allowable stress in windlass supporting structure

	Bending stress, in N/mm^2	Shear stress, in N/mm^2	Combined stress, in N/mm^2
Allowable stress	$\dfrac{150}{k}$	$\dfrac{87}{k}$	$\dfrac{213}{k}$
k = material factor, *see* Pt 3, Ch 2,1.2			

8.11.10 The axial tensile and compressive forces in 8.11.4 and the lateral forces in 8.11.5 are also to be considered in the design of the supporting structure.

8.12 Structural requirements associated with towing and mooring

8.12.1 The following requirements are applicable to bollards and bitts, fairleads, stand rollers and chocks used for the normal mooring and towing of the vessel, the supporting structure and their attachment to it. They are also applicable to the supporting structure of capstans, winches and similar items used for the normal mooring and towing of the vessel. Any weld, bolt or equivalent device connecting the shipboard fitting to the supporting structure is part of the shipboard fitting and is subject to the National or International standard applicable to that shipboard fitting.

8.12.2 The design criteria in this sub-Section are to be used to derive the net scantlings of the supporting structure. A corrosion addition of 2 mm is to be added to the net thickness derived.

8.12.3 Shipboard fittings for towing or mooring are to be located on longitudinals, beams and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the load. Other arrangements will be specially considered provided that the strength is confirmed as adequate for the service.

8.12.4 The design load applied to shipboard fittings and supporting hull structure is not to be less than that given in Table 13.8.5.

Table 13.8.5 Minimum design load for deck fittings and supporting structure

Use/Item	Minimum design load(1)
Normal towing (harbour/manoeuvring)	1,25 times the intended maximum towing load as indicated on the towing and mooring arrangements plan
Escort towing	minimum breaking strength of the towline given in Table 13.7.3 for the ship's corresponding equipment number(2)
Mooring	1,25 times the breaking strength of the mooring line given in Table 13.7.3 for the ship's corresponding equipment number(2)(3)
Winches, etc.	1,25 times the intended maximum brake holding power
Capstans	1,25 times the maximum hauling in force

NOTES
1. If a greater design load is specified by the designer then this load is to be used.
2. The equipment number calculation is to include the maximum projected area of all deck cargo.
3. Note 7 in Table 13.7.3 is applicable.

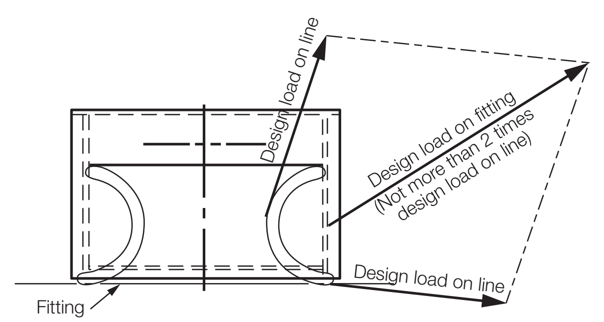


Fig. 13.8.3 Design load applied to fittings

8.12.5 The design load is to be applied according to the arrangement shown on the towing and mooring arrangement plan. The point of action of the force on the fitting is to be taken as the point of attachment of the mooring line or towline or at a change in its direction. The total design load applied to a fitting need not be more than twice the design load, *see* Fig. 13.8.3.

8.12.6 The selection of shipboard fittings is to be made by the shipyard in accordance with an acceptable National or International standard (e.g. ISO3913 Shipbuilding Welded Steel Bollards). If the shipboard fitting is not selected from an acceptable National or International Standard then the design load used to assess its strength and its attachment to the ship is to be in accordance with the design load given in Table 13.8.5 and the design is to be submitted for approval.

8.12.7 The reinforced members beneath shipboard fittings are to be effectively arranged for any variation of the direction, in both the lateral and vertical plane, of the forces acting through the arrangement.

8.12.8 The stress within the supporting structure of fittings is not to exceed that given in Table 13.8.6.

Table 13.8.6 Allowable stress within the supporting structure of shipboard fittings

	Normal stress, in N/mm^2	Shear stress, in N/mm^2
Allowable stress	$\dfrac{235}{k}$	$\dfrac{141}{k}$

where

$k = \dfrac{235}{\sigma_0}$

σ_0 = specified minimum yield strength of the material in N/mm^2

8.12.9 The Safe Working Load (SWL) of a shipboard fitting used for normal towing and mooring is not to be greater than 80 per cent of the design load. The SWL of a shipboard fitting used for escort towing is not to be greater than the design load. For fittings used for both operations, the greater design load is to be used.

8.12.10 The SWL of each shipboard fitting is to be marked, by weld bead or equivalent, on the fitting and relates to a single post basis.

8.12.11 When determining the minimum design load for deck fitting and supporting structure the 'Mooring Equipment Number' is to be calculated as follows:

$$\text{Mooring Equipment Number} = \Delta^{2/3} + 2BH + \frac{A}{10}$$

where

A = area, in m^2, in profile view of the hull including the projected area of all deck cargo, within the Rule length of the vessel, and of superstructures and houses above the summer load waterline, which are within the Rule length of the vessel, and also having a breadth greater than $\dfrac{B}{4}$
See also 8.12.12 and 8.12.13

B = greatest moulded breadth, in metres

H = freeboard amidships, in metres, from the summer load waterline to the upper deck, plus the sum of the heights at the centreline, in metres, of each tier of houses having a breadth greater than $\dfrac{B}{4}$
See also 8.12.12, 8.12.13 and 8.12.14

Δ = moulded displacement, in tonnes, to the summer load waterline.

8.12.12 In the calculation of H and A, sheer and trim are to be ignored. Where there is a local discontinuity in the upper deck, H is to be measured from a notional deckline.

8.12.13 If a house having a breadth greater than $\dfrac{B}{4}$ is above a house with a breadth of $\dfrac{B}{4}$ or less, then the wide house is to be included, but the narrow house ignored.

8.12.14 Screens and bulwarks more than 1,5 m in height are to be regarded as parts of houses when determining H and A. Where a screen or bulwark is of varying height, the portion to be included is to be that length, the height of which exceeds 1,5 m.

■ *Section 9* Mooring of ships at single point moorings

9.1 General

9.1.1 These requirements are applicable to ships intended to utilise the fittings standardised for single point moorings and include the type, strength and location of the required fittings.

9.1.2 A ship provided with mooring arrangements in accordance with the requirements of this Section will be eligible to be assigned the Class notation **SPM4** where a single mooring line arrangement is provided for and **DSPM4** where a dual mooring line arrangement is provided for, *see* Fig. 13.9.1.

9.2 Arrangements

9.2.1 The ship is to be fitted with bow chain stoppers and/or Smit-Type Brackets, and bow fairleads. In addition, pedestal roller fairleads may be required for alignment purposes but a direct straight lead from the chain stopper to the winch storage drum is the preferred arrangement. However, consideration of safety and protection from risk of injury to mooring personnel should take priority in determining whether pedestal rollers should be fitted as well as their number and positioning.

9.2.2 In order to ensure matching with terminal mooring equipment, the requirements for shipboard fittings are specified in association with ranges of ship deadweight as shown in Table 13.9.1.

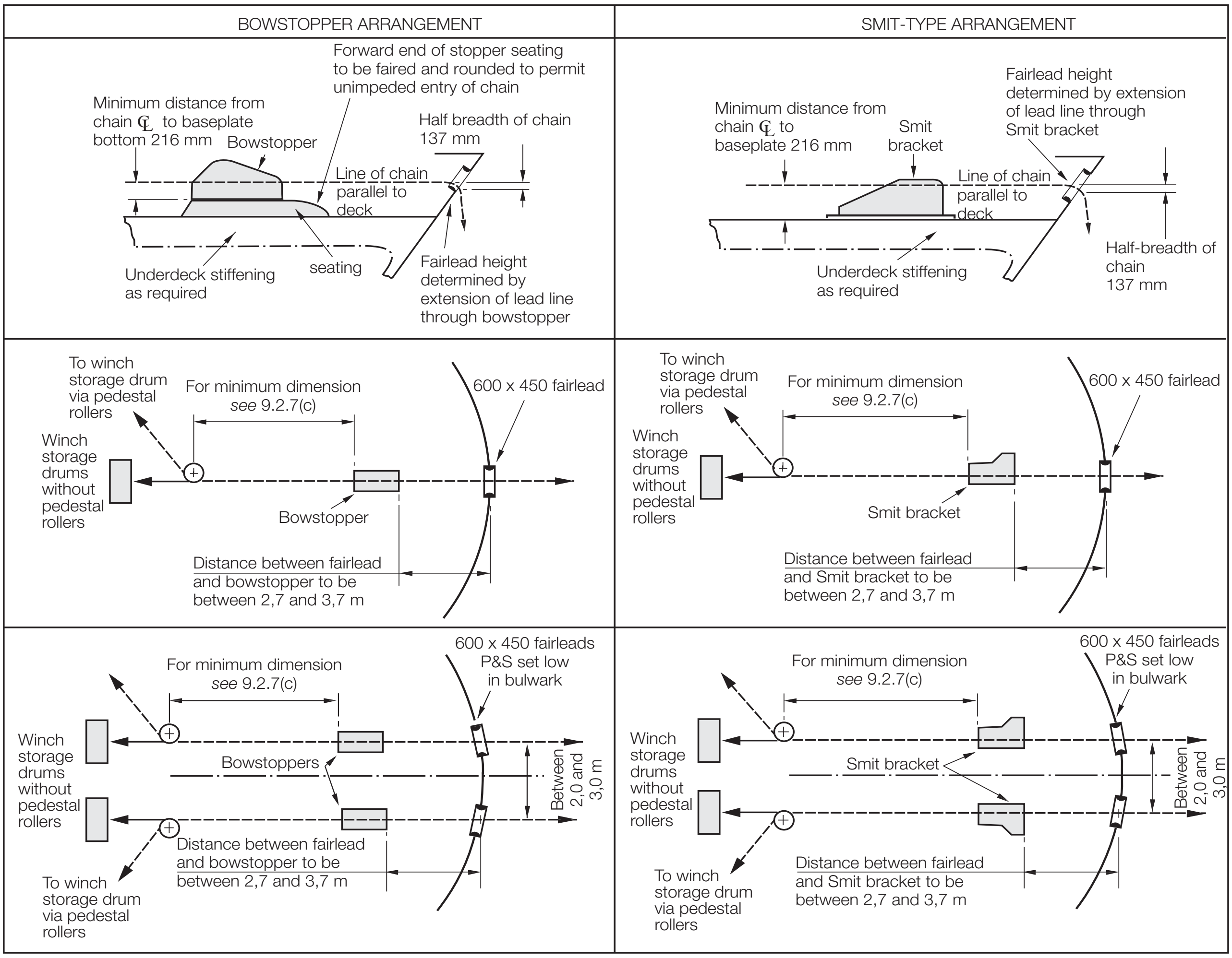


Fig. 13.9.1 Positioning of fairleads, chainstoppers and pedestal roller leads

Table 13.9.1 Deadweight group for shipboard fittings requirements

Group	Deadweight in tonnes	
I	≤ 100 000	
II	> 100 000	≤ 150 000
III	> 150 000	

9.2.3 Bow chain stoppers:

(a) The number, chain cable size and minimum safe working load of bow chain stoppers should be as given in Table 13.9.2.

(b) Bow chain stoppers should be located between 2,7 m and 3,7 m aft of the bow fairlead and should be positioned so as to give correct alignment with the bow fairlead and the pedestal fairlead or the storage drum of the winch, *see* Fig. 13.9.1.

(c) The leading edge of the stopper base plate is to be suitably faired to allow unimpeded entry of the combination chafe chain into the stopper. The chain referred to, forms part of the standardised SPM equipment.

(d) The safety factor on yield of bow chain stoppers should be a minimum of 2 when the safe working load is applied.

(e) Details of bow chain stoppers should be submitted for approval.

Table 13.9.2 Fittings requirements for deadweight group

Group	Chain size, in mm	No. of chain stoppers	SWL, in kN (tonnes)
I	76	1, *see* Note	1960 (200)
II	76	1, *see* Note	2450 (250)
III	76	2	3430 (350)
NOTE Ships in this size range may elect to fit two stoppers to ensure full range terminal acceptance, *see* 9.1.2.			

9.2.4 Smit-Type Brackets:

(a) Smit-Type Brackets may be fitted in lieu of bow chain stoppers for Group I and II. The fitting of Smit-Type Brackets in lieu of bow chain stoppers for Group III will be specially considered. The required number and safe working load are as given in Table 13.9.2 for bow chain stoppers.

(b) The scantlings of the pin, connecting brackets and welded attachments to the baseplate are to be determined in association with a horizontal load of 2 x SWL and a permissible shear stress of 78 N/mm^2 (8 kg/mm^2).

(c) Where fitted, Smit-Type Brackets should be located between 2,7 m and 3,7 m aft of the bow fairlead and should be positioned so as to give correct alignment with the bow fairlead and pedestal fairlead or the storage drum of the winch, *see* Fig. 13.9.1.

(d) To facilitate connection to the terminal equipment it is recommended that each Smit-Type Bracket be provided with a length of chain cable comprising a pear link, an open link, and a special shackle, *see* Fig. 13.9.2. The safe working load should be as given in Table 13.9.2 for bow stoppers.

(e) Adjacent to each Smit-Type Bracket a lug with a recommended safe working load of 490 kN (50 tonnes) should be attached to the doubler plate. The lug should be provided with a hole of sufficient size to accept the pin of a 490 kN (50 tonnes) SWL shackle and should be used as a securing point for the chafe chain holding stopper.

(f) Details of Smit-Type Brackets should be submitted for approval.

9.2.5 The forecastle deck in way of bow chain stoppers or Smit-Type Brackets is to have a minimum thickness of 15 mm and is to be suitably reinforced to resist horizontal loads equal to 2 x SWL as given in Table 13.9.2.

9.2.6 Bow fairleads:

(a) One centrally located bow fairlead should be provided for ships fitted with one bow chain stopper or Smit-Type bracket. Two bow fairleads should be provided for ships fitted with two bow chain stoppers or Smit-type brackets, *see* Fig. 13.9.1.

(b) Bow fairlead openings should be at least 600 x 450 mm for 76 mm chafe chain size. Where more than one bow fairlead is installed, the spacing of centres should be between 2 m and 3 m.

(c) The height of the centre of the bow fairlead opening above the forecastle deck should be determined by the extension, parallel to the deck, of the lead line of the chain cable to the bow chain stopper or Smit-Type Bracket, *see* Fig. 13.9.1. The fairlead should have a minimum radius equal to seven times the chain radius.

(d) The scantlings of the fairlead are to be determined in association with a load of 2 x SWL with hawser angles up to 90 degrees from the ship's centre line, both port and starboard in the horizontal plane and to 30 degrees above and below horizontal in the vertical plane.

(e) Details of bow fairleads and their attachment to the bulwark should be submitted for approval.

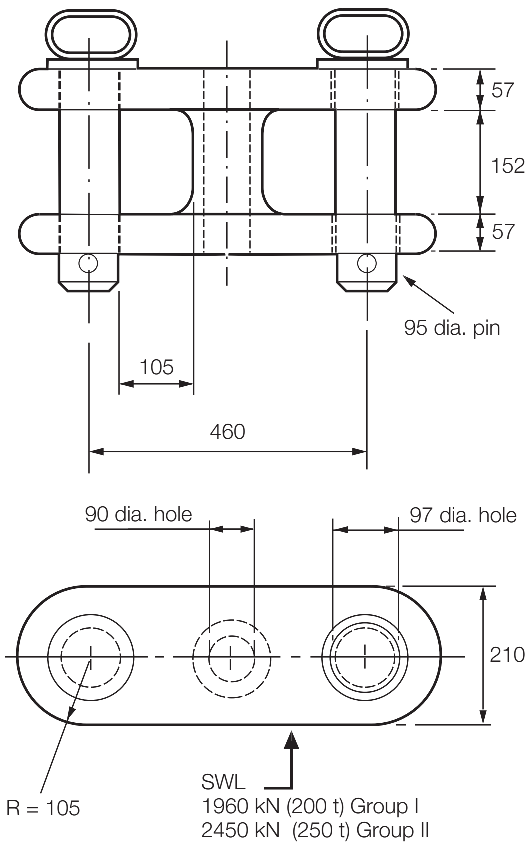


Fig. 13.9.2 Special shackle
Dimensions in mm unless otherwise stated

9.2.7 Pedestal roller fairleads:

(a) Pedestal roller fairleads should have a minimum radius equal to 10 times the radius of wire mooring ropes with a fibre core, seven times the radius of wire mooring ropes with a steel core or three times the radius of synthetic mooring ropes.

(b) The number of pedestal roller fairleads used for each bow chain stopper should not exceed two and the angle subtended by the change of direction of the pick-up rope should be minimal.

(c) The minimum distance of pedestal roller fairleads from the bow chain stopper or Smit-Type Bracket should be 3,0 m. Any variation in the minimum distance will be specially considered.

(d) Details of local strengthening of the forecastle deck in way of pedestal roller fairleads should be submitted for approval.

9.2.8 The winch drum used for handling the mooring gear should be capable of exerting a continuous duty pull of not less than 147 kN (15 tonnes) and be of sufficient size to accommodate 150 m of 80 mm diameter rope. Winch drum ends (warping ends) to handle pick-up ropes should be avoided. Remotely-operated winch storage drums are recommended.

Section 10
Emergency towing arrangements

10.1 Structural requirements

10.1.1 For ships equipped with emergency towing arrangements in accordance with IMO Resolution MSC 35(63), the deck and its supporting structure in way of strongpoints and fairleads are to be suitably reinforced to resist design loads of at least 1,3 x specified breaking strength of the weakest component of the emergency towing arrangement, for angles of tow as specified in IMO Resolution MSC 35(63). The deck in way of strongpoints and fairleads is to have a minimum thickness of 15 mm.

10.1.2 Where a ship is provided with an emergency towing arrangement and the supporting structure complies with the requirements of this Section, the ship will be eligible to be assigned the descriptive note **ETA** which will be entered in column 6 of the *Register Book*.

10.1.3 Stresses induced in the supporting structure and welds in way of strongpoints and fairleads, determined using the design loads from 10.1.1, are not to exceed the permissible values given in Table 13.10.1. The capability of the structure to withstand buckling is also to be assessed.

Table 13.10.1 Permissible stress values

	Permissible stress N/mm^2 (kgf/mm^2)
Direct stress	σ_o
Shear stress	$\frac{\sigma_o}{\sqrt{3}}$
Combined stress	σ_o
Symbols	
σ_o = specified minimum yield stress, in N/mm^2 (kgf/mm^2)	

10.1.4 The structural arrangement is to be such that continuity will be ensured. Abrupt changes of shape or section, sharp corners and other points of stress concentration are to be avoided.

10.2 Chafing chain and wire or fibre rope for Emergency Towing Arrangements

10.2.1 Chafing chains are to be manufactured, tested and certified in accordance with Ch 10,2 of the Rules for Materials Grades U2 and U3.

10.2.2 The outboard end of the chafing chain is to include a pear-shaped link allowing connection to a shackle corresponding to the type of ETA and chain grade. A typical arrangement is shown in Fig. 13.10.1.

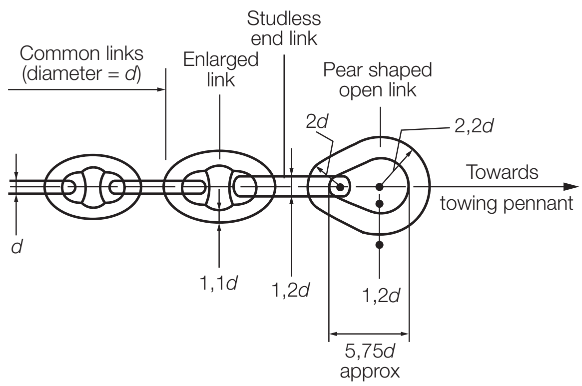


Fig. 13.10.1 Typical outboard chafing chain end

10.2.3 The chafing chain is to be able to withstand a breaking load not less than twice the safe working load (SWL). The nominal diameter of common link for chafing chains is to comply with the value indicated in Table 13.10.2.

Table 13.10.2 Nominal diameter of common link for chafing chains for ETA

Type of ETA	Nominal diameter of common link, *d*, min	
	Grade U2	Grade U3
ETA 1000	62 mm	52 mm
ETA 2000	90 mm	76 mm

10.2.4 Steel wire ropes are to be manufactured, tested and certified in accordance with Ch 10,6 of the Rules for Materials.

10.2.5 Fibre ropes are to be manufactured, tested and certified in accordance with Ch 10,7 of the Rules for Materials.

■ *Section 1* General

1.1 Application

1.1.1 All cargo ships, regardless of tonnage, except those engaged solely in the carriage of either liquid or solid bulk cargoes, are to be provided with a Cargo Securing Manual approved by the Flag Administration, as required by SOLAS 1974 (as amended). Sections 2, 4, 7 (if applicable) and 10 apply to all ships for which a Cargo Securing Manual is required. It is recommended that the container securing arrangements in the Cargo Securing Manual be designed in accordance with Sections 3, 5, 6, 8 and 9. Furthermore, it is recommended that the container securing arrangements be submitted to Lloyd's Register (hereinafter referred to as LR), for formal approval. In cases where LR is authorised to carry out the approval of the Cargo Securing Manual on behalf of a National Administration and the container securing arrangements have not been designed on the basis of the LR Rules nor received formal LR approval, the Cargo Securing Manual will be annotated accordingly, highlighting this fact. In general, Cargo Securing Manuals can be approved by LR if authorised by the National Authority.

1.1.2 Fixed fittings which are part of the container lashing equipment or which may affect the strength of the ship's hull are subject to approval on the basis of the requirements of this Chapter. Details of the connection and the supporting ship structure require approval to satisfy the design loads determined in accordance with Section 8 or the safe working load of the fixed fitting, as applicable. Drawings are to be submitted showing details of the fittings, the attachment, the local foundations and information about the intended materials and welding.

1.1.3 The requirements for container securing arrangements have been framed in relation to ISO Standard Series 1 ISO 1496-1:1990, including Amendment Nos. 1, 2 and 3, Freight Containers. For previous ISO 1496-1:1984 containers, reference should be made to the July 2008 LR Rules. Proposals to consider higher allowable forces in accordance with ISO 1496-1, including Amendment No. 4, 2006, will be specially considered. Proposals for the securing of other types of containers will be specially considered.

1.1.4 Containers are to be loaded so as not to exceed the weights and distribution within the stack according to the Cargo Securing Manual (CSM). The permissible loading patterns are to be clearly indicated on the Container Securing Arrangement Plan carried on board the ship.

1.1.5 Containers may be approved and certified using LR's *Container Certification Scheme*.

1.1.6 Where it is intended and specified that loose or fixed parts of the container securing system are used for lifting appliance purposes, e.g., pedestal sockets and fittings used for lifting of hatch covers, or twistlocks used for vertical tandem lifting, the requirements of LR's *Code for Lifting Appliances in a Marine Environment* are applicable. If no approval from lifting aspects is sought, the devices will be considered as part of a container securing arrangement only.

1.1.7 For ships having the class notation **Container Ship**, an effective breakwater is to be fitted to protect the containers against green sea impact loads. As a minimum, an effective breakwater is to extend above the mid-height of the outermost containers that are to be considered as protected. For other ships which are equipped for the carriage of containers on deck, protection of the cargo is recommended by the provision of a breakwater.

1.1.8 Forward of 0,75*L*, it is recommended that all door ends face aft in order to improve the performance of the container walls to withstand green sea loads.

1.1.9 Improper ship handling related to course and speed or threshold phenomena like parametric rolling can create adverse forces acting on the ship and the cargo which are in excess of the forces determined on the basis of Section 8. It is the responsibility of the Master to apply good seamanship in order to mitigate excessive ship motions to reduce forces acting on the cargo stowage arrangements.

1.2 Classification notations and descriptive notes

1.2.1 Ships with container securing arrangements which are designed and constructed in accordance with this Chapter will be eligible to be assigned the special features notation **CCSA** (certified container securing arrangements). In addition to the fixed fittings, the Initial and Periodical Survey requirements of Section 10 for all loose fittings are applicable. Where loose container securing fittings are supplied for part container stowage only, the special features notation will be suitably modified.

1.2.2 Ships with container securing arrangements which are designed and constructed in accordance with this Chapter, but where the Initial and Periodical Survey requirements for loose fittings in Section 10 are not requested, will be eligible to be assigned the descriptive note **CSA** (container securing arrangement) and for an entry to be made in column 6 of the *Register Book*.

1.2.3 The advantage of having an onboard lashing program to calculate forces acting on the stowage arrangement is highlighted. It is recommended that all ships carrying containers on a regular basis be equipped with such a tool. This may be an extension to the loading instrument covered under Ch 4,8.3. It is recommended that the program be approved by LR. If the program to carry out lashing calculations is approved by LR and installed and maintained in accordance with the requirements of this Chapter, the ship will be eligible to be assigned the special features notation **BoxMax**.

1.2.4 It is a prerequisite for assignment of the special features notation **BoxMax** that the container securing arrangements in the Cargo Securing Manual are designed in accordance with this Chapter and submitted to Lloyd's Register for formal approval.

1.2.5 The container securing arrangements of a container ship may take into account specific voyage routes and seasons, provided the ship is eligible for the special features notation **BoxMax**, *see* 1.2.3, the onboard lashing program is capable of performing calculations specific to defined sea areas and seasons and the weather-dependent factors for these areas and seasons have been supplied by LR. In this case, if the weather-dependent factors have been supplied by LR for specific sea areas, the ship will be eligible to be assigned the special features notation **BoxMax(V)**. If the factors have been supplied by LR for specific sea areas and seasons, the ship will be eligible to be assigned the special features notation **BoxMax(V,W)**. *See* Ch 4,8.4.

1.3 Plans and information required

1.3.1 For all fixed cargo securing arrangements, except container securing arrangements, the following information and plans are to be submitted:

(a) Details of certification including safe working load (SWL) of fixed cargo securing fittings.
(b) Plans of structure in way of fixed cargo securing fittings.
(c) Direction of loads imposed on the ship's fixed cargo securing fittings.
(d) A general arrangement of fixed cargo securing fittings.

1.3.2 For container securing arrangements, the following plans and information are to be submitted:

(a) General arrangement plan showing the disposition and design weights of the containers.
(b) Details of materials, design, scantlings of cell guides structure, lashing bridges, pedestals, and other container securing arrangements, where fitted.
(c) Details of certification, including safe working load (SWL), of fixed and loose container securing fittings.
(d) Plans of structure in way of fixed container securing fittings and arrangements.
(e) Design values of the following ship parameters for the container load departure and arrival conditions:
    (i) Moulded draught (T_c)
    (ii) Transverse metacentric height (*GM*).
(f) Design wind speed (V_W).
(g) The lashing calculations in the Cargo Securing Manual are to be based on two design *GM* values. The lower design value is to be taken as 2,5 per cent of the breadth *B*, and the upper design value is to be taken as 7,5 per cent of *B*. In addition to these two design *GM* values, actual *GM* values of the ship in the container loaded condition from the approved trim and stability booklet are to be included when the actual design *GM* values are outside the above range.

1.3.3 Where containers of types other than ISO containers are to be incorporated in the stowage arrangement, the Cargo Securing Manual is to indicate clearly the locations where these containers are stowed. The manual is also to indicate the container weights and required securing arrangements for stacks composed entirely of ISO Standard containers.

1.4 Securing systems

1.4.1 Containers are to be secured by one, or a combination, of the following systems:

- Corner locking devices.
- Rod, wire or chain lashings.
- Buttresses, shores or equivalent structural restraint.
- Cell guides.

Alternative systems will be considered on the basis of their suitability for the intended purpose.

1.4.2 Dunnage is not to be used in association with approved container securing systems except where forming part of an approved line load stowage, *see* 5.5.

1.5 Symbols and definitions

1.5.1 The following definitions are applicable to this Chapter, except where otherwise stated:

a = breadth of the container, in metres (for longitudinally stowed containers)
b = length of the container, in metres (for longitudinally stowed containers)
c_i = height of container i, in metres
d_i = flange thickness of container securing device (e.g., twistlock) below container i, in metres

a_0 = acceleration parameter

= $f_{HS}\,(1{,}58 - 0{,}47C_b)\left(\dfrac{2{,}4}{\sqrt{L}} + \dfrac{34}{L} - \dfrac{600}{L^2}\right)$

a_{surge} = longitudinal acceleration due to surge, in m/s^2

= $0{,}275a_0$ g

a_{sway} = transverse acceleration due to sway, in m/s^2

= $0{,}55a_0$ g

a_{heave} = vertical acceleration due to heave, in m/s^2

= a_0 g

a_{roll} = roll acceleration at the centre of motion of the vessel, in rad/s^2

= $0{,}69\ \dfrac{\phi}{T_r^2}$

a_{pitch} = acceleration due to pitch, in rad/s^2

$0{,}69\left(1 + \dfrac{0{,}98}{\sqrt{L}}\right)\dfrac{\Psi}{T_p^2}$

T_p = period of pitch of the ship, in seconds, to be taken as specified in Table 14.8.1

T_r = period of roll of the ship, in seconds, to be taken as specified in Table 14.8.1

ϕ = maximum single amplitude of roll, in degrees, to be taken as specified in Table 14.8.1

Ψ = maximum single amplitude of pitch, in degrees, to be taken as specified in Table 14.8.1

e = base of natural logarithms

= 2,7183

f_{ap} = hull form coefficient

for Motion Case MC1:

= $1{,}2R_A^{0{,}3}$ for $R_A > 1{,}0$

= 1,2 for $R_A \le 1{,}0$

for all other Motion Cases:

= 1,0

R_A = area ratio factor for combined stern and bow shape, defined in Pt 4, Ch 2,2.4. For the purpose of container stowage calculation, R_A is to be taken as 1,5 if this value is not available

f_{BK} = bilge keel coefficient

= 1,2 for ships without bilge keels

= 1,0 for ships with bilge keels

f_{Hs} = weather-dependent factor for acceleration

= 1,0 for unrestricted worldwide service

f_{HsP} = weather-dependent factor for pitch

= 1,0 for unrestricted worldwide service

f_{HsR} = weather-dependent factor for roll

= 1,0 for unrestricted worldwide service

f_{HsW} = weather-dependent factor for whipping acceleration

= 1,0 for unrestricted worldwide service

C_{p1} = hull whipping factor

= $1 + f_{MC}\, f_{wh}\, f_{HsW}$

f_{MC} = Motion Case coefficient

= $1{,}0f_{wl}$ for MC1

= 0 for MC2

= $0{,}5f_{wl}$ for MC3

= $0{,}25f_{wl}$ for MC4

= $0{,}5f_{wl}$ for MC5

= 0 for MC6

f_{wh} = whipping coefficient

= 0,55 for $x_c/L \le 0{,}25$

= 0,20 at $x_c/L = 0{,}5$

= 0,45 for $x_c/L \ge 0{,}75$

intermediate values are to be obtained by linear interpolation

f_{wl} = length-dependent factor for whipping

= 0 for $L \le 250$ m

= 1,0 for $L \ge 350$ m

intermediate values are to be obtained by linear interpolation

g = acceleration due to gravity and is to be taken as 9,81 m/s^2

x_c = longitudinal centre of gravity of a container forward of the AP, in metres

z_c = vertical centre of gravity of a container above the keel, in metres

x_i = longitudinal coordinate of the centre of container *i*, in metres, from O_m measured positive forwards in ship coordinate system, *see* Fig. 14.1.1

= $x_c - x_{om}$

y_i = transverse coordinate of the centre of container *i*, in metres, from O_m measured positive to port in ship coordinate system, *see* Fig. 14.1.1

z_i = vertical coordinate of the centre of container *i*, in metres, from O_m measured positive upwards in ship coordinate system, *see* Fig. 14.1.1

= $z_c - z_{om}$

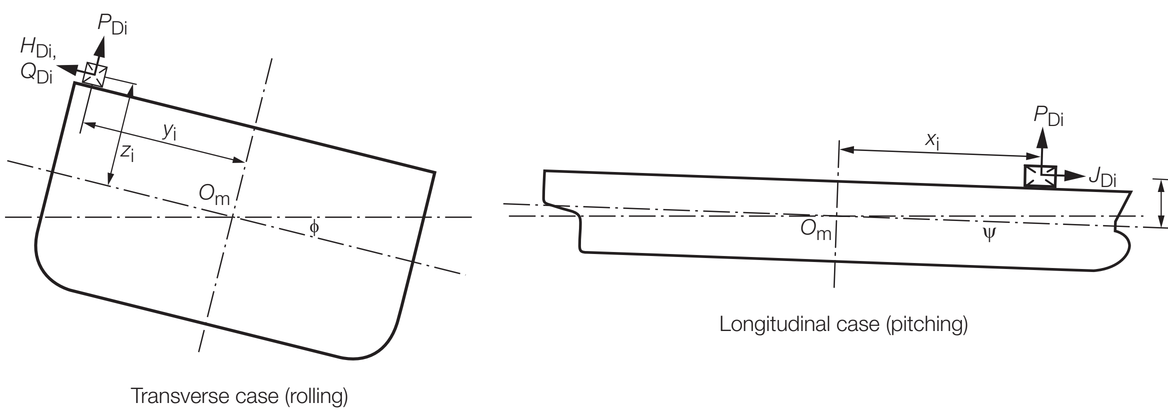


Fig. 14.1.1 Diagrammatic representation of symbols

x_{om} = longitudinal centre of motion forward of the AP. To be taken at the LCF of the ship

z_{om} = vertical centre of motion above the keel. To be taken as the greater of $2T_c/3 + KG/3$ above the keel T_c or $D/2$

A = side area of the container, in m^2

GM = transverse metacentric height of the ship, in metres

KG = vertical distance of the centre of gravity of the ship above the keel, in metres

L = Rule length, in metres, *see* Ch 1,6.1.1

C_b = block coefficient, *see* Ch 1,6.1.6

MCn = Motion Case n

LCF = longitudinal centre of flotation. To be taken as 0,48L

O_m = centre of motion, to be taken on the centreline at x_{om} and z_{om}, *see* Figs. 14.1.1 and 14.1.2

R = the rating, or maximum operating gross weight for which the container is certified, and is equal to the tare weight plus payload of the container, in tonnes

T_c = moulded draught in the container load condition, in metres

V_w = wind speed, in m/s. For ships with an unrestricted worldwide service area notation, a wind speed of 40 m/s is to be applied

W = weight of the container and contents, in tonnes. The following minimum weights W are to be used:
= 2,5 tonnes for 20 ft containers
= 3,5 tonnes for 40 ft containers
= 4,0 tonnes for 45 ft containers
= 4,5 tonnes for 48 ft and 53 ft containers.

1.5.2 The sign convention for ship motions and accelerations is shown in Fig. 14.1.2. This is based on a right-handed coordinate system. The roll, pitch and yaw motions are defined positive clockwise as shown. For instance, positive sway is defined as the translation toward port and positive pitch as the rotation of the bow down and stern up.

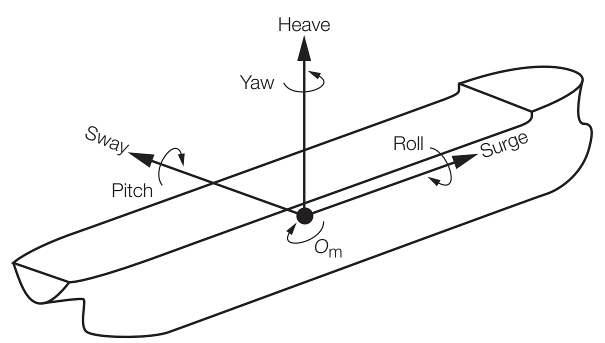


Fig. 14.1.2
Ship coordinate system and sign convention of motions

Section 2
Fixed cargo securing fittings, materials and testing

2.1 General

2.1.1 Randomly selected samples of fixed cargo securing fittings are to be subjected to prototype testing and, upon satisfactory completion, will be granted General Approval.

2.1.2 Randomly selected samples drawn from production runs are to be subjected to production testing prior to delivery to the ship.

2.1.3 Cargo securing fittings, certified by an organisation other than LR, will be accepted where the certification scheme is to the satisfaction of LR.

2.2 Materials and design

2.2.1 Steel used for the construction of the fixed cargo securing fittings is to comply with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) or with an equivalent specification acceptable to LR. Due account is to be taken of the grade and tensile strength of the hull material in way of the attachment. The chemical composition of the steel is to be such as to ensure acceptable qualities of weldability. Where necessary, tests are to be carried out to establish specific welding procedures.

2.2.2 Where securing arrangements are intended to operate at low ambient temperatures, special consideration is to be given to the specification of the steel.

2.2.3 Proposals for the use of materials other than steel will be specially considered.

2.2.4 Attention is drawn to the need for measures to be taken to prevent water accumulation in pockets or recesses that could lead to excessive corrosion.

2.3 Prototype testing

2.3.1 Prototype tests to determine the breaking or failure loads are to be carried out on at least two randomly selected samples of each item used in the securing system. The relationship between design breaking load and safe working load (SWL) is to be as indicated in Table 14.2.1.

2.3.2 The Surveyor is to be satisfied that the design and materials of the fittings are in accordance with the approved plans.

2.3.3 For acceptance, no permanent deformation (other than due to initial embedding of component parts) is to be induced by test loads up to the proof load given in Table 14.2.1.

Table 14.2.1 Design breaking loads and proof loads for fixed cargo securing fittings

Minimum design breaking load		Minimum proof load	
for SWL ≤ 400 kN	for SWL > 400 kN	for SWL ≤ 400 kN	for SWL > 400 kN
2 x SWL	SWL + 400 kN	1,5 x SWL	SWL + 200 kN
NOTE Breaking and proof loads for fixed cargo securing fittings of a material other than steel will be specially considered.			

2.3.4 When considering the test modes, all expected directions of operation are to be taken into account. Jigs are to be employed, where necessary, in order that satisfactory simulation is obtained.

2.3.5 In the interest of standardisation of the strength of container securing fittings, safe working loads in accordance with Table 14.2.2 are recommended.

2.3.6 Where one of the required two randomly selected test samples fails before the design breaking load is reached, this can be accepted, provided that:

(a) the failure is not less than 95 per cent of the design breaking load;
(b) an additional randomly selected sample is tested satisfactorily; and
(c) the average failure load of the three randomly selected samples is equal to or greater than the design breaking load.

2.4 Production testing

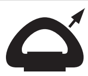
2.4.1 The nature and extent of proposed production testing will be considered by LR, but the arrangements are to be at least equivalent to one of the following testing procedures:

(a) One randomly selected sample from every 50 pieces, or from each batch if fewer than 50 pieces, is to be proof loaded in accordance with Table 14.2.1.
(b) All fittings are to be loaded to the SWL of the item.

2.4.2 Consideration will be given to a reduced frequency of the mechanical production testing proposed in 2.4.1, provided that:

(a) the prototype test results indicate a breaking load at least 50 per cent greater than that required by Table 14.2.1; and
(b) a suitable non-destructive inspection procedure is agreed.

Table 14.2.2 Test loads and test modes for fixed container securing fittings

Item No.	Description	Required test modes		Recommended minimum, in kN		
				SWL	Proof load	Breaking load
1	Flush socket		Pull-out load	250	375	500
2	Pedestal socket		Pull-out load	250	375	500
			Tangential load	200	300	400
3	‘D’ ring	 45°	Tensile load	250	375	500
4	Lashing plate	 45°	Tensile load	250	375	500

NOTES
1. For items 3 and 4, where specifically designed for use with chain or steel wire rope (SWR) lashings, a lesser SWL may be considered.
2. For items 1 and 2, where multiple flush sockets or pedestal sockets are involved, test loads are to be applied simultaneously to each socket opening which can be loaded simultaneously in service.
3. For item 4, where multiple lashing points are fitted in one deck plate fitting, testing is to be similarly arranged as for Note 2.
4. Where containers with strength higher than required for ISO containers are used, consideration will be given to the required minimum loads.
5. The test modes illustrated above are diagrammatic only.

2.4.3 Permanent deformation (other than that due to initial embedding of component parts) will not be accepted unless tests are conducted in accordance with 2.4.1(a) and the SWL of the sample is 250 kN or greater. In this case, consideration may be given to acceptance of permanent deformation in the load range between SWL + 125 kN and the proof load, provided that satisfactory manual operation can be achieved after completion of tests.

2.4.4 In the event of premature failure or serious plastic deformation occurring in a test sample, a further randomly selected sample is to be selected for testing. In the event that this sample is found to be unsatisfactory, the associated batch will be rejected.

■ *Section 3*
Loose container securing fittings, materials and testing

3.1 General

3.1.1 Randomly selected samples of loose container securing fittings are to be subjected to prototype testing and, upon satisfactory completion, will be granted General Approval.

3.1.2 Randomly selected samples drawn from production runs are to be subjected to production testing prior to delivery to the ship in accordance with 3.4.

3.1.3 Loose container securing fittings, certified by an organisation other than LR, will be accepted where the certification scheme is to the satisfaction of LR.

3.1.4 In the following, the term 'fully automatic fitting' is used to describe fittings which do not require manual operation during unloading of the containers. It should be noted that usually these fittings do not mechanically secure the container in the vertical direction (perpendicular to the hatch cover) in the upright condition when subjected to pure vertical motions. Other modes of operation and novel design will be specially considered.

3.2 Materials and design

3.2.1 Steel used for loose container securing fittings is to comply with the requirements of the Rules for Materials or with an equivalent specification acceptable to LR.

3.2.2 Where loose container securing fittings are intended to operate at low ambient temperatures, special consideration is to be given to the specification of the steel.

3.2.3 Proposals for the use of materials other than steel will be specially considered.

3.2.4 Locking devices and other fittings which are inserted into the container castings on the quayside before lifting on board are to be such as to minimise the risk of them working loose under the effects of vibration and the risk of them falling out.

3.2.5 For twistlocks, bottom twistlocks, midlocks, stackers with intermediate plates and fully automatic fittings, the contact areas, for both tension and compression between the fitting and the corner castings of the containers, are to be such as not to exceed a bearing stress of 300 N/mm^2 under the safe working load of the fitting. No increase in the permissible stress level will be given due to higher strength material of the fittings. In the case where the design is such that the contact area is sloped or inclined and not parallel to the container corner casting, the effective contact area will be specially considered.

3.3 Prototype testing

3.3.1 Prototype tests are to be in accordance with 2.3.1 to 2.3.6, except that Tables 14.3.1 and 14.3.2 are to be applied in lieu of Tables 14.2.1 and 14.2.2 respectively. For vertical lashing, *see* 5.4.7(b).

3.4 Production testing

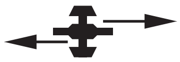
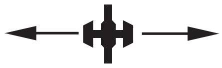
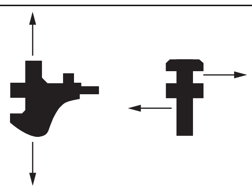
3.4.1 The nature and extent of proposed production testing will be considered by LR, but the arrangements are to be at least equivalent to one of the following testing procedures:

Table 14.3.1 Design breaking loads and proof loads for loose container securing fittings

Item	Min. proof load		Min. design breaking load	
	SWL ≤ 400 kN	SWL > 400 kN	SWL ≤ 400 kN	SWL > 400 kN
Lashings Wire rope Rod: higher tensile steel Chain: mild steel higher tensile steel	1,5 x SWL	SWL + 200 kN	3 x SWL 2 x SWL 3 x SWL 2,5 x SWL	SWL + 400 kN
Other loose container securing fittings	1,5 x SWL		2 x SWL	

NOTES
1. Higher tensile steel is defined for this purpose as steel having a yield stress not less than 315 N/mm^2.
2. Breaking and proof loads for lashings of material other than steel will be considered.

Table 14.3.2 Test loads and test modes for loose container securing fittings

Item No.	Description	Required test modes		Recommended minimum, in kN		
				SWL	Proof load	Breaking load
1	Lashing rod			180	270	360
2	Lashing rod (HTS)			250	375	500
3	Lashing chain (MS)			80	–	200
4	Lashing chain (HTS)			100	–	300
5	Lashing steel wire rope			120	–	360
6	Turnbuckle		Tensile load	250	375	500
7	Twistlock (manual, semi-automatic and fully automatic fittings)		Shear load	200	300	400
			Tensile load	250	375	500
8	Midlock		Shear load	200	300	400
			Tensile load	250	375	500
9	Stacker		Shear load	200	300	400

NOTES
1. Where containers with strength higher than required for ISO containers are used, special consideration will be given to the required minimum loads.
2. The test modes illustrated above are diagrammatic only.
3. Other fittings not covered in this Table may be specially considered, *see also* 3.5.1.
4. For assessment of a para-lash arrangement, *see* 5.4.4, where each lashing rod is modelled, the SWL is to be taken as 0,75 times the SWL of a single lashing. Where a single lashing rod is used to model both rods, the SWL is to be taken as 1,5 times the SWL of a single lashing. *See also* 9.5.2.

(a) For:
- (i) **Loose container securing fittings except chain or wire rope lashings**. One randomly selected sample from every 50 pieces, or from each batch if fewer than 50 pieces, is to be proof loaded in accordance with Table 14.3.1.
- (ii) **Chain or wire rope lashings**. One randomly selected sample from every 50 pieces, or from each batch if fewer than 50 pieces, is to be tested to breaking.

(b) All fittings, securing devices and lashings are to be proof loaded to the SWL of the item and in addition, one randomly selected sample from every batch of chain or wire rope lashings is to be tested to breaking.

3.4.2 Permanent deformation (other than that due to initial embedding of component parts) will not be accepted unless tests are conducted in accordance with 3.4.1(a)(i) and the SWL of the sample is 250 kN or greater. In this case, consideration may be given to acceptance of permanent deformation in the load range between SWL + 125 kN and the proof load, provided that satisfactory manual operation can be achieved after completion of tests.

3.4.3 In the event of premature failure or serious plastic deformation occurring in a test sample, a further randomly selected sample is to be selected for testing. In the event that this sample is found to be unsatisfactory, the associated batch will be rejected.

3.5 Function and environmental testing

3.5.1 For fittings of novel design or with special features, in addition to the prototype and production testing, a function test may be required to demonstrate that the fitting is fit for purpose. Details of the function test will be considered on an individual basis, taking into consideration the mode of operation of the fitting. In addition, LR reserves the right to require environmental tests. The actual test depends on the individual design of the fitting. The tests are to verify that environmental and ageing effects, such as corrosion, icing, debris contamination, etc., do not impinge on the safe operation of the fitting. In this case, LR reserves the right to require the submission of maintenance instructions as part of the approval procedure.

■ *Section 4* Ship structure

4.1 General

4.1.1 The ship structure and hatch covers in way of fixed cargo securing fittings are to be strengthened as necessary, *see* 1.1.2.

4.1.2 A breakwater may be required, *see* 1.1.7.

4.2 Strength

4.2.1 The SWL of the fixed cargo securing fitting is to be used as the design load when approving the weld attachments and the support structure of the fixed cargo securing fitting.

4.2.2 For container securing arrangements, the design load when approving the weld attachment and supporting structure is to be calculated in accordance with Section 9.

4.2.3 When considering the loads, all expected directions of operation are to be taken into account.

4.2.4 Stresses induced in the weld attachments, supporting structure, cell guides, lashing bridges and other structures serving as fixed cargo securing points, determined using the design loads as defined in 4.2.1 to 4.2.3, are not to exceed the permissible values given in Table 14.4.1.

Table 14.4.1 Permissible stress values

	Permissible stress, N/mm^2
Normal stress (bending, tension, compression)	$0{,}67\sigma_o$
Shear stress	$0{,}4\sigma_o$
Combined stress	$0{,}86\sigma_o$
Symbols	
σ_o = specified minimum yield stress, in N/mm^2	

■ *Section 5* Container securing arrangements for stowage on exposed decks without cell guides

5.1 General

5.1.1 Containers stowed on deck or on hatch covers are generally to be aligned in the fore and aft direction (longitudinally stowed), but alternative arrangements will be considered.

5.1.2 Containers are to be stowed so that they do not extend beyond the ship's side. Adequate support is to be provided where they overhang hatch coamings or other deck structures. The stowage arrangements are to be such as to permit safe access for personnel in the necessary working of the ship, and to provide sufficient access for operation and inspection of the securing devices.

5.1.3 Where containers are stowed on hatch covers, the covers are to be effectively restrained against sliding by approved type stoppers or equivalent. Details of the locations of stoppers relative to the supporting structure are to be submitted at an early stage.

5.1.4 Stanchions and similar structure supporting containers and securing devices, such as D-rings for lashings, are to be of adequate strength for the imposed loads and of sufficient stiffness to minimise any deflection which could lead to a reduction in the effectiveness of the securing device.

5.1.5 In the region forward of 0,75*L*, additional securing devices may be required due to green sea forces, *see* 8.2.8.

5.1.6 In general, stowage of heavy containers on top of lighter containers is to be avoided, unless validated as being satisfactory by an approved onboard lashing program or covered by the approved container securing arrangement.

5.1.7 Regarding the use of fully automatic fittings, the following requirements apply:

(a) For fittings where the locking method requires defined clearances between the corner castings and the fixed foundations, such fittings are not to be used at the lowest tier of a stack which is resting with one side on a hatch cover panel and bridging to a container stanchion. The same applies if the stack is resting on different hatch cover panels or foundations where relative deflection during ship operation can occur.

(b) If the lashing system consists of a combination of fully automatic fittings with lashing rods, only internal cross lashings are to be used. No external lashings or vertical lashings are to be applied, unless the clearance of the loose securing fitting under safe working loads is insignificantly small. Alternative arrangements will be specially considered, taking into consideration the clearances of the fittings.

5.2 Containers in one tier

5.2.1 Containers are to be secured at their lower corners by approved locking devices.

5.2.2 Alternatively, containers may be secured by lashings fitted diagonally or vertically at both ends of each container, in association with cone fittings at each container corner.

5.3 Containers in two tiers

5.3.1 Containers are to be secured at their lower corners at each tier by approved locking devices.

5.3.2 Where the calculations indicate that separation forces will not occur at any point in the stack, double stacking cones may be fitted at all internal corners of the stack and bridge fittings used to connect the tops of the rows in the transverse direction. Locking devices are to be fitted at all external corners.

5.3.3 Alternatively, containers may be secured by lashings in association with stacking cones or, where the calculations indicate that separation forces may occur, with locking devices.

5.4 Containers in more than two tiers

5.4.1 Containers are to be secured at their lower corners at each tier by approved locking devices.

5.4.2 Alternatively, containers may be secured by lashings. One or two tiers of lashings may be fitted in association with stacking cones or, where the calculations indicate that separation forces may occur, with locking devices.

5.4.3 When lashings are employed, they are usually fitted to the bottom corner casting of a container. Proposals to attach lashings to the top casting of a container will be considered. The reduced strength of the upper corner casting compared to the lower corner castings is to be taken into account.

5.4.4 Proposals to use lashings in pairs (para-lash arrangements) will be considered. Lashings in pairs are generally to be attached one to the bottom corner fitting of the upper tier and the other to the top corner fitting of the lower tier container. Suitable connections are to be provided at the lower ends. The effectiveness of paired lashings is to be taken as equal to 1,5 times that of a single lashing.

5.4.5 Where tiers are fitted at higher levels, they are to be secured by locking devices at each corner and each tier.

5.4.6 Proposals to use horizontal lashings connected to lashing bridges will be specially considered. The forces in such securing systems are to be determined by direct calculations, taking into account the following effects:

- stiffness of the container walls, the lashings and the lashing bridge; and
- the possible horizontal displacements of the containers relative to the lashing bridge due to the clearances of the hatch cover stoppers and the container securing fittings.

5.4.7 When vertical lashings are used in combination with container securing fittings, consideration is to be given to the vertical clearances between the fittings and the container corner castings:

(a) The lashing assembly is to remain elastic when subject to an elongation equating to the number of interface fittings fitted below the point where the vertical lashing is applied to the stack. In order to avoid overstressing of the rod and the turnbuckle, provision of spring or elastic elements incorporated into the turnbuckle may be advantageous. When lashing from lashing bridge level, the number of interfaces is to be counted down to the level where the lowest container is resting. The lashing rod is to be fitted to the bottom casting of the container. For container securing fittings having design clearances in accordance with ISO 3874, a nominal clearance per fitting of 10 mm is to be taken to determine the total elongation of the lashing system. For fittings having clearances in excess of 10 mm, the total elongation is to be calculated, taking into consideration the higher clearances.

(b) A prototype test is to be carried out to demonstrate that the vertical lashing has a safe working load of 150 kN when elongated up to the calculated total design clearance plus 10 per cent without plastic deformation.

(c) It is recommended that the load-bearing effect of vertical lashing arrangements be explicitly taken into account when performing lashing calculations. Where this is not done, it is acceptable to allow the permissible calculated lifting force to be increased by 150 kN in addition to the safe working load of the container securing fitting. The nominal lifting force is not to exceed 400 kN at the securing fittings below the fitting position of the vertical lashing.

5.4.8 For stowage arrangements incorporating fully automatic fittings which do not mechanically secure the container in pure vertical direction when subject to vertical motions, it is to be ensured that no separation occurs under the load cases specified in Section 8. In addition, where exposed stacks are secured with fully automatic fittings without internal cross lashings, provision is to be made to prevent buoyancy forces acting on the container which could disengage the containers. In this case, the use of effective side screens is required. Otherwise, the first tier of containers is to be secured by manual or semi-automatic twistlocks.

5.4.9 If the carriage of one or more tiers of 20 ft containers being overstowed with at least one tier of 40 ft containers, the so-called ‘Russian Stow Arrangement’, is desired, the following requirements apply.

(a) At the 20 ft gap the containers are to be secured by means of midlocks, whereas the fore and aft ends are to be secured by twistlocks and if necessary supplemented by lashing rods.

(b) The 40 ft overstow container is to be secured by twistlocks or if necessary with a combination of twistlocks and lashing rods. The stack is to be assessed in a two-step procedure, as follows:
   (i) For location at the 40 ft ends, the entire mixed stack is to be considered as a 40 ft stack. The weights of the 40 ft containers are to be considered in the calculations. For the tiers of 20 ft containers, the weight of one 20 ft container is to be taken as the basis for the calculation at each tier.
   (ii) For the location of the 20 ft tiers at the mid-bay position, the assessment is to be carried out as for an unlashed stack. The 40 ft overstow container does not need to be taken into consideration.

5.5 Line Load stowage

5.5.1 Where the containers are supported on bearers placed to distribute the stackweight as Line Loads, the following requirements are to be complied with:

(a) The stack is, in general, to comprise a maximum of two tiers of loaded containers.
(b) The load from the upper tier is to be transferred through the container corners. Line loading is not to be used between tiers.
(c) The load on each vertical corner post of the bottom tier, calculated in accordance with Section 9, is not to exceed one half of the Rated Load of the container.
(d) Where the calculations indicate that lifting forces may occur, locking devices are to be fitted at the container corners.
(e) The clearance below the bottom container corner casting is to be such that the stacking cone or equivalent cannot be dislodged under shear loading.

5.5.2 Where an approved Line Load stowage system is installed, the special features notation will be suitably modified.

5.6 Systems incorporating structural restraint

5.6.1 Containers may be secured by the use of a fixed structure providing permanent buttresses in association with portable frameworks. Proposals to adopt such systems will be considered on the basis of the loads developed in the structure and the corresponding stresses.

5.6.2 The framework or other devices securing the containers are to be aligned with the container corner fittings and any clearance gap is to be kept to the minimum to reduce shifting.

■ *Section 6*
Container securing arrangements for underdeck stowage without cell guides

6.1 General

6.1.1 Containers are generally to be stowed in holds in the fore and aft direction, but alternative arrangements will be considered. The securing arrangements are to be designed on the basis of the most severe distribution of loads which may arise in the container stack.

6.1.2 Containers may be secured by locking devices only or by a combination of locking devices, buttresses, shores or lashings. Containers are, in general, to be restrained at every corner at the base of the stack and at all intermediate levels.

6.1.3 Where stacks consist of one or two tiers only, consideration will be given to the omission of corner locking devices. Containers must, however, be secured by a minimum of two corner locking devices.

6.1.4 Where the calculations indicate that separation forces could occur at any particular level, twistlocks or equivalent means of securing are to be fitted at that level. Elsewhere, consideration will be given to the use of double stacking cones.

6.1.5 Where the calculations indicate that separation forces will not occur between containers at any level, consideration will be given to the use of stacking cones in lieu of locking devices throughout.

6.1.6 Buttresses are generally to be of the tension and compression type and are to be provided with means of adjustment to ensure tightness when fitted in place. Where applicable, the attachment to the ship's structure is also to include means for vertical adjustment of the buttress to match container stacks of different heights.

6.1.7 Shores of the compression-only type may be permanently attached to the ship structure or they may be hinged or portable. When in place they are to abut the container corner fittings with minimal clearance. Means are to be provided to prevent slackening of the device.

6.1.8 Adjacent stacks of containers are to be linked in line with buttresses or shores in order to transmit lateral loads. The fittings used for these linkages are to be of adequate strength to transmit the loads imposed.

6.1.9 The ship's structure supporting shores and buttresses is to be reinforced as necessary.

6.1.10 Proposals for alternative securing systems, including systems relying on minimal clearance between containers and hull structure, will be specially considered.

6.1.11 Attention is drawn to the safety at work aspects for fittings which require operation on top of containers, e.g., double stacking cones, bridge fittings, buttresses and shores. Where these fittings are used, fall protection is to be provided.

■ *Section 7*
Container securing arrangements for stowage using cell guides

7.1 General

7.1.1 Cell guide systems may be fitted to support containers stowed in holds or on exposed decks.

7.1.2 The cell guides are not to form an integral part of the ship's structure. The guide system is generally to be so designed as to keep it free of the main hull stresses.

7.1.3 Cell guides are to be designed to resist loads caused by loading and unloading of the containers, to prevent shifting of the containers and to transmit the loads caused by motions of the ship into the main hull structure.

7.2 Arrangement and construction

7.2.1 Cell guides are to be of robust construction and generally fabricated from steel plate and rolled sections. They are to have sufficient vertical extent and continuity to provide efficient support to containers. Guide bars are to be effectively attached to the supporting structure to prevent tripping or distortion resulting from container loading.

7.2.2 The intersection between cell guide and cross ties is to provide adequate torsional stability.

7.2.3 Intermediate brackets are to be fitted to vertical cell guides at suitable intervals.

7.2.4 The cell guides are to give a total clearance between the container and guide bars not exceeding 25 mm in the transverse direction and 40 mm in the longitudinal direction. The deviation of the cell guide bar from its intended line is not generally to exceed 4 mm in the transverse direction and 5 mm in the longitudinal direction.

7.2.5 Athwartship cross ties are to be fitted between cell guides at a spacing determined from the loading on the guides but, generally, not more than 3,0 m apart. Wherever possible, cross ties are to be arranged in line with the corners of the containers as stowed and are to be supported against fore and aft movement at a minimum of two points across the breadth of the hold. Where, however, the maximum fore and aft deflection in the cross tie can be shown not to exceed 20 mm, one support point may be accepted.

7.2.6 Longitudinal tie bars may be required to be fitted where shown necessary by the force calculations for the structure. Where fitted, they are to comply with the requirements of 7.2.5.

7.2.7 Where, at the sides or ends of holds, the guide rails are fitted to transverse or longitudinal bulkheads, the bulkhead is to be locally reinforced to resist the additional loads.

7.2.8 If the carriage of 45 ft Euro containers complying with EU Directive 96/53 is specified to be carried in 45 ft cell guides, attention is to be paid to the arrangement of the corner castings, *see* Fig. 14.7.1. The guide bars need to be increased in order to ensure that a minimum design overlap, *a*, of 20 mm is achieved, taking into account the design clearances and tolerances defined in 7.2.4. Consideration is to be given to the torsional loads being applied to the guide bars.

7.3 Carriage of 20 ft containers in 40 ft cell guides in holds

7.3.1 Where the cell guides are arranged for the carriage of 40 ft containers, provision may be made for the installation of temporary intermediate cell guides for 20 ft containers. The permanent structure is to be designed such that it is suitable for either loading pattern.

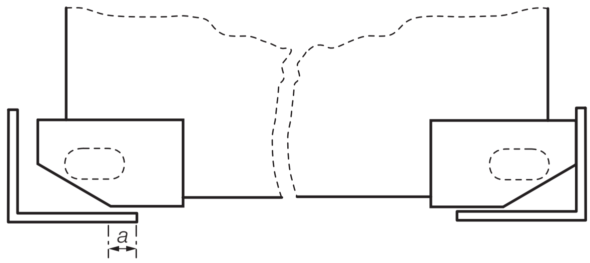


Fig. 14.7.1 45 ft euro container in cell guides

7.3.2 Alternatively, permanent means for the support of 20 ft containers at the mid-length of a cell arranged for 40 ft containers will be considered. Such means may include the following:

(a) A pillar (inboard) and vertical rest bar (on the longitudinal bulkhead) against which the container stack may rest. The pillar is to be supported laterally by the deck structure over and is to be sufficiently stiff to control lateral deflection of the container stacks.
(b) Guide bars supported transversely by slim structure within the gap between containers and with longitudinal ties as necessary.

Details of proposals will be individually considered, taking into account the loads on the support structure and the resulting deflections.

7.3.3 Where it is desired to stow 20 ft containers without external support at the mid-bay location with or without 40 ft overstow, so-called ‘mixed stowage’ arrangements meeting the following requirements are applicable:

(a) Maximum homogeneous container weights for 20 ft containers stowed in cell guides with no 40 ft container overstowed can be derived from Tables 14.7.1 and 14.7.2, depending on the transverse acceleration and the number of tiers in the stack.
(b) Maximum homogeneous container weights for 20 ft containers stowed in cell guides with at least one 40 ft container overstowed can be derived from Table 14.7.3, depending on the transverse acceleration and the number of tiers in the stack.
(c) Tables 14.7.1 to 14.7.3 have been derived on the basis of all containers in a stack having the same homogeneous weight. Where it is intended to carry non-homogeneous mixed stowage stacks, containers heavier than specified in Tables 14.7.1 to 14.7.3 can be loaded in the lower tiers provided that the total stack weight derived from the Tables is not exceeded. Furthermore, no container having a weight in excess of the maximum weight stated in the Tables is to be stowed on top of a lighter container. However, the total accumulated stack weight derived from the above mentioned Tables may be increased by loading the lowest container in the stack up to its maximum rated weight.
(d) Means are to be provided to prevent transverse sliding of the bottom of the stacks of 20 ft containers at the mid-bay position. This is to be in the form of permanently attached chocks at the inner bottom or equivalent. The design clearance is to be the same as for the cell guides and in accordance with 7.2.4.

(e) Stacking cones are to be fitted at each corner between tiers of the 20 ft containers to prevent transverse and longitudinal sliding. In addition, where a 40 ft container is required to be stowed above 20 ft containers, stacking cones are to be fitted at the ends of the 40 ft container between the 40 ft container and the 20 ft containers below.
(f) The 20 ft containers are to have closed steel walls and top (no open frame containers, e.g., tank or bulk containers).
(g) The orientation of the containers is to be such that all front ends or door ends are facing in one direction.
(h) Cones are to be fitted on the inner bottom in way of the cell guides to restrain container movement in the longitudinal direction.
(j) The containers are to be stowed in the hold in block stowage. In general, free standing stacks due to adjacent empty stacks are to be avoided.

Proposals for stowage arrangements other than the above will be individually considered and are to be accompanied by supporting calculations.

7.4 Cell guide systems on exposed decks

7.4.1 Analysis methods for the strength of the cell guide structure are to take due account of the interactive effects between guide structure and supporting deck structure and also of the deformation of the hull girder.

7.4.2 At its lower end the guide structure is to be efficiently connected to the deck structure. Cross ties are to be arranged between guides in a transverse direction at a spacing determined by the loading on the guides but in general not more than 3 m apart. Cross-bracing members of adequate strength and sufficient number are to be fitted in the transverse and longitudinal directions to prevent excessive deflection of the guide structure.

7.4.3 The height of guide bars above the deck is to be sufficient to ensure adequate restraint to the uppermost container tiers.

7.4.4 Where the cell guide structure is attached to highly stressed hull or deck elements, such as sheerstrakes, special attention is to be given to the design of the connection and the grade and quality of steel utilised.

7.5 Entry guide devices

7.5.1 A device to pre-centre the container and direct it into the cell guides is normally to be fitted at the top of the guide bars. Such devices include:
- fixed even peaks,
- fixed high and low peaks,
- ‘flip-flop’ systems,

but other devices will be considered. The device is to be of robust construction.

Table 14.7.1 Maximum container weights of ISO 1496-1:1990 20 ft containers stowed in 40 ft cell guides with no overstow; Container's rated Weight = 24 t

Lowest tier transverse acceleration (= a_y/g), *see* 8.2.5	Maximum homogeneous container weights, in tonnes									
	3 tiers	4 tiers	5 tiers	6 tiers	7 tiers	8 tiers	9 tiers	10 tiers	11 tiers	12 tiers
0,350	24,0	24,0	24,0	20,2	17,3	14,8	13,4	11,6	10,6	9,5
0,355	24,0	24,0	24,0	20,2	17,1	14,6	13,3	11,6	10,6	9,4
0,360	24,0	24,0	24,0	19,7	16,9	14,5	13,2	11,5	10,5	9,3
0,365	24,0	24,0	24,0	19,5	16,7	14,3	13,1	11,4	10,4	9,3
0,370	24,0	24,0	23,9	19,3	16,5	14,1	13,0	11,3	10,3	9,2
0,375	24,0	24,0	23,6	19,0	16,3	14,0	12,9	11,3	10,3	9,2
0,380	24,0	24,0	23,3	18,8	16,1	13,8	12,7	11,2	10,2	9,1
0,385	24,0	24,0	23,0	18,6	15,9	13,6	12,6	11,1	10,1	9,0
0,390	24,0	24,0	22,7	18,4	15,8	13,5	12,5	11,0	10,0	9,0
0,395	24,0	24,0	22,5	18,2	15,6	13,3	12,4	10,9	9,9	8,9
0,400	24,0	24,0	22,2	18,0	15,4	13,2	12,3	10,8	9,9	8,9
0,405	24,0	24,0	22,0	17,8	15,3	13,1	12,1	10,7	9,8	8,8
0,410	24,0	24,0	21,8	17,6	15,1	13,0	12,0	10,7	9,7	8,8
0,415	24,0	24,0	21,5	17,5	15,0	12,9	11,8	10,6	9,7	8,7
0,420	24,0	24,0	21,3	17,3	14,8	12,7	11,7	10,4	9,6	8,7
0,425	24,0	24,0	21,1	17,2	14,7	12,6	11,5	10,3	9,5	8,6
0,430	24,0	24,0	20,9	17,0	14,6	12,5	11,4	10,2	9,4	8,6
0,435	24,0	24,0	20,7	16,9	14,5	12,4	11,3	10,1	9,4	8,5
0,440	24,0	24,0	20,6	16,8	14,4	12,4	11,1	10,0	9,3	8,5
0,445	24,0	23,9	20,4	16,6	14,3	12,3	11,0	9,9	9,2	8,4
0,450	24,0	23,7	20,2	16,5	14,1	12,2	10,9	9,9	9,2	8,3
0,455	24,0	23,6	20,0	16,4	14,0	12,1	10,8	9,8	9,1	8,3
0,460	24,0	23,4	19,9	16,2	13,9	12,0	10,7	9,7	9,0	8,2
0,465	24,0	23,3	19,7	16,1	13,8	11,9	10,6	9,6	8,9	8,1
0,470	24,0	23,1	19,6	16,0	13,7	11,8	10,6	9,5	8,9	8,1
0,475	24,0	23,0	19,5	15,9	13,6	11,7	10,5	9,4	8,8	8,0
0,480	24,0	22,9	19,3	15,8	13,5	11,6	10,5	9,4	8,7	7,9
0,485	24,0	22,7	19,2	15,7	13,4	11,5	10,4	9,3	8,6	7,9
0,490	24,0	22,6	19,1	15,6	13,3	11,4	10,3	9,2	8,5	7,8
0,495	24,0	22,5	18,9	15,5	13,2	11,3	10,3	9,1	8,5	7,7
0,500	24,0	22,4	18,8	15,4	13,1	11,2	10,2	9,1	8,4	7,7
0,505	24,0	22,3	18,7	15,3	13,0	11,2	10,1	9,0	8,3	7,6
0,510	24,0	22,1	18,6	15,2	13,0	11,1	10,1	8,9	8,3	7,6
0,515	24,0	22,0	18,4	15,1	12,9	11,0	10,0	8,9	8,2	7,5
0,520	24,0	21,9	18,3	15,0	12,8	10,9	9,9	8,8	8,1	7,4
0,525	24,0	21,8	18,2	14,9	12,7	10,9	9,9	8,7	8,1	7,4
0,530	24,0	21,7	18,1	14,8	12,6	10,8	9,8	8,7	8,0	7,3
0,535	24,0	21,6	18,0	14,7	12,5	10,7	9,7	8,6	8,0	7,3
0,540	24,0	21,5	17,9	14,6	12,4	10,6	9,6	8,5	7,9	7,2
0,545	24,0	21,4	17,7	14,5	12,3	10,6	9,6	8,5	7,8	7,1
0,550	24,0	21,3	17,6	14,4	12,3	10,5	9,5	8,4	7,8	7,1
0,555	24,0	21,2	17,5	14,3	12,2	10,4	9,4	8,4	7,7	7,0
0,560	24,0	21,1	17,4	14,2	12,1	10,4	9,3	8,3	7,7	7,0
0,565	24,0	21,0	17,3	14,2	12,0	10,3	9,3	8,3	7,6	6,9
0,570	24,0	20,9	17,2	14,1	11,9	10,2	9,2	8,2	7,6	6,9
0,575	24,0	20,8	17,1	14,0	11,9	10,2	9,1	8,2	7,5	6,8
0,580	24,0	20,7	17,0	13,9	11,8	10,1	9,0	8,1	7,5	6,8
0,585	24,0	20,6	16,9	13,8	11,7	10,1	9,0	8,1	7,4	6,8
0,590	24,0	20,5	16,8	13,7	11,6	10,0	8,9	8,0	7,4	6,7
0,595	24,0	20,4	16,7	13,7	11,6	9,9	8,8	8,0	7,3	6,7
0,600	24,0	20,4	16,6	13,6	11,5	9,9	8,8	7,9	7,3	6,6
0,605	24,0	20,3	16,5	13,5	11,4	9,8	8,7	7,9	7,2	6,6
0,610	24,0	20,2	16,5	13,4	11,4	9,8	8,7	7,8	7,2	6,5
0,615	24,0	20,1	16,4	13,4	11,3	9,7	8,6	7,8	7,1	6,5
0,620	24,0	20,0	16,3	13,3	11,2	9,7	8,6	7,7	7,1	6,5
0,625	24,0	20,0	16,2	13,2	11,2	9,6	8,6	7,7	7,0	6,4
0,630	24,0	19,9	16,1	13,1	11,1	9,6	8,5	7,6	7,0	6,4
0,635	24,0	19,8	16,0	13,1	11,1	9,5	8,5	7,6	6,9	6,3
0,640	24,0	19,7	15,9	13,0	11,0	9,5	8,4	7,5	6,9	6,3
0,645	24,0	19,7	15,9	12,9	10,9	9,4	8,4	7,5	6,9	6,3
0,650	24,0	19,6	15,8	12,9	10,9	9,4	8,4	7,5	6,8	6,2

Table 14.7.2 Maximum container weights of ISO 1496-1:1990 20 ft containers stowed in 40 ft cell guides with no overstow; Container's rated weight = 30,5 t

Lowest tier transverse acceleration (= a_y/g), *see* 8.2.5	Maximum homogeneous container weights, in tonnes									
	3 tiers	4 tiers	5 tiers	6 tiers	7 tiers	8 tiers	9 tiers	10 tiers	11 tiers	12 tiers
0,350	30,5	28,1	25,0	20,2	17,3	14,8	13,4	11,6	10,6	9,5
0,355	30,5	27,8	24,7	20,0	17,1	14,6	13,3	11,6	10,5	9,4
0,360	30,5	27,6	24,4	19,7	16,9	14,5	13,2	11,5	10,5	9,3
0,365	30,5	27,3	24,1	19,5	16,7	14,3	13,1	11,4	10,4	9,3
0,370	30,5	27,0	23,9	19,3	16,5	14,1	13,0	11,3	10,3	9,2
0,375	30,5	26,7	23,6	19,0	16,3	14,0	12,9	11,3	10,2	9,2
0,380	30,5	26,4	23,3	18,8	16,1	13,8	12,7	11,2	10,2	9,1
0,385	30,5	26,2	23,0	18,6	15,9	13,6	12,6	11,1	10,1	9,0
0,390	30,5	25,9	22,7	18,4	15,8	13,5	12,5	11,0	10,0	9,0
0,395	30,5	25,7	22,5	18,2	15,6	13,3	12,4	10,9	9,9	8,9
0,400	30,5	25,4	22,2	18,0	15,4	13,2	12,3	10,8	9,9	8,9
0,405	30,5	25,2	22,0	17,8	15,3	13,1	12,1	10,7	9,8	8,8
0,410	30,5	25,0	21,8	17,6	15,1	13,0	12,0	10,7	9,7	8,8
0,415	30,5	24,8	21,5	17,5	15,0	12,9	11,8	10,6	9,7	8,7
0,420	30,5	24,7	21,3	17,3	14,8	12,7	11,7	10,4	9,6	8,7
0,425	30,5	24,5	21,1	17,2	14,7	12,6	11,5	10,3	9,5	8,6
0,430	30,5	24,3	20,9	17,0	14,6	12,5	11,4	10,2	9,4	8,6
0,435	30,5	24,2	20,7	16,9	14,5	12,4	11,3	10,1	9,4	8,5
0,440	30,5	24,0	20,6	16,8	14,4	12,4	11,1	10,0	9,3	8,5
0,445	30,5	23,9	20,4	16,6	14,3	12,3	11,0	9,9	9,2	8,4
0,450	30,5	23,7	20,2	16,5	14,1	12,2	10,9	9,9	9,2	8,3
0,455	30,5	23,6	20,0	16,4	14,0	12,1	10,8	9,8	9,1	8,3
0,460	30,5	23,4	19,9	16,2	13,9	12,0	10,7	9,7	9,0	8,2
0,465	30,5	23,3	19,7	16,1	13,8	11,9	10,6	9,6	8,9	8,1
0,470	30,5	23,1	19,6	16,0	13,7	11,8	10,6	9,5	8,9	8,1
0,475	30,5	23,0	19,5	15,9	13,6	11,7	10,5	9,4	8,8	8,0
0,480	30,5	22,9	19,3	15,8	13,5	11,6	10,5	9,4	8,7	7,9
0,485	30,5	22,7	19,2	15,7	13,4	11,5	10,4	9,3	8,6	7,9
0,490	30,5	22,6	19,1	15,6	13,3	11,4	10,3	9,2	8,5	7,8
0,495	30,5	22,5	18,9	15,5	13,2	11,3	10,3	9,1	8,5	7,7
0,500	30,5	22,4	18,8	15,4	13,1	11,2	10,2	9,1	8,4	7,7
0,505	30,5	22,3	18,7	15,3	13,0	11,2	10,1	9,0	8,3	7,6
0,510	30,4	22,1	18,6	15,2	13,0	11,1	10,1	8,9	8,3	7,6
0,515	30,4	22,0	18,4	15,1	12,9	11,0	10,0	8,9	8,2	7,5
0,520	30,4	21,9	18,3	15,0	12,8	10,9	9,9	8,8	8,1	7,4
0,525	30,4	21,8	18,2	14,9	12,7	10,9	9,9	8,7	8,1	7,4
0,530	30,4	21,7	18,1	14,8	12,6	10,8	9,8	8,7	8,0	7,3
0,535	30,3	21,6	18,0	14,7	12,5	10,7	9,7	8,6	8,0	7,3
0,540	30,3	21,5	17,9	14,6	12,4	10,6	9,6	8,5	7,9	7,2
0,545	30,1	21,4	17,7	14,5	12,3	10,6	9,6	8,5	7,8	7,1
0,550	30,1	21,3	17,6	14,4	12,3	10,5	9,5	8,4	7,8	7,1
0,555	29,9	21,2	17,4	14,3	12,2	10,4	9,4	8,4	7,7	7,0
0,560	29,8	21,1	17,4	14,2	12,1	10,4	9,3	8,3	7,7	7,0
0,565	29,6	21,0	17,3	14,2	12,0	10,3	9,3	8,3	7,6	6,9
0,570	29,4	20,9	17,2	14,1	11,9	10,2	9,2	8,2	7,6	6,9
0,575	29,1	20,8	17,1	14,0	11,9	10,2	9,1	8,2	7,5	6,8
0,580	28,9	20,7	17,0	13,9	11,8	10,1	9,0	8,1	7,5	6,8
0,585	28,7	20,6	16,9	13,8	11,7	10,1	9,0	8,1	7,4	6,8
0,590	28,5	20,5	16,8	13,7	11,6	10,0	8,9	8,0	7,4	6,7
0,595	28,3	20,4	16,7	13,7	11,6	9,9	8,8	8,0	7,3	6,7
0,600	28,2	20,4	16,6	13,6	11,5	9,9	8,8	7,9	7,3	6,6
0,605	28,1	20,3	16,5	13,5	11,4	9,8	8,7	7,9	7,2	6,6
0,610	28,0	20,2	16,5	13,4	11,4	9,8	8,7	7,8	7,2	6,5
0,615	28,0	20,1	16,4	13,4	11,3	9,7	8,6	7,8	7,1	6,5
0,620	28,0	20,0	16,3	13,3	11,2	9,7	8,6	7,7	7,1	6,5
0,625	27,9	20,0	16,2	13,2	11,2	9,6	8,6	7,7	7,0	6,4
0,630	27,9	19,9	16,1	13,1	11,1	9,6	8,5	7,6	7,0	6,4
0,635	27,9	19,8	16,0	13,1	11,1	9,5	8,5	7,6	6,9	6,3
0,640	27,9	19,7	15,9	13,0	11,0	9,5	8,4	7,5	6,9	6,3
0,645	27,9	19,7	15,9	12,9	10,9	9,4	8,4	7,5	6,9	6,3
0,650	27,9	19,6	15,8	12,9	10,9	9,4	8,4	7,5	6,8	6,2

Table 14.7.3 Maximum container weights of ISO 1496-1:1990 20 ft containers stowed in 40 ft cell guides with overstow

Lowest tier transverse acceleration (= a_y/g), *see* 8.2.5	Maximum homogeneous container weights, in tonnes					
	3 tiers	4 tiers	5 tiers	6 tiers	7 tiers	8 tiers
0,400	24,0	24,0	24,0	19,6	17,1	15,2
0,405	24,0	24,0	23,6	19,4	17,0	15,1
0,410	24,0	24,0	23,3	19,2	16,8	14,9
0,415	24,0	24,0	22,9	19,1	16,7	14,8
0,420	24,0	24,0	22,5	18,9	16,5	14,7
0,425	24,0	24,0	22,1	18,8	16,4	14,5
0,430	24,0	24,0	21,8	18,6	16,2	14,4
0,435	24,0	24,0	21,5	18,4	16,1	14,3
0,440	24,0	24,0	21,2	18,3	15,9	14,1
0,445	24,0	24,0	21,0	18,1	15,8	14,0
0,450	24,0	24,0	20,8	18,0	15,7	13,9
0,455	24,0	24,0	20,6	17,8	15,5	13,7
0,460	24,0	24,0	20,5	17,7	15,4	13,6
0,465	24,0	24,0	20,3	17,5	15,2	13,5
0,470	24,0	24,0	20,2	17,3	15,1	13,3
0,475	24,0	24,0	20,1	17,2	14,9	13,2
0,480	24,0	23,9	19,9	17,0	14,8	13,1
0,485	24,0	23,8	19,8	16,9	14,6	12,9
0,490	24,0	23,6	19,6	16,7	14,5	12,8
0,495	24,0	23,4	19,4	16,5	14,3	12,7
0,500	24,0	23,2	19,3	16,4	14,2	12,5
0,505	24,0	23,1	19,1	16,2	14,1	12,4
0,510	24,0	22,9	18,9	16,1	13,9	12,2
0,515	24,0	22,7	18,8	15,9	13,8	12,1
0,520	24,0	22,5	18,6	15,7	13,6	12,0
0,525	24,0	22,4	18,5	15,6	13,5	11,8
0,530	24,0	22,3	18,3	15,4	13,3	11,7
0,535	24,0	22,2	18,2	15,3	13,2	11,6
0,540	24,0	22,1	18,1	15,1	13,0	11,4
0,545	24,0	22,0	18,0	15,0	12,9	11,3
0,550	24,0	21,8	17,9	14,8	12,8	11,2

NOTE
40ft overstow containers not included in the number of tiers.

■ *Section 8*
Determination of forces for container securing arrangements

8.1 General

8.1.1 The forces acting in the securing system are to be determined for each loading condition and associated set of motions of the ship. Although the operation of anti-roll devices or other systems may improve the behaviour of the ship in a seaway, the effect of such devices is not to be taken into account to reduce the determination of the forces for container securing arrangements.

8.1.2 The following forces are to be taken into account:
- Static gravity forces.
- Inertial forces generated by the ship motions in a seaway.
- Wind forces.
- Forces imposed by the securing arrangements.
- Wave impact forces and effects of consequential hull girder whipping.

8.1.3 Forces due to pre-tensioning the securing devices need not, in general, be included in the calculation, provided that they do not exceed 5 kN in any one item. Special consideration will be given to cases where forces obtained from pre-stressing are an integral part of the design of the system.

8.2 Ship motion, wind and green sea forces acting on containers

8.2.1 The forces acting on each container due to gravity, ship motion accelerations, ship rolling and pitching angles and wind forces and green sea forces are to be calculated as follows.

8.2.2 The ship motion amplitude and period for roll and pitch motions are given in Table 14.8.1. The equations for ship motion accelerations and other motion parameters are given in 1.5. These are to be used for the calculation of accelerations to derive the forces for the container securing arrangements. Alternatively, the ship motion values may be derived by direct calculation methods using the same principles as those used to derive the Rule equations.

Table 14.8.1 Ship motions

Motion	Maximum single amplitude, in degrees	Period, in seconds
Roll	$\phi = 55 f_{BK} f_{HsR} e^{(-0{,}025B)}$ ϕ is not to be taken less than f_{HsR} 22° but need not exceed 30°	$T_r = \dfrac{0{,}82B}{\sqrt{GM}}$
Pitch	$\psi = 1350 L^{-0{,}94} \left(1{,}0 + \left(\dfrac{0{,}82}{\sqrt{L}}\right)^{1{,}2}\right) f_{HsP}$ ψ need not exceed 8°	$T_p = 0{,}80\sqrt{C_1 L}$ where C_1 = 0,95 for MC1 = 0,52 for all other Motion Cases

8.2.3 The following six Motion Cases (MCs) are to be considered:

MC1: Head sea case that maximises vertical acceleration
MC2: Beam sea case that maximises roll motion
MC3: Oblique sea case that maximises pitch acceleration
MC4: Oblique sea case with forward speed that maximises roll motion
MC5: Oblique sea case that maximises combined transverse and vertical accelerations
MC6: Beam sea case that maximises heave acceleration

Each Motion Case comprises 2 or 4 Motion Combination Factor (MCF) sets representing an incoming wave crest or trough coming from either the port or starboard sides. Each MCF set represents an Equivalent Design Wave (EDW) that generates response values equivalent to the long-term response values of the critical load components for ship motion forces acting on containers. The Motion Combination Factors are given in Table 14.8.4.

8.2.4 The individual force components for each Motion Case due to gravity, ship motions, wind and green seas acting on a container *i* are to be determined as follows, *see* Figs. 14.1.1 and 14.9.1:

H_{Di} = force acting on container *i* in kN in transverse direction parallel to deck, positive to port
= $W a_y + H_{Gi}$

J_{Di} = force acting on container *i* in kN in longitudinal direction parallel to deck, positive forward
= $W a_x + J_{Gi}$

P_{Di} = upwards force acting on container *i* in kN normal to deck
= $W a_z + P_{Gi}$

Q_{Di} = wind force acting on exposed container *i* in kN in transverse direction parallel to deck
= $C_{wf}\, b\, c_i\, V_W^2 \cos^2 (C_{yG}\,\phi) \times 10^{-4}$

where

C_{wf} is given in Table 14.8.2 and C_{yG} is given in Table 14.8.4

NOTES

1. Q_{Di} is only to be applied when Q_{Di} will increase the transverse force H_{Di}.
2. When the green sea force H_{Gi} is also applicable, the wind force is only to be applied to container *i* when the wind force Q_{Di} is greater than the green sea force H_{Gi} acting on container *i*. In this case the wind force is to be reduced such that the total combined green sea and wind force is not greater than the originally calculated wind force.
3. *See also* 8.2.6 and 8.2.7.

H_{Gi} = green sea force acting on container *i*, in kN in transverse direction parallel to deck, positive to port
= $-b\, c_i\, P_{gs}$ for port side exposed containers
= $b\, c_i\, P_{gs}$ for starboard side exposed containers

J_{Gi} = green sea force acting on container *i*, in kN in longitudinal direction parallel to deck, positive forward
= $-a\, c_i\, P_{gs}$

P_{Gi} = green sea force acting on container *i*, in kN in the upwards direction normal to deck
= $1{,}5 a\, b$

where

P_{gs} = green sea pressure in kN/m^2, *see* 8.2.8 and 8.2.9.

Table 14.8.2 Wind force coefficient C_{wf}

Motion Case *see* Note 1	Wind force coefficient C_{wf}	
	Incoming wave from port (1P and 2P cases)	Incoming wave from starboard (1S and 2S cases)
	Only applied to the port exposed faces of containers, *see* Note 3	Only applied to the starboard exposed faces of containers, *see* Note 3
MC1, *see* Note 2	0	0
MC2	–8,25	8,25
MC3	–7,18	7,18
MC4	–7,18	7,18
MC5	–7,18	7,18
MC6	–8,25	8,25

NOTES
1. For definition of Motion Cases, *see* 8.2.3.
2. No wind loads are to be applied to Motion Case MC1.
3. For definition of exposed faces, *see* 8.2.7.

8.2.5 The total instantaneous acceleration values acting on container *i*, including the static gravitational term, are to be taken as:

- Longitudinal acceleration (parallel to deck, positive forward)

  $a_x = C_{xS}\, a_{surge} + C_{xP}\, a_{pitch}\, z_i - g \sin (C_{xG}\, \psi)$ m/s^2
- Transverse acceleration (parallel to deck, positive to port)

  $a_y = C_{yS}\, a_{sway} - C_{yR}\, a_{roll}\, z_i + g \sin (C_{yG}\, \phi)$ m/s^2
- Vertical acceleration (normal to deck, positive upwards)

  $a_z = C_{p1}\, (C_{zH}\, a_{heave} + C_{zR}\, a_{roll}\, y_i - f_{ap}\, C_{zP}\, a_{pitch}\, x_i\,) - g \cos (C_{xG}\, \psi) \cos (C_{yG}\, \phi)$ m/s^2

where the Motion Combination Factors C_{xS}, C_{xP}, C_{xG}, C_{yS}, C_{yR}, C_{yG}, C_{zH}, C_{zR} and C_{zP} for each Motion Case are given in Table 14.8.4.

8.2.6 Wind forces are generally to be based on a maximum wind speed, V_w, of 40 m/s. Only positive forces of wind pressure are to be applied; suction forces need not be included.

8.2.7 Wind forces are to be taken as acting athwartships on the exposed faces of the container stack. Where the air gap between adjacent rows of containers does not exceed one metre, wind forces on the adjacent inner stack may be taken as zero. Where the air gap is 5 m or more, the adjacent inner stack is to be treated as fully exposed. Wind forces on the inner stack for intermediate air gaps may be obtained by linear interpolation, *see* Fig. 14.8.1.

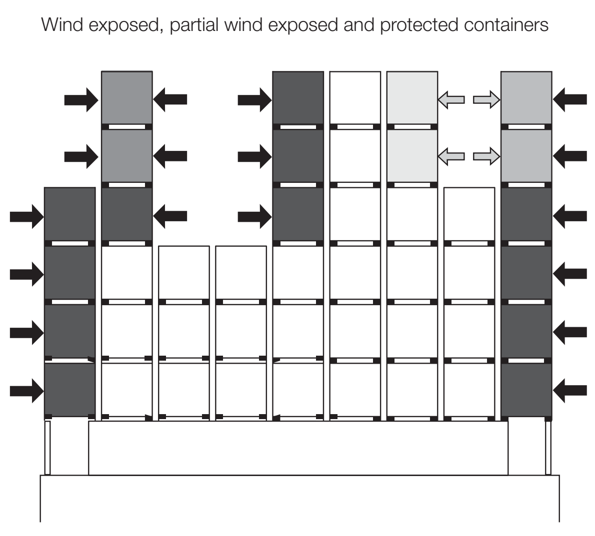


Fig. 14.8.1 Application of wind forces

8.2.8 The green sea force is to be applied as follows, *see* Fig 14.8.2:

- When the transverse force H_{Di} is acting inwards, the green sea force H_{Gi} is to be added to H_{Di} for each container in the lowest three tiers of the outermost two stack positions where $x_c > 0{,}75L$, unless they are protected by another container or effective wraparound breakwater or equivalent.
- When the longitudinal force J_{Di} is acting aftwards, the green sea force J_{Gi} is to be added to J_{Di} for each container in the lowest three tiers where $x_c > 0{,}75L$, unless the forward end of the container is protected by another container or effective breakwater or equivalent.
- When the vertical acceleration $a_z > -9{,}81$m/s^2 (less than g), the green sea force P_{Gi} is to be added to P_{Di} on the exposed underside of the lowest outboard container where $x_c > 0{,}75L$. The underside is considered exposed if it is raised above the hatch cover or deck by more than 0,5 m and not protected by an effective breakwater or equivalent.

NOTE

In general, Tier 1 position corresponds to lowest tier of containers sitting just above the deck and Tier 2 position corresponds to the lowest tier of containers sitting just above the hatch covers, *see* Fig. 14.8.2.

8.2.9 The green sea pressure is given by:

for L >100

$P_{gs} = C_{G1}\, L^2 + C_{G2}\, L + C_{G3}$ kN/m^2 but not less than 0

for $L \leq 100$, P_{gs} is to be taken as:

= 1,5 for Tier 1
= 1,0 for Tier 2
= 0,5 for Tier 3

where

C_{G1}, C_{G2}, C_{G3} are defined in Table 14.8.3

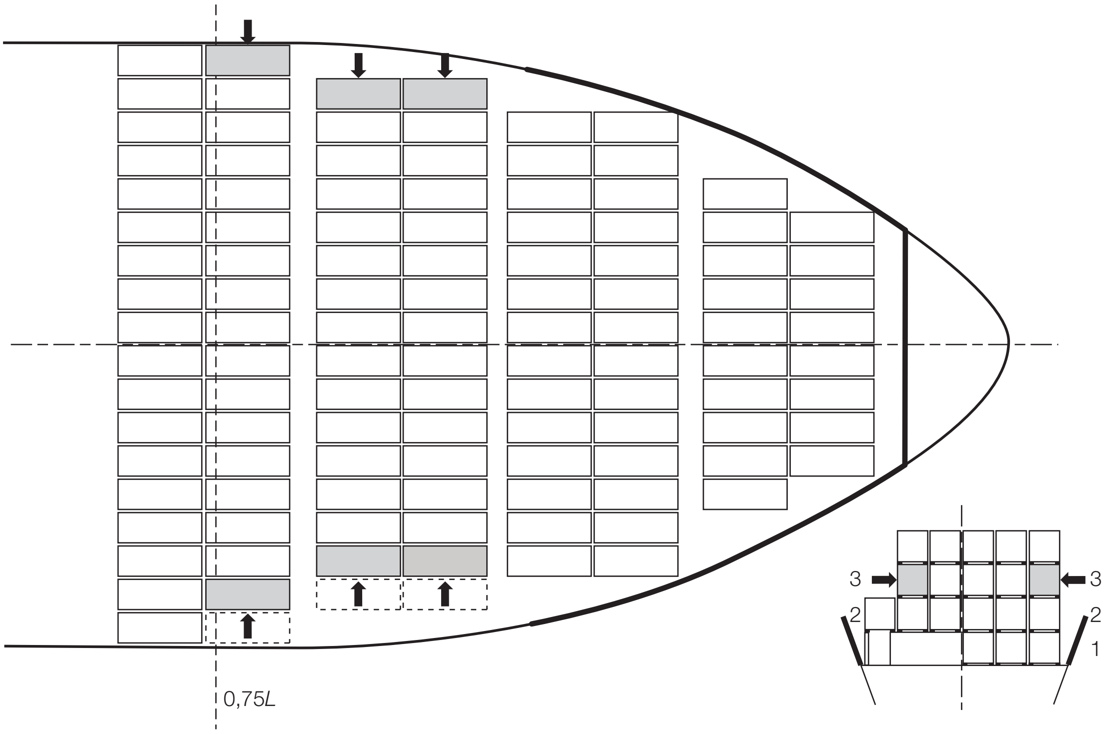
Proposals to use other values for green sea forces will be specially considered.

Table 14.8.3 Green sea pressure coefficients

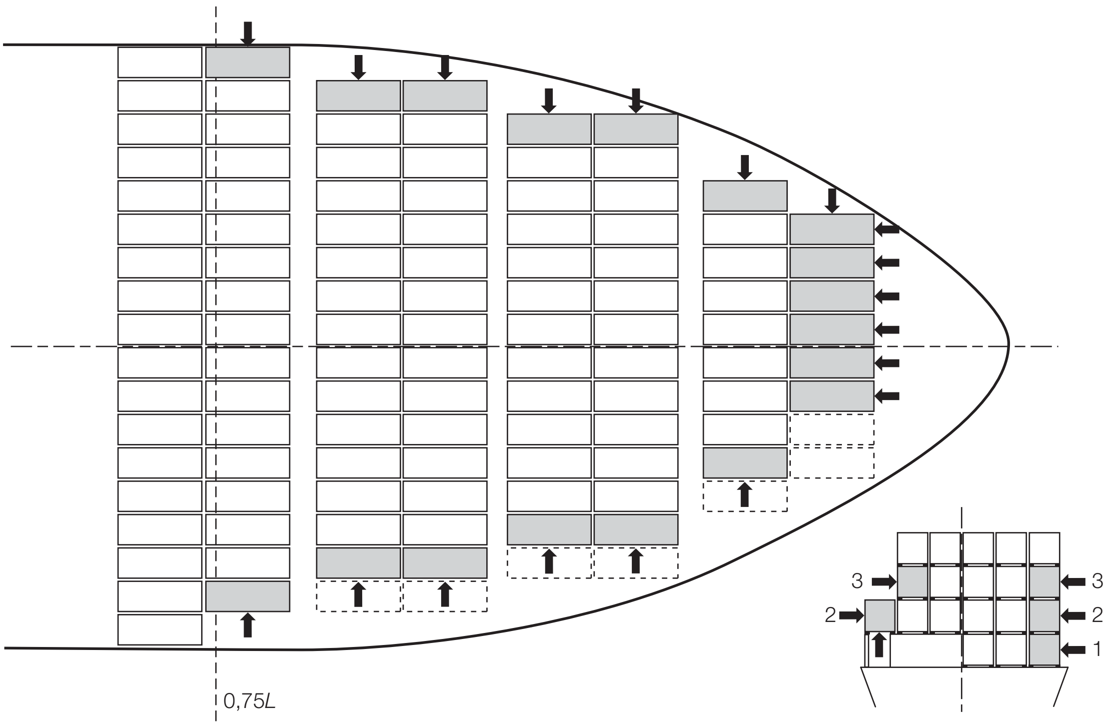
	C_{G1}	C_{G2}	C_{G3}
Tier 1	–0,000017	0,0035	1,32
Tier 2	–0,000020	0,0040	0,80
Tier 3	–0,000023	0,0045	0,28

Table 14.8.4 Motion Combination Factors (MCFs)

Motion Case	Heading	Incoming wave	MCF	Longitudinal acceleration			Transverse acceleration			Vertical acceleration		
				a-surge	*a*-pitch	*g**sinψ	*a*-sway	*a*-roll	*g**sinϕ	*a*-heave	*a*-roll	*a*-pitch
				C_{xS}	C_{xP}	C_{xG}	C_{yS}	C_{yR}	C_{yG}	C_{zH}	C_{zR}	C_{zP}
MC1	Head	From Bow	HS_1	–0,69	1,00	–0,85	0,00	0,00	0,00	–0,18	0,00	1,00
			HS_2	0,69	–1,00	0,85	0,00	0,00	0,00	0,18	0,00	–1,00
MC2	Beam	From PS	BS_1P	0,00	0,00	0,00	–0,09	0,66	–0,66	0,14	0,66	0,00
			BS_2P	0,00	0,00	0,00	0,09	–0,66	0,66	–0,14	–0,66	0,00
		From STB	BS_1S	0,00	0,00	0,00	0,09	–0,66	0,66	0,14	–0,66	0,00
			BS_2S	0,00	0,00	0,00	–0,09	0,66	–0,66	–0,14	0,66	0,00
MC3	Oblique	From PS	OS1_1P	–0,43	1,00	–0,86	–0,28	–0,22	0,05	–0,29	–0,22	1,00
			OS1_2P	0,43	–1,00	0,86	0,28	0,22	–0,05	0,29	0,22	–1,00
		From STB	OS1_1S	–0,43	1,00	–0,86	0,28	0,22	–0,05	–0,29	0,22	1,00
			OS1_2S	0,43	–1,00	0,86	–0,28	–0,22	0,05	0,29	–0,22	–1,00
MC4	Oblique	From PS	OS2_1P	0,00	0,00	0,00	–0,02	1,00	–1,00	0,00	1,00	0,00
			OS2_2P	0,00	0,00	0,00	0,02	–1,00	1,00	0,00	–1,00	0,00
		From STB	OS2_1S	0,00	0,00	0,00	0,02	–1,00	1,00	0,00	–1,00	0,00
			OS2_2S	0,00	0,00	0,00	–0,02	1,00	–1,00	0,00	1,00	0,00
MC5	Oblique	From PS	OS3_1P	0,62	–0,46	0,65	0,96	–0,36	0,12	0,11	–0,36	–0,46
			OS3_2P	–0,62	0,46	–0,65	–0,96	0,36	–0,12	–0,11	0,36	0,46
		From STB	OS3_1S	0,62	–0,46	0,65	–0,96	0,36	–0,12	0,11	0,36	–0,46
			OS3_2S	–0,62	0,46	–0,65	0,96	–0,36	0,12	–0,11	–0,36	0,46
MC6	Beam	From PS	BS2_1P	–0,07	–0,05	0,02	0,62	0,12	–0,01	1,00	0,12	–0,05
			BS2_2P	0,07	0,05	–0,02	–0,62	–0,12	0,01	–1,00	–0,12	0,05
		From STB	BS2_1S	–0,07	–0,05	0,02	–0,62	–0,12	0,01	1,00	–0,12	–0,05
			BS2_2S	0,07	0,05	–0,02	0,62	0,12	–0,01	–1,00	0,12	0,05



(a) Green sea loading on lowest three tiers only – Effective breakwaters (Forward and wrap around)



(b) Green sea loading on lowest three tiers only – No effective breakwater

Fig. 14.8.2 Example of application of green sea forces

Section 9
Strength of container securing arrangements

9.1 General

9.1.1 The securing system is to be designed on the basis of the most severe combination of the forces specified in Section 8 in such a manner that the resultant forces on the containers and securing devices are within allowable limits. Where different arrangements of securing devices are proposed for different locations on the ship, the forces are to be calculated for the most severe condition applicable to each arrangement.

9.1.2 The resultant forces in the containers are not to exceed the allowable values given in 9.6.

9.1.3 The resultant forces in the securing devices and supports are not to exceed the allowable working loads for which the device has been approved, *see* Sections 2 and 3.

9.1.4 The forces in lashing devices, where fitted, are not to exceed the allowable safe working loads (SWLs) of the lashings as determined from Section 3.

9.2 Applied forces to each container

9.2.1 The applied forces due to ship motion and environmental loads acting on each container in the stack in accordance with Section 8 are illustrated in Fig.14.9.1 and are assumed to be divided equally between the walls of the container, as follows:

H_i = transverse force on each end wall = $\dfrac{H_{Di}}{2}$ kN

J_i = longitudinal force on each side wall = $\dfrac{J_{Di}}{2}$ kN

P_i = vertical downwards force at the bottom of each corner post = $\dfrac{-P_{Di}}{4}$ kN

Q_i = wind force on each end wall = $\dfrac{Q_{Di}}{2}$ kN

The subscript i refers to any particular container.

9.2.2 Forces H_i and J_i are assumed to act at one third of the height of the container above its base. These forces are distributed as follows:

$\dfrac{H_i}{3}\left(\text{or } \dfrac{J_i}{3}\right)$ acting at the top of the container, and

$\dfrac{2H_i}{3}\left(\text{or } \dfrac{2J_i}{3}\right)$ acting at the bottom.

9.2.3 Wind force is assumed to be uniformly distributed over the side of the container and is therefore divided equally between the top and bottom of the container.

9.3 Total resulting forces in an unlashed stack

9.3.1 Where the stack is supported only by approved devices between the tiers of containers and at the base of the stack, the total forces in the stack are determined from Table 14.9.1. Fig.14.9.1 illustrates the applied forces acting on each container and the resulting total forces.

9.3.2 For exposed stacks forward of 0,75L, *see* 8.1.4.

9.3.3 To illustrate this calculation, the equations for calculation of the transverse forces only for the three-tier stack shown in Fig. 14.9.1 are listed below. For simplicity, the equations below do not include the longitudinal forces. The complete method to combine longitudinal and transverse forces for an unlashed stack is given in Table 14.9.1.

(a) Transverse racking force in each end wall:

Tier 3: $RA_{y3} = F_3$

Tier 2: $RA_{y2} = F_3 + F_2$

Tier 1: $RA_{y1} = F_3 + F_2 + F_1$

(b) Transverse shear force at each bottom corner fitting:

Tier 3: $SF_{y3} = 0{,}55\,(H_3 + Q_3)$

Tier 2: $SF_{y2} = 0{,}55\,(H_3 + H_2 + Q_3 + Q_2)$

Tier 1: $SF_{y1} = 0{,}55\,(H_3 + H_2 + H_1 + Q_3 + Q_2 + Q_1)$

(c) Compressive force at bottom of each port side corner post (i.e., force on the container below):

Tier 3: $V_{p3} = P_3 + \dfrac{F_3}{a}(c_3 + d_3)$

Tier 2: $V_{p2} = P_3 + P_2 + \dfrac{F_3}{a}(c_3 + c_2 + d_3 + d_2) + \dfrac{F_2}{a}(c_2 + d_2)$

Tier 1: $V_{p1} = P_3 + P_2 + P_1 + \dfrac{F_3}{a}(c_3 + c_2 + c_1 + d_3 + d_2 + d_1) + \dfrac{F_2}{a}(c_2 + c_1 + d_2 + d_1) + \dfrac{F_1}{a}(c_1 + d_1)$

(d) Compressive force at bottom of each starboard side corner post (i.e., force on the container below):

Tier 3: $V_{s3} = P_3 - \dfrac{F_3}{a}(c_3 + d_3)$

Tier 2: $V_{s2} = P_3 + P_2 - \dfrac{F_3}{a}(c_3 + c_2 + d_3 + d_2) - \dfrac{F_2}{a}(c_2 + d_2)$

Tier 1: $V_{s1} = P_3 + P_2 + P_1 - \dfrac{F_3}{a}(c_3 + c_2 + c_1 + d_3 + d_2 + d_1) - \dfrac{F_2}{a}(c_2 + c_1 + d_2 + d_1) - \dfrac{F_1}{a}(c_1 + d_1)$

A negative value in equations (c) and (d) indicates a separation force at that level.

Table 14.9.1 Total resulting forces in each end/side wall of an unlashed stack

Force	Equations for an unlashed stack
(a) Racking force in end/side wall of container *i*	
Transverse	$RA_{yi} = \sum_{j=i}^{N} F_j$ kN where the transverse force at level *j* is given by $F_j = \frac{2H_{(j+1)}}{3} + \frac{H_j}{3} + \frac{Q_{(j+1)}}{2} + \frac{Q_j}{2}$ kN for $j < N$ and $F_j = \frac{H_j}{3} + \frac{Q_j}{2}$ kN for $j = N$
Longitudinal	$RA_{xi} = \sum_{j=i}^{N} G_j$ kN where the longitudinal force at level *j* is given by $G_j = \frac{2J_{(j+1)}}{3} + \frac{J_j}{3}$ kN for $j < N$ and $G_j = \frac{J_j}{3}$ kN for $j = N$
(b) Shear force acting at bottom corner device of container *i*	
Transverse	$SF_{yi} = 0{,}55 \sum_{j=i}^{N} (H_j + Q_j)$ kN
Longitudinal	$SF_{xi} = 0{,}55 \sum_{j=i}^{N} J_j$ kN
Total shear force	$SF_i = \sqrt{SF_{xi}^2 + SF_{yi}^2}$ kN
(c) Compressive force in each corner post of container *i*	
Port fwd	$V_{pfi} = \sum_{j=i}^{N} P_j + \frac{1}{a} \sum_{j=i}^{N} F_j h_{ij} + \frac{1}{b} \sum_{j=i}^{N} G_j h_{ij}$ kN
Port aft	$V_{pai} = \sum_{j=i}^{N} P_j + \frac{1}{a} \sum_{j=i}^{N} F_j h_{ij} - \frac{1}{b} \sum_{j=i}^{N} G_j h_{ij}$ kN
Starboard fwd	$V_{sfi} = \sum_{j=i}^{N} P_j - \frac{1}{a} \sum_{j=i}^{N} F_j h_{ij} + \frac{1}{b} \sum_{j=i}^{N} G_j h_{ij}$ kN
Starboard aft	$V_{sai} = \sum_{j=i}^{N} P_j - \frac{1}{a} \sum_{j=i}^{N} F_j h_{ij} - \frac{1}{b} \sum_{j=i}^{N} G_j h_{ij}$ kN
Symbols	
h_{ij} is the height from the bottom of the fitting (e.g., twistlock) below corner post *i* to the top of container *j*, in metres $h_{ij} = \sum_{k=i}^{J} (c_k + d_k)$ N is the total numbers of tiers Q_j is only applied to the exposed container faces	

9.3.4 The transverse displacements of the container stack are to be calculated as follows. The displacement of the top corner of container *i* under the actions of the applied forces is given by:

$$\delta_{yi} = \sum_{j=1}^{i} \left(\frac{RA_{yj}}{k_{cy}}\right) \text{ mm}$$

δ_{yi} is to be calculated for each end wall of the container

where

RA_{yi} = transverse racking force in end wall of container *i*, *see also* Table 14.9.1

$$= \sum_{j=1}^{N} F_j \text{ kN}$$

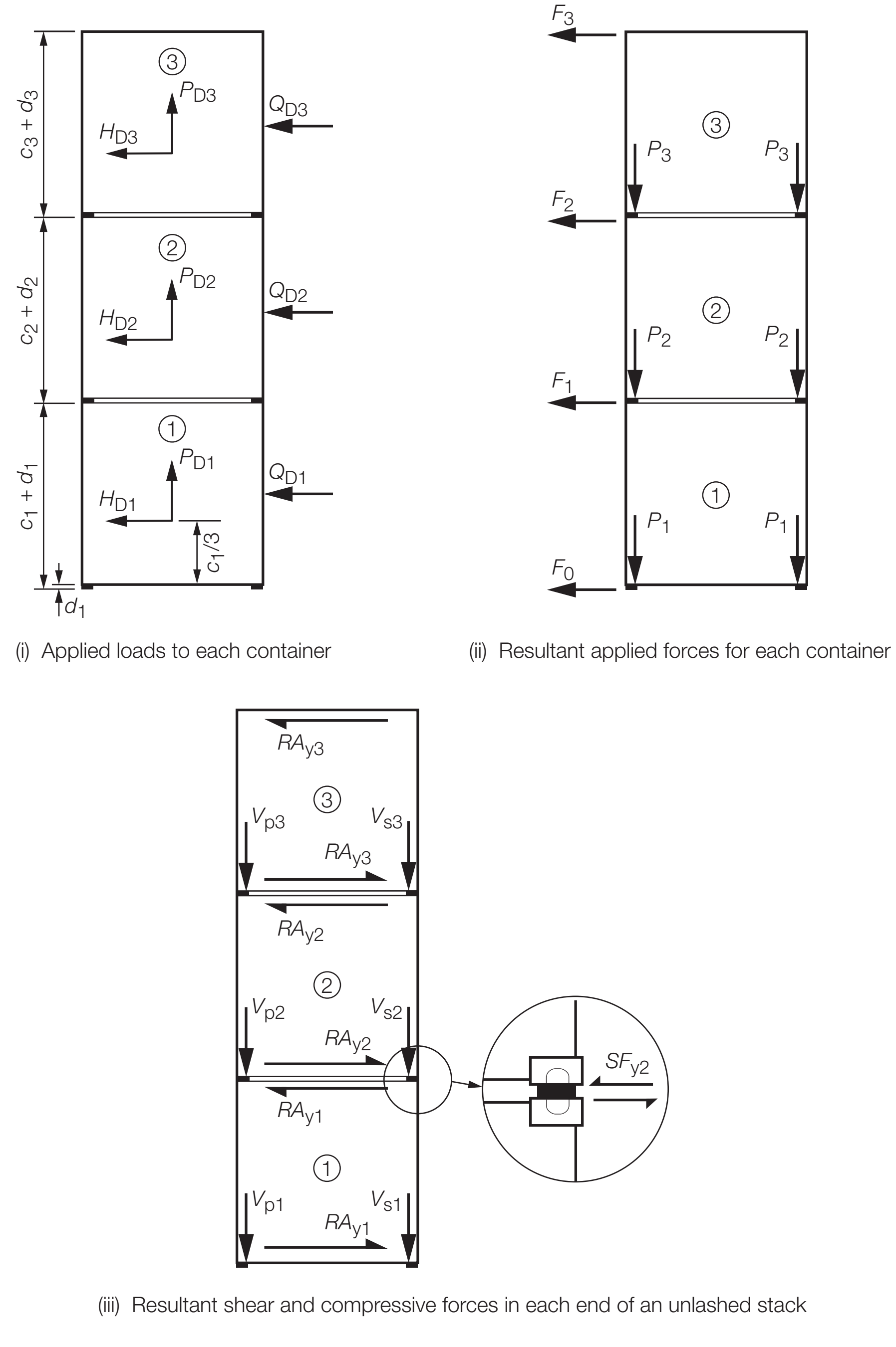


Fig. 14.9.1 Force derivation at one end of a three-tier stack

k_{cy} = shear spring stiffness of the end wall being considered, *see* Table 14.9.2.

Table 14.9.2 Shear spring stiffness of container walls

Container height, metres		Door end kN/mm	Closed end kN/mm	Side wall kN/mm
2,438	(8 ft)	3,7	16,7	6,1
2,591	(8 ft 6 in)	3,5	15,4	5,7
2,743	(9 ft)	3,3	14,3	5,4
2,896	(9 ft 6 in)	3,2	13,3	5,1

9.3.5 The longitudinal displacements of the container stack are to be calculated as follows. The displacement of the top corner of container *i* under the actions of the applied forces is given by:

$$\delta_{xi} = \sum_{j=1}^{i} \left(\frac{RA_{xj}}{k_{cx}} \right) \text{ mm}$$

δ_{xi} is to be calculated for each side wall of the container.

9.4 Total resulting forces in a stack incorporating lashings

9.4.1 Where the securing arrangements incorporate lashings, proper allowance is to be made for flexibility of the system. For this purpose, the following values may be adopted:

(a) **Racking deformation of the container**. Full scale testing of containers indicates that values of the shear spring stiffness constant (*see* Fig. 14.9.2) may be taken as in Table 14.9.2.

(b) **Horizontal movement of the containers**. Initial displacement of containers due to tolerances in container fittings will be considered in conjunction with the stowage arrangement proposed. Generally, initial displacement may be neglected in calculation procedures for conventional stowages.

(c) **Elongation of the lashings**. Elongation may be determined by reference to an effective cross-sectional area of lashing device and an effective modulus of elasticity of the lashing (allowance for straightening and stretching), which in the absence of actual test values may be taken as specified in Table 14.9.3.

Table 14.9.3 Effective modulus of elasticity of lashing devices

Lashing equipment	Effective modulus of elasticity (E_r) *see* 9.5.2
Steel rod lashings of hook type, including turnbuckle	98 kN/mm^2
Short (one tier) steel rod lashings (knob type), including turnbuckle and lashing eyes	140 kN/mm^2
Long (two tier) steel rod lashings (knob type), including turnbuckle and lashing eyes	175 kN/mm^2
Steel wire rope lashings	90 kN/mm^2
Steel chain lashings (based on the nominal diameter of the chain)	80 kN/mm^2
Adjustable tension/compression buttress	120 kN/mm^2
Aluminium or other materials	To be specially considered

9.4.2 Any other element introducing flexibility into the structure between the lashing point and the base of the container stack is to be evaluated and taken into account, if necessary. Examples of this could be flexibility of a lashing bridge, sliding of a hatch cover or torsional deformations of the hull.

9.4.3 The following lashing devices may be used:

- A shore device or similar that only accepts compressive loads, *see* 6.1.7. This may be modelled in a similar way to a lashing rod. However, where more than one stack is supported by the use of linkages between adjacent containers in line with the shore, the calculation model is to take this into account.
- A lashing bridge to allow lashing devices to be arranged high up in the container stack. Where open framework systems are fitted on deck to provide structural restraint, they are to be designed to absorb the full horizontal component of force at that level and to prevent movement of the container stack. For the purpose of these calculations, the deformation of the ship's structure in way of supports may be neglected.
- A buttress connection or tension/compression device that accepts compressive and tensile forces, *see* 6.1.6. These are normally used for hold stowage. Where more than one stack is supported by the use of linkages between adjacent containers in line with the buttress, the calculation model is to take this into account.

9.4.4 The applied forces due to ship motion and environmental loads on containers in the stack are to be determined in accordance with 9.2.

9.4.5 The tensile or compressive forces in lashing devices supporting the container stack are to be determined in accordance with 9.5.

9.4.6 The load system for a four-tier stack of containers with transverse upper and lower lashings is illustrated in Fig. 14.9.2. The containers and lashings are modelled as a system of springs whose stiffness may be calculated and hence the equilibrium condition for the system may be found, *see* Fig. 14.9.2(iii).

9.4.7 The calculations are to be made for each end of the container stack, that is, with all door ends together and with all closed ends together, and also for each side wall.

9.4.8 The transverse displacements of the container stack are to be calculated as follows. The displacement of the top corner of container *i* under the actions of the applied forces and supporting lashing devices is given by:

$$\delta_{yi} = \sum_{j=1}^{i} \left(\frac{RA_{yj}}{k_{cy}} \right) \text{ mm}$$

δ_{yi} is to be calculated for each end wall of the container, taking into account lashing devices attached to the top corner of container *i* and the bottom corner of container (*i* + 1)

where

RA_{yi} = transverse racking force in end wall of container *i*, taking into account lashing rods and otherlashing devices attached to the top corner of container *i* and above attached to the end wall being considered, *see also* Table 14.9.4

$$= \sum_{j=i}^{N} F_j + \sum_{r=1}^{R} TL_{yr} \text{ kN}$$

k_{cy} = shear spring stiffness of the end wall being considered, *see* Table 14.9.2

TL_{yr} = force in lashing device *r*, measured in the transverse direction, *see* 9.5.

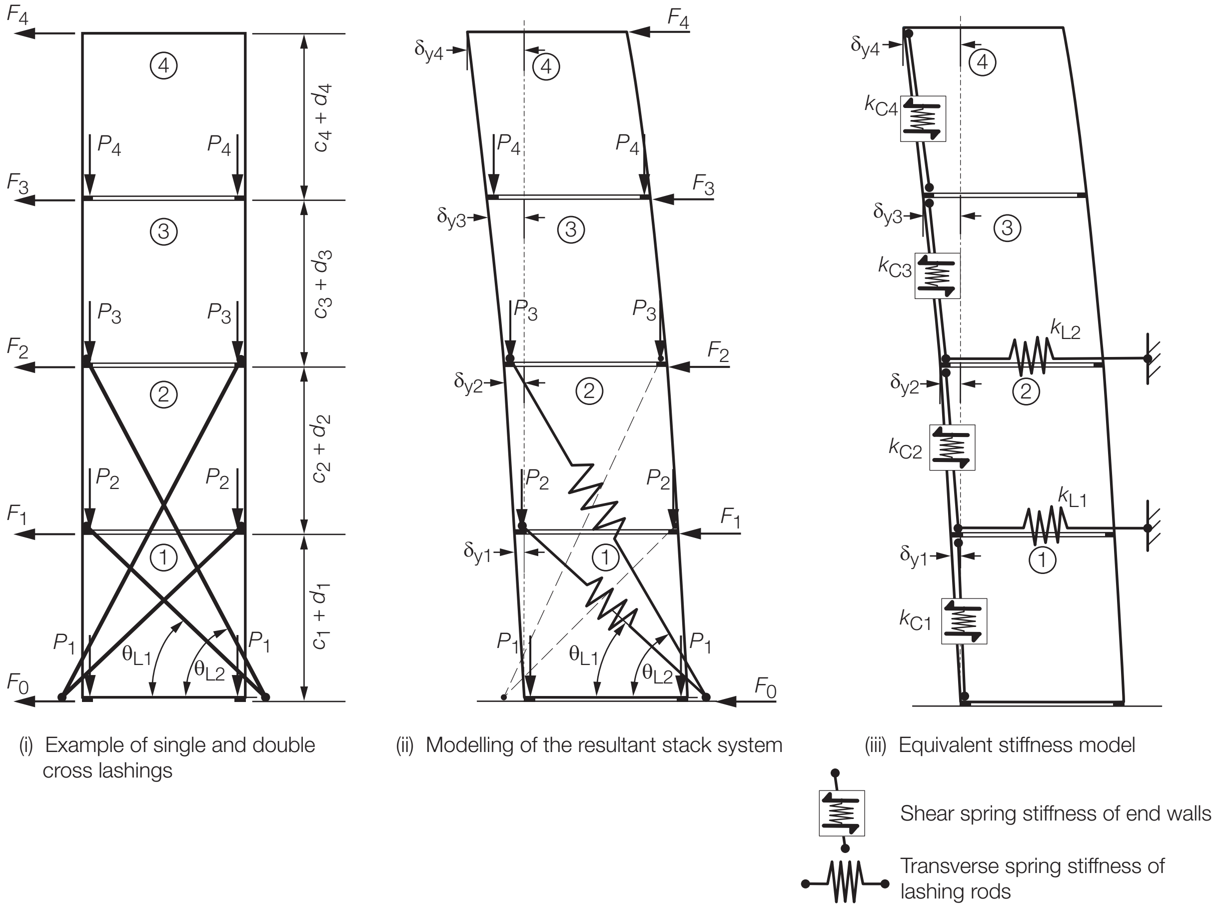


Fig. 14.9.2 Example of lashings at one end of a four-tier stack

9.4.9 The longitudinal displacements of the container stack are to be calculated as follows. The displacement of the top corner of container *i* under the actions of the applied forces and supporting lashing devices is given by:

$$\delta_{xi} = \sum_{j=1}^{i} \left(\frac{RA_{xj}}{k_{cx}}\right) \text{ mm}$$

δ_{xi} is to be calculated for each side wall of the container, taking into account lashing devices attached to the top corner of container *i* and the bottom corner of container (*i* + 1).

9.4.10 The final distribution of forces in the stack is to be obtained by equating the total transverse displacements of the container stack δ_{yi} due to the applied loads with the transverse elongations in the attached lashing devices ε_{Lyr}. This is illustrated in Fig. 14.9.2. Hence, at each lashing device, the following equation is to be satisfied:

$$\delta_{yi} = \varepsilon_{Lyr} \text{ mm}$$

where

ε_{Lyr} = elongation or strain in the transverse direction in the lashing device, in mm.

9.4.11 The equations for deriving the total forces in the stack with lashings are given in Table 14.9.4. The final distribution of forces in a stack can also be solved using matrix methods.

9.4.12 Similar calculations are to be applied in the longitudinal direction if any lashing device will resist longitudinal forces. For such lashings, the fixed lashing plates are to be suitably arranged to accommodate the additional forces due to the fore and aft inclination of the lashing rods. In addition, the design of the lashing rod head should be suitable for the angle of inclination of the lashing rod.

9.4.13 The above stiffness model assumes that the securing devices between tiers of containers are capable of resisting negative (separation) forces. That is, where separation forces are found, suitable locking devices are assumed to be fitted and transmitting load. When this is not the case, special consideration of the vertical displacements of the corners and forces in the lashing devices is necessary.

Table 14.9.4 **Total resulting forces in each end/side wall of a lashed stack**

Force	Equations for lashed stack
(a) Racking force in end/side wall of container *i* Taking into account lashing rods and other lashing devices attached to the top corner of container *i* and above	
Transverse	$RA_{yi} = \sum_{j=i}^{N} F_j + \sum_{r=1}^{R} TL_{yr}$ kN To be evaluated for each end wall of the container taking into account lashing devices attached to the wall being considered
Longitudinal	$RA_{xi} = \sum_{j=i}^{N} G_j + \sum_{r=1}^{R} TL_{xr}$ kN To be evaluated for each side wall of the container taking into account lashing devices attached to the wall being considered
(b) Shear force acting at bottom corner device (or similar) of container *i* Taking into account lashing rods and other lashing devices attached to the bottom corner of container *i* and above	
Transverse	$SF_{yi} = 0{,}55 \sum_{j=i}^{N} (H_j + Q_j) + 0{,}55 \sum_{r=1}^{R} TL_{yr}$ kN To be evaluated for each end wall of the container, taking into account lashing devices attached to the wall being considered
Longitudinal	$SF_{xi} = 0{,}55 \sum_{j=i}^{N} (J_j) + 0{,}55 \sum_{r=1}^{R} TL_{xr}$ kN To be evaluated for each side wall of the container, taking into account lashing devices attached to the wall being considered
Total shear force	$SF_i = \sqrt{SF_{xi}^2 + SF_{yi}^2}$ kN To be evaluated for each corner
(c) Compressive force in each corner post of container *i* Taking into account lashing rods and other lashing devices attached to the top corner of container *i* and above. The lashing device forces appropriate to the wall and corner are to be taken into account	
Port fwd	$V_{pfi} = \sum_{j=i}^{N} P_j + \frac{1}{a} \sum_{j=i}^{N} F_j h_{ij} + \frac{1}{b} \sum_{j=i}^{N} G_j h_{ij} + \sum_{r=1}^{R} TL_r \sin\theta_{Lr} + \frac{1}{a} \sum_{r=1}^{R} TL_{yr} h_{ir} + \frac{1}{b} \sum_{r=1}^{R} TL_{xr} h_{ir}$ kN
Port aft	$V_{pai} = \sum_{j=i}^{N} P_j + \frac{1}{a} \sum_{j=i}^{N} F_j h_{ij} - \frac{1}{b} \sum_{j=i}^{N} G_j h_{ij} + \sum_{r=1}^{R} TL_r \sin\theta_{Lr} + \frac{1}{a} \sum_{r=1}^{R} TL_{yr} h_{ir} - \frac{1}{b} \sum_{r=1}^{R} TL_{xr} h_{ir}$ kN
Starboard fwd	$V_{sfi} = \sum_{j=i}^{N} P_j - \frac{1}{a} \sum_{j=i}^{N} F_j h_{ij} + \frac{1}{b} \sum_{j=i}^{N} G_j h_{ij} + \sum_{r=1}^{R} TL_r \sin\theta_{Lr} - \frac{1}{a} \sum_{r=1}^{R} TL_{yr} h_{ir} + \frac{1}{b} \sum_{r=1}^{R} TL_{xr} h_{ir}$ kN
Starboard aft	$V_{sai} = \sum_{j=i}^{N} P_j - \frac{1}{a} \sum_{j=i}^{N} F_j h_{ij} - \frac{1}{b} \sum_{j=i}^{N} G_j h_{ij} + \sum_{r=1}^{R} TL_r \sin\theta_{Lr} - \frac{1}{a} \sum_{r=1}^{R} TL_{yr} h_{ir} - \frac{1}{b} \sum_{r=1}^{R} TL_{xr} h_{ir}$ kN
(d) Compressive/lifting force at the bottom fitting of each corner post of container *i* Taking into account lashing rods and other lashing devices attached to the bottom corner of container *i* and above. The lashing device forces appropriate to the wall and corner are to be taken into account. The equations for the 'Compressive force in each corner post' are applied except that the lashing rods attached to the bottom of the container are included. This only affects the $\sum_{r=1}^{R} TL_r \sin\theta_{Lr}$ term	
Symbols	
h_{ir} is the height from the bottom of the lower corner device of container *i* to lashing point *r*, in metres R is the total number of lashing devices Q_j is only applied to the exposed container faces	

9.5 Forces in the lashing devices

9.5.1 The tensile or compressive force in a lashing device is given by:

$TL_r = \varepsilon_{Lr} k_{Lr}$ kN

The lashing device force in the positive transverse direction (i.e., positive to port) is given by:

$TL_{yr} = \varepsilon_{Lr} k_{Lr} \cos\theta_{Lr} \sin\theta_{Lxyr}$ kN

The lashing device force in the positive longitudinal direction (i.e., positive forwards) is given by:

$TL_{xr} = \varepsilon_{Lr} k_{Lr} \cos\theta_{Lr} \sin\theta_{Lxyr}$ kN

where

k_{Lr} = stiffness of lashing rod or device *r*, in kN/mm, *see* 9.4.1.

9.5.2 The stiffness of a lashing rod may be derived as follows:

$$k_{Lr} = \frac{E_r A_r}{l_r} \text{ kN/mm}$$

if E_r and A_r are specified otherwise k_{Lr} may be directly specified

E_r = effective modulus of elasticity, *see* Table 14.9.3

A_r = cross-sectional area of lashing device

For a para-lash arrangement, where two lashing devices are modelled as a single device, the effective area is to be taken as 1,5 times the area of one device. If each device in a para-lash arrangement is modelled, the effective area for each device is to be taken as 0,75 times the area of the single device.

ε_{Lr} = total elongation, in mm, of lashing rod or device *r*

$$\varepsilon_{Lr} = \sqrt{(l_x - \delta_{xib})^2 + (l_y - \delta_{yib})^2 + (l_z + \delta_{zib})^2} - l_r$$

$\varepsilon_{Lr} \geq 0$ for a lashing rod device

$\varepsilon_{Lr} \leq 0$ for a shore device (compression-only device), *see* 6.1.7

ε_{Lr} can be negative or positive for a buttress lashing connection or tension/compression lashing device, *see* 6.1.6

i_b = $i - 1$ if lashing device is connected to the bottom of the container

i_b = i if lashing device is connected to the top of the container

l_x = longitudinal distance of lashing foundation from container corner fitting, in mm, positive forward

l_y = transverse distance of lashing foundation from container corner fitting, in mm, positive to port

l_z = vertical separation of lashing foundation from container corner fitting, in mm, positive downwards

l_r = length of lashing rod or device, in mm

$$= \sqrt{(l_x)^2 + (l_y)^2 + (l_z)^2}$$

δ_{xi} = total longitudinal racking deflection of the top corner of container *i*, in mm

δ_{yi} = total transverse racking deflection of the corner of container *i*, in mm

δ_{zi} = total vertical displacement of the bottom corner of container *i*, in mm

θ_{Lr} = angle of the lashing rod *r* in the vertical plane

$$\theta_{Lr} = \tan^{-1}\left(\frac{l_z}{\sqrt{l_x^2 + l_y^2}}\right) \text{ degrees}$$

NOTE

θ_{Lr} is 90° when l_x and l_y are both zero

θ_{Lxyr} = angle of the lashing rod *r* in the xy plane (projection onto the horizontal plane)

$$= \tan^{-1}\left(\frac{l_y}{l_x}\right) \text{ degrees}$$

Use the atan2 function to maintain sign of angle. θ_{Lxyr} is 0° when l_x is positive and l_y is zero, θ_{Lxyr} is +90° when l_x is 0 and l_y is positive, θ_{Lxyr} is –90° when l_x is 0 and l_y is negative.

9.5.3 Where external support is provided by a buttress or shore, the load is to be transmitted between adjacent stacks by linkages in line with the support. The force in the transverse end wall members of the containers adjacent to the support is given by:

$F_b\left(\frac{2N-1}{2N}\right)$ kN and the force in the linkage to the adjacent container is $F_b\left(\frac{N-1}{N}\right)$ kN

where

F_b = calculated force in the buttress or shore, in kN

N = number of rows of containers supported by the buttress or shore.

9.6 Allowable forces on containers

9.6.1 For ISO containers, the securing arrangements are to be designed so that the forces on the containers do not exceed the values shown in Table 14.9.5. The maximum forces for ISO 1496-1: 1990 including Amendment Nos. 1, 2 and 3 containers are illustrated in Fig. 14.9.3. Proposals to carry out the lashing calculations for containers manufactured in accordance with ISO 1496-1:1990/Amendment No. 4, 2006 will be specially considered.

9.6.2 The allowable forces for containers of other dimensions, e.g., 24 ft, 48 ft and 53 ft, will be determined on the basis of the values in Table 14.9.5 and of the forces for which the container has been certified.

9.6.3 Where 45 ft containers in accordance with ISO 1496-1:1990/Amendment No. 4, 2006 are stowed on top of a 40 ft container, the corner post load of the top castings of the 45 ft container is not to exceed a compression force of 404 kN. Consideration should be given to the strength of the container bottom structure to withstand the forces transmitted. No lashings are to be applied to the ends of the 45 ft container if stowed on top of a 40 ft unit.

Table 14.9.5 Allowable forces on ISO containers

	ISO 1496-1:1990 including up to Amendment No. 3 20ft	40ft
	in kN	
Horizontal force from a container fitting acting parallel to the side face	150	150
Horizontal force from lashing on container fitting acting parallel to the end face, *see* Note 1	225	225
Vertical force from lashing on container fitting acting parallel to the end or side face, *see* Note 1	250	250
Racking force on container end	150	150
Racking force on container side	150	150
Vertical forces at each top corner, tension	250	250
Vertical forces at each bottom corner, tension	250	250
Vertical forces at each top corner post, compression	848	848
Vertical forces at each bottom corner casting of the lowest container in a stack, compression	848 + (1,8Rg/4) *see* Note 3	848 + (1,8Rg/4) *see* Note 3
Transverse forces acting at the level of and parallel to the top face, tension or compression, *see* Note 2	340	340
Transverse forces acting at the level of and parallel to the bottom face, tension or compression, see Note 2	500	500

NOTES
1. In no case is the resultant of the horizontal and the vertical forces to exceed the limiting values derived from Fig. 14.9.3(a).The horizontal and vertical forces are the maximum components of a diagonal force and are not to be used as the maximum load if horizontal or vertical lashings are employed.
2. Where a buttress supports the stack at an intermediate level, the total transverse force in the containers at the level is not to exceed the sum of the appropriate top and bottom forces.
3. The vertical compression force on the lower corner casting on the closed end of the lowest container may exceed 848 + (1,8Rg/4) kN, provided the following conditions are complied with:
   (a) The vertical compression force acting on the lowest container from the container above does not exceed 848 kN.
   (b) The horizontal racking force acting on the lowest container from the container above does not exceed 150 kN.
   (c) The local ship side or hatch cover container foundation is designed and approved for the increased design compression force.
   (d) The loose bottom container securing fittings should have a contact area fulfilling the requirements of 3.2.5.

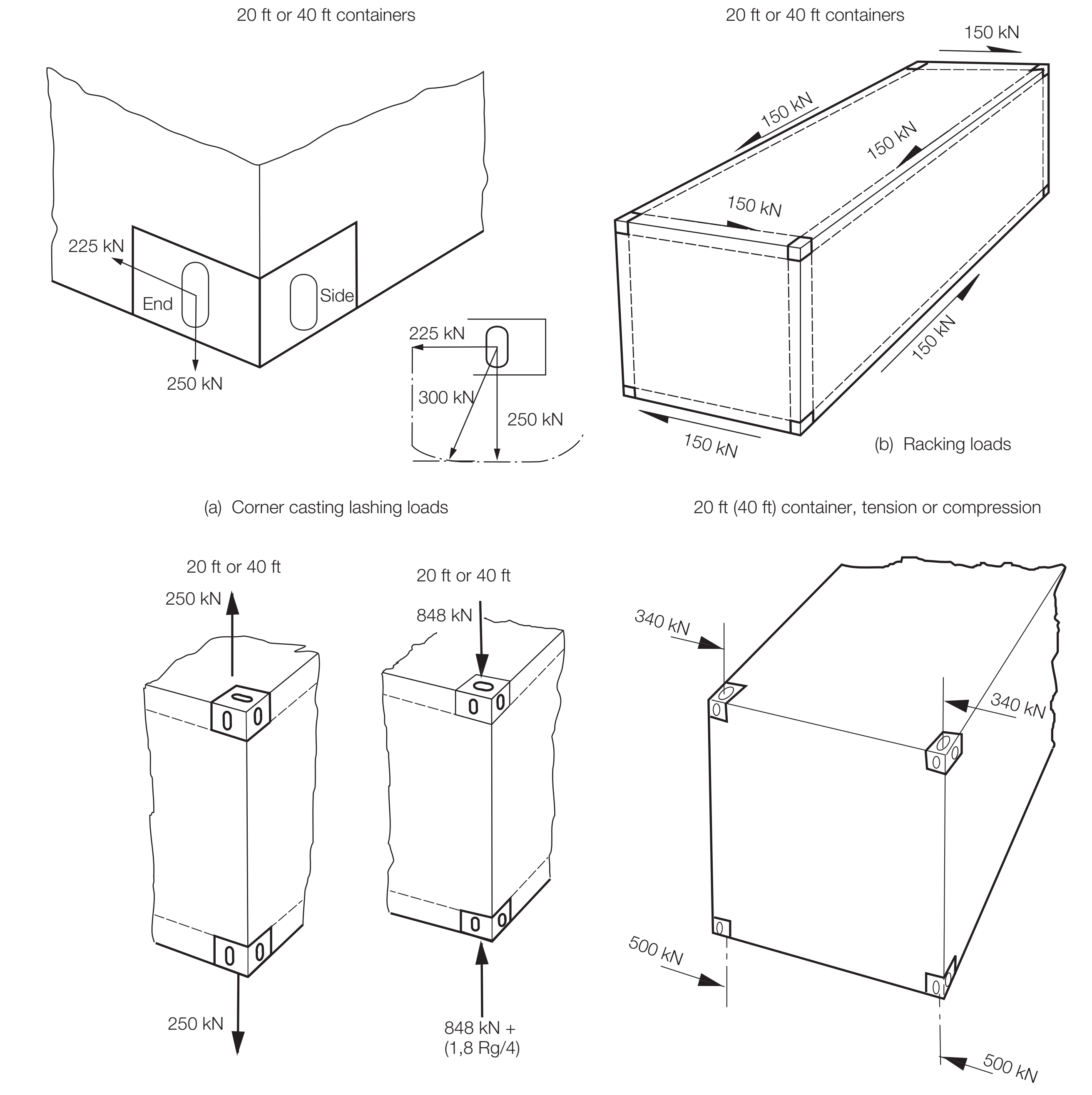


Fig. 14.9.3
Allowable forces for 20 ft or 40 ft containers constructed to ISO 1496-1:1990 including Amendment Nos. 1, 2 and 3

■ *Section 10* **Surveys**

10.1 Initial Survey

10.1.1 The following requirements are mandatory for fixed fittings, including cell guides, if fitted, on all ships. For ships having a **CCSA** class notation the requirements are also applicable for loose fittings.

10.1.2 The Surveyor is to be satisfied that the materials, workmanship and arrangements are satisfactory and in accordance with the requirements and the approved plans. Any items found not to be in accordance with the requirements or the approved plans, or any material, workmanship or arrangements found to be unsatisfactory are to be rectified.

10.1.3 A Register or plan is to be kept on board and up to date, and is to be made available to the Surveyor upon request. The Register or plan is to contain sufficient details to enable all fittings to be identified, including:

- a simple sketch;
- the name of the item;
- the number supplied;
- the manufacturer's mark or code; and
- the safe working load with the corresponding breaking load.

10.1.4 For container securing arrangements, a suitable Container Stowage Arrangement Plan is to accompany the Register. Where containers of types other than ISO containers are proposed to be carried, their stowage locations are to be clearly indicated on the plan.

10.1.5 The Register and stowage plans, if applicable, may be included in the Cargo Securing Manual.

10.2 Periodical Surveys

10.2.1 For the requirements for Periodical Surveys, *see* Pt 1, Ch 3,2.2 and Pt 1, Ch 3,5.3.

Section

■ *Section 1* General

1.1 Definitions

1.1.1 **Quality Assurance Scheme.** Lloyd's Register's (hereinafter referred to as 'LR') Quality Assurance requirements for the hull construction of ships are defined as follows:

- **Quality Assurance.** All activities and functions concerned with the attainment of quality including documentary evidence to confirm that such attainment is met.
- **Quality system.** The organisation structure, responsibilities, activities, resources and events laid down by Management that together provide organised procedures (from which data and other records are generated) and methods of implementation to ensure the capability of the shipyard to meet quality requirements.
- **Quality programme.** A documented set of activities, resources and events serving to implement the quality system of an organisation.
- **Quality plan.** A document derived from the quality programme setting out the specific quality practices, special processes, resources and activities relevant to a particular ship or series of sister ships. This document will also indicate the stages at which, as a minimum, direct survey and/or system monitoring will be carried out by the Classification Surveyor.
- **Quality control.** The operational techniques and activities used to measure and regulate the quality of hull construction to the required level.
- **Inspection.** The process of measuring, examining, testing, gauging or otherwise comparing the item with the approved drawings and the shipyard's written standards including those which have been agreed by LR for the purposes of classification of the specific ship type concerned.
- **Assessment.** The initial comprehensive review of the shipyard's quality systems, prior to the granting of approval, to establish that all the requirements of these Rules have been met.
- **Audit.** A documented activity aimed at verifying by examination and evaluation that the applicable elements of the quality programme continue to be effectively implemented.
- **Hold point.** A defined stage of manufacture beyond which the work must not proceed until the inspection has been carried out by all the relevant personnel.
- **System monitoring.** The act of checking, on a regular basis, the applicable processes, activities and associated documentation that the Shipbuilder's quality system continues to operate as defined in the quality programme.
- **Special process.** A process where some aspects of the required quality cannot be assured by subsequent inspection of the processed material alone. Manufacturing special processes include welding, forming and the application of protective treatments. Inspection and testing processes classified as special processes include non-destructive examination and pressure and leak testing.

1.2 Scope of the Quality Assurance Scheme

1.2.1 This Chapter specifies the minimum Quality System requirements for a shipyard to construct ships under LR's Quality Assurance Scheme.

1.2.2 For the purposes of this Chapter of the Rules, hull construction comprises the hull structure; containment systems, including those which are independent of the main hull structure; appendages; superstructures; deckhouses; and closing appliances all as required by the Rules.

1.2.3 Although the requirements of this Scheme are, in general, for steel ships of all welded construction, other materials for use in hull construction will be considered.

■ *Section 2* Application

2.1 Certification of the shipyard

2.1.1 LR will give consideration to a shipyard's Quality Assurance System provided, at all times, there is full commitment by all the shipyard personnel to the implementation and maintenance of this system. On satisfactory completion of assessments and audits LR will issue certificates of approval to the shipyard as indicated in 2.1.2.

2.1.2 LR's Quality Assurance Scheme comprises:

Part 1 The requirements of the Quality System for hull construction which are applicable to shipyards operating a quality programme but not necessarily constructing to LR's Class. Certificates of approval valid for three years will be issued, with intermediate audits at intervals of 6 months.

Part 2 The Quality System requirements for hull construction for application to ships under construction to LR's Class as part of the Special Survey. LR's particular requirements for construction of ships to its Class, and the continuous involvement in the hull construction process by a combination of direct survey and systems monitoring by LR's Surveyors, are provided for by Part 2. Where LR considers that there is a stage in construction at which a high degree of direct inspection by the Surveyors is desirable, this stage will be described on the Part 2 Approval Certificate.

Certificates of approval for Part 2 will be valid for one year, and will be issued after satisfactory assessment/audit carried out at a suitable stage during construction to LR's Class. Part 1 certification will automatically be issued, or re-issued as applicable, on attainment of Part 2 approval.

2.1.3 Chemical carriers with cargo tank structure of material other than carbon manganese steel and the cargo containment system on ships for liquefied gases will be specially considered. The procedure relating to the construction of such structure on chemical carriers and liquefied gas containment systems is to be separately prescribed in the Quality Plan which will be subject to approval by LR.

2.1.4 The Quality System at a shipyard will be examined for compliance with these Rules by the assessments and audits as laid down in Sections 4, 5 and 6. Initial and periodical approval of the system will be considered by the Committee on receipt of satisfactory assessment and audit reports.

2.1.5 All information and data submitted by a Shipbuilder for approval under this Scheme and for maintenance of approval will be treated by LR in strict confidence and will not be disclosed to any third party without the prior written consent of the Shipbuilder.

2.1.6 A list of shipyards approved under the Scheme will be held in the *List of Shipyards Approved to the Requirements of the Quality Assurance Scheme*.

■ *Section 3* Particulars to be submitted

3.1 Documentation and procedures

3.1.1 Under either Part of the Scheme, the documentation to meet the requirements of Section 4 is to be submitted. This documentation includes the Quality Manual, Quality Plans, documented procedures and work instructions.

3.1.2 Additionally, under Part 2 of the Scheme the documentation to meet the requirements of Section 5 is to be submitted for approval. Construction plans and all necessary particulars are also to be submitted for approval in accordance with the relevant requirements of the Rules, *see* Pt 1, Ch 2,3.2.1.

3.2 Amendments

3.2.1 Any major changes to the documentation or procedures required by Sections 4 or 5 are to be re-submitted.

■ *Section 4* Requirements of Parts 1 and 2 of the Scheme

4.1 General

4.1.1 The requirements of this Section are applicable to shipyards seeking approval under Parts 1 and 2 of the Scheme.

4.2 Policy statement

4.2.1 A policy statement, signed by the Chief Executive of the shipyard concerned, confirming the full commitment of all levels of personnel in the shipyard to the implementation and sustained operation of quality assurance methods is to be included in the Quality Manual.

4.3 Responsibility

4.3.1 Personnel responsible for functions affecting quality are to have defined responsibility and authority to identify, control and evaluate quality.

4.4 Management Representative

4.4.1 The Shipbuilder is to appoint a Management Representative, who is to be independent of other functions unless specifically agreed otherwise by LR, and who is to have the necessary authority and responsibility for ensuring that the requirements of the Scheme are complied with.

4.4.2 The Management Representative is to have the authority to stop production if serious quality problems arise.

4.5 Quality control and testing personnel

4.5.1 The Shipbuilder is to utilise quality control and testing personnel whose performance and continued freedom of influence from production pressures is to be systematically confirmed by the Management Representative.

4.6 Resources

4.6.1 Sufficient resources shall be provided by the shipyard to enable the requirements identified by the Quality Management System to be effectively implemented.

4.7 The Quality Management System

4.7.1 The Shipbuilder is to establish, document and maintain an effective Quality Management System that will ensure and demonstrate that materials and consumables used, and working processes employed, conform to the requirements for hull construction.

4.7.2 **Quality Manual**. The basic documentation is to be in the form of a Quality Manual which sets out the general quality policies and which references the detailed procedures, standards, etc., and includes the requirements of 4.2 to 4.24 and, where appropriate, 5.1 to 5.10.

4.7.3 **Procedures**. The Shipbuilder is to establish, document and maintain an adequate and defined control of the hull construction process comprising:

(a) defined and documented controls, processes, procedures, tolerances, acceptance/rejection criteria and workmanship standards; and
(b) the provision of Quality Plans for each ship or series of sister ships for the processes and procedures for manufacture, inspection and testing involved from receipt of material through to completion of the hull construction process.

4.7.4 **Work instructions**. The Shipbuilder is to develop and maintain clear and complete documented work instructions for the processes and standards involved in the construction of the hull. Such instructions are to provide directions to various levels of personnel.

4.8 Regulatory requirements

4.8.1 The Shipbuilder is to establish that the requirements of all applicable Regulations are clearly specified and agreed with the Owner/Classification Society/Regulatory Authority. These Regulations are to be made available for all functions that require them and their suitability is to be reviewed.

4.8.2 The Shipbuilder is to establish a design verification procedure to ensure that the regulatory requirements have been incorporated into the design output.

4.9 Control of hull drawings

4.9.1 The Shipbuilder is to establish, document and maintain a procedure for the submission to the Classification Society and other regulatory bodies of all the necessary drawings required for approval sufficiently early and in such a manner that the requirements of the Classification Society and other regulatory bodies can be included in the design before construction commences. This procedure is to include a provision which ensures that all amendments to approved drawings are incorporated in the working drawings and that design revisions are re-submitted for approval.

4.10 Documentation and change control

4.10.1 The Shipbuilder is to establish a procedure to ensure that:

(a) valid drawings, specifications, procedures, work instructions and other documentation necessary for each phase of the fabrication process are prepared;
(b) all necessary documents and data are made readily available at all appropriate work, testing and inspection locations;
(c) all amended drawings and changes to documentation are processed in a timely manner to ensure inclusion in the production process;
(d) records are maintained of amendments and changes to documentation; and
(e) provision is made for the prompt removal or immediate identification of all superseded drawings and documentation throughout the shipyard.

4.11 Purchasing data and receipt

4.11.1 The Shipbuilder is to maintain purchasing documents containing a clear description of the materials ordered for use in hull construction and the standards to which material must conform, and the identification and certification requirements.

4.11.2 For the requirements for receiving inspection of purchased items, *see* 4.15.

4.12 Owner supplied material

4.12.1 The Shipbuilder is to have procedures for the inspection, storage and maintenance of Owner supplied materials and equipment.

4.13 Identification and traceability

4.13.1 The Shipbuilder is to establish and maintain a procedure to ensure that materials and consumables used in the hull construction process are identified (by colour-coding and/or marking as appropriate) from arrival at the shipyard through to erection in such a way as to enable the type and grade to be readily recognised. The procedure is to ensure that the Shipbuilder has the ability to identify material in the completed vessel and ensure traceability to the mill sheets.

4.14 Fabrication control

4.14.1 The Shipbuilder is to establish, document and maintain suitable procedures to ensure that fabrication and construction operations are carried out under controlled conditions. Controlled conditions are to include:

(a) clearly documented work instructions defining material treatment, marking, cutting, forming, sub-assembly, assembly, erection, fitting of closing appliances, use of fabrication aids and associated fit-up, weld preparation, welding and dimensional control procedures;

(b) criteria for workmanship and manufacturing tolerances. These are to be documented in a clear manner and made available to the appropriate workforce, and are to include acceptance/rejection criteria; and
(c) documented instructions for the control of equipment and machines used in fabrication. These are to be made available to the appropriate workforce and supplied to individuals where necessary.

4.14.2 The Shipbuilder is to establish and control welding, non-destructive examination and painting which are part of the fabrication system, the equipment used in such processes and the environment in which they are employed. Operators of these special processes are to be properly qualified. Details of these processes are to be included in the relevant Quality Plans.

4.14.3 A list of approved welding procedures is to be maintained and made available to relevant personnel. Records of the results of testing for approval are also to be maintained. Lists of appropriately qualified welders are to be maintained. Procedures for distribution and recycling of welding consumables are to be implemented.

4.14.4 The Shipbuilder is to establish, document and maintain adequate maintenance schedules and standards for all equipment associated with the hull construction process.

4.15 Control of inspection and testing

4.15.1 The Shipbuilder is to be responsible for ensuring that all incoming plates, sections, castings, components, fabrications and consumables and other materials used in the hull construction process are inspected or otherwise verified as conforming to purchase order requirements.

4.15.2 The Shipbuilder is to provide an inspection system at suitable stages of the fabrication process from the material delivery to the completion of hull construction. The inspection system is to confirm and record the inspections carried out.

4.16 Indication of inspection status

4.16.1 The Shipbuilder is to establish and maintain a system for identifying the inspection status of structural components at appropriate stages of the fabrication process. This may include the direct marking of components. Records of inspection and measurements are to be identifiable to components to which they refer and be readily accessible to production and inspection personnel and to Classification Surveyors.

4.17 Inspection, measuring and test equipment

4.17.1 The Shipbuilder is to be responsible for the control, calibration, and maintenance of the inspection, measuring and test equipment used in the fabrication and non-destructive examination of the hull structure.

4.17.2 The calibration system is to allow traceability back to appropriate National Standards. Where these do not exist the basis of calibration is to be defined.

4.18 Non-conforming materials and corrective action

4.18.1 The Shipbuilder is to establish and define procedures to provide for:
(a) the clear identification and segregation from production areas of all plates, sections, castings, components, fabrications, consumables and other materials which do not conform to the agreed specification; and
(b) the initiation of authorised corrective or alternative action.

4.19 Protection and preservation of quality

4.19.1 The Shipbuilder is to establish and maintain a procedure to control handling and preservation processes for both the material used in fabrication and the structural components at all stages of the fabrication process. This procedure is to ensure conformance to specified requirements and established standards.

4.19.2 Welding consumables are to be stored, handled and recycled according to maker's recommendations.

4.20 Records

4.20.1 The Shipbuilder is to develop and maintain records that demonstrate achievement of the required quality and the effective operation of the Quality System. Records demonstrating sub-contractor achievement of these requirements are to be maintained. These records are to be retained and available for a defined period. These records are to include identification of materials and consumables used in fabrication, the number and class of defects found during fabrication and information regarding corrective action taken. Records of particular processes, e.g. plate surface preparation and priming, marking, cutting, forming, accuracy control, non-destructive examination, audits and all other records pertaining to the operation of the Quality System are also to be maintained.

4.21 Internal audit and management review

4.21.1 Internal audits of the performance of all aspects of the systems relating to design, production and testing are to be carried out systematically by appointed staff and recorded under the authority of the Management Representative. These staff members will not normally audit functions for which they are directly responsible.

4.21.2 Using data obtained from the audits and any other available relevant information, management reviews are to take place at specified intervals or more frequently as deemed necessary in order to review the performance of the Quality System.

4.21.3 The Shipbuilder is to establish, document and maintain a procedure for corrective application of data feedback from previous construction, including previous ships during the guarantee period.

4.21.4 The Shipbuilder is to establish, document and maintain a procedure to provide for the analysis of departures from manufacturing standards, steel material scrapped, reworked or repaired during the fabrication and construction process in order to detect trends, investigate the cause to determine the action needed to correct the processes and work procedures, or to identify the further training of operators as appropriate.

4.21.5 Agreed improvements to the Quality System are to be implemented within a time scale appropriate to the nature of the improvement.

4.22 Training

4.22.1 The Shipbuilder is to establish and maintain a system to identify training needs and ensure that all personnel involved in the fabrication, erection and quality-involved functions have adequate experience, training and qualifications. This requirement extends to sub-contractor personnel working within the shipyard. Records are to be available to the Classification Surveyor.

4.23 Sampling

4.23.1 Any sampling processes used by the Shipbuilder are to be in accordance with specified or Statutory Requirements or to the satisfaction of the Classification Surveyor as applicable.

4.24 Sub-contracted personnel, services and components

4.24.1 The requirements of the Scheme are applicable, as appropriate, to all sub-contractor personnel and sub-contracted services operating within the shipyard.

4.24.2 The requirements of the Scheme are not applicable to sub-contractor personnel or sub-contracted services operating at locations outside the shipyard. In these circumstances it will be necessary for inspections to be carried out by the LR Surveyor using conventional survey methods.

■ *Section 5* Additional requirements for Part 2 of the Scheme

5.1 Quality System procedures

5.1.1 The procedures detailed in 4.7 are to be submitted for approval.

5.2 Quality Plans

5.2.1 Quality Plans for ships which are to be classed by LR are to be submitted for approval well in advance of commencement of work, irrespective of any submissions that may have been made for sister ships under Part 1 of the Scheme. Such Quality Plans are to outline all of the manufacturing, testing and inspection operations to be performed by the Shipbuilder and by which personnel they will be carried out. The Quality Plans are then to be submitted to the LR Surveyors who will indicate all the stages at which they will perform system monitoring, carry out direct inspection and participate in hold point inspections. These hold points will include, but not be limited to, the following:

(a) Radiographs and other test records of non-destructive examinations as required for Classification purposes, *see* Ch 13,2.12 of the Rules for Materials.

(b) The items described in Ch 1,8 relevant to the scope of this Chapter.

5.2.2 Notwithstanding what may have been agreed in the Quality Plans, the LR Surveyors have the discretion to increase their involvement, *see also* 8.1.5.

5.3 Material supplier approval

5.3.1 The Shipbuilder is to ensure that hull construction materials and consumables used are selected from manufacturers who are approved by LR.

5.4 Identification and traceability

5.4.1 The procedure required by 4.13.1 is to be submitted for approval.

5.5 Fabrication control

5.5.1 The information required by 4.14.1(b) will be examined for acceptability.

5.5.2 Procedures for material treatment, forming, weld preparation and welding are to be submitted for approval.

5.5.3 Procedures required by 4.14.3 are to be submitted to the LR Surveyors for approval.

5.6 Control of inspection and testing

5.6.1 The inspection stages incorporated into the Scheme are to include specific checks for fit-up and welding which are to be carried out at each sub-assembly, assembly, pre-erection and erection stage as well as self-checking by the operator. The number of recorded checks at each stage will be agreed with the LR Surveyor, after consideration of documentary evidence of quality being achieved. Repairs, where required, are to be effected after each check. Collated Quality Control data to demonstrate the efficiency of the above self-check system are to be made available to the LR Surveyor by the Shipbuilder. The Quality Plans referred to in 4.7.3(b) provide the opportunity for the Shipbuilder and the LR Surveyor to consider the structural design and ship type fully in order to determine the most efficient and effective inspection stages.

5.7 Control of non-conforming materials and corrective action

5.7.1 All predetermined repair procedures are to be consistent with the requirements of 4.7.3(a) and are to be to the satisfaction of the LR Surveyor. Where a defect is found, whether by the LR Surveyor or through shipyard inspection, for which no agreed repair procedure exists, approval is to be obtained from the LR Surveyor before any corrective action is effected.

5.8 Records

5.8.1 The shipyard is to make data available to the LR Surveyor, to demonstrate the efficiency of the inspection system, *see* 5.6.1.

5.9 Training

5.9.1 The competence of the welding operators, non-destructive examination and other personnel involved in special processes and inspection are to be to the satisfaction of the LR Surveyor.

5.10 Sub-contracted personnel, services and components

5.10.1 The requirements of the Scheme are not applicable to those services operating at locations outside the shipyard. It will be necessary for inspections to be carried out by the LR Surveyor using conventional survey methods.

5.10.2 The methods of control for the requirements of 4.24.1 are to be submitted to the LR Surveyor.

■ *Section 6* Initial assessment of the shipyard

6.1 General

6.1.1 In the first instance applications for approval under this Scheme will be considered on the recommendation of the local Surveyors.

6.1.2 After receipt and appraisal of the main quality documentation, an assessment of the shipyard is to be carried out by the Surveyors to examine all aspects of the Quality System applicable to hull construction.

6.1.3 The Surveyors will review the quality arrangements proposed by the Shipbuilder at the shipyard. They may advise as to how the proposed Quality System might be improved and where it is considered inadequate, advise how it might be revised to be acceptable to LR.

6.1.4 For assessment to Part 1 of the Scheme, the Surveyors will review the Quality System in association with the quality documentation and will check that all aspects of the System are established and in accordance with the requirements of Section 3.

6.1.5 For assessment of Part 2 of the Scheme, the Surveyors will confirm that the requirements given in Section 3 have been fully implemented and are complied with by a detailed examination of work in progress and by confirming that workmanship and the quality level being consistently achieved are to their satisfaction.

■ *Section 7* Approval of the shipyard

7.1 General

7.1.1 If the initial assessment confirms that the shipyard's quality arrangements are satisfactory, the Committee will issue Part 1 or Part 2 and Part 1 of LR's Quality Assurance Approval Certificates as appropriate. Maintenance of approval will be subject to the provisions of Section 8.

7.1.2 Approval by another organisation will not be accepted as sufficient evidence that the arrangements for hull construction comply with these requirements.

■ *Section 8*
Maintenance of approval

8.1 General

8.1.1 For Part 2 of the Scheme, the arrangements approved at the shipyard are to be kept under review by the Surveyors to ensure that the approved Quality System is being maintained in a satisfactory manner. This is to be carried out by:

(a) Regular and systematic audits by the LR Surveyor.
(b) Comprehensive Annual Audits. The audit team leader will be formally nominated by LR.

8.1.2 Where a comprehensive audit cannot be carried out due to lack of a current building programme to Class, demonstration that the requirements of Part 1 of the Scheme are being maintained may be confirmed by audit review at intervals of six months, normally by the local Surveyors. Where necessary a comprehensive triennial audit would be carried out by a Surveyor formally nominated by LR. The degree of re-assessment for re-approval at the recommencement of building to LR's Class would be at the discretion of the Committee.

8.1.3 All documentation, including reports, is to be available to the Surveyors.

8.1.4 Minor alterations in the approved procedures may be permitted provided that the Surveyors are advised and their prior concurrence obtained. Major alterations would need to be submitted for approval and may require an additional audit.

8.1.5 In a shipyard constructing ships to LR's Class, the following are applicable:

(a) The LR Surveyor is to be allowed access at all reasonable times to all records pertaining to quality and to all parts of the shipyard involved in the implementation and maintenance of the Quality Assurance Programme.
(b) The LR Surveyor is immediately to advise the Management Representative of any matter pertaining to the Quality System with which he is not satisfied.
(c) When minor deficiencies in the approved procedures are discovered during audits, or if workmanship is considered unsatisfactory, the LR Surveyor will apply more intensive auditing and inspection.
(d) Notwithstanding any of the provisions of the Quality System, all work related to Classification of ships with LR is to be to the satisfaction of the LR Surveyor.

■ *Section 9*
Suspension or withdrawal of approval

9.1 General

9.1.1 When the Surveyors have drawn attention to significant faults or deficiencies in the Quality System or its operation and these have not been rectified within a period of time acceptable to LR, the approval of the system, together with the associated certification, will be withdrawn and the shipyard's name deleted from the *List of Shipyards Approved to the Requirements of the Quality Assurance Scheme*.

9.1.2 If a significant period of time elapses between such withdrawal and any application for reinstatement, the reapproval procedures, if agreed to by the Committee, may require a restructuring of the Quality Management System and will always require a complete re-examination as for an initial assessment.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter is applicable to all ship types and components with the exception of Sections 2 and 3 which are not applicable to Bulk Carriers or Double Hull Oil Tankers with a **CSR** notation, *see* Pt 1, Ch 2,2.3. The requirements are to be applied in conjunction with the relevant Chapters of Parts 3 and 4 applicable to the particular ship type, and the ShipRight procedures.

1.1.2 Details of Lloyd's Register's (hereinafter referred to as 'LR') ShipRight procedures are given in the *ShipRight Procedures Manual* and in this Chapter where related to particular items and notations.

1.1.3 Details of machinery ShipRight procedures are to be found in Pt 5, Ch 21.

1.2 Classification notations and descriptive notes

1.2.1 In addition to the hull class notations defined in Pt 1, Ch 2, ships complying with the requirements of this Chapter will be eligible to be assigned the additional class notations defined in Pt 1, Ch 2,2.1 and Ch 2,2.3 or descriptive notes as defined in Pt 1, Ch 2,2.7 and associated with the ShipRight procedures.

1.3 Information and plans required to be submitted

1.3.1 The information and plans required to be submitted are as specified in the relevant Chapters of Parts 3 and 4 applicable to the particular ship type and in this Chapter where related to particular items and notations.

■ *Section 2* Structural design assessment

2.1 Structural Design Assessment notation – SDA

2.1.1 The ship structure is to be examined using finite plate element methods to assess both the overall and detailed structural capability to withstand static and dynamic loadings. *See*:

- the applicable *ShipRight SDA Procedures Manual* for the procedure for each ship type; and
- the Section dealing with direct calculations in the relevant Chapter of Part 4 applicable to the particular ship type.

2.1.2 This procedure is mandatory, and additional to normal Rule structural design approval, for:

(a) bulk carriers and oil tankers without a **CSR** notation (*see* 1.1.1) greater than 190 m in length;
(b) container ships with a beam greater than 32 m;
(c) The primary structure of LNG ships;
(d) The primary structure of Type A LPG ships;
(e) Other ships of Type B and C where the type, size and structural configuration demand;
(f) passenger ships where it is considered that the superstructure will be subjected to a significant load from flexure of the hull girder; or, where it is required to utilise the load carrying capability of the superstructure for longitudinal strength; and
(g) other ships where type, size and structural configuration demand, *see also* Pt 1, Ch 2,2.3 and Ch 2,2.7.

2.1.3 In addition, and where applicable, the ship structure is to be examined for the structural capability to withstand dynamic loadings from partially filled tanks or the influence of thermal loadings.

■ *Section 3* Fatigue design assessment

3.1 Fatigue Design Assessment notations – FDA, FDA plus and FDA ICE

3.1.1 The ShipRight FDA procedures for assignment of the notations **ShipRight FDA** or **ShipRight FDA plus** are to be applied in conjunction with controls in construction tolerances, in addition to the normal Rule structural detail design appraisal.

3.1.2 At the Owner's request and in order to enhance safety, the **ShipRight FDA ICE** *Fatigue Induced by Ice Loading Procedure* may be applied. This procedure is supplementary to the FDA procedures and is to assess fatigue damage induced by ice loads for ships navigating in ice-covered regions. The objective of **ShipRight FDA ICE** procedure is to provide technical guidelines to assess fatigue at the end connections of ice belt regions under ice loading. *See* Pt 1, Ch 2,2.3.17.

■ *Section 4* Construction monitoring

4.1 Construction Monitoring notation – CM

4.1.1 Extended controls on structural alignment, fit up and workmanship standards will be applied to areas, shown by the structural design assessment and fatigue design assessment procedures specified in Sections 2 and 3, to be in need of particular attention. This procedure is mandatory for all ship types where either the SDA and/or FDA procedures have been applied on a mandatory basis. The procedure may also be applied on a voluntary basis in conjunction with the voluntary application of SDA and FDA procedures to ensure that the ship is designed and constructed to an enhanced structural standard. The requirements of Chapter 10, and the relevant procedures contained in the *Construction Monitoring Procedure* are to be complied with, *see also* Pt 1, Ch 2,2.3 and Ch 2,2.7.

4.1.2 The procedure is mandatory for all Bulk Carriers or Double Hull Oil Tankers greater than 190 m in length with a **CSR** notation, *see* Pt 1, Ch 2,2.3.

■ *Section 5* Ship Event Analysis

5.1 Ship Event Analysis

5.1.1 At the Owner's request and in order to enhance safety and awareness on board during ship operation, the *ShipRight Ship Event Analysis Procedure* applies to all ships where it is intended to provide a hull surveillance system for:

(a) Monitoring of the ship's hull girder stresses and motions, and warning the ship's personnel that these stress levels or the frequency and magnitude of slamming motions are approaching a level where corrective action is advisable.

(b) Monitoring of the ship's hull girder stresses and local ice loads when the ship is navigating in ice, and warning the ship's personnel that the load levels or the frequency and magnitude of ice impacts are approaching a level where corrective action is advisable.

■ *Section 6* Enhanced scantlings

6.1 Enhanced Scantlings – Descriptive note ES

6.1.1 Where scantlings in excess of the approved Rule minimum are fitted at defined locations, a descriptive note **ES**, Enhanced Scantlings, will be entered in column 6 of the *Register Book*. For example, the note **ES+1** will indicate that an extra 1 mm has been fitted to the hull envelope plating (i.e., deck, side and bottom).

■ *Section 7* Corrosion protection of internal tanks and spaces

7.1 Protective coating systems in dedicated sea-water ballast tanks and double-side skin spaces – ShipRight Notations ACS(B) or ACS(B,D)

7.1.1 For ships that are required to comply with IMO Resolution MSC.215(82), *Performance Standards for Protective Coatings*, all dedicated sea-water ballast tanks for all ship types and double-side skin spaces of bulk carriers are to have approved coating systems applied according to ShipRight Procedure *Anti-Corrosion Systems Notation*.

7.1.2 **ShipRight ACS(B)** or **ShipRight ACS(B,D)** will be entered in Column 4 of the Register Book to indicate that the ship's sea water ballast tanks and double-side skin spaces of bulk carriers are coated with approved coating systems according to IMO Resolution MSC.215(82), Performance Standards for Protective Coatings.

7.2 Protective coating systems in the cargo oil tanks of crude oil tankers – ShipRight Notation ACS(C)

7.2.1 For ships that are required to comply with IMO Resolution MSC.291(87), *Adoption of Amendments to the International Convention for the Safety of Life at Sea*, 1974, as amended, Owners may request to receive the optional notation **ShipRight ACS(C)**, which indicates that the cargo oil tanks are protected in compliance with IMO Resolution MSC.288(87), *Performance Standard for Protective Coatings for Cargo Oil Tanks of Crude Oil Tankers*, *see* ShipRight Procedure *Anti-Corrosion System Notation*.

7.2.2 **ShipRight ACS(C)** will be entered in Column 4 of the *Register Book* to indicate that the ship's cargo oil tanks are protected using approved materials in accordance with IMO Resolution MSC.291(87), *Adoption of Amendments to the International Convention for the Safety of Life at Sea*, 1974, as amended.

7.2.3 When in compliance with IMO Resolution MSC.291(87), but the **ShipRight ACS(C)** notation is not requested, this compliance may be indicated on the applicable certification.

7.3 Alternative means of corrosion protection for cargo oil tanks in crude oil tankers – ShipRight notation ACS(C*)

7.3.1 For ships that are required to comply with the IMO Resolution MSC.291(87), *Adoption of Amendments to the International Convention for the Safety of Life at Sea, 1974*, as amended, Owners may request to receive the optional notation **ShipRight ACS(C*)**, which indicates that all cargo tanks are protected in accordance with IMO Resolution MSC.289(87) *Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks of Crude Oil Tankers*, by application of Corrosion Resistant Steel, *see* Ch 3,1.3 of the Rules for Materials and ShipRight Procedure *Anti-Corrosion System Notation*.

7.3.2 **ShipRight ACS(C*)** will be entered in Column 4 of the *Register Book* to indicate that the ship's cargo oil tanks are protected using approved materials in accordance with IMO Resolution MSC.291(87), *Adoption of Amendments to the International Convention for the Safety of Life at Sea, 1974*, as amended.

7.3.3 When in compliance with IMO Resolution MSC.291(87), but the **ShipRight ACS(C*)** notation is not requested, this compliance may be indicated on the applicable certificate.

7.4 Protective coatings for void spaces on bulk carriers and oil tankers – ShipRight Notation ACS(V)

7.4.1 For ships within the scope of IMO Resolution MSC.244(83), *Adoption of Performance Standard for Protective Coatings for Void Spaces on Bulk Carriers and Oil Tankers*, Owners may request to receive the optional notation **ShipRight ACS(V)**, which indicates that the void spaces are protected according to the ShipRight Procedure *Anti Corrosion System Notation*.

7.4.2 **ShipRight ACS(V)** will be entered in Column 4 of the *Register Book* to indicate that the ship's void spaces are protected in accordance with IMO Resolution MSC.244(83), *Adoption of Performance Standard for Protective Coatings for Void Spaces on Bulk Carriers and Oil Tankers*.

7.4.3 When in compliance with IMO Resolution MSC.244(83), but the **ShipRight ACS(V)** notation is not requested, this compliance may be indicated on the applicable certificate.

7.5 Protective coating systems in dedicated sea-water ballast tanks – Descriptive note PCWBT

7.5.1 For ships that are not required to comply with IMO Resolution MSC.215(82), *Performance Standards for Protective Coatings*, all sea-water ballast spaces having boundaries formed by the hull envelope are to have a corrosion protection coating applied, *see* ShipRight Procedure *Protective Coatings in Water Ballast Tanks (PCWBT)*.

7.5.2 Where requested, a descriptive note **PCWBT** (Protective Coating in Water Ballast Tanks) will be entered in column 6 of the *Register Book* to indicate that all sea-water ballast spaces having boundaries formed by the hull envelope have a corrosion protection coating applied, and that the coating remains efficient and is maintained in good condition. If the coatings have broken down, particularly at more critical areas, and no effort is being made to maintain the coatings, then this note will be placed in parentheses, i.e., **(PCWBT)**. In either case, the date of the last survey will be placed in parentheses after the note.

■ *Section 8*
Ship Emergency Response Service

8.1 Ship Emergency Response Service – Descriptive note SERS

8.1.1 This service, offered by LR, provides a rapid computer assisted analysis of a damaged ship's stability and damaged longitudinal strength in the event of a casualty to the ship.

8.1.2 Where an Owner adopts this service, the descriptive note **SERS**, 'Ship is registered with LR's Ship Emergency Response Service', will be entered in column 6 of the *Register Book*.

■ *Section 9*
Assessment of Ballast Water Management Plans

9.1 Ballast Water Management Plan – Descriptive note BWMP

9.1.1 Compliance with this procedure is optional. A ship meeting the requirements of this procedure will be eligible for an appropriate **ShipRight BWMP** descriptive note, which will be recorded in column 6 of the *Register Book*.

Section 10 Inventory of hazardous materials

10.1 Inventory of hazardous materials – Descriptive note IHM

10.1.1 Compliance with this procedure is optional. A ship meeting the requirements of this procedure will be eligible for a ShipRight **IHM** Descriptive Note, which will be recorded in column 6 of the *Register Book*, except as indicated in 10.1.2.

10.1.2 If a ship has been assigned the **ECO** notation, then it will not be eligible for an **IHM** Descriptive Note. Instead, **IHM** will be referenced in the **ECO** notation, i.e., **ECO(IHM)**.

Section 11 Safe return to port and orderly evacuation

11.1 Safe Return to Port and Orderly Evacuation – Descriptive Note SRtP

11.1.1 Compliance with this procedure is optional. A ship meeting the requirements of this procedure will be eligible for a ShipRight **SRtP** Descriptive Note, which will be recorded in column 6 of the *Register Book*.

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Rules and Regulations for the Classification of Ships

Part 4

Ship Structures (Ship Types)

July 2014

Lloyd's Register

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■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to sea-going ships designed primarily for the carriage of general cargo. The requirements are intended to cover the midship region, but may also apply with suitable modification to the taper regions forward and aft in way of cargo spaces.

1.2 Structural configuration

1.2.1 The Rules provide for a basic structural configuration of a multi-deck or a single deck hull which includes a double bottom, or a single bottom arrangement. The structural configuration may also include a single or multiple arrangement of cargo hatch openings, and side tanks.

1.2.2 Individual consideration may be required where the ship incorporates double hull construction, large deck openings or other special design features.

1.2.3 Longitudinal framing is, in general, to be adopted at the strength deck outside line of openings and at the bottom, but special consideration will be given to proposals for transverse framing in these regions.

1.3 Class notations

1.3.1 In general, ships complying with the requirements of this Chapter will be eligible to be classed **100A1**.

1.3.2 Where a ship has been specially strengthened for heavy cargoes in accordance with the requirements listed in Ch 7,8.2, it will be eligible to be classed **100A1 strengthened for heavy cargoes**.

1.3.3 The following additional notations and annotations can be appended to the main class notation giving further detailed description of the loading criteria incorporated into the design:

(a) **RD** (Relative density):
Where a ship has tanks appraised for a maximum permissible relative density greater than 1,025, the notation **RD(specified tank names, density)** may be added.

(b) **WDL(+)** (Weather deck load):
The notation **WDL(+)** may be added. If requested, the maximum permissible weather deck load and extent can be identified in the notation, e.g., **WDL(5,0 t/m^2 from Aft to Fr. 26)**.

1.3.4 Ships intended to be operated only in suitable areas or conditions which have been agreed by the Committee, as defined in Pt 1, Ch 2,2.3.6 to 2.3.10, will receive individual consideration on the basis of the Rules with respect to the environmental conditions agreed for the design basis and approval.

1.3.5 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.4 Information required

1.4.1 For the information required, *see* Pt 3, Ch 1,5. In addition the following are to be supplied:

(a) Cargo loadings on decks, hatchways and inner bottom if these are to be in excess of Rule. Where concentrated or point loads occur, their magnitude and points of application are to be defined.

(b) The maximum pressure head in service on tanks, also details of any double bottom tanks interconnected with side tanks.

(c) Details of the proposed depths of any partial fillings where water ballast or liquid cargo is intended to be carried in the holds, or large deep tanks.

1.5 Symbols and definitions

1.5.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, D, T and V as defined in Pt 3, Ch 1,6

k_L,k = higher tensile steel factor, *see* Pt 3, Ch 2,1

e = base of natural logarithms, 2,7183

l = overall length of stiffening member, or pillar, in metres, *see* Pt 3, Ch 3,3

l_e = effective length of stiffening member, or pillar, in metres, *see* Pt 3, Ch 3,3

t = thickness of plating, in mm

s = spacing of secondary stiffeners, in mm

A = cross-sectional area of stiffening member, in cm^2

C = stowage rate, in m^3/tonne, *see* Pt 3, Ch 3,5

C_w = a wave head in metres
= $7,71 \times 10^{-2} L e^{-0,0044L}$ where L is not to be taken greater than 227

I = inertia of stiffening member, in cm^4, *see* Pt 3, Ch 3,3

S = spacing or mean spacing of primary members, in metres
Z = section modulus of stiffening member, in cm^3, *see* Pt 3, Ch 3,3
ρ = relative density (specific gravity) of liquid carried in a tank but is not to be taken less than 1,025.

Section 2 Materials and protection

2.1 Materials and grades of steel

2.1.1 Materials and grades of steel are to comply with the requirements of Pt 3, Ch 2.

2.2 Protection of steelwork

2.2.1 For the protection of steelwork, in addition to the requirements specified in Pt 3, Ch 2,3 the requirements of 2.2.2 to 2.2.4 are to be complied with.

2.2.2 Ceiling is to be laid on the inner bottom under cargo hatchways, but may be omitted provided that the inner bottom plating is increased by 2 mm. In any ship which is regularly to be discharged by grabs, ceiling is to be laid on the inner bottom, and the inner bottom plating increased by 3 mm. Alternatively, the ceiling may be omitted provided that the inner bottom plating is increased in thickness by a minimum of 5 mm. The ceiling is to be 76 mm thick in softwood or 65 mm thick in hardwood, and is to be laid at right angles to the inner bottom stiffening. Where it is intended to use plywood or other forms of ceiling of an approved type instead of planking, the thickness will be considered for each case. Ceiling is also to be laid over bilges, and fitted with portable sections which are to be readily removable. The spaces between the frames at the top of the bilge ceiling are to be closed by steel plates, wood chocks, cement or other suitable means. Inner bottom manhole covers or fittings, where projecting above the inner bottom plating, are to be provided with a steel protection coaming around each manhole, and a wood or steel cover is to be fitted.

2.2.3 Where plated decks are sheathed with wood or approved compositions, the minimum thicknesses given in 4.2, Pt 3, Ch 5,2 and Pt 3, Ch 6,2 may be reduced by 10 per cent for a 50 mm sheathing thickness or five per cent for 25 mm, with intermediate values in proportion. The steel deck is to be coated with a suitable material in order to prevent corrosive action, and the sheathing or composition is to be effectively secured to the deck. *See also* the fire protection requirements relating to deck coverings in the relevant SOLAS Regulations or Pt 6, Ch 4,3 as applicable.

2.2.4 Where cargo battens or equivalent are fitted in the holds of dry cargo ships, the descriptive note ‘SF’ will be entered in the *Register Book.* The battens, when fitted, are to extend from above the upper part of the bilge to the underside of beam knees in the holds, and in all cargo spaces in the ’tween decks and superstructures, up to the underside of beam knees. Wood cargo battens are to be not less than 50 mm in thickness, and the clear space between adjacent rows is, in general, not to exceed 230 mm. The dimensions and spacing of battens made of other materials will be considered. Nets may be adopted in lieu of battens, and other alternative proposals will be specially considered. For arrangements in way of a refrigerated hold, *see* Pt 6, Ch 3,4.

Section 3 Longitudinal strength

3.1 General

3.1.1 Longitudinal strength calculations are to be made in accordance with the requirements given in Pt 3, Ch 4.

3.1.2 The requirements of Pt 3, Ch 4,8.3 regarding loading instruments are not applicable to general cargo ships under 120 m.

3.2 Fast cargo ships

3.2.1 The hull section modulus for ships of length, L, between 120 m, and 170 m, and maximum service speed greater than 17,5 knots in association with a bow shape factor, ψ, of more than 0,15, is to comply with the requirements of this sub-Section.

3.2.2 The bow shape factor is defined as:

$$\Psi = \frac{100\,\Sigma A_b}{L^{1,5}\,B}$$

where
a_0 = projection of upper deck at waterline (F.P.), in metres
a_1 = projection of upper deck at waterline (0,1L from F.P.), in metres
a_2 = projection of upper deck at waterline (0,2L from F.P.), in metres
b = projection of upper deck at waterline (F.P. to bow line), in metres

$$\Sigma A_b = \frac{ba_0}{2} + 0{,}1L\,(a_1 + a_2)\quad \text{m}^2$$

See also Fig. 1.3.1.

3.2.3 For longitudinal strength requirements, the Rule minimum hull midship section modulus and the distribution of longitudinal material in the forward half-length will be considered. In general, the following requirements are to be complied with:

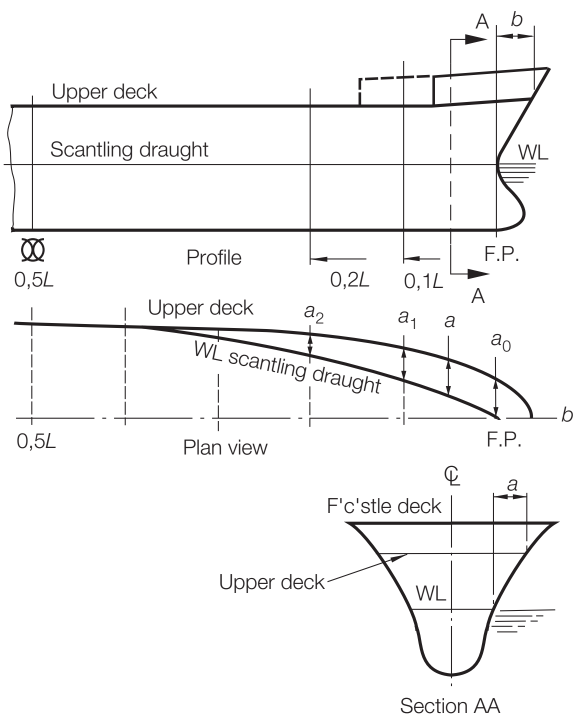


Fig. 1.3.1 Derivation of bow shape factor

(a) The vertical hull midship section modulus, about the horizontal neutral axis, at deck is to be not less than $331Lk\Sigma A_b$ cm^3, or that required by Pt 3, Ch 4,5, whichever is the greater. ΣA_b is defined in 3.2.2.

(b) The horizontal hull midship section modulus, about a vertical axis through the ship centreline, is to be not less than $32{,}5L^2D$ cm^3.

(c) In the forward half-length, the hull section modulus is not to be a lesser percentage of the midship value than that shown in Table 1.3.1.

(d) Any load or ballast condition resulting in a sagging still water bending moment, or a hogging moment less than 80 per cent of the Rule value of still water bending moment, will be specially considered with a view to minimising the compressive stresses in the deck in waves.

Table 1.3.1 Fast cargo ships

Position	Percentage of midship vertical modulus (modulus about horizontal axis)	Percentage of midship horizontal modulus (modulus about vertical axis)
Station 10 (mid-L_{pp})	100	100
12	98	87
14	95	62
16	81	38
18	44	17
20 (F.P.)	0	0

NOTES
1. Intermediate values to be obtained by interpolation.
2. L_{pp} as defined in Pt 3, Ch 1,6.

3.2.4 For local strength, in general the following requirements are to be complied with:

(a) Longitudinal deck stiffening is to be carried forward to the fore peak bulkhead or as far forward as practical. Where a long forecastle is fitted, the buckling strength of the proposed structure will be specially considered.

(b) Substantial web frames in way of deck transverses are to be fitted in the forward half-length. Scantlings of webs and frames are to be based on actual lengths, not 'tween deck heights, and collars are to be fitted at ends of members in way of high shear.

(c) Scantlings of bottom structure in forward part are to be specially considered.

(d) Deck and side shell panels forward of 0,5*L* from F.P. are to be examined to establish the critical buckling stress from the following formula:

$$\sigma_c = \frac{\pi^2 E}{12\,(1-\nu^2)} \left(\frac{t}{s}\right)^2 K_c \quad \text{N/mm}^2\ (\text{kgf/mm}^2)$$

where

s = length of shorter edge, in mm

t = thickness of plating, in mm

E = Young's modulus, in N/mm^2 (kgf/mm^2)

K_c = a factor depending on aspect ratio and boundary restraint
= 4 for longitudinally stiffened plating or as shown in Fig. 1.3.2 for transversely stiffened plating

ν = Poisson's ratio (0,3 for steel and aluminium alloy).

Where the buckling stresses, as evaluated, exceed 50 per cent of yield stress, the actual critical buckling stress is given by:

$$\sigma_{ac} = \sigma_o \left(1 - \frac{\sigma_o}{4\sigma_c}\right) \quad \text{N/mm}^2\ (\text{kgf/mm}^2)$$

where

σ_{ac} = corrected critical buckling stress, in N/mm^2 (kgf/mm^2)

σ_o = yield stress, in N/mm^2 (kgf/mm^2)

The critical buckling stress from the above formulae must be not less than 176,6 N/mm^2 (18,0 kgf/mm^2) within 0,4*L* amidships, nor less than 147,2 N/mm^2 (15,0 kgf/mm^2) for the deck forward of this, nor less than 117,7 N/mm^2 (12,0 kgf/mm^2) for the side shell between the first and second deck forward of 0,5*L* from F.P. For higher tensile steel plating, the above permissible stresses are to be divided by *k*.

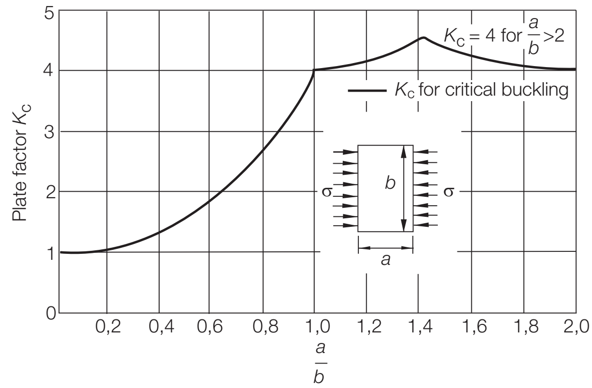


Fig. 1.3.2 Plate factor, K_c

(e) In order to obtain the necessary critical buckling strength, either of the following is to be applied:
   (i) plate thickness to be increased, or
   (ii) panel aspect ratio to be altered by the fitting of additional panel stiffening.

Section 4 **Deck structure**

4.1 General

4.1.1 Longitudinal framing is, in general, to be adopted at the strength deck outside line of openings, but special consideration will be given to proposals for transverse framing. Requirements are given in this Section for longitudinal and transverse framing systems of all deck structure, except decks in way of erections. For erection decks, *see* Pt 3, Ch 8.

4.2 Deck plating

4.2.1 The thickness of strength/weather deck plating in the midship region is to comply with the requirements of Table 1.4.1. Outside the line of openings the thickness is also to be that necessary to give the hull section modulus required by Pt 3, Ch 4,5.

4.2.2 The thickness of lower deck plating in the midship region is to comply with the requirements of Table 1.4.2.

4.2.3 The thickness of the strength deck stringer plate is to be increased by 20 per cent at the ends of bridges, poop and forecastle.

4.2.4 The deck plating thickness and supporting structure are to be suitably reinforced in way of cranes, masts, derrick posts and deck machinery.

4.2.5 Where long, wide hatchways are arranged on lower decks, it may be necessary to increase the deck plating thickness to ensure effective support for side framing.

4.3 Deck stiffening

4.3.1 The scantlings of strength/weather deck longitudinals in the midship region are to comply with the requirements of Table 1.4.3.

4.3.2 The lateral and torsional stability of longitudinals together with web and flange buckling criteria are to be verified in accordance with Pt 3, Ch 4,7.

4.3.3 The scantlings of cargo and accommodation deck longitudinals are to comply with the requirements of Table 1.4.4.

4.3.4 End connections of longitudinals to bulkheads are to provide adequate fixity and, so far as is practicable, direct continuity of longitudinal strength. Where L exceeds 215 m, the deck longitudinals are to be continuous through transverse structure, including bulkheads, but alternative arrangements will be considered. Higher tensile steel deck longitudinals are to be continuous irrespective of the ship length.

Table 1.4.1 Strength/weather deck plating

Location	Minimum thickness, in mm, *see also* 4.2.1	
	Longitudinal framing	Transverse framing
(1) Outside line of openings (*see* Notes 1 and 2)	The greater of the following: (a) $t = 0{,}001 s_1 (0{,}059 L_1 + 7)\sqrt{\dfrac{F_D}{k_L}}$ (b) $t = 0{,}00083 s_1 \sqrt{Lk} + 2{,}5$	The greater of the following: (a) $t = 0{,}001 s_1 f_1 (0{,}083 L_1 + 10)\sqrt{\dfrac{F_D}{k_L}}$ (b) $t = 0{,}001 s_1 \sqrt{Lk} + 2{,}5$
(2) Inside line of openings (*see* Note 2)	$t = 0{,}00083 s_1 \sqrt{Lk} + 2{,}5$ but not less than 6,5	$t = 0{,}00083 s_1 \sqrt{Lk} + 1{,}5$ but not less than 6,5
(3) In way of the crown of a tank	$t = 0{,}004 s f \sqrt{\dfrac{\rho k h_4}{1{,}025}} + 3{,}5$ or as (1) or (2), whichever is the greater, but not less than 7,5 mm where $L \geq 90$ m, or 6,5 mm where $L < 90$ m	

Symbols

L, k_L, k, ρ, s, S as defined in 1.5.1

$f = 1{,}1 - \dfrac{s}{2500S}$ but not to be taken greater than 1,0

$f_1 = \dfrac{1}{1 + \left(\dfrac{s}{1000S}\right)^2}$

h_4 = tank head, in metres, as defined in Pt 3, Ch 3,5

s_1 = s but is not to be taken less than the smaller of $470 + \dfrac{L}{0{,}6}$ mm or 700 mm

F_D = as defined in Pt 3, Ch 4,5.7

L_1 = L but need not be taken greater than 190 m

NOTES
1. The thickness derived in accordance with (1) is also to satisfy the buckling requirements of Pt 3, Ch 4,7.
2. The deck thickness is to be not less than the basic end deck thickness as given in Pt 3, Ch 5 and Ch 6.

Table 1.4.2 Lower deck plating

Symbols	Location	Minimum thickness, in mm: Second deck	Minimum thickness, in mm: Third or platform decks
s, S, k, ρ as defined in 1.5.1 b = breadth of increased plating, in mm f = $1{,}1 - \dfrac{s}{2500S}$ but not to be taken greater than 1,0 h_4 = tank head, in metres, as defined in Pt 3, Ch 3,5 s_1 = s but is not to be taken less than the smaller of $470 + \dfrac{L}{0{,}6}$ mm or 700 mm A_f = girder face area, in cm^2 K_1 = 2,5 mm at bottom of tank = 3,5 mm at crown of tank	(1) Outside line of openings	$t = 0{,}012s_1\sqrt{k}$ but not less than 6,5	$t = 0{,}01s_1\sqrt{k}$ but not less than 6,5
	(2) Inside line of openings	$t = 0{,}01s_1\sqrt{k}$ but not less than 6,5	
	(3) In way of the crown or bottom of a tank	$t = 0{,}004sf\sqrt{\dfrac{\rho k h_4}{1{,}025}} + K_1$ but not less than 7,5 where $L \geq 90$ m, or 6,5 where $L < 90$ m	
	(4) Plating forming the upper flange of underdeck girders	Clear of deck openings, $t = \sqrt{\dfrac{A_f}{1{,}8k}}$ In way of deck openings, $t = 1{,}1\sqrt{\dfrac{A_f}{1{,}8k}}$ Minimum breadth, b = 760 mm	

NOTE
Where a deck loading exceeds 43,2 kN/m^2 (4,4 tonne-f/m^2), the thickness of plating will be specially considered.

Table 1.4.3 Strength/weather deck longitudinals

Symbols	Location	Modulus, in cm^3	Inertia, in cm^4
L, s, k_L, k, ρ as defined in 1.5.1 b = 1,4 for rolled or built sections = 1,6 for flat bars $c_1 = \dfrac{60}{225 - 165 F_D}$ d_w = depth of longitudinal, in mm $F_1 = 0{,}25c_1$ h_1 = weather head, in metres, as defined in Pt 3, Ch 3,5 h_4 = tank head, in metres, as defined in Pt 3, Ch 3,5 l_e = as defined in 1.5.1, but not to be taken less than 1,5 m F_D = as defined in Pt 3, Ch 4,5.7 $h_{T1} = \dfrac{L_1}{56}$ for Type 'B–60' ships = the greater of $\dfrac{L_1}{70}$ or 1,20 m for Type 'B' ships L_1 = L but need not be taken greater than 190 m L_2 = L but need not be taken greater than 215 m	(1) In way of dry cargo spaces, *see* Note 1 (a) Outside line of openings (b) Inside line of openings	 $Z = 0{,}043\, s\, k\, h_{T1}\, l_e^2\, F_1$ $Z = s\, k\,(400h_1 + 0{,}005\,(l_e\, L_2)^2) \times 10^{-4}$	 — —
	(2) In way of the crown or bottom of a tank	$Z = \dfrac{0{,}0113\, \rho\, sk\, h_4\, l_e^2}{b}$ or as (1)(a) or (1)(b) above, whichever is the greater	$I = \dfrac{2{,}3}{k}\, l_e Z$
	(3) In way of superstructure	To be specially considered	—

NOTES
1. Where weather decks are intended to carry deck cargo and the load is in excess of 8,5 kN/m^2 (0,865 tonne-f/m^2), the scantlings of longitudinals may be required to be increased to comply with the requirements for location (1) Table 1.4.4 using the equivalent design head, for specified cargo loading, for weather decks given in Table 3.5.1 in Pt 3, Ch 3.
2. The buckling requirements of Pt 3, Ch 4,7 are to be complied with. The ratio of the web depth d_w to web thickness t is to comply with the following requirements:
   (a) Built up profiles and rolled angles:
   $\dfrac{d_w}{t} \leq 60\sqrt{k_L}$
   (b) Flat bars:
   $\dfrac{d_w}{t} \leq 18\sqrt{k_L}$ when continuous at bulkheads
   $\dfrac{d_w}{t} \leq 15\sqrt{k_L}$ when non-continuous at bulkheads
3. The web depth of longitudinals, d_w is to be not less than 60 mm.

Table 1.4.4 Cargo and accommodation deck longitudinals

Symbols	Location	Modulus, in cm^3	Inertia, in cm^4
L, s, k, ρ as defined in 1.5.1 d_w = web depth of longitudinal, in mm, *see* Note 2 h_2 = cargo head, in metres, as defined in Pt 3, Ch 3,5 h_3 = accommodation head, in metres, as defined in Pt 3, Ch 3,5 h_4 = tank head, in metres, as defined in Pt 3, Ch 3,5 l_e = as defined in 1.5.1, but not to be taken less than 1,5 m L_1 = L but need not be taken greater than 190 m γ = 1,4 for rolled or built sections = 1,6 for flat bars	(1) Cargo decks (a) $L \geq 90$ m (b) $L < 90$ m	 $Z = sk(5{,}9L_1 + 25h_2 l_e^2) \times 10^{-4}$ $Z = 0{,}005 s k h_2 l_e^2$	 — —
	(2) Accommodation decks (a) $L \geq 90$ m (b) $L < 90$ m	 $Z = sk(5{,}1L_1 + 25h_3 l_e^2) \times 10^{-4}$ $Z = 0{,}00425 s k h_3 l_e^2$ *See* Note 1	 — —
	(3) In way of the crown or bottom of a tank	As in (1) or (2) as applicable, or $Z = \dfrac{0{,}0113\rho s k h_4 l_e^2}{\gamma}$ whichever is the greater	$I = \dfrac{2{,}3}{k} l_e Z$

NOTES
1. The section modulus of accommodation deck longitudinals need not be taken greater than the value required by location (1)(a), in Table 1.4.3.
2. The web depth of longitudinals, d_w, to be not less than 60 mm.

Table 1.4.5 Strength/weather, cargo and accommodation deck beams

Symbols	Location	Modulus, in cm^3	Inertia, in cm^4
B, D, T, s, k, ρ as defined in 1.5.1 d_w = depth of beam, in mm h_1 = weather deck head h_2 = cargo head h_3 = accommodation head h_4 = tank head (h_1 to h_4: in metres, *see* Pt 3, Ch 3,5) l_e as defined in 1.5.1, but to be taken as not less than 1,83 m B_1 = B, but need not be taken greater than 21,5 m K_1 = a factor dependent on the number of decks (including poop and bridge superstructures) at the position of the beam under consideration: 1 deck 20,0 3 decks 10,5 2 decks 13,3 4 or more 9,3 K_2 = a factor dependent on the location of the beam: at short bridge and poops 133 elsewhere 530 K_3 = a factor dependent on the location of the beam: span adjacent to the ship side 3,6 elsewhere 3,3 γ = 1,4 for rolled or built sections = 1,6 for flat bars	(1) Strength/weather decks	The lesser of the following: (a) $Z = (K_1 K_2 T D + K_3 B_1 s h_1 l_e^2) k \times 10^{-4}$ (b) $Z = 2K_3 B_1 s k h_1 l_e^2 \times 10^{-4}$	—
	(2) Cargo decks	$Z = (400K_1 T D + 38{,}8 s h_2 l_e^2) k \times 10^{-4}$	—
	(3) Accommodation decks	$Z = (530K_1 T D + 38{,}8 s h_3 l_e^2) k \times 10^{-4}$	—
	(4) In way of the crown or bottom of a tank	As in (1), (2) or (3) as applicable, or $Z = \dfrac{0{,}0113\rho s k h_4 l_e^2}{\gamma}$ whichever is the greater	$I = \dfrac{2{,}3}{k} l_e Z$

NOTES
1. Where weather decks are intended to carry deck cargo and the load is in excess of 8,5 kN/m^2 (0,865 tonne-f/m^2), the scantlings of beams may be required to be increased to comply with the requirements for location (2) using the equivalent design head, for specified cargo loading, for weather decks given in Table 3.5.1 in Pt 3, Ch 3.
2. The web depth of beams, d_w, is to be not less than 60 mm.

4.3.5 The scantlings of strength/weather, cargo and accommodation deck transverse beams are to comply with the requirements of Table 1.4.5.

4.3.6 The end connections of beams are to be in accordance with the requirements of Pt 3, Ch 10,3.

4.4 Deck supporting structure

4.4.1 **Girders and transverses** supporting deck longitudinals and beams, also hatch side girders and hatch end beams, are to comply with the requirements of Table 1.4.6. In general, transverses, webs or frames of increased scantlings, *see* Table 1.6.2, are to be arranged in way of hatch end beams and deck transverses, and these are to be in line with the double bottom floors where practicable. Equivalent transverse ring scantling arrangements will be considered.

Table 1.4.6 Deck girders, transverses and hatch beams

Location and arrangements	Modulus, in cm^3	Inertia, in cm^4
(1) Girders and transverses in way of dry cargo spaces and clear of hatch openings: (a) supporting up to three point loads	*See also* Note Z to be determined from calculations using Note and stress $\frac{123,5}{k}$ N/mm^2 $\left(\frac{12,6}{k}\text{ kgf/mm}^2\right)$ and assuming fixed ends	$I = \frac{1,85}{k}\, l_e Z$
(b) supporting four or more point loads or a uniformly distributed load	$Z = 4,75k\, S\, H_g\, l_e^2$	
(2) Hatch side girders in way of dry cargo spaces at weather decks (with deep coamings): (a) supporting up to three point loads	Z to be determined from calculations using Note and stress $\frac{100,4}{k}$ N/mm^2 $\left(\frac{10,25}{k}\text{ kgf/mm}^2\right)$ and assuming fixed ends	$I = \frac{2,3}{k}\, l_e Z$
(b) supporting four or more point loads or a uniformly distributed load	$Z = 5,85k\, S_1\, H_g\, l_e^2$	
(3) Hatch side girders in way of dry cargo spaces at lower decks (without deep coamings): (a) supporting up to three point loads	Z to be determined from calculations using stress $\frac{112,5}{k}$ N/mm^2 $\left(\frac{11,5}{k}\text{ kgf/mm}^2\right)$	$I = \frac{1,85}{k}\, l_e Z$
(b) supporting four or more point loads or a uniformly distributed load	$Z = 5,20k\, S_1\, H_g\, l_e^2$	
(4) Hatch end beams in way of dry cargo spaces and supported at centreline, *see* Fig. 1.4.1: (a) In association with longitudinal framing when there is no transverse between the hatch end beam and adjacent transverse bulkhead or equivalent supporting structure	$Z = 19k\, K_1\, H_g\, l_e\, S_1\, l_1 + 2,37k\, S_e H_g\, l_e^2$	$I = \frac{2,8}{k}\, l_e Z$
(b) In association with longitudinal framing where there is one or more transverse between the hatch end beam and adjacent transverse bulkhead or equivalent supporting structure	$Z = 19k\, K_1\, H_g\, l_e\, (S_1\, l_1 + S_2\, l_2)$	
(c) In association with transverse framing when the hatch end beam supports the hatch side girder and in line girder only	$Z = 19k\, K_1\, H_g\, l_e\, (S_1\, l_1 + S_3\, l_3)$	
(d) In association with transverse framing when the hatch end beam supports the hatch side girder, an in line girder and an additional girder between the hatch side and the centreline	$Z = 19k\, H_g\, l_e\, (K_1\, (S_1\, l_1 + S_4\, l_4) + K_2\, S_5\, l_5)$	
(5) Girders and transverses in way of the crown or bottom of a tank	$Z = 11,7\rho\, k\, h_4\, S\, l_e^2$	$I = \frac{2,8}{k}\, l_e Z$

Symbols

S, l_e, k, ρ as defined in 1.5.1
h_4 = tank head, in metres, as defined in Pt 3, Ch 3,5
l_1, l_2, l_3, l_4, l_5, in metres, as indicated in Fig. 1.4.1
B_h = breadth of hatchway, in metres, as used to determine K_1
H_g = weather head h_1, or cargo head h_2, or accommodation head h_3, in metres, as defined in Pt 3, Ch 3,5, whichever is applicable

K_1, K_2 = factors, dependent on the girder arrangements, as follows:

$\frac{B_h}{2l_e}$ or $\frac{X}{l_e}$	K_1 or K_2
0,2	0,143
0,3	0,177
0,4	0,191
0,5	0,187
0,6	0,179
0,7	0,169
0,8	0,141
0,9	0,085
1,0	0,000

S_e, S_1, S_2, S_3, S_4, S_5, in metres as indicated in Fig. 1.4.1
X = distance, in metres, from centreline of ship to an additional girder, if fitted, as shown in Fig. 1.4.1, as used to determine K_2

NOTE
In single deck ships the section modulus of deck transverses is to be increased by 15 per cent.

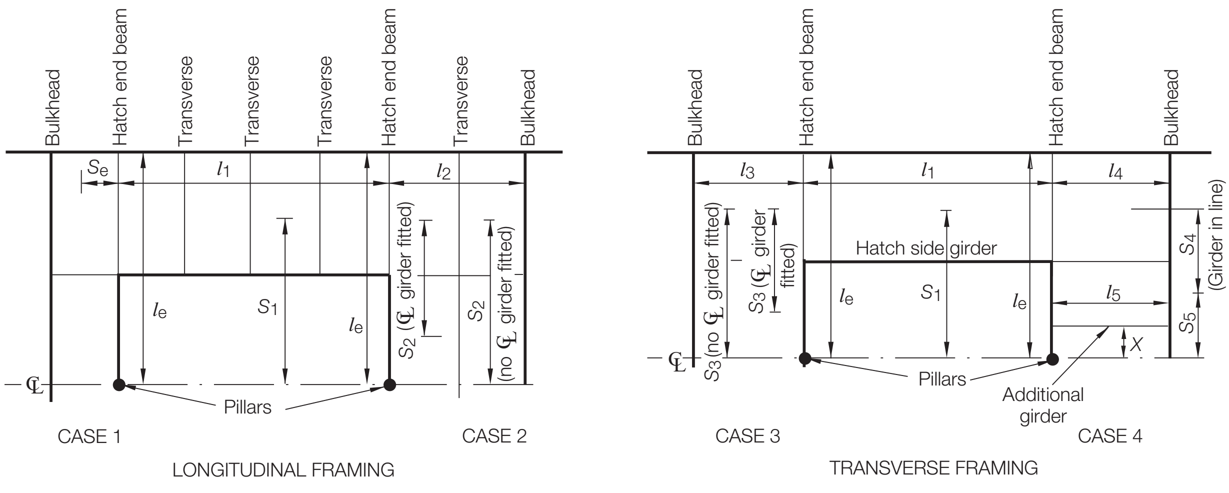


Fig. 1.4.1 Hatch end beam arrangements

4.4.2 **Transverses** supporting deck longitudinals are, in general, to be spaced not more than 3,8 m apart where the length, *L*, is 100 m or less, and (0,006*L* + 3,2) m apart where *L* is greater than 100 m.

4.4.3 The web thickness, stiffening arrangements and end connection of primary supporting members are to be in accordance with Pt 3, Ch 10,4.

4.4.4 Where a girder is subject to concentrated loads, such as pillars out of line, the scantlings are to be suitably increased. Also, where concentrations of loading on one side of the girder may occur, the girder is to be adequately stiffened against torsion. Reinforcements may be required in way of localised areas of high stress.

4.4.5 **Pillars** are to comply with the requirements of Table 1.4.7.

4.4.6 Pillars are to be fitted in the same vertical line wherever possible, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

4.4.7 Tubular and hollow square pillars are to be attached at their heads to plates supported by efficient brackets, in order to transmit the load effectively. Doubling or insert plates are to be fitted to the inner bottom under the heels of tubular or hollow square pillars, and to decks under large pillars. The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be well distributed by means of longitudinal and transverse brackets.

4.4.8 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided, and where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

4.4.9 Where pillars are fitted inside tanks or under watertight flats, the tensile stress in the pillar and its end connections is not to exceed 108 N/mm^2 (11,0 kgf/mm^2) at the test heads. In general, such pillars should be of built sections, and end brackets may be required.

4.4.10 Pillars are to be fitted below deckhouses, windlasses, winches, capstans and elsewhere where considered necessary.

4.4.11 **Non-watertight pillar bulkheads** are to comply with the requirements of Table 1.4.8.

4.4.12 **Cantilevers** and their supporting frames are to comply with the requirements of Table 1.4.9.

Table 1.4.7 Pillars

Symbols	Parameter	Requirement
b = breadth of side of a hollow rectangular pillar or breadth of flange or web of a built or rolled section, in mm d_p = mean diameter of tubular pillars, in mm k = local scantling higher tensile steel factor, *see* Pt 3, Ch 2,1.2.3, but not less than 0,72 l = overall length of pillar, in metres l_e = effective length of pillar, in metres, and is taken as: for hold pillars 0,65l for 'tween deck pillars 0,80l l_p = distance, in metres, between centres of the two adjacent spans of girder, or transverse, supported by the pillar r = least radius of gyration of pillar cross-section, in mm, and may be taken as: $r = 10\sqrt{\frac{I}{A_p}}$ mm A_p = cross-sectional area of pillar, in cm^2 C, S as defined in 1.5.1 H_g as defined in Table 1.4.6 I = least moment of inertia of cross-section, in cm^4 P = load, in kN (tonne-f), supported by the pillar and is to be taken as $\frac{9,81\,SH_g\,l_p}{C} + P_a \quad \left(\frac{SH_g\,l_p}{C} + P_a\right)$ but not less than 19,62 kN (2 tonne-f) P_a = load, in kN (tonne-f), from pillar or pillars above (zero if no pillars over)	(1) Cross-sectional area of all types of pillar	$A_p = \dfrac{k\,P}{12,36 - 51,5\,\dfrac{l_e}{r\sqrt{k}}}$ cm^2 $\left(A_p = \dfrac{k\,P}{1,26 - 5,25\,\dfrac{l_e}{r\sqrt{k}}} \text{ cm}^2\right)$ *See* Note
	(2) Minimum wall thickness of tubular pillars	The greater of the following: (a) $t = \dfrac{P}{d_p\left(0,392 - 1,53\,\dfrac{l_e}{r}\right)}$ mm (a) $\left(t = \dfrac{P}{d_p\left(0,04 - 0,156\,\dfrac{l_e}{r}\right)}\right)$ mm (b) $t = \dfrac{d_p}{40}$ mm but not to be less than t = 5,5 mm where L < 90 m, or = 7,5 mm where $L \geq$ 90 m
	(3) Minimum wall thickness of hollow rectangular pillars or web plate thickness of I or channel sections	The lesser of (b) and (c), but not to be less than (a): (a) $t = \dfrac{P}{b\left(0,5 - 1,95\,\dfrac{l_e}{r}\right)}$ mm (a) $\left(t = \dfrac{P}{b\left(0,05 - 0,2\,\dfrac{l_e}{r}\right)}\right)$ mm (b) $t = \dfrac{br}{600\,l_e}$ mm (c) $t = \dfrac{b}{55}$ mm but to be not less than t = 5,5 mm where L < 90 m, or = 7,5 mm where $L \geq$ 90 m
	(4) Minimum thickness of flanges of angle or channel sections	The lesser of the following: (a) $t_f = \dfrac{br}{200\,l_e}$ mm (b) $t_f = \dfrac{b}{18}$ mm
	(5) Minimum thickness of flanges of built or rolled I sections	The lesser of the following: (a) $t_f = \dfrac{br}{400\,l_e}$ mm (b) $t_f = \dfrac{b}{36}$ mm

NOTE

As a first approximation A_p may be taken as $\dfrac{\sqrt{k}\,P}{9,32}\left(\dfrac{\sqrt{k}\,P}{0,95}\right)$ and the radius of gyration estimated for a suitable section having this area.

If the area calculated using this radius of gyration differs by more than 10 per cent from the first approximation, a further calculation using the radius of gyration corresponding to the mean area of the first and second approximation is to be made.

Table 1.4.8 Non-watertight pillar bulkheads

Symbols	Parameter	Requirement: Ships with L < 90 m	Requirement: Ships with $L \geq 90$ m
d_w, t_p, b, c as defined in Pt 3, Ch 3,3 r = radius of gyration, in mm, of stiffener and attached plating $= 10\sqrt{\frac{I}{A}}$ mm for rolled, built or swedged stiffeners $= d_w\sqrt{\frac{3b + c}{12\,(b + c)}}$ mm for symmetrical corrugation I = moment of inertia, in cm^4, of stiffener and attached plating s = spacing of stiffeners, in mm A = cross-sectional area, in cm^2, of stiffener and attached plating $A_1 = \dfrac{P}{12{,}36 - 51{,}5\dfrac{l_e}{r}}$ cm^2 $\left(A_1 = \dfrac{P}{1{,}26 - 5{,}25\dfrac{l_e}{r}}\text{ cm}^2\right)$ As a first approximation A_1 may be taken as $\dfrac{P}{9{,}32}\left(\dfrac{P}{0{,}95}\right)$ $A_2 = \dfrac{P}{4{,}9 - 14{,}7\dfrac{l_e}{r}}$ cm^2 $\left(A_2 = \dfrac{P}{0{,}5 - 1{,}5\dfrac{l_e}{r}}\text{ cm}^2\right)$ As a first approximation A_2 may be taken as $\dfrac{P}{3{,}92}\left(\dfrac{P}{0{,}4}\right)$ P, l_e as defined in Table 1.4.7 $\lambda = \dfrac{b}{c}$	(1) Minimum thickness of bulkhead plating	5,5 mm in holds and 'tween decks	7,5 mm in holds 6,5 mm in 'tween decks
	(2) Maximum stiffener spacing	1500 mm	1500 mm
	(3) Minimum depth of stiffeners or corrugations	100 mm in holds 75 mm in 'tween decks	150 mm in holds 100 mm in 'tween decks
	(4) Cross-sectional area (including plating) for rolled, built or swedged stiffeners supporting beams, longitudinals, girders or transverses	(a) Where $\frac{s}{t} \leq 80$ (b) Where $\frac{s}{t} \geq 120$ (c) Where $80 < \frac{s}{t} < 120$	$A = A_1$ $A = A_2$ A is obtained by interpolation between A_1 and A_2
	(5) Cross-sectional area (including plating) for symmetrical corrugation	(a) Where $\frac{b}{t_p} \leq \frac{750\lambda l_e}{(\lambda + 0{,}25)\,r}$ (b) Where $\frac{b}{t_p} > \frac{750\lambda l_e}{(\lambda + 0{,}25)\,r}$	$A = A_1$ $A = A_2$

4.5 Deck openings

4.5.1 The corners of main cargo hatchways in the strength deck within 0,5L amidships are to be elliptical, parabolic or rounded, with a radius generally not less than 1/24 of the breadth of the opening. Rounded corners are to have a minimum radius of 300 mm if the deck plating extends inside the coaming, or 150 mm if the coamings are welded to the inner edge of the plating in the form of a spigot. Where elliptical corners are arranged, the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than 2 to 1 nor greater than 2,5 to 1, and the minimum half-length of the major axis is to be defined by l_1 in Fig. 1.4.5. Where parabolic corners are arranged, the dimensions are also to be as shown in Fig. 1.4.5.

4.5.2 Where the corners of large openings in the strength deck are parabolic or elliptical, insert plates are not required. For other shapes of corner, insert plates of the size and extent shown in Fig. 1.4.6 will, in general, be required. The required thickness of the insert plate is to be not less than 25 per cent greater than the adjacent deck thickness, outside line of openings with a minimum increase of 4 mm. The increase need not exceed 7 mm.

4.5.3 Welded attachments close to or on the free edge of the hatch corner plating are to be avoided (e.g., welded protection strips or shedder plates) and the butt welds of corner insert plates to the adjacent deck plating are to be located well clear of butts in the hatch coaming.

Table 1.4.9 **Cantilever beams** (*see continuation*)

Location and supporting arrangements	Required modulus, in cm^3, *see* Notes	
	Cantilever beam	Supporting frame
(1) Any position – no support from end girders	$Z_o = 8{,}67kM_o$ ($Z_o = 85kM_o$)	$Z_v = \dfrac{v}{H_1}\left(\dfrac{fZ_o}{u} - kZ_t\right)$
(2) At hatch side – uniform loading, partial support received from hatch side girder, *see* Fig. 1.4.3: (a) Hatch side girder supported by Rule hatch end beams or pillars at hatch corners (b) Hatch side girder supported by end bulkheads of hold – no Rule hatch end beams or pillars (c) No transverse bulkheads between hatchways, no Rule hatch end beams or pillars, *see* Notes (d) At hatch side – concentrated loading	(a) $Z_u = 0{,}9Z_o - kG$ (b) Z_u as in (a) or the following formula, whichever is the greater: $\left(\dfrac{n+1}{n}\right)\left(0{,}45\left(1+\dfrac{1}{\beta}\right)Z_o - k\beta G - (1-\beta)\,kE\right)$ (c) Z_u as in (a) or the following formula, whichever is the greater: $\left(\dfrac{n+1}{n}\right)\left(\dfrac{Z_o}{\beta} - 0{,}5kE\right)$ (d) Z_u as in (a), (b) or (c), whichever is applicable, or as the following formula, whichever is the greater: $Z_o - kG_1$	$Z_v = \dfrac{v}{H_1}\left(\dfrac{fZ_u}{u} - kZ_t\right)$
	Required inertia, in cm^4	
Case (1) or (2)	$I_u = \dfrac{9u}{k}Z_u$	—

NOTES

1. Where a transverse bulkhead is fitted at only one end of a hatchway the section modulus of cantilever beams is to be a mean of the values obtained from (2)(b) and (2)(c).
2. Where only cantilevers in the length of a hatchway consist of two or three close together at the mid-length of hatchway, their modulus is to be determined by calculating the modulus of a single cantilever at mid-length and dividing this by the actual number of cantilevers.
3. If a negative value is obtained for the required section modulus, cantilevers are not necessary for the arrangement considered.
4. In calculating the actual section modulus of a cantilever or supporting frame, the effective area of attached plating is to be as given in Pt 3, Ch 3,3. Intermediate beams or frames within the effective breadth may be included in the calculation.
5. Rule hatch end beams are those with scantlings determined from Table 1.4.6, assuming that the hatch side girder has a span between hatch end beams.
6. The section modulus of cantilever beams is to be not less than that determined from Table 1.4.5 for beams in the same position.
7. The section modulus of side frames, pillars or pillar bulkhead stiffeners supporting cantilevers is to be not less than that required for ordinary side frames. pillars or pillar bulkhead stiffeners, as determined from the appropriate Sections of the Rules.
8. The scantlings of the cantilever bracket within the shaded area shown in Fig. 1.4.2 are to be as follows:
   (a) Where tripping brackets are not fitted:
   $$t = (0{,}0075d_c + 5)\sqrt{k} \text{ mm}$$
   $$A_f = \left(\frac{27Z_d}{e}\left(1 - \frac{e}{1420f}\right) - \frac{et}{300}\right)k \text{ cm}^2$$
   (b) Where tripping brackets are fitted at the positions indicated in Fig. 1.4.2:
   $$t = (0{,}0075d_c + 5)\sqrt{k} \text{ mm}$$
   $$A_f = \left(\frac{20Z_d}{e}\left(1 - \frac{e}{1420f}\right) - \frac{et}{200}\right)k \text{ cm}^2$$
   In general the radius at the throat of the cantilever bracket is to be not less than d_c.
9. The cantilever beam and supporting frame face plates may be gradually tapered from the limits of the shaded area shown in Fig. 1.4.2. The web depth of the supporting frame may be tapered to a minimum of $0{,}5d_f$ at the base.
10. Where the web thickness of cantilevers or supporting frames is less than $\dfrac{d_w}{60\sqrt{k}}$ transverse web stiffeners are to be fitted spaced approximately $1{,}5d_w$ apart. In no case is the web thickness outside the limits of the cantilever brackets to be less than $\dfrac{d_w}{85\sqrt{k}}$
    Where stiffeners are fitted parallel to the face plates, the stiffening arrangements will be specially considered.

Table 1.4.9 Cantilever beams (*conclusion*)

Symbols

f = overall length of cantilever, in metres

k = higher tensile steel factor as defined in 1.5.1

l_b = distance, in metres, between transverse bulkheads, *see* Fig. 1.4.4. Where there is no bulkhead midway between hatchways, l_b is to be measured to a point midway between hatchways

l_h = length of hatchway, in metres, *see* Fig. 1.4.4

C = cargo stowage rate in m^3/tonne as defined in Pt 3, Ch 3,5, and is to be taken as 1,39 m^3/tonne unless specified otherwise

Z_a = section modulus, in cm^3, of hatch side girder which is to be not less than that calculated from Table 1.4.6, taking the span between cantilevers

Z_b = mean of section moduli, in cm^3, of longitudinal girders in line with hatch side girder (Z_b is to be taken not greater than Z_a)

$Z_d = \dfrac{fZ_u}{u}$

Z_o = section modulus, in cm^3, of cantilever beam, not supported by end girder, at distance u from outer end

Z_t = section modulus, in cm^3, of frame or stiffener above cantilever, *see* Fig. 1.4.2. (Where there is no frame or stiffener above cantilever Z_t = 0)

Z_u = section modulus, in cm^3, of cantilever beam, partially supported by hatch side girder at end, at distance u from outer end

Z_v = section modulus, in cm^3, of supporting frame, at distance v from lower end

Z_1, Z_2, Z_3 = mean of section moduli, in cm^3, of hatch end beams calculated for the positions shown in Fig. 1.4.3. Z_2 is to be taken as the smaller modulus of the two sections adjacent to the hatch side

$\beta = \dfrac{l_h}{l_b}$

E is determined as follows:

When centreline bulkheads or pillars are fitted:

$$E = \frac{4}{n+1}\left((Z_1 + Z_2) + \frac{2u}{B_h}(Z_2 + Z_3)\right)$$

Where there is no centreline support:

d_c = web depth of cantilever, at root of bracket, in mm, *see* Fig. 1.4.2

d_f = web depth of frame at root of bracket, in mm, *see* Fig. 1.4.2

d_w = web depth of cantilever or frame, in mm

e = web depth, in mm, as shown in Fig. 1.4.2

n = number of cantilevers between the hatch end beams

t = thickness of cantilever bracket, in mm

u, v = lever arms, in metres, as shown in Fig. 1.4.2

A_f = sectional area, in cm^2, of cantilever bracket face plate

B_h = breadth of hatch, in metres, *see* Fig. 1.4.4

$$E = \frac{4}{n+1}(Z_1 + Z_2)$$

$$G = \frac{7u}{(n+1)l_h}(Z_a + Z_b)$$

$$G_1 = \frac{3{,}5uZ_a}{S_c}$$

H_1, H_2, H_3 = mean height of hold or 'tween deck, in metres, as shown in Fig. 1.4.2. At weather decks, H_2 and H_3 are to be taken equivalent to the weather head h_1 as defined in Pt 3, Ch 3,5

M_o = bending moment, in kN m (tonne-f m), on the cantilever beam due to the load supported by a single cantilever. This bending moment is to be calculated about an axis at a distance u from the end. For hatch side cantilevers with uniformly distributed loading this will equal

$$\frac{4{,}9S_c\,u}{C}(H_2B_h + H_3\,u)$$

$$\left(\frac{0{,}5S_c\,u}{C}(H_2B_h + H_3\,u)\right)$$

S_c = spacing of cantilevers, in metres, *see* Fig. 1.4.4

4.5.4 Openings in the strength deck outside the line of hatch openings are to be kept to the minimum number consistent with operational requirements. Openings are to be arranged clear of hatch corners and, so far as possible, clear of one another. Where, within 0,4*L* amidships, deck openings have a total breadth or shadow area breadth, in one transverse section that exceeds the limitation given in Pt 3, Ch 3,3.4.4 and 3.4.5, compensation will be required to restore the excess. This is generally to be arranged by increasing the deck plate thickness, but other proposals will be considered. Plate panels in which openings are cut are to be adequately stiffened, where necessary, against compression and shear buckling. The corners of all openings are to be well rounded and the edges smooth.

4.5.5 Openings in the strength deck outside the line of hatch openings having a stress concentration factor in excess of 2,4 will require edge reinforcements in the form of a spigot of adequate dimensions, but alternative arrangements will be considered. The area of any edge reinforcement which may be required is not to be taken into account in determining the required sectional area of compensation for the opening. Alternatively, the shape of the opening is to be such that a stress concentration factor of 2,4 is not exceeded. In this respect, reinforcement will not in general, be required in way of:

(a) elliptical openings having their major axis fore and aft and a ratio of length to breadth not less than 2 to 1, or

(b) openings of other shapes provided that it has been shown by suitable tests that the stress concentration factor does not exceed 2,4.

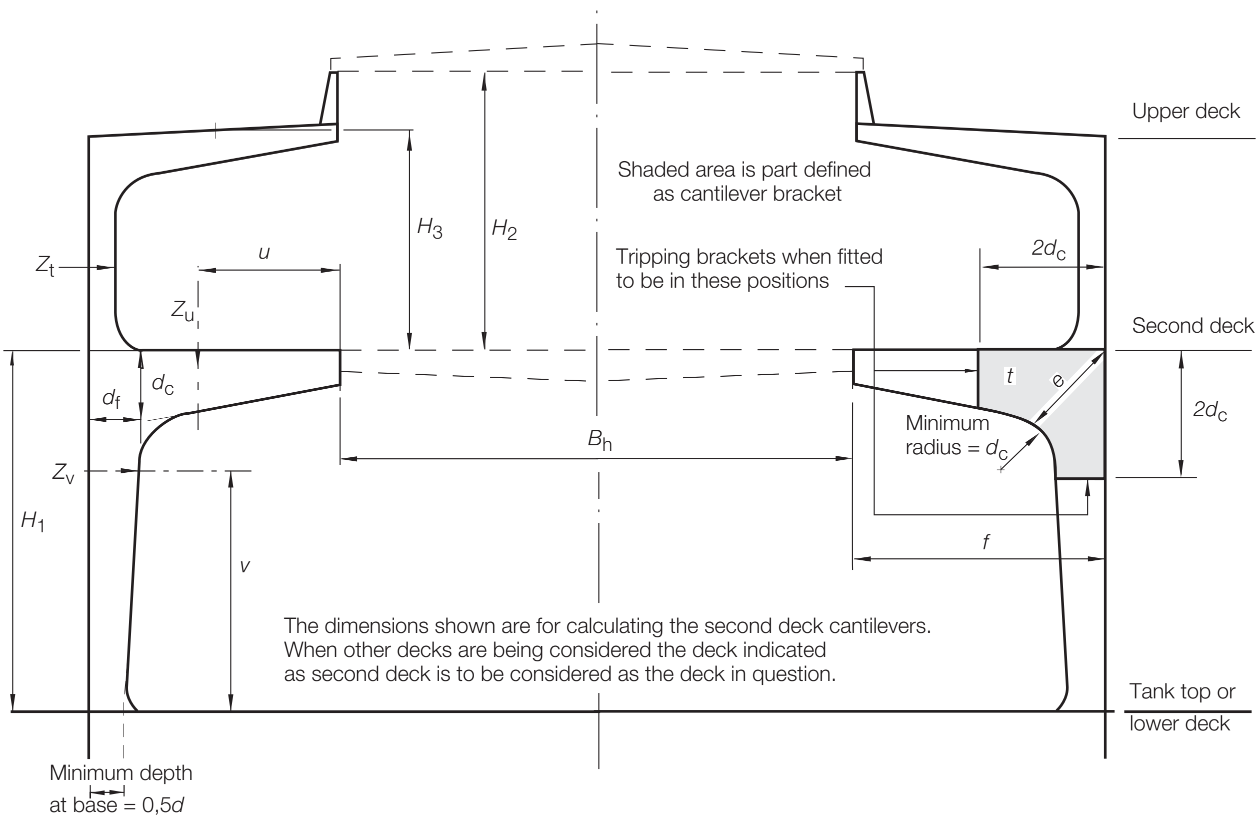


Fig. 1.4.2 Deck cantilevers

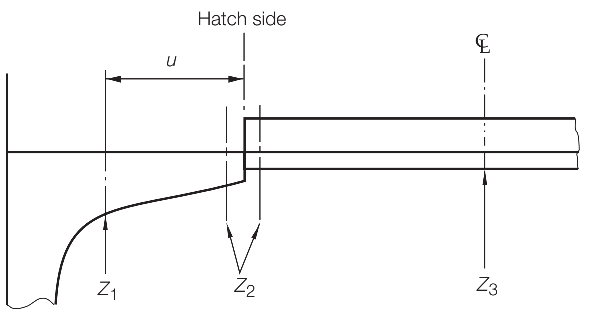


Fig. 1.4.3 Section moduli of hatch end beams

4.5.6 Lower deck openings should be kept clear of main hatch corners and the areas of high stress, so far as possible. Compensation will not, in general, be required unless the total width of openings in any frame space, or between any two transverses, exceeds 15*k* per cent of the original effective plating width. The requirements of 4.5.4 also apply to lower deck openings except that:

(a) the thickness of inserts, if required, for the second deck hatch corners is to be 2,5 mm greater than the deck thickness,

(b) inserts will not generally be required for hatch corners on third decks, platform decks and below, and

(c) reinforcement will not generally be required for circular openings, provided that the plate panels in which they are situated are otherwise adequately stiffened against compression and shear buckling.

4.5.7 All openings are to be adequately framed; attention is to be paid to structural continuity, and abrupt changes of shape, section or plate thickness are to be avoided. Arrangements in way of corners and openings are to be such as to minimise the creation of stress concentrations. Where a deck longitudinal is cut, compensation is to be arranged to ensure full continuity of strength.

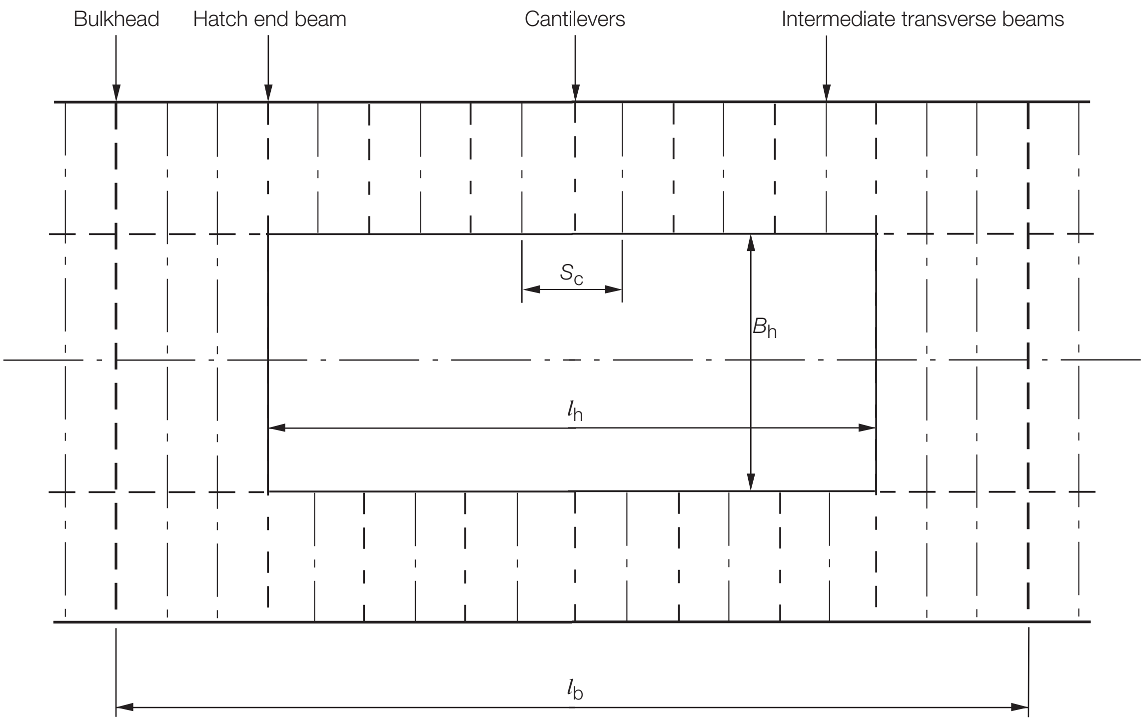


Fig. 1.4.4 Deck supporting structure

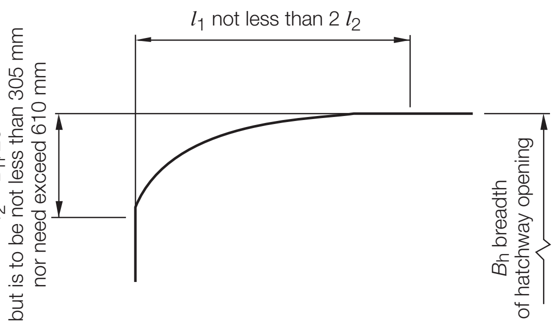


Fig. 1.4.5 Elliptical and parabolic corners

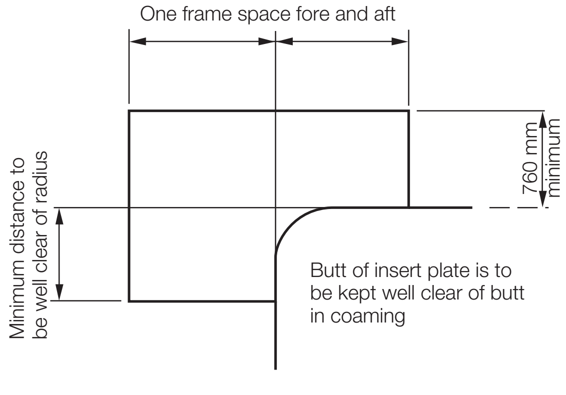


Fig. 1.4.6 Insert plates for large openings

Section 5
Shell envelope plating

5.1 General

5.1.1 Requirements are given in this Section for longitudinal or transversely framed shell plating, and attention is drawn to the requirements of 6.1.1. In ships with a transversely framed bottom construction, the bottom shell plating is, in general, to be reinforced with additional continuous, or intercostal, longitudinal stiffeners, *see also* 7.1.2. Alternative arrangements will be considered.

5.1.2 For ships intended to load or unload while aground, *see* Pt 3, Ch 9,9.

5.2 Keel

5.2.1 The cross-sectional area and thickness of bar keels, and the width and thickness of plate keels, are to comply with the requirements of Table 1.5.1. Forged or rolled bar keels are also to comply with the material requirements of Chapter 3 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

Table 1.5.1 Bar and plate keels

Item and parameter	Requirement
(1) Bar keels: Cross-sectional area Thickness	A = $(1{,}8L - 16)$ cm^2 t = $(0{,}6L + 8)$ mm
(2) Plate keels: Breadth Thickness	b = $70B$ mm but need not exceed 1800 mm and is not to be less than 750 mm t = $(t_1 + 2)$ mm where t_1 is as in location (1) in Table 1.5.2, using the spacing in way of the keel plate t is to be taken not less than the adjacent bottom shell thickness
Symbols	
L, B as defined in 1.5.1 b = breadth of keel, in mm t = thickness of keel, in mm A = cross-sectional area, in cm^2	

5.3 Bottom shell and bilge

5.3.1 In the midship region the thickness of bottom shell plating to the upper turn of bilge is to be that necessary to give the hull section modulus required by Pt 3, Ch 4,5, and is to be not less than the minimum values given by Table 1.5.2.

5.4 Side shell

5.4.1 In the midship region, the thickness of side shell and sheerstrake plating including the sides of bridge superstructures is to be not less than the values given by Table 1.5.3, but may be required to be increased locally on account of high shear forces in accordance with Pt 3, Ch 4,6.

5.4.2 Sea inlets, or other openings, are to have well rounded corners and so far as possible, are to be kept clear of the bilge radius. Openings on, or near to, the bilge radius are to be elliptical. The thickness of sea inlet box plating is to be the same as the adjacent shell, but not less than 12,5 mm and need not exceed 25 mm.

5.4.3 Where a rounded sheerstrake is adopted the radius should, in general, be not less than 15 times the thickness.

5.4.4 The sheerstrake thickness is to be increased by 20 per cent at the ends of a bridge superstructure extending out to the ship's side. In the case of a bridge superstructure exceeding 0,15L, the side plating at the ends of the superstructure is also to be increased by 25 per cent and tapered gradually into the upper deck sheerstrake.

5.4.5 In general, compensation will not be required for holes in the sheerstrake which are clear of the gunwale or any deck openings situated outside the line of the main hatchways and whose depth does not exceed 20 per cent of the depth of the sheerstrake or 380 mm, whichever is the lesser. Openings are not to be cut in a rounded gunwale. Cargo door openings are to have well rounded corners, and the proposed compensation for the door openings will be individually considered.

Table 1.5.2 Bottom shell and bilge plating

<table>
<tr><th rowspan="2">Location</th><th colspan="2">Minimum thickness, in mm, see also 5.3.1</th></tr>
<tr><th>Longitudinal framing</th><th>Transverse framing</th></tr>
<tr><td>(1) Bottom plating, see Notes 1 and 2</td><td>The greater of the following:
(a) $t = 0{,}001 s_1 (0{,}043 L_1 + 10) \sqrt{\dfrac{F_B}{k_L}}$ (see Note 4)
(b) $t = 0{,}0052 s_1 \sqrt{\dfrac{h_{T2} k}{1{,}8 - F_B}}$</td><td>The greater of the following:
(a) $t = 0{,}001 s_1 f_1 (0{,}056 L_1 + 16{,}7) \sqrt{\dfrac{F_B}{k_L}}$ (see Note 4)
(b) $t = 0{,}0063 s_1 \sqrt{\dfrac{h_{T2} k}{1{,}8 - F_B}}$</td></tr>
<tr><td>(2) Bilge plating – where framed, see Notes 1 and 2</td><td>t as for (1)</td><td>t as for (1)</td></tr>
<tr><td>(3) Bilge plating – where unframed, see Note 3</td><td colspan="2">Provided that transverses or adequate bilge brackets are spaced not more than
$\dfrac{8t^2}{DR_B} \sqrt{\dfrac{t}{R_B}} \times 10^6$ mm apart
$t = \dfrac{R_B F_B}{165 k_L}$ but is to be not less than the adjacent bottom plating</td></tr>
<tr><th colspan="3">Symbols</th></tr>
<tr><td colspan="3">L, D, T, s, S, k_L, k as defined in 1.5.1
C_w is as defined in 1.5.1. Where $L > 227$ m, C_w is not to be taken less than 6,446 m
$f_1 = \dfrac{1}{1 + \left(\dfrac{s}{1000S}\right)^2}$
h_{T2} = $(T + 0{,}5\, C_w)$, in metres but need not be taken greater than $1{,}2T$ m
s_1 = s, but is not to be taken less than the smaller of $470 + \dfrac{L}{0{,}6}$ mm or 700 mm
F_B = as defined in Pt 3, Ch 4,5.7
L_1 = L but need not be taken greater than 190 m
R_B = bilge radius, in mm, see Note 3</td></tr>
<tr><td colspan="3">NOTES
1. The thickness derived in accordance with (1) is also to satisfy the buckling requirements of Pt 3, Ch 4,7.
2. The thickness of bottom shell or bilge plating is to be not less than the basic shell end thickness for taper as given in Pt 3, Ch 5,3 and Ch 6,3.
3. Where longitudinally framed and the lowest side longitudinal lies a distance a mm above the uppermost turn of bilge and/or the outermost bottom longitudinal lies a distance b inboard of the lower turn of bilge, the bilge radius is to be taken as $R_B + \dfrac{(a + b)}{2}$ mm.
In no case is a or b to be greater than s.
4. Where separate maximum sagging and hogging still water bending moments are assigned, F_B may be based on the hogging moment.</td></tr>
</table>

Table 1.5.3 Side shell plating

Location	Thickness, in mm, *see also* 5.4.1 — Longitudinal framing	Thickness, in mm, *see also* 5.4.1 — Transverse framing
(1) Side shell clear of sheerstrake, *see* Notes 1, 2, 4 and 5	(a) Above $\frac{D}{2}$ from base: The greater of the following: (i) $t = 0{,}001s_1\,(0{,}059L_1 + 7)\sqrt{\frac{F_D}{k_L}}$ (ii) $t = 0{,}0042s_1\sqrt{h_{T1}\,k}$	(a) Within $\frac{D}{4}$ from the gunwale: The greater of the following: (i) $t = 0{,}00085s_1\,f_1\,(0{,}083L_1 + 10)\sqrt{\frac{F_D}{k_L}}$ (ii) $t = 0{,}0042s_1\sqrt{h_{T1}\,k}$
	(b) At upper turn of bilge, *see* Note 3: The greater of the following: (i) $t = 0{,}001s_1\,(0{,}059L_1 + 7)\sqrt{\frac{F_B}{k_L}}$ (ii) $t = 0{,}0054s_1\sqrt{\frac{h_{T2}\,k}{2 - F_B}}$	(b) Within $\frac{D}{4}$ from mid-depth: The greater of the following: (i) $t = 0{,}001s_1\,(0{,}059L_1 + 7)\sqrt{\frac{F_M}{k_L}}$ (ii) $t = 0{,}0051s_1\sqrt{h_{T1}\,k}$
	(c) Between upper turn of bilge and $\frac{D}{2}$ from base: The greater of the following: (i) t from (b)(i) (ii) t from interpolation between (a)(ii) and (b)(ii)	(c) Within $\frac{D}{4}$ from base (excluding bilge plating), *see* Note 3: The greater of the following: (i) $t = 0{,}00085s_1\,f_1\,(0{,}083L_1 + 10)\sqrt{\frac{F_B}{k_L}}$ (ii) $t = 0{,}0056s_1\sqrt{\frac{h_{T2}\,k}{1{,}8 - F_B}}$
(2) Sheerstrake, *see* Notes 1, 2 and 5	The greater of the following: (i) $t = 0{,}001s_1\,(0{,}059L_1 + 7)\sqrt{\frac{F_D}{k_L}}$ (ii) $t = 0{,}00083s_1\sqrt{Lk} + 2{,}5$ but t is to be not less than the thickness of the adjacent side plating	The greater of the following: (i) $t = 0{,}001s_1\,f_1\,(0{,}083L_1 + 10)\sqrt{\frac{F_D}{k_L}}$ (ii) $t = 0{,}001s_1\sqrt{Lk} + 2{,}5$ but t is to be not less than the thickness of the adjacent side plating

Symbols

L, D, T, S, s, k_L, k, as defined in 1.5.1

C_W is as defined in 1.5.1. Where $L > 227$ m, C_W is not to be taken less than 6,446 m

$$f_1 = \frac{1}{1 + \left(\frac{s}{1000S}\right)^2}$$

h_{T1} = $T + C_W$ m but need not be taken greater than $1{,}36T$

h_{T2} = $T + 0{,}5C_W$ m but need not be taken greater than $1{,}2T$

s_1 = s, but is not to be taken less than the smaller of

$$470 + \frac{L}{0{,}6} \text{ mm or } 700 \text{ mm}$$

F_D, F_B = as defined in Pt 3, Ch 4,5.7

F_M = the greater of F_D or F_B

L_1 = L, but need not be taken greater than 190 m

NOTES

1. The thickness is also to satisfy the buckling requirements of Pt 3, Ch 4,5.6.
2. The thickness of side shell or sheerstrake is to be not less than the basic shell end thickness for taper, as given in Pt 3, Ch 5,3 and Ch 6,3. The width of the sheerstrake (where of different thickness from the side shell) is to be not less than that required by Table 2.2.1 in Pt 3, Ch 2.
3. The thickness of side shell need not exceed that determined from Table 1.5.2 for bottom shell, but using the spacing of side frames or longitudinals.
4. Outside the Rule minimum region of higher tensile steel as defined in Pt 3, Ch 3,2.6.1 the value of k_L may be taken as 1,0.
5. For the expressions contained in (i), where separate maximum sagging and hogging still water bending moments are assigned, F_D may be based on the sagging moment and F_B on the hogging moment.

Section 6
Shell envelope framing

6.1 General

6.1.1 Longitudinal framing is, in general, to be adopted at the bottom, but special consideration will be given to proposals for transverse framing in this region. Transverse or longitudinal framing can be adopted for the side shell. Requirements are given in this Section for longitudinal and transverse framing systems.

6.1.2 End connections of longitudinals to bulkheads are to provide adequate fixity and, so far as practicable, direct continuity of longitudinal strength. Where L exceeds 215 m, the bottom longitudinals are to be continuous in way of both watertight and non-watertight floors, but alternative arrangements will be considered. Higher tensile steel longitudinals within 10 per cent of the ship's depth at the bottom and deck are to be continuous irrespective of the ship length, *see also* Pt 3, Ch 10,5.2.

6.1.3 Stiffeners and brackets on side transverses, where fitted on one side and connected to higher tensile steel longitudinals between the base line and $0{,}8D_2$ above the base line, are to have their heels well radiused to reduce stress concentrations. Where a symmetrical arrangement is fitted, i.e., bracket or stiffening on both sides, and it is connected to higher tensile steel longitudinals, the toes of the stiffeners or brackets are to be well radiused. Alternative arrangements will be considered if supported by appropriate direct calculations, *see also* Pt 3, Ch 10,5.2.

6.1.4 Where higher tensile steel side longitudinals pass through transverse bulkheads in the cargo area, well radiused brackets of the same material are to be fitted on both the fore and aft side of the connection between the upper turn of bilge and $0{,}8D_2$ above the base line. Particular attention should be given to ensuring the alignment of these brackets. Alternative arrangements will be considered if supported by appropriate direct calculations, *see also* 6.2.3.

6.1.5 For ships intended to load or unload while aground, *see* Pt 3, Ch 9,9.

6.2 Longitudinal stiffening

6.2.1 For non-**CSR** tankers, bulk carriers and ore carriers (*see* Pt 1, Ch 2,2.3) the scantlings of bottom and side longitudinals in the midship region are to comply with the requirements given in Table 1.6.1(b). In general other ships are to comply with Table 1.6.1(a).

6.2.2 The lateral and torsional stability of longitudinals together with web and flange buckling criteria are to be verified in accordance with Pt 3, Ch 4,7.

6.2.3 Where higher tensile steel asymmetrical sections are adopted in double bottom tanks which are interconnected with double skin side tanks or combined hopper and topside tanks the requirements of 6.1.3 and 6.1.4 are to be complied with regarding arrangements to reduce stress concentrations. Alternatively, it is recommended that bulb plate or symmetrical sections are adopted.

6.3 Transverse stiffening

6.3.1 The scantlings of main and 'tween deck frames, and bottom frames in way of bracket floors, in the midship region are to comply with the requirements given in Table 1.6.2.

6.3.2 The scantlings of main frames are normally to be based on Rule standard brackets at top and bottom, whilst the scantlings of 'tween deck frames are normally to be based on a Rule standard bracket at the top only.

6.3.3 End connections of transverse main and 'tween deck frames are to be in accordance with Pt 3, Ch 10,3.

6.4 Primary supporting structure

6.4.1 Side transverses supporting longitudinal stiffening, and webs and stringers supporting transverse side stiffening, are to comply with the requirements of Table 1.6.3.

6.4.2 Side transverses are to be spaced not more than 3,8 m apart when the length, L, is less than 100 m and ($0{,}006L + 3{,}2$) m apart where L is greater than 100 m.

Table 1.6.1(a) Shell framing (longitudinal)

Location	Modulus, in cm^3
(1) Side longitudinals in way of dry spaces, including double skin construction, *see* Note 2	The lesser of the following: (a) $Z = 0{,}056\, s k h_{T1}\, l_e^2\, F_1\, F_s$ (b) Z from (3)(a) evaluated using s, k and l_e for the longitudinal under consideration and the remaining parameters evaluated at the base line
(2) Side longitudinals in way of double skin tanks or deep tanks, *see* Note 2	The greater of the following: (a) Z as from (1) (b) As required by Ch 1,9 for deep tanks
(3) Bottom and bilge longitudinals, *see* Notes 1, 2, 3 and 4	The greater of the following: (a) $Z = \gamma\, s\, k\, h_{T2}\, l_e^2\, F_1$ (b) $Z = \gamma\, s\, k\, h_{T3}\, l_e^2\, F_1\, F_{sb}$

Symbols

L, D, T, s, k, k_L, ρ as defined in 1.5.1

l_e = as defined in 1.5.1, but is not to be taken less than 1,5 m except in way of the centre girder brackets required by 8.5.3 where a minimum span of 1,25 m may be used

l_{e1} = l_e in metres, but is not to be taken less than 2,5 m and need not be taken greater than 5,0 m

$c_1 = \dfrac{60}{225 - 165F_D}$ at deck

$= 1{,}0$ at $\dfrac{D_2}{2}$

$= \dfrac{75}{225 - 150F_B}$ at base line

intermediate values by interpolation

D_1 = D_2, in metres, but is not to be taken less than 10 and need not be taken greater than 16

D_2 = D, in metres, but need not be taken greater than $1{,}6T$

F_B, F_D as defined in Pt 3, Ch 4,5.7

$F_1 = \dfrac{D_2\, c_1}{4D_2 + 20h_5}$ for side longitudinals above $\dfrac{D_2}{2}$

$= \dfrac{D_2\, c_1}{25D_2 - 20h_5}$ for side longitudinals below $\dfrac{D_2}{2}$ and bottom longitudinals

minimum $F_1 = 0{,}14$

L_1 = L but need not be taken greater than 190 m

F_s is a fatigue factor for side longitudinals to be taken as follows:

(a) For built sections and rolled angle bars

$F_s = \dfrac{1{,}1}{k}\left[1 - \dfrac{2b_{f1}}{b_f}(1-k)\right]$ at $0{,}6D_2$ above the base line

$= 1{,}0$ at D_2 and above, and F_{sb} at the base line intermediate values by linear interpolation

(b) For flat bars and bulb plates $\dfrac{b_{f1}}{b_f}$ may be taken as 0,5

F_{sb} is a fatigue factor for bottom longitudinals = $0{,}5\,(1 + F_s$ at $0{,}6D_2)$

where

b_{f1} = the minimum distance, in mm, from the edge of the face plate of the side longitudinal under consideration to the centre of the web plate, *see* Fig. 9.5.1 in Chapter 9

$h_{T1} = C_W\left(1 - \dfrac{h_6}{D_2 - T}\right) F_\lambda$, in metres, for longitudinals above the waterline, at draught T, where $C_W\left(1 - \dfrac{h_6}{D_2 - T}\right)$ is not to be taken less than $\dfrac{L_1}{56}$ m for Type ‘B-60’ ships and the greater of $\dfrac{L_1}{70}$, or 1,20 m for Type ‘B’ ships

$= \left[h_6 + C_W\left(1 - \dfrac{h_6}{2T}\right)\right] F_\lambda$, in metres, for longitudinals below the waterline at draught T

h_{T1} need not exceed $0{,}86\left(h_5 + \dfrac{D_1}{8}\right)$ for $F_1 \le 0{,}14$ and $\left(h_5 + \dfrac{D_1}{8}\right)$ for $F_1 > 0{,}14$

h_{T2} = $(T + 0{,}5C_W)$, in metres for bottom longitudinals need not be taken greater than $1{,}2T$ m

h_{T3} = $h_4 - 0{,}25T$, in metres

h_4 = load head required by Ch 1,9 for deep tanks

h_5 = vertical distance, in metres, from longitudinal to deck at depth, D_2

h_6 = vertical distance, in metres, from the waterline at draught T to the longitudinal under consideration

b_f = the width of the face plate, in mm, of the side longitudinal under consideration, *see* Fig. 9.5.1 in Chapter 9

C_W = a wave head, in metres = $7{,}71 \times 10^{-2} L e^{-0{,}0044L}$ where e = base of natural logarithms 2,7183

F_λ = 1,0 for $L \le 200$ m

= $[1{,}0 + 0{,}0023(L - 200)]$ for $L > 200$ m

$\gamma = 0{,}002 l_{e1} + 0{,}046$

NOTES

1. The buckling requirements of Pt 3, Ch 4,7 are to be complied with. The ratio of the web depth, d_w, to web thickness, t, is to comply with the following requirements:
   (a) Built up profiles and rolled angles:
   $\dfrac{d_w}{t} \le 60\sqrt{k_L}$
   (b) Flat bars:
   $\dfrac{d_w}{t} \le 18\sqrt{k_L}$ when continuous at bulkheads
   $\dfrac{d_w}{t} \le 15\sqrt{k_L}$ when non-continuous at bulkheads
2. Where struts are fitted midway between transverses in way of double bottom tanks, or double skin construction, the modulus of the bottom or side longitudinals may be reduced by $50k$ per cent from that obtained from the locations (1), (2), or (3) as applicable.
3. Where the bilge radius exceeds the Rule height of a double bottom the modulus of the longitudinal above this nominal height is to be derived from the location (1) or (2) as applicable.
4. Where no bilge longitudinals are fitted and bilge brackets are required by location (3) in Table 1.5.2, at least two brackets are to be fitted.

Table 1.6.1(b) Shell framing (longitudinal)

Location	Modulus, in cm^3
(1) Side longitudinals in way of dry spaces, including double skin construction, *see* Note 2	The lesser of the following: (a) $Z = 0{,}056\, s k h_{T1}\, l_e^2\, F_1\, F_s$ (b) Z from (3)(a) evaluated using s and l_e for the longitudinal under consideration and the remaining parameters evaluated at the base line
(2) Side longitudinals in way of double skin tanks or deep tanks, *see* Note 2	The greater of the following: (a) Z as from (1) (b) As required by Ch 1,9 for deep tanks, using h_{T3} instead of h_4, but need not exceed Z from (3)(b) evaluated using γ, s and l_e for the longitudinal under consideration and the remaining parameters evaluated at the base line
(3) Bottom and bilge longitudinals, *see* Notes 1, 2, 3 and 4	The greater of the following: (a) $Z = \gamma\, s\, k\, h_{T2}\, l_e^2\, F_1\, F_{sb}$ (b) $Z = \gamma\, s\, k\, h_{T3}\, l_e^2\, F_1\, F_{sb}$

Symbols

L, D, T, s, k, ρ as defined in 1.5.1

l_e = as defined in 1.5.1, but is not to be taken less than 1,5 m except in way of the centre girder brackets required by 8.5.3 where a minimum span of 1,25 m may be used

l_{e1} = l_e in metres, but is not to be taken less than 2,5 m and need not be taken greater than 5,0 m

$c_1 = \dfrac{60}{225 - 165F_D}$ at deck

$= 1{,}0$ at $\dfrac{D_2}{2}$

$= \dfrac{75}{225 - 150F_B}$ at base line

intermediate values by interpolation

D_1 = D_2, in metres, but is not to be taken less than 10 and need not be taken greater than 16

D_2 = D, in metres, but need not be taken greater than 1,6T

F_B, F_D as defined in Pt 3, Ch 4,5.7

$F_1 = \dfrac{D_2\, c_1}{4D_2 + 20h_5}$ for side longitudinals above $\dfrac{D_2}{2}$

$= \dfrac{D_2\, c_1}{25D_2 - 20h_5}$ for side longitudinals below $\dfrac{D_2}{2}$ and bottom longitudinals

minimum $F_1 = 0{,}14$

L_1 = L but need not be taken greater than 190 m

F_s is a fatigue factor for side longitudinals to be taken as follows:

(a) For built sections and rolled angle bars

$$F_s = \frac{1{,}1}{k}\left[1 - \frac{2b_{f1}}{b_f}(1 - k)\right] \text{ at } 0{,}6D_2 \text{ above the base line}$$

$= 1{,}0$ at D_2 and above, and F_{sb} at the base line intermediate values by linear interpolation

(b) For flat bars and bulb plates $\dfrac{b_{f1}}{b_f}$ may be taken as 0,5

F_{sb} is a fatigue factor for bottom longitudinals = 0,5 (1 + F_s at 0,6D_2)

where

b_{f1} = the minimum distance, in mm, from the edge of the face plate of the side longitudinal under consideration to the centre of the web plate, *see* Fig. 9.5.1 in Chapter 9

$h_{T1} = C_W\left(1 - \dfrac{h_6}{D_2 - T}\right)F_\lambda$, in metres, for longitudinals above the waterline, at draught T, where $\left(1 - \dfrac{h_6}{D_2 - T}\right)$ is not to be taken less than 0,7

$= \left[h_6 + C_W\left(1 - \dfrac{h_6}{2T}\right)\right]F_\lambda$, in metres, for longitudinals below the waterline at draught T

h_{T1} and h_{T2} need not exceed $0{,}86\left(h_5 + \dfrac{D_1}{8}\right)$ for $F_1 \le 0{,}14$ and $\left(h_5 + \dfrac{D_1}{8}\right)$ for $F_1 > 0{,}14$

h_{T2} = $(T + 0{,}5C_W)\,F_\lambda$, in metres for bottom longitudinals

h_{T3} = $h_4 - 0{,}25T$, in metres, at the base line

= h_4, in metres, at and above $T/4$ from the base line, intermediate values by linear interpolation

h_4 = load head required by Ch 1,9 for deep tanks

h_5 = vertical distance, in metres, from longitudinal to deck at depth, D_2

h_6 = vertical distance, in metres, from the waterline at draught T to the longitudinal under consideration

b_f = the width of the face plate, in mm, of the side longitudinal under consideration, *see* Fig. 9.5.1 in Chapter 9

C_W = a wave head, in metres = $7{,}71 \times 10^{-2} L e^{-0{,}0044L}$

where e = base of natural logarithms 2,7183

F_λ = 1,0 for $L \le 200$ m

= $[1{,}0 + 0{,}0023(L - 200)]$ for $L > 200$ m

γ = $0{,}002 l_{e1} + 0{,}046$

NOTES

1. The buckling requirements of Pt 3, Ch 4,7 are to be complied with. The ratio of the web depth, d_w, to web thickness, t, is to comply with the following requirements:
   (a) Built up profiles and rolled angles:
   $$\frac{d_w}{t} \le 60\sqrt{k_L}$$
   (b) Flat bars:
   $$\frac{d_w}{t} \le 18\sqrt{k_L} \text{ when continuous at bulkheads}$$
   $$\frac{d_w}{t} \le 15\sqrt{k_L} \text{ when non-continuous at bulkheads}$$
2. Where struts are fitted midway between transverses in way of double bottom tanks, or double skin construction, the modulus of the bottom or side longitudinals may be reduced by 50k per cent from that obtained from the locations (1), (2), or (3) as applicable.
3. Where the bilge radius exceeds the Rule height of a double bottom the modulus of the longitudinal above this nominal height is to be derived from the location (1) or (2) as applicable.
4. Where no bilge longitudinals are fitted and bilge brackets are required by location (3) in Table 1.5.2, at least two brackets are to be fitted.

Table 1.6.2 Shell framing (transverse)

Location	Modulus, in cm^3	Inertia, in cm^4
(1) Main, 'tween deck and superstructure frames in dry spaces, *see* Note 3	The greater of the following: (a) $Z = C\,s\,k\,h_{T1}\,H^2 \times 10^{-3}$ (b) $Z = 9{,}1 s\,k\,D_1 \times 10^{-3}$	$I = \frac{3{,}2}{k} HZ$
(2) Main and 'tween deck frames in way of fuel or water ballast tanks or cargo holds used for water ballast	The greater of the following: (a) $1{,}15 \times Z$ from (1) (b) $Z = 6{,}7 s\,k\,h\,H_2^2 \times 10^{-3}$	$I = \frac{3{,}2}{k} HZ$
(3) Frames supporting hatch end beams or deck transverses, *see* Note 2	The greater of the following: (a) Z from (1) (b) $Z = 2{,}5\,(0{,}2 l_s^2 + H_1^2)\,k\,S_1\,H_g$	$I = \frac{3{,}2}{k} HZ$
(4) Bottom frames of double bottom bracket floors	$Z = 2{,}15 s\,k\,T\,l_e \times 10^{-2}$	—

Symbols

D, T, s, k as defined in 1.5.1

C = end connection factor
= 3,4 where two Rule standard brackets are fitted
= $3{,}4\,(1{,}8 - 0{,}8\,(l_a/l))$ where one Rule standard bracket and one reduced bracket are fitted
= $3{,}4\,(2{,}15 - 1{,}15\,(l_{amean}/l))$ where two reduced brackets are fitted
= 6,1 where one Rule standard bracket is fitted
= $6{,}1\,(1{,}2 - 0{,}2\,(l_a/l))$ where one reduced bracket is fitted
= 7,3 where no bracket is fitted
The requirements for frames where brackets larger than Rule standard are fitted will be specially considered

l_a = equivalent arm length, in mm, as derived from Pt 3, Ch 10,3.4.1

l_{amean} = mean equivalent arm length, in mm, for both brackets

h_{T1} = head, in metres, at middle of H
= $C_w \left(1 - \frac{h_6}{D_1 - T}\right) F_\lambda$, in metres for frames where the mid-length of frame is above the waterline, at draught T
where $\left(1 - \frac{h_6}{D_1 - T}\right)$ is not to be taken less than 0,7
= $\left[h_6 + C_w \left(1 - \frac{h_6}{2T}\right)\right] F_\lambda$, in metres for frames where the mid-length of frame is below the waterline at draught T

h = h_4 or h_5, whichever is the greater

h_4 = tank head, in metres, as defined in Pt 3, Ch 3,5

h_5 = head, in metres, measured from the mid-length of H, to the deck at side

h_6 = vertical distance in metres, from waterline at draught T to the mid-length of H

l_s = distance, in metres, from side shell to inboard support of beam or transverse

l_e = effective length, in metres, of bottom frames for double bottom bracket floors

l_h = length, in metres, of hatch side girder

C_w = a wave head, in metres,
= $7{,}71 \times 10^{-2}\,L e^{-0{,}0044L}$
where e = base of natural logarithms 2,7183

F_λ = 1,0 for $L \leq 200$ m
= $(1{,}0 + 0{,}0023\,(L - 200))$ for $L > 200$ m

D_1 = D, but need not be taken greater than $1{,}6T$

H = H_{MF} or H_{TF} as applicable, *see* Note 1

H_{MF} = vertical framing depth, in metres, of main frames, as shown in Fig. 1.6.1, but is to be taken not less than 3,5 m

H_{TF} = vertical framing depth, in metres, of 'tween deck frames, as shown in Fig. 1.6.1, but is to be taken not less than 2,5 m

H_1 = H, but need not be taken greater than 3,5 m

H_2 = H, where H_{MF} is to be taken not less than 2,5 m

H_9 = weather head, h_1, or cargo head, h_2, in metres, as defined in Pt 3, Ch 3,5, whichever is applicable

S = spacing, in metres, of deck transverses

S_1 = $\frac{l_h}{4}$ for hatch end beams
= S for transverses

NOTES
1. Where frames are inclined at more than 15° to the vertical, H_{MF} or H_{TF} is to be measured along a chord between span points of the frame.
2. If the modulus obtained from (3) for frames under deck transverses exceeds that obtained from (1) and (2), the intermediate frames may be reduced provided that the combined modulus is maintained and the reduction in any intermediate frame is not greater than 35 per cent. The reduced modulus is to be not less than that given by (1)(b).
3. The scantlings of main frames are not to be less than those of the 'tween deck frames above.

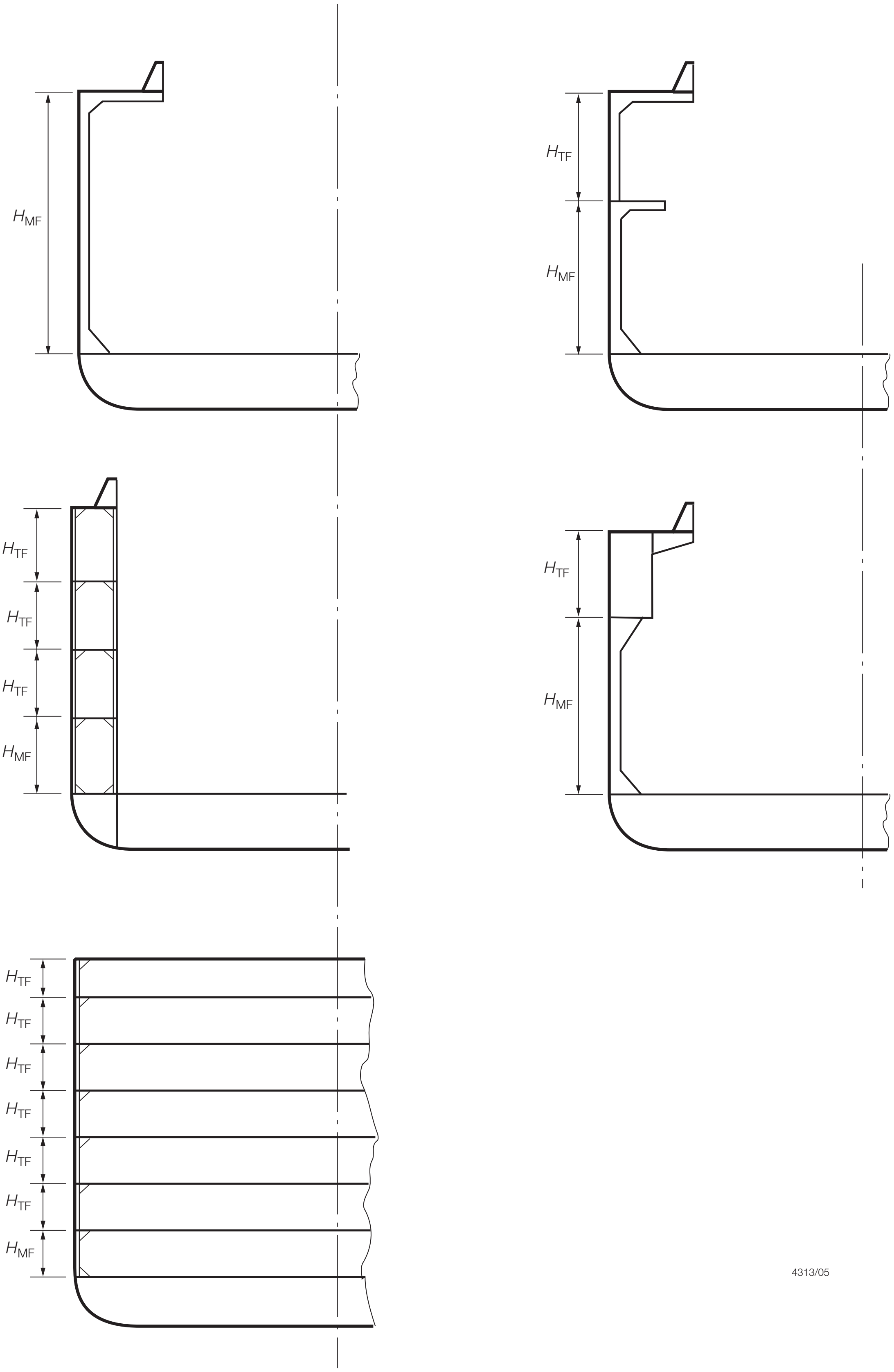


Fig. 1.6.1 Framing depths for various structural configurations

Table 1.6.3 Primary structure

Item and location	Modulus, in cm^3	Inertia, in cm^4
Longitudinal framing system:		
(1) Side transverses in dry cargo spaces	$Z = 10k\,S\,h_{T1}\,l_e^2$	—
(2) Side transverses in deep tanks	$Z = 11{,}7\rho\,k\,S\,h_4\,l_e^2$ or as (1) above, whichever is the greater	$I = \frac{2{,}5}{k}\,l_e\,Z$
Transverse framing system:		
(3) Side stringers in dry cargo spaces	$Z = 7{,}75k\,S\,h_{T1}\,l_e^2$	—
(4) Side stringers in deep tanks	$Z = 11{,}7\rho\,k\,S\,h_4\,l_e^2$ or as (3) above, whichever is the greater	$I = \frac{2{,}5}{k}\,l_e\,Z$
(5) Web frames supporting side stringers	Z determined from calculation based on following assumptions: (a) fixed ends (b) point loadings (c) head h_4 or h_{T1} as applicable (d) bending stress $\frac{93{,}2}{k}$ N/mm^2 $\left(\frac{9{,}5}{k}\text{ kgf/mm}^2\right)$ (e) shear stress $\frac{83{,}4}{k}$ N/mm^2 $\left(\frac{8{,}5}{k}\text{ kgf/mm}^2\right)$	$I = \frac{2{,}5}{k}\,l_e\,Z$

Symbols

T, S, l_e, k, ρ as defined in 1.5.1

h_4 = tank head, in metres, as defined in Pt 3, Ch 3,5

h_{T1} = head, in metres, at mid-length of span

= $C_w\left(1 - \frac{h_6}{D_1 - T}\right) F_\lambda$, in metres where the mid-length of span is above the waterline at draught T, where $\left(1 - \frac{h_6}{D_1 - T}\right)$ is not to be taken less than 0,7

= $\left[h_6 + C_w\left(1 - \frac{h_6}{2T}\right)\right] F_\lambda$, in metres where the mid-length of span is below the waterline at draught T

where

h_6 = vertical distance, in metres, from the waterline at draught T, to the mid-length of span

F_λ = 1,0 for $L \leq 200$ m
= $[1{,}0 + 0{,}0023\,(L - 200)]$ for $L > 200$ m

C_w = a wave head, in metres
= $7{,}71 \times 10^{-2}\,L e^{-0{,}0044L}$
where e = base of natural logarithms 2,7183

D_1 = D but need not be taken greater than $1{,}6T$

■ *Section 7* Single bottom structure

7.1 General

7.1.1 Requirements are given in this Section for single bottom construction in association with transverse framing, and are generally applicable to the following ships:

(a) Cargo ships of less than 500 tons gross tonnage.
(b) Ships not propelled by mechanical means.
(c) Trawlers and fishing vessels.

Cases where a single bottom structure is adopted in association with longitudinal framing will be considered.

7.1.2 Ships with single bottoms are to have a centre girder fitted. In addition, one side girder is to be fitted on each side of the centreline where B does not exceed 10 m, and two side girders on each side where B is greater than 10 m and does not exceed 17 m. In addition, continuous or intercostal longitudinal stiffeners are to be fitted where the panel size exceeds the ratio 4 to 1. Centre and side girders are to extend as far forward and aft as practicable, and where they are cut at bulkheads the longitudinal strength is to be maintained.

7.1.3 Plate floors are to be fitted at every frame, and the tops of floors, in general, may be level from side to side, but in ships having considerable rise of floor, and towards the ends, the depth of the floor plates is to be increased. Floor plates forming part of a watertight or deep tank bulkhead are to be not less than 900 mm in depth measured at the centreline, and the thickness is to be not less than that required for the bottom strake of a bulkhead.

7.1.4 For ships intended to load or unload while aground, *see* Pt 3, Ch 9,9.

Table 1.7.1 Single bottom girders and floors

Item	Depth, in mm	Thickness, in mm	Face plate area, in cm^2
(1) Centre girder	As for floors	$t = \sqrt{Lk} + 2$ but not less than 6,0	$A_f = 0{,}67Lk$ but not less than 12,5 *See* Notes 2 and 3
(2) Side girders	As for floors	$t = \sqrt{Lk}$ but not less than 6,0	$A_f = (0{,}25L + 5)\,k$ but not less than 10,0 *See* Note 3
(3) Floors	Where $B \leq 10$ m: $d_f = 40\,(B + T)$ Where $B > 10$ m: $d_f = 40\,(1{,}5B + T) - 200$ (*see* Note 1)	$t = \dfrac{s\sqrt{k}}{s_1}\left(\dfrac{d_f}{100} + 3\right)$ but not less than 6,0	$A_f = \dfrac{5Tsk}{s_1}\left(1 - \dfrac{2{,}5}{B}\right)$ *See* Notes 2 and 3

Symbols

L, B, T, s, k as defined in 1.5.1
b_f = breadth of face plate, in mm
d_f = overall depth of floor at the centreline, in mm
s_1 = a standard frame spacing, in mm, and is to be taken as $2(L + 240)$
A_f = cross-sectional area of face plate, in cm^2

NOTES
1. If the side frames are attached to the floors by brackets, the Rule depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame and are to be the same as the reduced floor depth given above.
2. The face plate thickness of floors and centre girder is to be not less than the floor plate thickness.
3. The thickness of face plates is to be:
   not less than $\dfrac{b_f}{16\sqrt{k}}$ nor more than $\dfrac{b_f}{8}$

7.1.5 Provision is made for the free passage of water from all parts of the bottom to the suctions, taking into account the pumping rates required.

7.2 Girders and floors

7.2.1 The scantlings of girders and floors are to comply with the requirements of Table 1.7.1.

■ *Section 8* Double bottom structure

8.1 Symbols and definitions

8.1.1 The symbols used in this Section are defined as follows:

L, B, T as defined in 1.5.1
d_{DB} = Rule depth of centre girder, in mm
d_{DBA} = actual depth of centre girder, in mm
h_{DB} = head from top of inner bottom to top of over-flow pipe, in metres
s = spacing of stiffeners, in mm
H_{DB} = height from tank top, at position under consideration, to deck at side amidships, in metres
Z_{BF} = section modulus of bottom frame at bracket floor, in cm^3.

8.2 General

8.2.1 Except as specified in 8.2.4, cargo ships other than tankers are to be fitted with a double bottom extending from the collision bulkhead to the after peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

8.2.2 Where a double bottom is required to be fitted, its depth at the centreline, d_{DB}, is to be in accordance with 8.3.1 and the inner bottom is to be continued out to the ship's side in such a manner as to protect the bottom to the turn of the bilge.

8.2.3 Small wells constructed in the double bottom, in connection with the drainage arrangements of holds, are not to extend in depth more than necessary. A well extending to the outer bottom, may however, be permitted at the after end of the shaft tunnel of the ship. Other well arrangements (e.g., for lubricating oil under main engines) may be considered provided they give protection equivalent to that afforded by the double bottom. In no case shall the vertical distance from the bottom of such a well to a plane coinciding with the keel line be less than 500 mm for passenger ships and cargo ships other than tankers. Keel line is defined in SOLAS Chapter II-1, Part A, Regulation 1.

8.2.4 A double bottom need not be fitted in way of watertight compartments used exclusively for the carriage of liquids, provided the safety of the ship in the event of bottom damage is not thereby impaired. In addition, a double bottom need not be fitted on the following ships:
(a) Cargo ships of less than 500 tons gross tonnage.
(b) Ships not propelled by mechanical means.
(c) Trawlers and fishing vessels.

8.2.5 This Section provides for longitudinal or transverse framing in the double bottom, but for ships exceeding 120 m in length and for ships strengthened for heavy cargoes, longitudinal framing is, in general, to be adopted. For the additional requirements for ships specially strengthened for heavy cargoes, *see* Ch 7,1.3.

8.2.6 For ships intended to load or unload while aground, *see* Pt 3, Ch 9,9.

8.2.7 Girders and the side walls of duct keels are to be continuous, and the structure in way is to be sufficient to withstand the forces imposed by dry-docking the ship.

8.2.8 Adequate access is to be provided to all parts of the double bottom. The edges of all holes are to be smooth. The size of opening should not, in general, exceed 50 per cent of the double bottom depth, unless edge reinforcement is provided. In way of ends of floors and fore and aft girders at transverse bulkheads, the number and size of holes are to be kept to a minimum, and the openings are to be circular or elliptical. Edge stiffening may be required in these positions.

8.2.9 Provision is to be made for the free passage of air and water from all parts of the tank to the air pipes and suctions, account being taken of the pumping rates required. To ensure this, sufficient air holes and drain holes are to be provided in all longitudinal and transverse non-watertight primary and secondary members. The drain holes are to be located as close to the bottom as is practicable, and air holes are to be located as close to the inner bottom as is practicable, *see also* Pt 3, Ch 10,5.3 and Pt 4, Ch 9,5.8.

8.3 Girders

8.3.1 The minimum depth of the centre girder is to be taken as the greater of the following:

(a) $d_{DB} = 28B + 205\sqrt{T}$ mm

(b) $d_{DB} = 50B$ mm, but need not be taken as greater than 2000 mm

(c) $d_{DB} = 760$ mm.

8.3.2 The centre girder thickness is to be not less than:

$$t = (0{,}008d_{DB} + 4)\sqrt{k} \quad \text{mm}$$

nor less than 6,0 mm. The thickness may be determined using the value for d_{DB} without applying the minimum depths specified in 8.3.1(b) and (c).

8.3.3 **In transversely framed ships** where the breadth, *B*, does not exceed 10 m, no side girders are required, and one vertical stiffener is to be fitted to the floors on each side, about midway between the centreline and the margin plate. One side girder is to be fitted where the breadth, *B*, exceeds 10 m but does not exceed 20 m, and for greater breadths two girders are to be fitted on each side of the centreline. The non-watertight side girders are to extend as far forward and aft as practicable and are to have a thickness not less than:

$$t = (0{,}008d_{DB} + 1)\sqrt{k} \quad \text{mm}$$

nor less than 6,0 mm.

8.3.4 Vertical stiffeners are to be fitted at every bracket floor (*see* 8.5.7), and are to have a depth not less than the depth of the tank top frame or 150 mm, whichever is the greater. For ships with a length, *L*, less than 90 m, stiffeners are to have a depth of not less than 1,65*L* mm with a minimum of 50 mm. The thickness is to be as required for the girder. Watertight side girders are to have a thickness 1 mm greater than required by 8.3.3 for non-watertight side girders. Where the double bottom tanks are interconnected with side tanks or cofferdams, the thickness is to be as for deep tanks (*see* 9.2.1) with *h*, in metres, measured to the highest point at the side tank or cofferdam.

8.3.5 **In longitudinally framed ships** one side girder is to be fitted where the breadth, *B*, exceeds 14 m, and two girders are to be fitted on each side of the centreline where *B* exceeds 21 m. The girders are to extend as far forward and aft as practicable and are to have a thickness not less than:

$$t = (0{,}0075d_{DB} + 1)\sqrt{k} \quad \text{mm}$$

nor less than 6,0 mm.
In general, a vertical stiffener, having a depth not less than 100 mm and a thickness equal to the girder thickness, is to be arranged midway between floors.

8.3.6 **Watertight side girders** are to have a plating thickness corresponding to the greater of the following:

(a) $t = (0{,}0075d_{DB} + 2)\sqrt{k}$ mm, or

(b) thickness *t* as for deep tanks (*see* 9.2.1) with *h*, in metres, measured to the highest point of the side tank, or cofferdam if the double bottom is interconnected with these tanks.

8.3.7 Watertight side girder stiffeners are to be in accordance with the requirements for watertight floors, *see* 8.5.4 and 8.5.5.

8.3.8 **Duct keels,** where arranged, are to have a thickness of side plates corresponding to the greater of the following:

(a) $t = (0{,}008d_{DB} + 2)\sqrt{k}$ mm, or

(b) thickness *t*, as for deep tanks (*see* 9.2.1) with *h*, in metres, measured to the highest point of the side tank, or cofferdam if the double bottom tank is interconnected with these tanks.

8.3.9 The sides of duct keels are, in general, to be spaced not more than 2,0 m apart. Where the sides of the duct keels are arranged on either side of a centreline or side girder, each side is, in general, to be spaced not more than 2,0 m from the centreline or side girder. The inner bottom and bottom shell within the duct keel are to be suitably stiffened. The primary stiffening in the transverse direction is to be suitably aligned with the floors in the adjacent double bottom tanks. Where the duct keels are adjacent to double bottom tanks which are interconnected with side tanks or cofferdams, the stiffening is to be in accordance with the requirements for deep tanks, *see* 9.2.1. Access to the duct keel is to be by watertight manholes or trunks.

8.3.10 The buckling requirements of Pt 3, Ch 4,7 are also to be satisfied.

8.4 Inner bottom plating and stiffening

8.4.1 The thickness of the inner bottom plating in the holds is to be not less than:

$$t = 0{,}00136\,(s + 660)\ \sqrt[4]{k^2\,LT}\ \text{mm}$$

nor less than 6,5 mm in holds and 7,5 mm under hatchways if no ceiling is fitted.

8.4.2 The thickness of the inner bottom plating as determined in 8.4.1 is to be increased by 2 mm under the hatchways if no ceiling is fitted. If cargo is to be regularly discharged by grabs, *see* 2.2.2.

8.4.3 A margin plate, if fitted, is to have a thickness throughout 20 per cent greater than that required for inner bottom plating.

8.4.4 Where the double bottom tanks are common with side tanks or cofferdams, the thickness of the inner bottom plating is to be not less than that required for deep tanks (*see* 9.2.1), with h, in metres, taken to the highest point of the side tank or cofferdam, and K_1 is to be taken as 'elsewhere'.

8.4.5 Inner bottom longitudinals, or tank top frames at bracket floors within the range of cargo holds, are to have a section modulus not less than 85 per cent of the Rule value for bottom longitudinals (*see* 6.2.1) or bottom frames in way of bracket floors (*see* 6.3.1), whichever is applicable. The unsupported span of tank top frames is generally not to exceed 2,5 m. Where the double bottom tanks are inter-connected with side tanks, hopper and topside tanks or cofferdams, the scantlings are to be not less than those required for deep tanks, *see* 9.2.1. For higher tensile steel inner bottom longitudinals the requirements of 6.2.2 are to be complied with where applicable.

8.4.6 The buckling requirements of Pt 3, Ch 4,7 are also to be satisfied.

8.5 Floors

8.5.1 **In longitudinally framed ships**, plate floors are to be fitted under bulkheads and elsewhere at a spacing not exceeding 3,8 m. The thickness of non-watertight plate floors is to be not less than:

$$t = (0{,}009 d_{DB} + 1)\sqrt{k}\ \text{mm}$$

nor less than 6,0 mm. The thickness need not be greater than 15 mm, but the ratio between the depth of the double bottom and the thickness of the floor is not to exceed $130\sqrt{k}$. This ratio may, however, be exceeded if suitable additional stiffening is fitted. Vertical stiffeners are to be fitted at each longitudinal, having a depth not less than 150 mm and a thickness equal to the thickness of the floors. For ships of length, L, less than 90 m, the depth is to be not less than 1,65L mm, with a minimum of 50 mm.

8.5.2 The thickness of watertight floors for longitudinally framed ships is to be not less than:

(a) $t = (0{,}008 d_{DB} + 3)\sqrt{k}$ mm, or

(b) $t = (0{,}009 d_{DB} + 1)\sqrt{k}$ mm

whichever is the greater,

but need not exceed 15 mm on floors of normal depth. The thickness is also to satisfy the requirements for deep tanks (*see* 9.2.1) with h, in metres, taken to the highest point of the side tank, or cofferdam if the double bottom tank is interconnected with these tanks. The scantlings of stiffeners are to be in accordance with the requirements of 9.2.1 for deep tanks, or as required by 8.5.4 whichever is the greater. The stiffeners are to be connected to the inner bottom and shell longitudinals.

8.5.3 Between plate floors, transverse brackets having a thickness not less than $0{,}009 d_{DB}$ mm are to be fitted, extending from the centre girder and margin plate to the adjacent longitudinal. The brackets, which are to be suitably stiffened at the edge, are to be fitted at every frame at the margin plate, and those at the centre girder are to be spaced not more than 1,25 m.

8.5.4 **In transversely framed ships,** plate floors are to be fitted under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 3,0 m. The shell inner bottom plating between these floors is to be supported by bracket floors. The thickness of non-watertight plate floors is to be not less than:

$$t = (0{,}008 d_{DB} + 1)\sqrt{k}\ \text{mm}$$

but need not exceed 15 mm and is to be not less than 6 mm. Watertight or strengthened floors are to be fitted below, or in the vicinity of, watertight bulkheads, and their thickness is to be 2 mm greater than that derived above for non-watertight floors, but need not exceed 15 mm on floors of normal depth. If the depth of such floors exceeds 915 mm but does not exceed 2000 mm, the floors are to be fitted with vertical stiffeners spaced not more than 915 mm apart and having a section modulus not less than:

$$Z = 5{,}41 d_{DBA}{}^2\, h_{DB}\, s\, k \times 10^{-9}\ \text{cm}^3$$

The ends of the stiffeners are to be sniped.

8.5.5 Where the double bottom tanks are interconnected with side tanks or cofferdams, or where the depth of floor exceeds 2000 mm, the scantlings of watertight floors are to be not less than those required for deep tanks (*see* 9.2.1), and the ends of the stiffeners are to be bracketed top and bottom.

8.5.6 Where floors form the boundary of a sea inlet box, the thickness of the plating is to be the same as the adjacent shell, but not less than 12,5 mm and need not exceed 25 mm. The scantlings of stiffeners, where required are, in general, to comply with 9.2.1 for deep tanks. Sniped ends for stiffeners on the boundaries of these spaces are to be avoided wherever practicable. The stiffeners should be bracketed or the free end suitably supported to provide alignment with backing structure.

8.5.7 **Where bracket floors** are fitted, the bottom frames are to be derived from 6.3.1. The unsupported span of the frames is not to exceed 2,5 m. The breadth of the brackets attaching the frames and the reverse frames to the centre girder and margin plate is to be three-quarters of the depth of the centre girder. The brackets are to be flanged on the unsupported edge and are to have the same thickness as the plate floors.

8.5.8 **Where struts** are fitted to reduce the unsupported span of the frames, reverse frames and longitudinals, they are to have a cross-sectional area of not less than:

(a) $A = 0{,}32 Z_{BF}$ cm^2 for $Z_{BF} \leq 83{,}5$, or

(b) $A = 23{,}2 + \dfrac{Z_{BF}}{25}$ cm^2 for $Z_{BF} > 83{,}5$

where Z_{BF} is the modulus, in cm^3, of the frame or longitudinal based on the effective length between floors as defined in Pt 3, Ch 3,3.

■ *Section 9* Bulkheads

9.1 General

9.1.1 The requirements of this Section cover watertight and deep tank transverse and longitudinal bulkheads. Requirements are also given for shaft tunnel boundaries and non-watertight bulkheads. For transverse bulkheads in way of ballast holds, stools may be required, *see* Ch 7,10.2.

9.1.2 The requirements of this Section apply to a vertical system of stiffening on bulkheads. They may also be applied to a horizontal system of stiffening provided that equivalent end support and alignment are provided.

9.1.3 For number and disposition of transverse watertight bulkheads, *see* Pt 3, Ch 3,4.

9.1.4 The buckling requirements of Pt 3, Ch 4,7 are also to be satisfied.

9.2 Watertight and deep tank bulkheads

9.2.1 The scantlings of watertight and deep tank bulkheads are to comply with the requirements of Tables 1.9.1 to 1.9.3. Where bulkhead stiffeners support deck girders, transverses or pillars over, the requirements of 4.4.11 are also to be satisfied.

9.2.2 In way of partially filled holds or tanks, the scantlings and structural arrangements of the boundary bulkheads are to be capable of withstanding the loads imposed by the movement of the liquid in those spaces. The magnitude of the predicted loadings, together with the scantling calculations may require to be submitted, *see* Pt 3, Ch 3,5.4.

9.2.3 In deep tanks, oil fuel or oil carried as cargo is to have a flash point of 60ºC or above (closed-cup test). Where tanks are intended for other liquid cargoes of a special nature the scantlings and arrangements will be considered in relation to the nature of the cargo.

9.2.4 Where watertight bulkhead stiffeners are cut in way of watertight doors in the lower part of a bulkhead, the opening is to be suitably framed and reinforced. Where stiffeners are not cut but the spacing between the stiffeners is increased on account of watertight doors, the stiffeners at the sides of the doorways are to be increased in depth and strength so that the efficiency is at least equal to that of the unpierced bulkhead, without taking the stiffness of the door frame into consideration. Watertight recesses in bulkheads are generally to be so framed and stiffened as to provide strength and stiffness equivalent to the requirements for watertight bulkheads.

9.2.5 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side of the ship and are intended for the carriage of oil fuel for the ship's use. The bulkhead may be intact or perforated as desired. If intact, the scantlings are to be as required for boundary bulkheads. If perforated, the modulus of the stiffeners may be 50 per cent of that required for boundary bulkheads, using h_4 measured to the crown of the tank. The stiffeners are to be bracketed at top and bottom. The area of perforation is to be not less than five per cent nor more than 10 per cent of the total area of the bulkhead. Where brackets from horizontal girders on the boundary bulkheads terminate at the centreline bulkhead, adequate support and continuity are to be maintained.

Table 1.9.1 Watertight and deep tank bulkhead scantlings

Item and requirement	Watertight bulkheads	Deep tank bulkheads
(1) Plating thickness for plane, symmetrically corrugated and double plate bulkheads	$t = 0{,}004 s\, f \sqrt{h_4 k}$ mm but not less than 5,5 mm	$t = 0{,}004 s\, f \sqrt{\dfrac{\rho h_4 k}{1{,}025}} + 2{,}5$ mm but not less than 6,5 mm, where $L < 90$ m nor less than 7,5 mm, where $L \geq 90$ m
	In the case of symmetrical corrugations, s is to be taken as b or c in Fig. 3.3.1 in Pt 3, Ch 3, whichever is the greater	
(2) Modulus of rolled and built stiffeners, swedges, double plate bulkheads and symmetrical corrugations	$Z = \dfrac{s\, k\, h_4\, l_e^2}{71\gamma\,(\omega_1 + \omega_2 + 2)}$ cm^3	$Z = \dfrac{\rho\, s\, k\, h_4\, l_e^2}{22\gamma\,(\omega_1 + \omega_2 + 2)}$ cm^3
	In the case of symmetrical corrugations, s is to be taken as p, *see also* Note 2	
(3) Inertia of rolled and built stiffeners and swedges	—	$I = \dfrac{2{,}3}{k} l_e Z$ cm^4
(4) Symmetrical corrugations and double plate bulkheads	Additional requirements to be complied with as detailed in Table 1.9.2	
(5) Stringers or webs supporting vertical or horizontal stiffening		
(a) Modulus	$Z = 5{,}5 k\, h_4\, S\, l_e^2$ cm^3	$Z = 11{,}7\rho\, k\, h_4\, S l_e^2$ cm^3
(b) Inertia	—	$I = \dfrac{2{,}5}{k} l_e Z$ cm^4

Symbols

s, S, I, k, ρ as defined in 1.5.1

d_w = web depth of stiffening member, in mm

$f = 1{,}1 - \dfrac{s}{2500S}$ but not to be taken greater than 1,0

h_4 = load head, in metres measured as follows:

(a) For watertight bulkhead plating, the distance vertically from a point one-third of the height of the plate above its lower edge to a point 0,91 m above the bulkhead deck at side or perpendicular to the deepest equilibrium waterline in damaged condition obtained from applicable damage stability calculations, whichever is the greater, *see also* Fig. 3.5.2 in Pt 3, Ch 3

(b) For deep tank bulkhead plating, the distance from a point one-third of the height of the plate above its lower edge to the top of the tank, or half the distance to the top of the overflow, whichever is the greater, *see also* Fig. 3.5.2 in Pt 3, Ch 3

(c) For watertight bulkhead stiffeners or girders, the distance vertically from the middle of the effective length to a point 0,91 m above the bulkhead deck at side, or perpendicular to the deepest equilibrium waterline in damaged condition obtained from applicable damage stability calculations, whichever is the greater, *see also* Fig. 3.5.2 in Pt 3, Ch 3

(d) For deep tank bulkhead stiffeners or girders, the distance from the middle of the effective length to the top of the tank, or half the distance to the top of the overflow, whichever is the greater, *see also* Fig. 3.5.2 in Pt 3, Ch 3

l_e = effective length of stiffening member, in metres, and for bulkhead stiffeners, to be taken as $l - e_1 - e_2$, *see also* Fig. 1.9.1

p = spacing of corrugations as shown in Fig. 3.3.1 of Pt 3, Ch 3

γ = 1,4 for rolled or built sections and double plate bulkheads
= 1,6 for flat bars
= 1,1 for symmetrical corrugations of deep tank bulkheads
= 1,0 for symmetrical corrugations of watertight bulkheads

ω, e = as defined in Table 1.9.3, *see also* Fig. 1.9.1

NOTES

1. In no case are the scantlings of deep tank bulkheads to be less than the requirements for watertight bulkheads where watertight bulkheads are required by Pt 3, Ch 3,5.
2. In calculating the actual modulus of symmetrical corrugations, the panel width b is not to be taken greater than that given by Pt 3, Ch 3,3.2.
3. For rolled or built stiffeners with flanges or face plates, the web thickness is to be not less than $\dfrac{d_w}{60\sqrt{k}}$ whilst for flat bar stiffeners the web thickness is to be not less than $\dfrac{d_w}{18\sqrt{k}}$

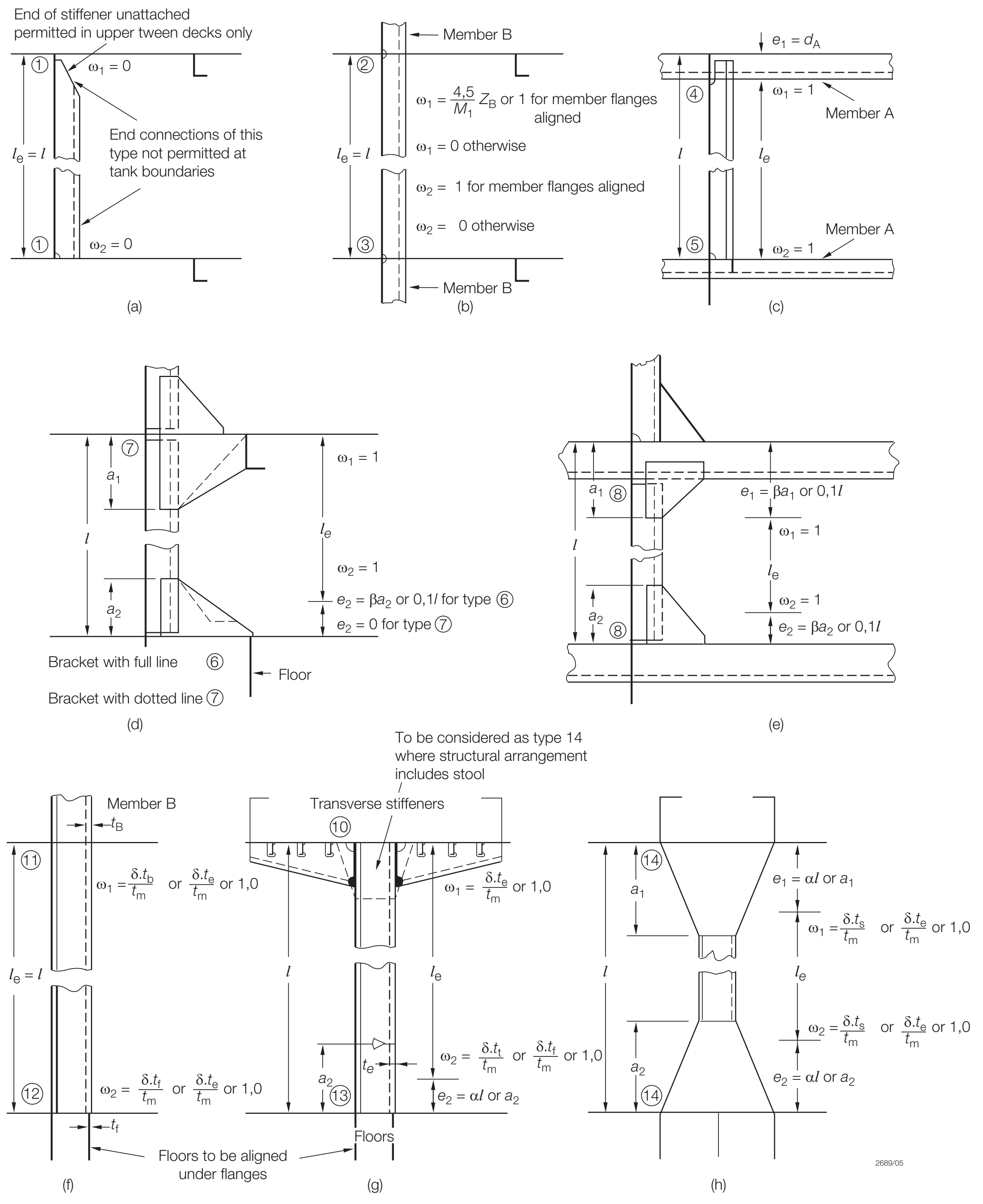


Fig. 1.9.1 End connections

Table 1.9.2 Symmetrical corrugations and double plate bulkheads (additional requirements)

<table>
<tr><th>Symbols</th><th>Type of bulkhead</th><th>Parameter</th><th>Watertight bulkheads</th><th>Deep tank bulkheads</th></tr>
<tr><td rowspan="3">s, k as defined in 1.5.1
b = panel width as shown in Fig. 3.3.1 in Pt 3, Ch 3
d = depth, in mm, of symmetrical corrugation or double plate bulkhead
l_e as defined in Table 1.9.1
A_w = shear area, in cm^2, of webs of double plate bulkhead
θ = angle of web corrugation to plane of bulkhead</td><td rowspan="3">Symmetrically corrugated, see also Notes 1 and 2</td><td>$\dfrac{b}{t}$</td><td>Not to exceed:
$85\sqrt{k}$ at top, and
$70\sqrt{k}$ at bottom</td><td>Not to exceed:
$70\sqrt{k}$ at top, and
at bottom</td></tr>
<tr><td>d</td><td>—</td><td>To be not less than: $39l_e$ mm</td></tr>
<tr><td>θ</td><td colspan="2">To be not less than 40°</td></tr>
<tr><td rowspan="4">NOTES
1. The plating thickness at the middle of span l_e of corrugated or double plate bulkheads is to extend not less than $0,2l_e$ m above mid-span.
2. Where the span of corrugations exceeds 15 m, a diaphragm plate is to be arranged at about mid-span.
3. See also Pt 3, Ch 10,5.2.1.</td><td rowspan="4">Double plate, see also Notes 1 and 3</td><td>$\dfrac{s}{t}$</td><td colspan="2">Not to exceed: $75\sqrt{k}$ at top, and
$65\sqrt{k}$ at bottom</td></tr>
<tr><td>$\dfrac{d}{t_w}$</td><td colspan="2">Not to exceed: $85\sqrt{k}$ at top, and
$75\sqrt{k}$ at bottom</td></tr>
<tr><td>d</td><td>—</td><td>To be not less than: $39l_e$ mm</td></tr>
<tr><td>A_w</td><td>To be not less than:
$\dfrac{0,12Z}{l_e}$ cm^2 at top, and
$\dfrac{0,18Z}{l_e}$ cm^2 at bottom</td><td>To be not less than:
$\dfrac{0,07Z}{l_e}$ cm^2 at top, and
$\dfrac{0,10Z}{l_e}$ cm^2 at bottom</td></tr>
</table>

9.3 Shaft tunnels

9.3.1 Where shaft tunnels are required as specified in Pt 3, Ch 3,4 the thickness of the tunnel plating is to comply with Table 1.9.1 for holds or deep tanks as appropriate. If the top plating is well curved, the thickness may be reduced by 10 per cent in dry cargo holds. If the top plating is flat, it is to be not less than 1,1 times the thickness required for watertight bulkheads in dry cargo holds. Under hatchways the top plating is to be increased by 2 mm, unless covered with wood not less than the thickness specified in 2.2.2, which is to be secured by fastenings which do not penetrate the plating. Where it is intended to use plywood or other forms of ceiling of an approved type instead of planking, the thickness will be considered in each case. The tunnel stiffeners are to comply with Table 1.9.1 for holds or deep tanks, as appropriate. When the section modulus of curved stiffeners is determined, the values of ω_1 and ω_2 are to be taken as 1,0. The span of the stiffener, l_e, is to be taken as the overall height of the tunnel, measured vertically at the centreline of the tunnel. If the tunnel top is flat, scantlings of the stiffeners are also to comply with 4.3. The lower end connection to the tank top is to be welded. Additional strengthening is to be fitted under the heels of pillars or masts stepped on the tunnel.

9.4 Non-watertight bulkheads

9.4.1 The scantlings are to be in accordance with Table 1.4.8.

Table 1.9.3 Bulkhead end constraint factors (*see continuation*)

<table>
<tr><th>Type</th><th colspan="3">End connection (see Fig. 1.9.1)</th><th>ω</th><th>e</th><th>μ</th></tr>
<tr><td colspan="7">Rolled or built stiffeners and swedges</td></tr>
<tr><td>1</td><td colspan="3">End of stiffeners unattached or attached to plating only</td><td>0</td><td>0</td><td>–</td></tr>
<tr><td>2</td><td rowspan="2">Members with webs and flanges (or bulbs) in line and attached at deck or horizontal girder, see also Note 1</td><td colspan="2">Adjacent member of B of smaller modulus</td><td>The lesser of $\dfrac{4,5Z_B}{M_1}$ or 1,0</td><td>0</td><td>–</td></tr>
<tr><td>3</td><td colspan="2">Adjacent member of B of same or larger modulus</td><td>1,0</td><td>0</td><td>–</td></tr>
<tr><td>4</td><td rowspan="2">Bracketless connection to longitudinal member</td><td colspan="2">Member A within length l</td><td>1,0</td><td>$\dfrac{d_A}{1000}$</td><td>–</td></tr>
<tr><td>5</td><td colspan="2">Member A outside length l</td><td>1,0</td><td>0</td><td>–</td></tr>
<tr><td>6</td><td rowspan="3">Bracketed connection</td><td rowspan="2">To transverse member</td><td>Bracket extends to floor</td><td>1,0</td><td>The lesser of βa or $0,1l$</td><td>–</td></tr>
<tr><td>7</td><td>Otherwise</td><td>1,0</td><td>0</td><td>–</td></tr>
<tr><td>8</td><td colspan="2">To longitudinal member</td><td>1,0</td><td>The lesser of βa or $0,1l$</td><td>–</td></tr>
<tr><td colspan="7">Symmetrical corrugations or double plate bulkheads</td></tr>
<tr><td>9</td><td rowspan="2">Welded directly to deck – no bulkhead in line</td><td colspan="2">No longitudinal brackets</td><td>0</td><td>0</td><td>–</td></tr>
<tr><td>10</td><td colspan="2">With longitudinal brackets and transverse stiffeners supporting corrugated bulkhead</td><td>The lesser of $\dfrac{\delta\, t_e}{t_m}$ or 1,0</td><td>0</td><td>–</td></tr>
<tr><td>11</td><td>Welded directly to deck or girder</td><td colspan="2">Bulkhead B, having same section, in line</td><td>The least of $\dfrac{\delta\, t_B}{t_m}$ or $\dfrac{\delta\, t_e}{t_m}$ or 1,0</td><td>0</td><td>–</td></tr>
<tr><td>12</td><td rowspan="2">Welded directly to tank top and effectively supported by floors in line with each bulkhead flange, see also Note 2</td><td colspan="2">Thickness at bottom same as that at mid-span</td><td>The least of $\dfrac{\delta\, t_f}{t_m}$ or $\dfrac{\delta\, t_e}{t_m}$ or 1,0</td><td>0</td><td>–</td></tr>
<tr><td>13</td><td colspan="2">Thickness at bottom greater than that at mid-span</td><td>The least of $\dfrac{\delta\, t_f}{t_m}$ or $\dfrac{\delta\, t_e}{t_m}$ or 1,0</td><td>The lesser of αl or a</td><td>The lesser of $\dfrac{t_f}{t_m}$ or $\dfrac{t_e}{t_m}$</td></tr>
<tr><td>14</td><td colspan="3">Welded to stool efficiently supported by ship's structure</td><td>For deep tank bulkheads 1,0
For watertight bulkheads the least of
$\dfrac{\delta\, t_s}{t_m}$ or $\dfrac{\delta\, t_e}{t_m}$ or 1,0</td><td>The lesser of αl or a</td><td>$\dfrac{10Z_s}{M_2}$</td></tr>
</table>

Table 1.9.3 Bulkhead end constraint factors (*conclusion*)

Symbols

s, l, ρ, k, as defined in 1.5.1

a = height, in metres, of bracket or end stool or lowest strake of plating of symmetrically corrugated or double plate bulkheads, *see* Fig. 1.9.1

d_A = overall depth, in mm, of adjacent member A

e = effective length, in metres, of bracket or end stool, *see* Fig. 1.9.1

h_o = h_4 but measured from the middle of the overall length l

l_e, p, h_4 as defined in Table 1.9.1

t_B = thickness, in mm, of flange plating of member B

t_f = thickness, in mm, of supporting floor

t_m, t_e = thickness, in mm, of flange plating of corrugation or double plate bulkhead at mid-span or end, respectively

Subscripts 1 and 2 when applied to ω, e, and a refer to the top and bottom ends of stiffener

$M_1 = \dfrac{h_4\, s\, l_e^2}{71}$ for watertight bulkheads

$= \dfrac{\rho\, h_4\, s\, l_e^2}{22}$ for deep tank bulkheads

$M_2 = \dfrac{h_o\, s\, l^2}{71}$ for watertight bulkheads

$= \dfrac{\rho\, h_o\, s\, l^2}{22}$ for deep tank bulkheads

In the case of symmetrical corrugations $s = p$

Z_B = section modulus, in cm^3, of adjacent member B

Z_s = section modulus, in cm^3, of horizontal section of stool adjacent to deck or tank top over breadth s or p (as applicable)
All material which is continuous from top to bottom of stool may be included in the calculation

α = a factor depending on μ and determined as follows:
where $\mu \leq 1,0$ $\quad \alpha = 0$
where $\mu > 1,0$ $\quad \alpha = 0,5 - \dfrac{1}{\sqrt{2\mu + 2}}$

β = a factor depending on the end bracket stiffening and to be taken as:
- 1,0 for brackets with face bars directly connected to stiffener face bars
- 0,7 for flanged brackets
- 0,5 for unflanged brackets

μ = a factor representing end constraint for symmetrical corrugation and double plate bulkheads

ω = an end constraint factor relating to the different types of end connection, *see* Fig. 1.9.1

t_s = thickness, in mm, of stool adjacent to bulkhead

δ = 1,0 generally

$= \dfrac{0,932\sqrt{k}}{\xi}$ for corrugated watertight bulkheads

ξ = 1,0 where full continuity of corrugation webs is provided at the ends
= greater of 1,0 and (η + 0,333) where full continuity is not provided

η = lesser of 1,0 and $\dfrac{50\, t_m \sqrt{k}}{b}$ for welded sections

= lesser of 1,0 and $\dfrac{60\, t_m \sqrt{k}}{b}$ for cold formed sections

NOTES
1. Where the end connection is similar to type 2 or 3, but member flanges (or bulbs) are not aligned and brackets are not fitted, $\omega = 0$.
2. Where the end connection is similar to type 12 or 13, but a transverse girder is arranged in place of one of the supporting floors, special consideration will be required.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to sea-going roll on-roll off cargo ships, passenger ships, sailing passenger ships and passenger yachts, defined as follows:

(a) A passenger ferry is defined as a ship specially designed and constructed for the carriage of passengers on a regular scheduled service between specified ports operating in reasonable weather conditions.

(b) A passenger/vehicle ferry is defined as a ship specially designed and constructed for the carriage of passengers and vehicles on a regular scheduled service between specified ports operating in reasonable weather conditions.

(c) A roll on-roll off cargo ship is defined as a ship specially designed and constructed for the carriage of vehicles, and cargo in pallet form or in containers, and loaded/unloaded by wheeled vehicles.

(d) A passenger ship is defined as a ship specially designed and constructed for the carriage of more than 12 passengers.

(e) A sailing passenger ship is defined as a ship specially designed and constructed for the carriage of more than 12 passengers and incorporating sail devices which are intended to be the primary means of propulsion.

(f) A passenger yacht is defined as a yacht that is specially designed and constructed in accordance with Administration requirements for passenger yachts with due regard to the applicability of the conventions as given in Pt 1, Ch 2,1.1.9, as determined in accordance with the British Red Ensign Group *Code of Practice for Yachts Carrying 13 to 36 Passengers (Passenger Yacht Code)*, and subsequent revisions.

1.1.2 Ships intended to operate only in certain areas or conditions which have been agreed by the Committee, as defined in Pt 1, Ch 2, will receive individual consideration on the basis of the Rules with respect to the environmental conditions agreed for the design basis and approval.

1.1.3 The scantlings and arrangements are to be as required by Chapter 1 except as otherwise specified in this Chapter.

1.1.4 The scantlings of the primary supporting structure for multi-decked passenger ships are to be assessed by direct calculation, in accordance with the *ShipRight Structural Design Assessment Procedure* for passenger ships, wherever:

(a) the superstructure will be subjected to significant load from flexure of the hull girder; or

(b) it is required to utilise the load-carrying capability of the superstructure for longitudinal strength; or

(c) a limited number of transverse bulkheads above the bulkhead deck are present to carry the racking response.

See also 1.3.7 and Section 13.

1.1.5 The scantlings of the primary supporting structure of a vehicle ferry, passenger/vehicle ferry, roll on–roll off cargo ship, roll on–roll off passenger ship or vehicle carrier are to be assessed by direct calculation in accordance with the *ShipRight Structural Design Assessment Procedure* for Ro–Ro ships and the *ShipRight Construction Monitoring Procedure*. *See also* 1.3.7 and Section 13.

1.1.6 For the purpose of providing operational information to the Master for safe return to port after a flooding casualty, passenger ships having a Load Line length of 120 m or more or having three or more main vertical zones are to have:

(a) an onboard stability computer; or

(b) shore-based support.

Where an onboard computer system having a stability computation capability is provided, the system is to be certified in accordance with LR's document entitled *Approval of Longitudinal Strength and Stability Calculations Programs*, *see also* Pt 1, Ch 2,1.1.11.

1.2 Structural configuration

1.2.1 The requirements provide for a basic structural configuration of a multi-deck hull which includes a double bottom, and in some cases wing tanks up to the lowest deck.

1.2.2 For passenger ships, the structural arrangements detailed in Chapter II-1, Part B, of the *International Convention for the Safety of Life at Sea, 1974*, and applicable amendments as they apply to passenger ships are to be complied with in their entirety.

1.2.3 Where bulkheads are omitted in accordance with Pt 3, Ch 3,4, a system of partial bulkheads, web frames and deck transverses should be fitted to provide equivalent transverse strength.

1.2.4 Longitudinal framing is, in general, to be adopted at the strength deck and at the bottom, but special consideration will be given to proposals for transverse framing in these regions.

1.2.5 Reference should be made to the Regulations of the *International Convention for the Safety of Life at Sea, 1974* and applicable amendments and to the relevant Statutory Requirements of the National Authority of the country in which the ship is to be registered.

1.2.6 Attention is also drawn to the requirements for passenger ships given in:

- Bulkhead requirements, *see* Pt 3, Ch 3,4
- Closing arrangements for shell, deck and bulkheads, *see* Pt 3, Ch 11,6, Ch 11,8 and Ch 11,9
- Electrical installations, *see* Pt 6, Ch 2
- Fire protection, detection and extinction, *see* SOLAS Reg. II-2/B and C.

1.2.7 Attention is drawn to National Authority requirements relating to the stowage and securing of vehicles and cargo units on board roll on-roll off ships. Steel used for the construction of fixed securing fittings attached to the ship's structure is to comply with the requirements of *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), or with an equivalent acceptable specification. Due account is to be taken of the grade and tensile strength of the hull material in way of the attachment and the chemical composition of the steel is to be such as to ensure acceptable qualities of weldability.

1.2.8 Sailing passenger ships are to be fitted with auxiliary propulsive power to ensure adequate speed and manoeuvrability of the vessel in conditions when the sail systems are not available for use. The auxiliary propulsion and other essential machinery are to comply with the requirements of Part 5 of the Rules, as applicable.

1.2.9 Sail systems may be made up in the form of soft sails, semi-rigid and rigid sail configurations including wind turbines or systems incorporating rotating cylinders.

1.2.10 For sailing vessels, a continuous visual read out of the apparent wind speed and direction is to be available to the ship's master when the vessel is under way. Sail control and service systems are to provide adequate speed of response to neutralise the sail system in the event of high wind conditions. Sufficient information and evidence is to be submitted to substantiate that the foregoing arrangements are in place.

1.2.11 For sailing passenger ships, the Rules for classification will, in principle, apply to the mast arrangements and standing gear, but will exclude running gear, yards, booms and sail arrangements.

1.2.12 For sailing passenger ships, the equipment requirements will be in accordance with the letter and numeral two grades higher than that corresponding to the calculated Equipment Numeral.

1.3 Class notations

1.3.1 In general, ships complying with the requirements of this Chapter will be eligible to be classed:

'**100A1 passenger ferry**', or
'**100A1 passenger/vehicle ferry**', or
'**100A1 roll on-roll off cargo ship**', or
'**100A1 roll on-roll off passenger ship**', or
'**100A1 vehicle carrier**', or
'**100A1 passenger ship**', or
'**100A1 passenger yacht**', or
'**100A1 sailing passenger ship**'.

1.3.2 For passenger ships that comply with the requirements of the European Council Directive 98/18/EC of 17 March 1998 on safety rules and standards for passenger ships, and subsequent revisions, the following class notations may be appended to the main class notation:

(a) **EU(A)**. This class notation will be assigned to a passenger ship engaged on domestic voyages other than voyages covered by Classes B, C and D.

(b) **EU(B)**. This class notation will be assigned to a passenger ship engaged on domestic voyages in the course of which it is at no time more than 20 miles from the line of coast, where shipwrecked persons can land, corresponding to the medium tide height.

(c) **EU(C)**. This class notation will be assigned to a passenger ship engaged on domestic voyages in sea areas where the probability of exceeding 2,5 m significant wave height is smaller than 10 per cent over a one-year period for all-year-round operation, or over a specific restricted period of the year for operation exclusively in such period (e.g., summer period operation), in the course of which it is at no time more than 15 miles from a place of refuge, nor more than 5 miles from the line of coast, where shipwrecked persons can land, corresponding to the medium tide height.

(d) **EU(D)**. This class notation will be assigned to a passenger ship engaged on domestic voyages in sea areas where the probability of exceeding 1,5 m significant wave height is smaller than 10 per cent over a one-year period for all-year-round operation, or over a specific restricted period of the year for operation exclusively in such period (e.g., summer period operation), in the course of which it is at no time more than 6 miles from a place of refuge, nor more than 3 miles from the line of coast, where shipwrecked persons can land, corresponding to the medium tide height.

1.3.3 A ship assigned a class notation incorporating the word 'passenger', which is also designed to fulfil other functions not associated with passenger carrying, is to comply with the requirements of this Chapter for passenger ships together with the requirements of the relevant Chapter of this Part for the particular ship type.

1.3.4 Where ferries are specially reinforced for the carriage of trains on fixed rails, the class notation will also include the word 'train'.

1.3.5 The Regulations for the classification and assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.3.6 The 'ShipRight Procedures' for hull construction of ships are detailed in Pt 3, Ch 16 and the classification notations and descriptive notes associated with these procedures are given in Pt 1, Ch 2,2.

1.3.7 The 'Structural Design Assessment' (**SDA**) and 'Construction Monitoring' (**CM**) procedures detailed in the *ShipRight Procedures Manual*, published by Lloyd's Register (hereinafter referred to as 'LR'), are mandatory for passenger ships where it is considered that the superstructure will be subjected to a significant load from flexure of the hull girder; or, where it is required to utilise the load carrying capability of the superstructure for longitudinal strength, and for other passenger ships of abnormal hull form, or of unusual structural configuration or complexity.

1.4 Information required

1.4.1 In addition to the information and plans required by Pt 3, Ch 1,5, the following details are to be submitted:

- The intended service areas required for ships designed to operate within specified geographical limits.
- Stern or bow ramps.
- Bow, stern and side doors.
- Movable decks, if fitted, including stowing arrangements for portable components.
- Sail plans and associated operational and design conditions, including apparent wind speeds (sailing ships).
- Masts and all structural components of the standing rigging (sailing ships).
- The standing rigging and all standing rigging attachments (sailing ships).
- The design deck loadings including details of wheeled vehicles, *see* Pt 3, Ch 9,3, and trains, where applicable.
- Locations of fixed securing points for wheeled vehicles, with indication of the magnitude and direction of the imposed lashing force.

1.5 Symbols

1.5.1 For the definition of symbols not defined in this Chapter, *see* Ch 1,1.5.

1.5.2 The following definitions apply to ships employing sails:

Standing rigging	– Rigging of fixed length used to support masts/bowsprit.
Running rigging	– Rigging used to control yards, booms and sails and which may pass over revolving sheaves.
Apparent wind speed	– The vector resultant of the combination of real wind speed and ship velocity.

■ *Section 2* Longitudinal strength

2.1 General

2.1.1 Longitudinal strength calculations are to be made in accordance with the requirements given in Pt 3, Ch 4 and the additional notes contained in this Section.

2.1.2 The design vertical wave bending moments and design wave shear forces to be used in Pt 3, Ch 4 are to be determined in accordance with 2.3 and 2.4 below. For ships of unusual hullform or where their design parameters are outwith the applicability of the Rules, *see* Pt 3, Ch 4, special consideration will be given to the values and distributions of the wave induced global loads.

2.1.3 The still water bending moment and shear force envelopes are to take into account the requirements of 2.3.

2.1.4 For ships where the side shell or side casings contain large openings or where the effectiveness of the superstructures in resisting hull girder bending loads is expected to be reduced by the presence of large numbers of windows or openings, the combined hull and superstructure response may require to be verified using direct calculation techniques.

2.2 Calculation of hull section modulus

2.2.1 The calculation of section modulus is to be in accordance with Pt 3, Ch 3, 3.4 and the additional notes in this Section. In general, the effective sectional area of continuous longitudinal strength members, after deduction of openings, is to be used for the calculation of midship section modulus. For ships where the effectiveness of the superstructure is only partial due to the presence of large or numerous shell openings or discontinuities in the shell envelope, an equivalent section modulus for the purposes of this Section may be derived using direct calculations in accordance with the SDA procedure relevant to the ship type.

2.2.2 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performances.

2.2.3 In general, short superstructures, *see also* Pt 3, Ch 3,3.4.2, or deckhouses will not be accepted as contributing to the global longitudinal or transverse strength of the ship. However, where it is proposed to include substantial continuous stiffening members, special consideration will be given to their inclusion on submission of the designer's/ Builder's calculations, *see also* 2.6.

2.2.4 Adequate transition arrangements are to be fitted at the ends of effective continuous longitudinal strength members in the deck and bottom structures.

2.2.5 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section stiffness requirements determined from Ch 4,5 are to be maintained within 0,4L amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the 0,4L part, bearing in mind the desire not to inhibit the ship's loading and operational flexibility.

2.2.6 Structural material which is longitudinally continuous but which is not considered to be fully effective for longitudinal strength purposes may be specially considered. The global longitudinal strength assessment must take into account the presence of such material when it can be considered effective. The consequences of failure of such structural material and subsequent redistribution of stresses into or additional loads imposed on the remaining structure is to be considered.

2.2.7 In particular, all longitudinally continuous material will be fully effective in tension whereas this may not be so in compression due to a low buckling capability. In this case, it may be necessary to derive and apply different hull girder section moduli to the hogging and sagging bending moment cases.

2.3 Still water bending moments and shear forces

2.3.1 The design still water hogging and sagging bending moment distribution envelope, M_S, is to be taken as the maximum sagging (negative) and maximum hogging (positive) still water bending moments, calculated at each position along the ship. The maximum moments from all loading conditions are to be used to define the still water bending moment distribution envelope.

2.3.2 It is normal for ships which have a low deadweight requirement or a uniform loading rate in association with a low block coefficient to have a hogging still water bending moment in all conditions of loading. For these ships, the maximum design sagging still water bending moment may be taken as the minimum actual hogging bending moment.

2.3.3 The design still water shear force distribution envelope, Q_S, is to be taken as the maximum positive and negative shear force values, calculated at each position along the ship. The maximum shear forces from all loading conditions are to be used to define the still water shear force distribution envelope.

2.4 Design vertical wave bending moments

2.4.1 The minimum value of vertical wave bending moment, M_w at any position along the ship may be taken as follows:

$M_w = f_1 f_2 C_2 M_{wo}$ kNm (tonne-f m)

where

$M_{wo} = 0{,}1 C_1 L^2 B_{WL} (C_b + 0{,}7)$ kNm
($M_{wo} = 0{,}0102 C_1 L^2 B_{WL} (C_b + 0{,}7)$ tonne-f m)
B_{WL} = maximum waterline breadth, in metres
C_1, C_2, L and C_b are given in Pt 3, Ch 4,5

and

f_1 is given in Pt 3, Ch 4,5
f_2 is the hogging, f_{fH}, or sagging, f_{fS}, correction factor based on the amount of bow flare, stern flare, length and effective buoyancy of the aft end of the ship above the waterline
f_{fS} is the sagging (negative) moment correction factor and is to be taken as
$f_{fS} = -1{,}10 R_A^{0,3}$ for values of $R_A > 1{,}0$
$f_{fS} = -1{,}10$ for values of $R_A \leq 1{,}0$
f_{fH} is the hogging (positive) moment correction factor and is to be taken as

$$f_{fH} = \frac{1{,}9 C_b}{(C_b + 0{,}7)}$$

R_A is an area ratio factor, *see* 2.4.2.

2.4.2 The area ratio factor, R_A, for the combined stern and bow shape is to be derived as follows:

$$R_A = \frac{30\,(A_{BF} + 0{,}5 A_{SF})}{L\,B_{WL}}$$

where

A_{BF} is the bow flare area, in m^2
A_{SF} is the stern flare area, in m^2

2.4.3 The bow flare area, A_{BF}, is illustrated in Fig. 2.2.1 and may be derived as follows:

$A_{BF} = A_{UB} - A_{LB}$ m^2

where

A_{UB} is half the water plane area at a waterline of $T_{C,U}$ of the bow region of the hull forward of 0,8L from the AP
A_{LB} is half the water plane area at the design draught of the bow region of the hull forward of 0,8L from the AP

NOTE
The AP is to be taken at the aft end of L
The design draught is to be taken as T, *see* Pt 3, Ch 1,6.1.

Alternatively the following formula may be used

$A_{BF} = 0{,}05L\,(b_0 + 2b_1 + b_2) + b_0\,a/2$ m^2

where

b_0 = projection of $T_{C,U}$ waterline outboard of the design draught waterline at the FP, in metres, *see* Fig. 2.2.1
b_1 = projection of $T_{C,U}$ waterline outboard of the design draught waterline at 0,9L from the AP, in metres
b_2 = projection of $T_{C,U}$ waterline outboard of the design draught waterline at 0,8L from the AP, in metres
a = projection of $T_{C,U}$ waterline forward of the FP, in metres
$T_{C,U}$ is a waterline taken $C_1/2$ m above the design draught

$$T_{C,U} = T + \frac{C_1}{2} \text{ m}$$

C_1 is given in Pt 3, Ch 4, Table 4.5.1

For ships with large bow flare angles above the $T_{C,U}$ waterline the bow flare area may need to be specially considered.

2.4.4 The stern flare area, A_{SF}, is illustrated in Fig. 2.2.1 and is to be derived as follows:

$A_{SF} = A_{US} - A_{LS}$ m^2

where

A_{US} is half the water plane area at a waterline of $T_{C,U}$ of the stern region of the hull aft of 0,2L from the AP

A_{LS} is half the water plane area at a waterline of $T_{C,L}$ of the stern region of the hull aft of 0,2L from the AP

$T_{C,L}$ = is a waterline taken C_1/2 m below the design draught

$$T_{C,L} = T - \frac{C_1}{2} \text{ m}$$

For ships with tumblehome in the stern region, the maximum breadth at any waterline less than $T_{C,U}$ is to be used in the calculation of A_{US}. The effects of appendages including bossings are to be ignored in the calculation of A_{LS}.

2.4.5 Direct calculation methods may be used to derive the vertical wave bending moments, *see* Pt 3, Ch 4,2.5.

2.4.6 The sagging correction factor, f_{fS}, in the vertical wave bending moment formulation in 2.3.1 may be derived by direct calculation methods. Appropriate direct calculation methods include a combination of long-term ship motion analysis, non linear ship motion analysis and static balance on a wave crest or trough.

2.5 Design wave shear force

2.5.1 The design vertical wave shear force, Q_w, at any position along the ship is given by:

$Q_w = 3f_1 K_f M_{wo}/L$ kN (tonne-f)

where

K_f is to be taken as follows, *see also* Fig. 2.2.2:

(a) Positive shear force:

K_f = 0 at aft end of L
= +0,836f_{fH} between 0,2L and 0,3L from aft
= +0,70f_{fH} between 0,4L and 0,5L from aft
= –0,65f_{fS} between 0,5L and 0,6L from aft
= –0,91f_{fS} between 0,7L and 0,85L from aft
= 0 at forward end of L

(b) Negative shear force:

K_f = 0 at aft end of L
= +0,836f_{fS} between 0,15L and 0,3L from aft
= +0,65f_{fS} between 0,4L and 0,5L from aft
= –0,70f_{fH} between 0,5L and 0,6L from aft
= –0,91f_{fH} between 0,7L and 0,85L from aft
= 0 at forward end of L

Intermediate values to be determined by linear interpolation.

f_1, M_{wo}, f_{fS} and f_{fH} are defined in 2.4.1.

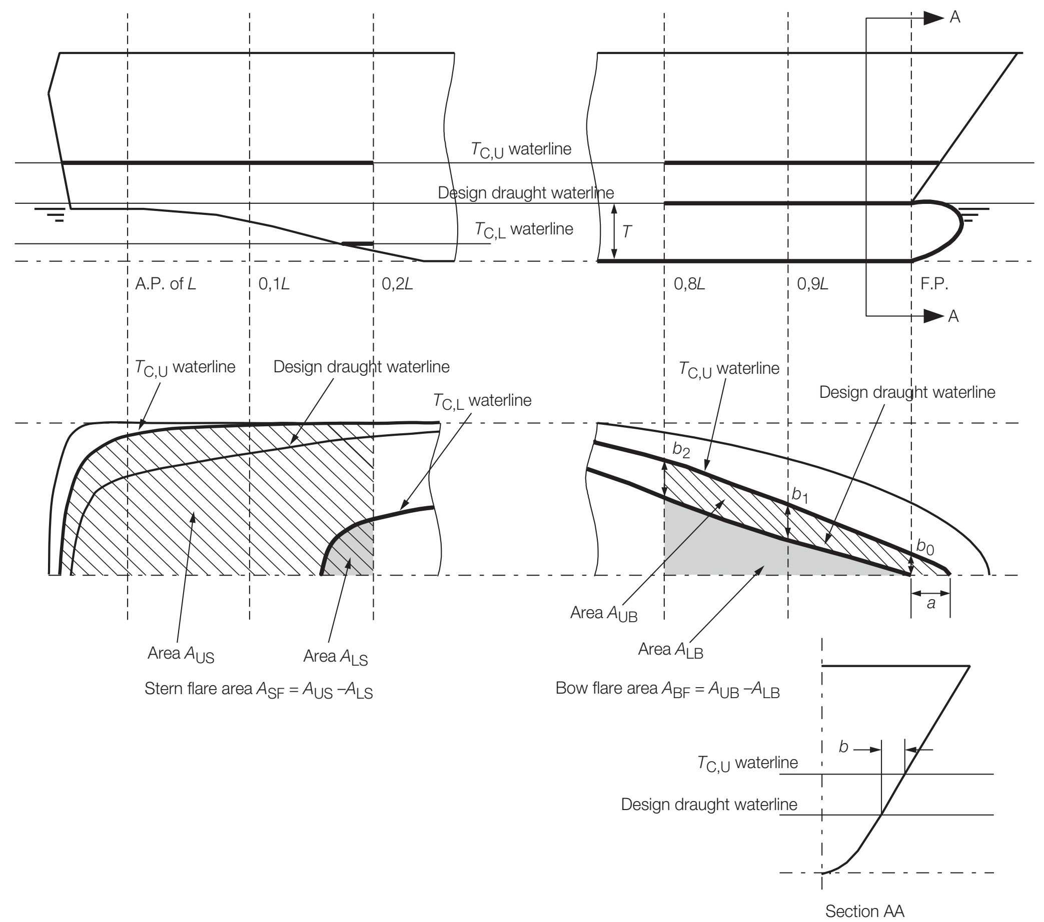


Fig. 2.2.1 Derivation of bow and stern flare areas

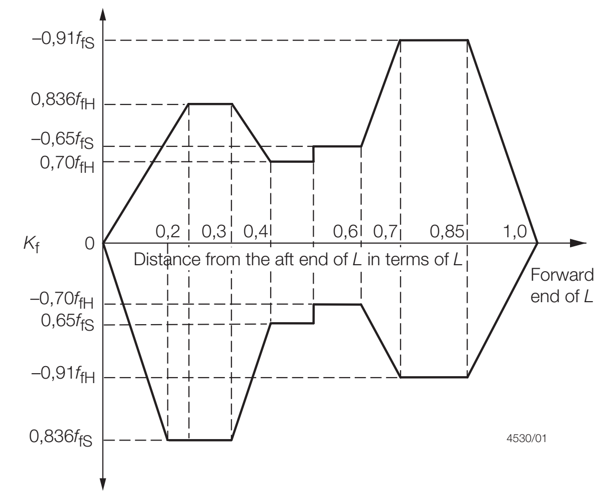


Fig. 2.2.2 Shear force factor K_f

2.6 Buckling strength

2.6.1 The buckling requirements in Pt 3, Ch 4,7 are to be applied to plate panels and longitudinals subject to hull girder compression and shear stresses. The design stresses are to be based on the design values of still water and wave bending moments and shear forces and are given in 2.4.1 and 2.5.1.

2.6.2 The standard deduction for corrosion, d_t, to be applied to plating and longitudinals is to be taken in accordance with Table 4.7.1 in Pt 3, Ch 4.

2.6.3 The buckling factors of safety, λ, to be applied to the corrected critical buckling stress, σ_{CRB}, of plate panels and longitudinals subjected to hull girder compression are given in Table 2.2.1, where the corrected critical buckling stress is to be determined in accordance with Pt 3, Ch 4,7.3.

2.6.4 The shear buckling requirements of Pt 3, Ch 4,7.3 are to be applied.

Table 2.2.1 Buckling factors of safety, λ

Structural item	Buckling factor of safety, λ
Longitudinally effective plating	1,0
Longitudinal stiffeners when the buckling failure mode of the attached plating is elasto-plastic, *see* Note	1,1
Longitudinal stiffeners when the buckling failure mode of the attached plating is elastic, *see* Note	1,25
NOTE The buckling mode of failure of the attached plating is defined as follows: elastic $\sigma_E \leq 0{,}5\ \sigma_o$ elasto-plastic $\sigma_E > 0{,}5\ \sigma_o$ where σ_E = the elastic critical buckling stress, *see* Pt 3, Ch 4,7.3 σ_o = specified minimum yield stress, in N/mm^2 (kgf/mm^2).	

Section 3
Deck structure

3.1 Loading

3.1.1 In general, loadings for decks should comply with the requirements of Chapter 1 except where specified in this Section.

3.1.2 Vehicle decks for the carriage of cars, trucks, etc., are to have a loading for wheeled vehicles as specified in Pt 3, Ch 9,3. Where vehicle decks are also used for the carriage of cargo, the loadings derived from Pt 3, Ch 9,3 are to be not less than would be required by Chapter 1.

3.1.3 For ferries and passenger ships classed **100A1**, the minimum design loadings for decks are not to be taken as less than those in Table 2.3.1.

Table 2.3.1 Design deck loadings (ferries and passenger ships only)

Deck	Design pressures P_s, in kN/m^2 (tonne-f/m^2)	
	Secondary structures	Primary structures
Decks in way of accommodation and public spaces, *see* Note	6,38 (0,65)	3,12 (0,32)
Deck supporting baggage spaces	$3{,}53H_t$ ($0{,}36H_t$)	$3{,}53H_t$ ($0{,}36H_t$)
Decks in way of stores and refrigerated spaces	14,13 (1,44)	14,13 (1,44)
Decks in way of workshop and machinery spaces (excludes A/C machinery spaces)	18,34 (1,87)	18,34 (1,87)
Magradomes	2,45 (0,25)	2,45 (0,25)
Balconies	3,92 (0,40)	1,96 (0,20)
Weather exposed superstructure decks	2,26 (0,23)	2,26 (0,23)
Weather exposed lifeboat deck	8,44 (0,86)	8,44 (0,86)
Symbols		
H_t = 'tween deck height, in metres		
NOTE The design pressure, P_s, may be reduced by 12 per cent for ferries and passenger ships with a specified operating area service notation.		

3.1.4 For ferries and passenger ships classed **100A1** with a specified operating area service notation, the loadings for decks in way of baggage and accommodation spaces are to be in accordance with Table 2.3.1.

3.1.5 Mooring decks, afterward and forward, other than when part of the strength deck, are to comply with the requirements for forecastles, *see* Pt 3, Ch 8. Canopy decks or aprons protecting mooring decks are to be designed using the weather head for forecastle decks reduced by 0,3 m.

3.1.6 For movable decks, *see* Pt 3, Ch 9,4.

3.1.7 For train decks, the minimum design loading will be specially considered.

3.2 Deck plating

3.2.1 For ferries and passenger ships classed **100A1** the minimum thicknesses of decks are to be in accordance with Table 2.3.2.

Table 2.3.2 Thickness of deck plating

Deck location	Plating thickness (mm)
Accommodation and public spaces	$t = 0{,}008s\sqrt{k}$
Baggage handling and storage	$t = 0{,}009s\sqrt{k}$
Storerooms	$t = 0{,}01s\sqrt{k}$
Workshops and machinery spaces	$t = 0{,}01s\sqrt{k}$
Weather exposed lifeboat deck	$t = 0{,}00083s_1\sqrt{Lk} + 2{,}5$
The thickness of deck plating is in no case to be less than 5,0 mm	

3.2.2 For roll on-roll off cargo ships, the thickness of deck plating (other than for vehicle decks) will generally be in accordance with Chapter 1.

3.2.3 Where decks are required to resist hull girder bending, the thickness is to satisfy the requirements of Pt 3, Ch 4,7.

3.2.4 Where deck plating is required to form the effective flange of deck primary members, the thickness may need to be increased locally taking account of the compressive forces acting, *see also* Pt 3, Ch 10, Table 10.4.1.

3.2.5 Vehicle deck plating is to satisfy the requirements for plating loaded by wheeled vehicles as specified in Pt 3, Ch 9,3. Where vehicle decks are also to be used for the carriage of cargo, the thickness of plating derived from Pt 3, Ch 9,3 is to be not less than would be required by Ch 1,4.2.

3.2.6 The thickness of all other decks will generally be in accordance with Chapter 1.

3.3 Deck stiffening

3.3.1 For ferries, roll on-roll off cargo ships and passenger ships, the deck stiffening (other than for vehicle decks) will generally be in accordance with Chapter 1. However, in view of the complexity of some multi-deck arrangements in association with large freeboards, deck stiffening may require special consideration.

3.3.2 Vehicle deck beams and longitudinals are to have scantlings in accordance with the requirements for wheeled vehicles as specified in Pt 3, Ch 9,3. Where vehicle decks are also to be used for the carriage of cargo, the scantlings derived from Pt 3, Ch 9,3 are to be not less than would be required by Ch 1,4.3.

3.3.3 In multi-decked ships with high freeboards, the section modulus of deck beams and longitudinals is to be not less than the value given by Table 2.3.3.

Table 2.3.3 Modulus of deck beams and longitudinals for multi-decked ships with high freeboards

Position of beam/longitudinal	Modulus, in cm^3
Decks, excluding those for the stowage of cargo or vehicles	$Z = 0{,}00083 f_R P_s l_e^2 s k$ $(Z = 0{,}0081 f_R P_s l_e^2 s k)$ but not less than: $Z = 0{,}025s$
Symbols	
l_e, s, Z, and k as defined in Ch 1,1.5 P_s = deck loading in kN/m^2 (tonne-f/m^2), *see* Table 2.3.1 f_R = 1, for ships with unrestricted service f_R = 0,81 for ships with a specified operating area service notation	

3.4 Deck supporting primary structure

3.4.1 The section modulus of primary members supporting four or more point loads or a uniformly distributed load is not to be taken as less than:

$$Z = 0{,}673\, S\, P_s\, k\, l_e^2 \quad (cm^3)$$

$$(Z = 6{,}60\, S\, P_s\, k\, l_e^2) \quad (cm^3)$$

where

l_e, S, Z and k are as defined in Ch 1,1.5

P_s = deck design loading, in kN/m^2 (tonnes/m^2), *see* Table 2.3.1.

3.4.2 The moment of inertia of primary members supporting more than four point loads is not to be taken as less than:

$$I = \frac{1{,}85}{k}\, l_e Z \quad (cm^4)$$

Z and l_e as defined in 3.4.1.

3.4.3 Scantlings of primary structure are to be verified for the following cases using direct calculation methods.

(a) The structural support arrangement is complex either due to arrangement or loading pattern.

(b) Large openings are incorporated in the webs of primary members.

(c) The structure is of novel or unusual design.

The stress criteria in Table 1.4.6 in Chapter 1 are to be complied with.

3.4.4 Direct calculations should be carried out in accordance with the SDA procedure relevant to the ship type.

3.4.5 Vehicle deck structure is to be of adequate strength for the upward forces imposed at fixed securing points. Local reinforcement is to be fitted as necessary.

■ *Section 4*
Shell envelope plating

4.1 Bottom and side shell

4.1.1 For ferries and passenger ships classed **100A1** with a specified operating area service notation the keel thickness for 0,4L amidships is to be as required by Ch 1,5. At ends, the keel thickness may be reduced by 25 per cent from the above value, but is to be not less than that of the adjacent shell plating.

4.1.2 The thickness of side shell plating above 1,6T including superstructures may require special consideration depending on the particular structural arrangement, hull vertical bending and shear stresses and position of the shell above the waterline. In no case are the shell scantlings above 1,6T be less than the following:

(a) $t_{zm} = t_{shell} - (Z_m - 1{,}6T)\,(0{,}24 + 0{,}0012L)\sqrt{\dfrac{k\,s_1}{s_b}}$

(b) $t_{zm} = (4 + 0{,}02L)\sqrt{\dfrac{k\,s_1}{s_b}}$

(c) as required by Pt 3, Ch 8

where

t_{shell} = minimum required shell thickness above D/2 for the specific location, as calculated in Ch 1,5

t_{zm} = minimum shell thickness at Z_m

Z_m = vertical height in metres above base

L and T as defined in Pt 3, Ch1,1.5.

s_1, s_b as defined in Table 5.3.1 in Pt 3, Ch 5 for fore end or Table 6.3.1 in Chapter 6 for aft end.

4.1.3 Openings in the side shell and superstructure plating for windows and doors are to be suitably stiffened and the thickness and grade of plating in way will be specially considered.

4.1.4 For ships with broad flat counter stern sections which are liable to be subjected to large wave impact loading, the effect of wave impact loading on the plating and framing of the local shell structure is to be additionally considered, *see* 4.3 and 5.2.

4.1.5 The plating and framing of the forward shell structure for ships with significant bow flare is to be additionally considered with regard to wave impact loading, *see* 4.3 and 5.2.

4.1.6 The minimum thickness of the shell plating at ends and for taper is to be not less than the values given in Table 2.4.1, and is in no case to be less than 6 mm.

Table 2.4.1 End shell thickness

Scantling length	Thickness, in mm
70 m and below	$(6{,}5 + 0{,}033L)\sqrt{\dfrac{k\,s_1}{s_b}} - 1{,}0$
Between 70 m and 110 m	$(6{,}5 + 0{,}033L)\sqrt{\dfrac{k\,s_1}{s_b}} - 0{,}5$
Over 110 m	Pt 3, Ch 5 and Ch 6
Symbols	
L as defined in Pt 3, Ch 1,1.5 s_1, s_b as defined in Table 5.3.1 in Pt 3, Ch 5 for fore end or Table 6.3.1 in Chapter 6 for aft end	

4.1.7 For ferries and passenger ships classed **100A1** with a specified operating area service notation, the bottom and side shell minimum thickness at ends may be taken 20 per cent less than that required by Table 2.4.1 and Pt 3, Ch 5 and Ch 6, but is in no case to be less than 6 mm.

4.2 Bow flare and wave impact pressures

4.2.1 This Section is applicable to:

(a) bow flare region;

(b) sides and undersides of sponsons; and

(c) other parts of the side shell plating close to and above the design waterline that are expected to be subjected to wave impact pressures.

The wave impact pressure, P_{bf} , in kN/m^2 due to relative motion is to be taken as:

$$P_{bf} = 0{,}5\,(K_{bf}\,V_{bf}^2 + K_{rv}\,H_{rv}\,V_{rv}^2)\ \text{kN/m}^2$$

where

K_{bf} = hull form shape coefficient for wave impacts

$= \dfrac{\pi}{\tan\psi}$ for $\psi \geq 10$

$= 28\,(1 - \tan(2\psi))$ for $\psi < 10$

V_{bf} = wave impact velocity, in m/s, and is given by

$= \sqrt{V^2_{thbf} + 2m_1\,\ln(N_{bf})}$ for $N_{bf} \geq 1$

$= 0$ for $N_{bf} < 1$

V_{thbf} = threshold velocity for wave impact, in m/s, to be taken as:

$= \dfrac{\sqrt{10}}{\cos\alpha_p}$

In ( ) is the natural logarithm

N_{bf} = No. of wave impacts in a three hour period and is given by

$= 1720\, PR_{bf} \sqrt{\dfrac{m_1}{m_0}}$

PR_{bf} = probability of a wave impact and is given by

$= e^{-u}$

$u = \left(\dfrac{Z^2_{wl}}{2m_0} + \dfrac{V^2_{thbf}}{2m_1} \right)$

Z_{wl} = distance of the centroid of the area of plating or stiffener above the local design waterline

m_1 = variance of the relative vertical velocity

$= 0{,}25(\omega_e\, f_{sl}\, H_{rm})^2$

m_0 = variance of the relative vertical motion

$= 0{,}25\,(f_{sl}\, H_{rm})^2$

ω_e = effective encounter wave frequency

$= \omega \left(1 + \dfrac{0{,}4 q \omega\, V_{sl}}{g} \right)$

where

q = 1,0 for $\dfrac{x}{L} \geq 0{,}5$

= –0,6 for $\dfrac{x}{L} < 0{,}5$

ω = effective wave frequency based on 80 per cent ship length

$= \sqrt{\dfrac{2\pi\, g}{0{,}8 L_{WL}}}$

f_{sl} = probability level correction factor for relative vertical motion

= 1,0 for $C_b \leq 0{,}6$

= 1,2 for $C_b > 0{,}6$

V_{sl} = $0{,}515V$, in m/s

K_{rv} = hull form shape coefficient for impact due to forward speed

$= \dfrac{\pi}{\tan (90 - \alpha_p)}$ for $\alpha_p \leq 80$

$= 28\,(1 - \tan (2\,(90 - \alpha_p)))$ for $\alpha_p > 80$

H_{rv} = relative wave heading coefficient

for $\dfrac{x}{L} \geq 0{,}5$

= 1 for $\gamma_p > 45$

$= \cos(45 - \gamma_p)$ for $\gamma_p \leq 45$

for $\dfrac{x}{L} < 0{,}5$

= 0

The point at which the following angles are to be measured for assessment of plating and stiffeners is detailed in Table 2.4.2:

V_{rv} = relative forward speed, in m/s

$= 0{,}515V \sin \gamma_p$

α_p = buttock angle measured in the longitudinal plane, in degrees, *see* Fig. 2.4.1 and Table 2.4.2

ψ = effective deadrise angle, in degrees
For $C_b > 0{,}6$, ψ is to be taken as the maximum of α_p and β_p, *see* Fig. 2.4.1 and Table 2.4.2
For $C_b \leq 0{,}6$, ψ is to be taken as the maximum of α_p and β

where

β = $\beta_p - 10°$, but is to be taken as not less than 0°

NOTE
The 10° deduction is to allow for the effects of roll motion on the impact pressures.

γ_p = waterline angle measured in the horizontal plane, in degrees, *see* Fig. 2.4.1 and Table 2.4.2.

Table 2.4.2 Positions at which α_p, β_p and γ_p are to be measured

Framing system	Plating	Secondary stiffeners
Longitudinally framed	Mid-distance between longitudinals	Mid-distance between frames
Transversely framed	0,5*s* from the bottom edge of the plate strake or primary member	Mid-distance between primary members

NOTE
Where only two angles are known and are measured in orthogonal planes, the third angle may be obtained by the following expression:

$\alpha_p = \tan^{-1} (\tan \beta_p \tan \gamma_p)$

The relative vertical motion, H_{rm}, is to be taken as

$$H_{rm} = C_{w,min} \left(1 + \frac{4{,}5}{(C_b + 0{,}2)} \left(\frac{x_{wL}}{L_{wL}} - x_m \right)^2 \right)$$

where

$C_{w,min} = \dfrac{C_w}{\sqrt{2}\, k_m}$

C_w = a wave head in metres

$= 0{,}0771 L_{WL}\, (C_b + 0{,}2)^{0{,}3}\, e^{(-0{,}0044 L_{WL})}$

$k_m = 1 + \dfrac{4{,}5\,(0{,}5 - x_m)^2}{(C_b + 0{,}2)}$

$x_m = 0{,}45 - 0{,}6F_n$ but is not to be less than 0,2

$F_n = \dfrac{0{,}515V}{\sqrt{g\, L_{WL}}}$

L_{WL} = waterline length at summer load draught

x_{wL} = longitudinal distance, in metres, measured forwards from the aft end of the L_{WL} to the location being considered

V = speed, in knots

for $\dfrac{x}{L} \geq 0{,}5$

= is to be taken as the maximum service speed, in knots, as defined in Pt 3, Ch 1,6. For passenger yachts not required to maintain high speeds in severe weather, the value of V may be specially considered, but is not to be taken as less than the greater of $\dfrac{V}{3}$ or 5 knots. Where V has been specially considered it is to be noted in the classification records as a memorandum that should state: "A design speed of … knots has been used for the assessment of bow structure with regards to bow flare impacts. It should be noted that this speed

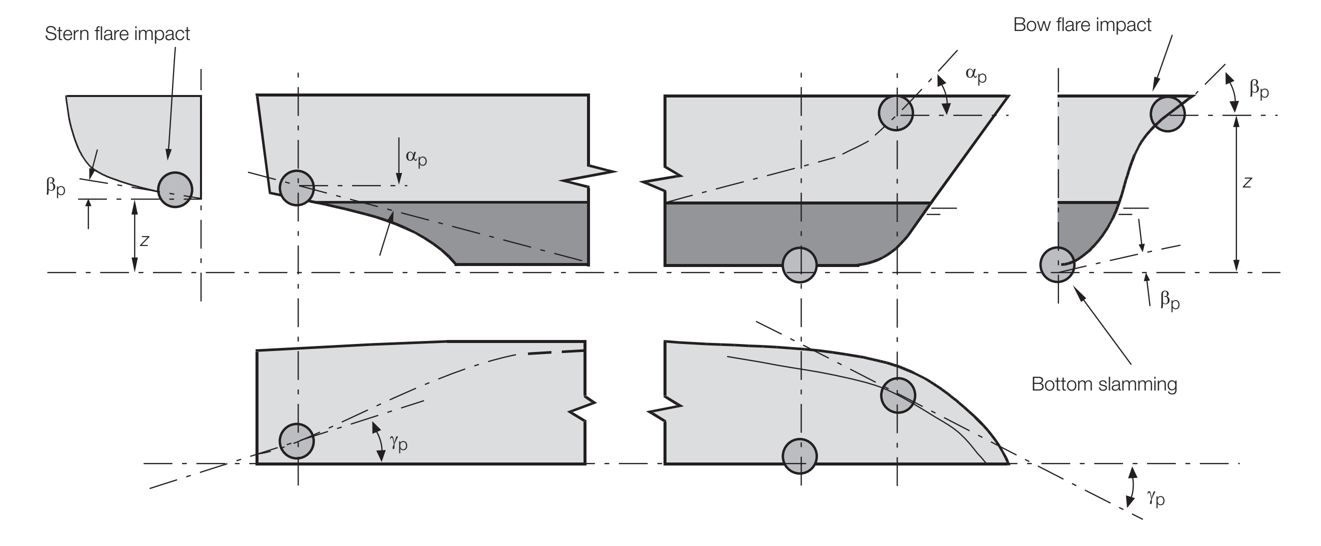


Fig. 2.4.1 Bow flare and bottom slamming angles

may not be appropriate for all conditions and it is the responsibility of the Master to apply good Seamanship to minimise bow flare slamming."

for $\frac{x}{L} < 0,5$

= 0 knots, for passenger ships
= 5 knots, for all other ship types
C_b = Rule block coefficient.

4.2.2 Alternatively, P_{bf} may be derived by the direct calculations carried out in accordance with a procedure agreed by LR.

4.3 Strengthening for wave impact loads

4.3.1 The shell envelope in the forward and after portions of the hull are to be strengthened against bow flare or wave impact pressure. Typically, strengthening is to be considered over the following areas:

- over the after body in way of a flat counter stern which is close to the waterline;
- over the fore end side and bow structure above the waterline and up to the deck at side;
- other areas where the hull exhibits significant flare.

4.3.2 The thickness of the side shell plating is to be not less than:

$$t = 3,2 s_c \sqrt{k\, h_s}\ C_R \times 10^{-2} \text{ mm}$$

where
s_c = is the length of the shorter edge of a plating panel framed by primary and secondary members, *see* Fig. 2.4.2
h_s = equivalent wave impact head, in metres
h_s = $0,1 P_{bf}$ m
P_{bf} = is defined in 4.2.1
C_R = panel ratio factor

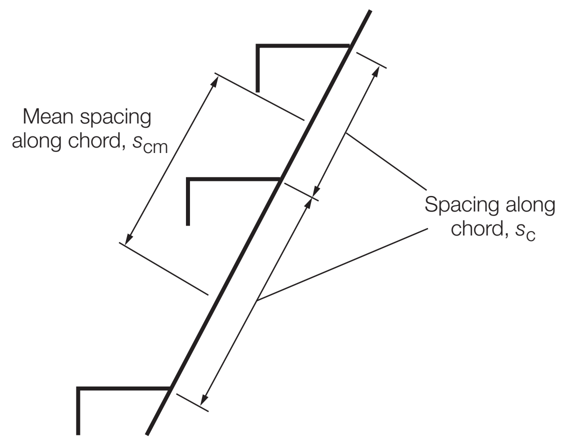


Fig. 2.4.2 Chord spacing and mean chord spacing for secondary members

$C_R = \left(\frac{l}{s_c}\right)^{0,41}$ but is not to be taken less than 0,06 or greater than 0,1
l = overall panel length, in metres, measured along a chord between the primary members.

4.3.3 The structural scantlings required in areas strengthened against bow flare slamming are to be tapered to meet the normal shell envelope requirements.

4.3.4 The side structure scantlings required by this Section must in no case be taken less than those required by the remaining Sections of Chapter 2.

Section 5
Shell envelope framing

5.1 Side structure

5.1.1 The scantlings of frames, or side longitudinals, web frames or transverses, and stringers below 1,6T above base are to satisfy the requirement of Chapter 1 and this Section, but may be required to be confirmed by direct calculation. The scantlings of these members above 1,6T from base may require special consideration on the basis of the particular structural arrangements, design deck loading, hull vertical bending stresses, and position of the member above the waterline.

5.1.2 The scantlings of side transverses supporting shell longitudinals above 1,6T are to satisfy the requirements of:

(a) Ch 1,6, Pt 3, Ch 5,4 and Pt 3, Ch 6,4.

(b) The minimum geometric properties required in order to provide rotational constraint to the end of the deck transverse in way:

$$Z_s = \frac{0{,}677 S\, k\, P_s\, L_d^3}{\left(\left(\frac{I_d}{I_s}\right) L_s + L_d\right)} \text{ cm}^3$$

but is not to be less than $0{,}339 S\, k\, P_s\, L_d^2$ cm^3

I_s is not to be less than $I_d \left(\frac{L_s}{L_d}\right)\left(\frac{Z_{dR}}{Z_d}\right)$ cm^4

where

P_s = deck design loading, in kN/m^2, *see* Table 2.3.1
L_d = span of adjacent deck transverse, in metres
Z_d = actual modulus of adjacent deck transverse, in cm^3
Z_{dR} = Rule modulus of adjacent deck transverse, in cm^3
I_d = moment of inertia of adjacent deck transverse, in cm^4
L_s = span of side shell transverse, in metres
I_s = moment of inertia of side shell transverse, in cm^4
S, k = as defined in 1.5.1

Due account should be taken of the shell window dimensions when determining the effective width of attached plating.

5.1.3 The required modulus of transverse main and 'tween deck frames, which may have reasonably constant convex curvature over their entire length, may be corrected for curvature as follows:

$$Z_{min} = Z_{rule} \left(\frac{1}{\cosh\left(\frac{2\pi\, Y_c}{l_e}\right)}\right)^3 \text{ cm}^3$$

where

Z_{rule} = modulus requirement, in cm^3, from Chapter 1 using l_e
l_e = distance between span support points, in metres, as shown in Fig. 2.5.1
Y_c = curvature measured from a line intersecting the end support points to the frame at mid-span, in metres, as shown in Fig. 2.5.1
Z_{min} = is not to be less than 0,5Z_{rule}.

5.1.4 Where ramp openings are fitted adjacent to the ship's side, adequate support for the side framing is to be provided.

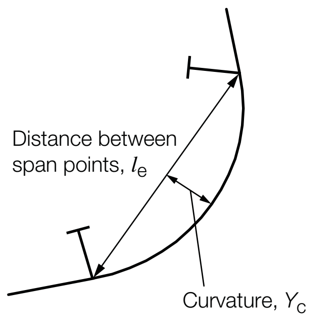


Fig. 2.5.1
Distance between span support points and curvature

5.2 Strengthening for wave impact loads

5.2.1 The side structure in the forward and after portions of the hull is to be strengthened against bow flare or wave impact pressure. Typically, strengthening is to be considered over the following areas:

- over the after body in way of a flat counter stern which is close to the waterline.
- over the fore end side and bow structure above the waterline and up to the deck at side.
- other areas where the hull exhibits significant flare.

5.2.2 The scantlings of secondary stiffeners are not to be less than:

(a) Effective plastic section modulus of stiffeners:

$$Z_p = 3{,}75\, h_s\, s_{cm}\, k\, l_e^2 \times 10^{-3} \text{ cm}^3$$

where
h_s = wave impact head, in metres, as defined in 4.3.2
s_{cm} = mean spacing of secondary stiffeners, in mm, measured along a chord between parallel adjacent members or equivalent supports, as shown in Fig. 2.4.2

Other symbols are as defined in 1.5.2.

(b) Web area of secondary stiffeners

$$A = 3{,}7 s_{cm}\, k\, h_s \left(l_e - \frac{s_{cm}}{2000}\right) \times 10^{-4} \text{ cm}^2$$

where
s_{cm} = mean spacing of secondary stiffeners, in mm, measured along a chord between parallel adjacent members or equivalent supports, as shown in Fig. 2.4.2
h_s = wave impact head, in metres, as defined in 4.3.2

Other symbols are as defined in 1.5.2.

5.2.3 The effective section properties of secondary stiffeners are to be taken as:

(a) Plastic section modulus of secondary stiffeners, Z_p, is to be taken as:

$$Z_p = 2{,}8 \times 10^{-4}\, s_{cm}\, t_p^2 - 10^{-3}\, b_f\, b_{fc}\, t_f \sin\theta_e + 5 \times 10^{-4} (h_w^2\, t_w + 2 b_f\, t_f\, h_w) \cos\theta_e \text{ cm}^3$$

where
θ_e = $C_0 (90 - \varphi)$
C_o = 1,1

φ = the angle between the stiffener and the side shell, in degrees
b_{fc} = 0,5 ($b_f - t_w$) for L profiles
= 0 for flat bar and T profiles
= *see* Fig. 4.7.1 in Pt 3, Ch 4, for bulb profiles
h_w = height of stiffener web, in mm
t_w = web thickness, in mm
b_f = breadth of flange, in mm
t_f = flange thickness, in mm
t_p = thickness of attached plating, in mm

(b) Web area of secondary stiffeners, A_s, is to be taken as:

$A_s = 0{,}01\ (h_w + t_p)\ t_w \sin\varphi$ cm^2

5.2.4 Where the stiffener web is not perpendicular to the plating, tripping brackets have to be fitted in order to obtain adequate lateral stability.

5.2.5 The scantlings of primary members are not to be less than:

(a) Section modulus of primary members

$Z = 2\,\gamma_Z\,k\,h_s\,q\,v\,l_e^2$ cm^3

(b) Web area of primary members

$A = 0{,}2\,\gamma_A\,k\,h_s\,q\,v\,l_e$ cm^2

where

h_s = wave impact head, in metres, as defined in 4.3.2

and

γ_A and γ_Z are strength factors dependent on the load position

for $q < 1$ $\gamma_A = q^3 - 2q^2 + 2$ and $\gamma_Z = 3q^3 - 8q^2 + 6q$

for $q = 1$ $\gamma_A = 1$ and $\gamma_Z = 1$

$q = \dfrac{u}{l_e}$ but ≤ 1

for web frames:
u is the minimum of g_{bfv} or l_e
v is the minimum of g_{bfh} or S_{cm}

for primary stringers:
u is the minimum of g_{bfh} or l_e
v is the minimum of g_{bfv} or S_{cm}

where
l_e is the effective length of the primary member, in metres
S_{cm} is the mean spacing between primary members along the plating, in metres, *see* Fig. 2.5.2
g_{bfv} and g_{bfh} are defined in 5.2.6
Other symbols are as defined in 1.5.2.

(c) The web of the primary member is to be adequately stiffened.

5.2.6 The extents of the wave impact pressure are to be derived as follows:

(a) the vertical extent, g_{bfv}, is to be taken as:

$$g_{bfv} = \frac{4}{\sin\psi\,\sqrt{8K_{bf}}}\ \text{m}$$

(b) the horizontal extent, g_{bfh}, is to be taken as:

g_{bfh} = 4 m

where

K_{bf} and ψ are given in 4.2.1.

5.2.7 For primary members with cut-outs for the passage of secondary stiffeners, and which may have web stiffeners connected to the secondary stiffener, buckling checks are to be carried out to ensure that the primary member web plating and web stiffener will not buckle under the design load. The buckling procedure to be followed is given in Table 5.1.3 in Pt 3, Ch 5. Where the web stiffener is fitted with a bracket, the buckling capability of the web stiffener in way of the cut-out is to take account of the bracket. Where no web stiffener is fitted, the buckling capability of the primary member web plating is to be checked for the total load transmitted to the connection.

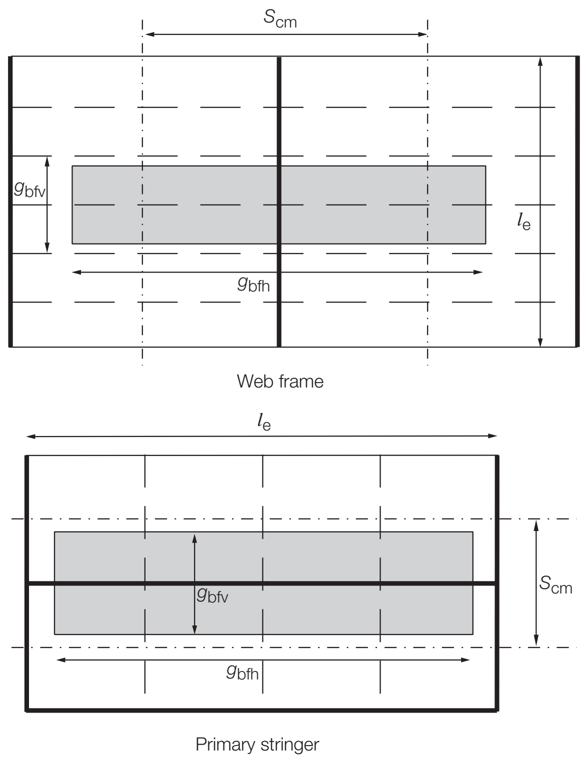


Fig. 2.5.2
Mean spacing between primary members, S_{cm}, and the extents of wave impact pressure g_{bfh} and g_{bfv}

5.2.8 Where the angle between the primary structure web and the plating is less than 70°, the effective section modulus and shear area are to take account of the non-perpendicularity.

5.2.9 The structural scantlings required in areas strengthened against bow flare slamming are to be tapered to meet the normal shell envelope requirements.

5.2.10 The side structure scantlings required by this Section must in no case be taken less than those required by the remaining Sections of Chapter 2.

■ *Section 6*
Double bottom

6.1 General

6.1.1 A double bottom is to be fitted in accordance with Pt 4, Ch 1,8.

6.1.2 Where podded drive systems are to be employed, adequate floors and girders are to be arranged in order to efficiently integrate the unit into the aft structure. The adequacy of the hull structure supporting the unit is to be verified using the maximum external forces and moments stated by the manufacturer. Due account is to be taken of additional forces induced by ship motion accelerations.

6.2 Transmission of pillar loads

6.2.1 In ships where the deck centreline supports are widely spaced, transmission of the pillar loads to the double bottom structure will be specially considered, and additional reinforcement may be required if high shear and bending stresses are induced by the concentrated loads. The reinforcement should take the form of additional floors, and fore and aft girders. The final reinforcement is to be confirmed by direct calculation.

6.2.2 Where, in multi-decked passenger ships, the Rule deck loadings from Table 2.3.1 have been used to determine the primary deck supporting structure, the cumulative pillar load P_p may be taken as:

$P_p = \Sigma (b_p S_p) P_s$ kN

where

b_p = breadth of deck supported by pillar
S_p = mean spacing between pillars
P_s *see* Table 2.3.1.

6.2.3 Pillars are to be provided with suitable pads at their heels. Long pillars, and those terminating at the inner bottom are to be bracketed. At pillar heads, the free edges of deck primary structure face plates are to be at least 20 mm clear of the pillar head attachment weld. Where necessary, gusset plates are to be fitted at primary member intersections in way of pillars. These gussets may be applied as doublers onto the primary member face plates and should be at least equal in thickness to the pillar or the face plate, whichever is greater. Where pillars act in tension, the gussets are to be integral with the primary member face plates. The axial stress in tensile pillars is not to exceed 110/k N/mm^2 and full penetration welds are to be arranged in way of the end connections.

6.3 Ferries and passenger ships with a specified operating area service

6.3.1 The thickness of double bottom centre girders may be reduced by 10 per cent, and the thickness of double bottom side girders and floors may be reduced by five per cent, from the values required by Ch 1,8, but is in no case to be less than 6 mm.

■ *Section 7*
Peak, watertight and deep tank bulkheads

7.1 General

7.1.1 The scantlings of watertight and deep tank bulkheads are to comply with the requirements of Chapter 1.

7.1.2 The load head, h_4 to be used in watertight bulkhead scantlings for passenger ships is, in addition, to comply with the following:

- For watertight bulkhead plating, the distance from a point one-third of the height of the plate above its lower edge to a point 0,91 m above the bulkhead deck at side, or to the deepest intermediate/equilibrium waterline in damaged condition obtained from applicable damage stability calculations, whichever is the greater.
- For watertight bulkhead stiffeners or girders, the distance from the middle of the effective length to a point 0,91 m above the bulkhead deck at side, or to the deepest intermediate/equilibrium waterline in damaged condition obtained from applicable damage stability calculations, whichever is the greater.

7.1.3 Partial watertight bulkheads and webs fitted above the bulkhead deck which are to be included in damage stability calculations, are to be assessed as watertight, *see* 7.1.2.

7.2 Ferries and passenger ships with a specified operating area service

7.2.1 The thickness of bulkhead plating for peak tanks and deep tanks, other than the collision bulkhead, may be reduced by 0,5 mm, and the modulus of bulkhead stiffeners, swedges, corrugations and girders may, in general, be reduced by 20 per cent from the values required by Ch 1,9.

■ *Section 8*
Bow doors and inner doors

8.1 Symbols

8.1.1 The symbols used in this Section are defined as follows:

a = vertical distance, in metres, from the bow door pivot to the centroid of the vertical projected area of bow door, *see* Fig. 2.8.1
b = horizontal distance, in metres, from the bow door pivot to the centroid of the horizontal projected area of the bow door, *see* Fig. 2.8.1
c = horizontal distance, in metres, from bow door pivot to centre of gravity of bow door, *see* Fig. 2.8.1
d = vertical distance, in metres, from bow door pivot to the centre of gravity of the bow door, *see* Fig. 2.8.1

h = height of the door, in metres, between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser, *see* Fig. 2.8.2

k = material factor (*see* Pt 3, Ch 2,1.2), but is not to be taken less than 0,72 unless demonstrated otherwise by a direct strength analysis with regard to relevant modes of failure

l = projected length, in metres, of the door at a height of $\frac{h}{2}$ above the bottom of the door, *see* Fig. 2.8.2

w = width of bow door at half height, in metres

A_z = area, in m^2, of the horizontal projection of the bow door, between the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is the lesser, *see* Fig. 2.8.1. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is the lesser

A_s = area of stiffener web, in cm^2

A_x = area, in m^2, of the transverse vertical projection of the bow door, between the bottom of the door and the top of the door or between the bottom of the door and the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is the lesser, *see* Fig. 2.8.1. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. In determining the height from the bottom of the door to the upper deck or to the top of the door, the bulwark is to be excluded

A_y = area, in m^2, of the longitudinal vertical projection of the bow door, between the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is the lesser, *see* Fig. 2.8.1. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is the lesser

W = weight of bow visor, in tonnes

q = distance, in metres, from the centroid of the hydrostatic head profile, to the top of the cargo space

C_H = 0,0125L where L < 80 m
= 1,0 where $L \geq$ 80 m

L = length of ship, but need not be taken greater than 200 m

V as defined in 1.5.1

λ = coefficient depending on the area where the ship is intended to be operated
= 1,0 for sea-going ships
= 0,8 for ships operated in coastal waters
= 0,5 for ships operated in sheltered waters

σ = bending stress, in N/mm^2 (kgf/mm^2)

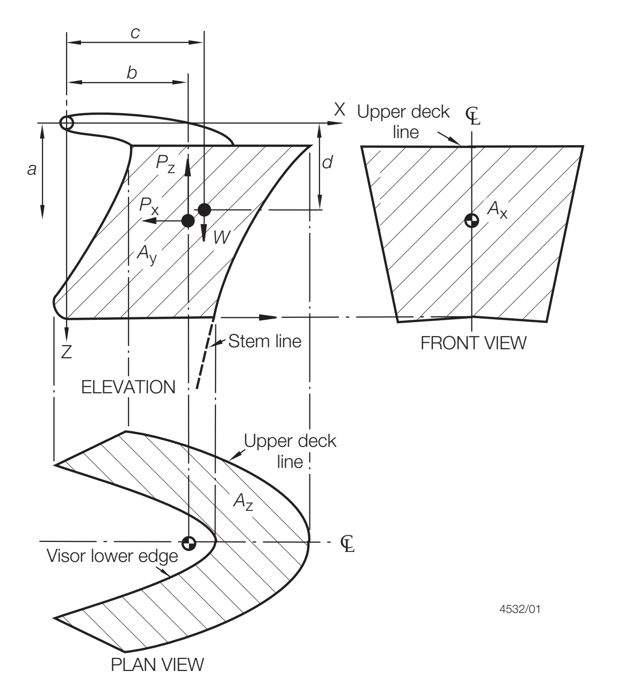


Fig. 2.8.1 Bow door (upward hinging)

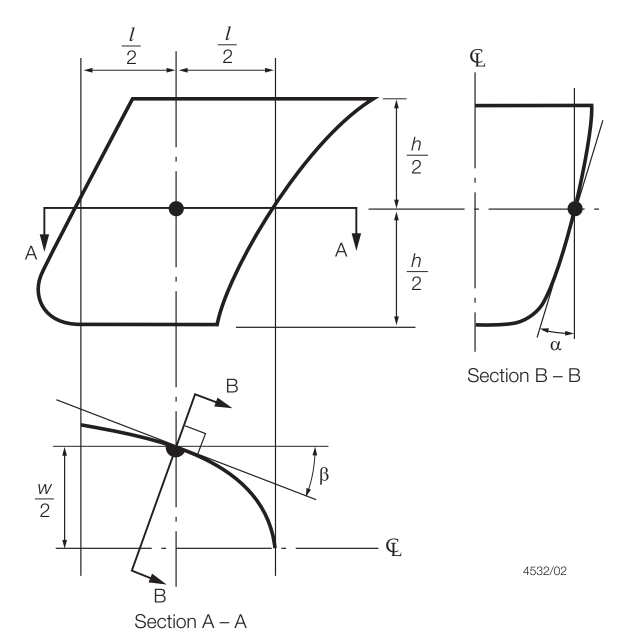


Fig. 2.8.2 Definition of α and β

σ_e = equivalent stress, in N/mm^2 (kgf/mm^2)
$= \sqrt{\sigma^2 + 3\tau^2}$

σ_y = yield stress of the bearing material, in N/mm^2 (kgf/mm^2)

τ = shear stress, in N/mm^2 (kgf/mm^2).

8.2 General

8.2.1 Bow doors are defined by the following types:

(a) Visor doors opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary structure of the door by longitudinally arranged lifting arms.

(b) Side-opening doors opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the ship. It is expected that side-opening bow doors will be arranged in pairs.

Other bow door types will be specially considered.

8.2.2 Bow doors are to be situated above the freeboard deck. A watertight recess in the freeboard deck located forward of the collision bulkhead and above the deepest waterline, fitted for arrangement of ramps or other related mechanical devices, may be regarded as a part of the freeboard deck for the purpose of this requirement.

8.2.3 Where bow doors lead to a complete or long forward enclosed superstructure, or to a long non-enclosed superstructure which is fitted to attain minimum bow height equivalence, an inner door is to be fitted. The inner door is to be part of the collision bulkhead. Where a sloping vehicle ramp forming the collision bulkhead above the freeboard deck is arranged, the inner door may be omitted if the ramp is weathertight over its complete length and fulfils the requirements of Pt 3, Ch 3 concerning the position of the collision bulkhead.

8.2.4 Bow doors are to be fitted with arrangement for ensuring weathertight sealing, such as gaskets, and to give effective protection to inner doors.

8.2.5 Inner doors forming part of the collision bulkhead are to be watertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

8.2.6 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a second separate inner weathertight door, complying with 8.2.5, is to be installed.

8.2.7 The requirements for inner doors are based on the assumption that vehicles and cargo are effectively lashed and secured against movement from the stowed position.

8.2.8 For ships complying with the requirements of this Section, the securing, supporting and locking devices are defined as follows:

(a) A securing device is used to keep the door closed by preventing it from rotating about its hinges.

(b) A supporting device is used to transmit external and internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the ship's structure.

(c) A locking device locks a securing device in the closed position.

8.2.9 The scantlings and arrangements of side shell and stern doors are to be in accordance with the requirements of Pt 3, Ch 11,8.

8.3 Scantlings

8.3.1 The strength of the bow door is to be equivalent to the surrounding structure, as given in Pt 3, Ch 5,6.

8.3.2 For bow doors, including bulwark, of unusual form or proportions, the areas and angles used for the determination of design values of external forces are to be specially considered.

8.3.3 Bow doors of the visor or hinged opening type are to be adequately stiffened, and means are to be provided to prevent lateral or vertical movement of the doors when closed. Care is to be taken to ensure that adequate strength is provided in the connections of the hinge or linking arms to the door structure and to the ship structure.

8.3.4 The thickness of the bow door plating is not to be less than the side shell plating calculated with the door stiffener spacing, and in no case to be less than the minimum shell plate end thickness or forecastle side thickness as appropriate.

8.3.5 The section modulus of horizontal or vertical stiffeners is not to be less than required for end framing. Consideration is to be given, where necessary, to differences in fixity between ship frames and bow door stiffeners.

8.3.6 The stiffener webs are to have a net sectional area not less than:

$$A_s = \frac{10Q}{\tau} \text{ cm}^2$$

τ is to be taken as $\frac{100}{k}$ N/mm^2 $\left(\frac{10,2}{k}\text{ kgf/mm}^2\right)$

where

Q = shear force, in kN (tonne-f) calculated using the uniformly distributed external sea pressure, p_e, defined in 8.5.15.

8.3.7 Bow door secondary stiffeners are to be supported by primary members constituting the main stiffening elements of the door.

8.3.8 The scantlings of such primary members are to be based on direct strength calculations. Normally, formulae for simple beam theory may be applied to determine the bending stress. Members are to be considered to have simply supported end connections. The design load, P_e, is the uniformly distributed external sea pressure. The formulae for P_e given in 8.6.1, may be used with α and β defined as:

α = flare angle, in degrees, generally to be measured normal to the shell between the vertical axis and the vertical tangent to the outer shell of the door measured at the point on the bow door, one half of the projected length (l/2) aft of the stern line on the plane at the half height of the door (h/2) (*see* Fig. 2.8.2)

β = entry angle, in degrees, generally to be measured on the outer shell of the door between the longitudinal axis and the waterplane tangent measured at the point on the bow door, one half of the projected length (l/2) aft of the stem line on the plane at the half height of the door (h/2) (*see* Fig. 2.8.2)

The permissible stresses are as follows:

$$\tau = \frac{80}{k} \text{ N/mm}^2 \left(\frac{8,2}{k} \text{ kgf/mm}^2\right)$$

$$\sigma = \frac{120}{k} \text{ N/mm}^2 \left(\frac{12,2}{k} \text{ kgf/mm}^2\right)$$

$$\sigma_e = \frac{150}{k} \text{ N/mm}^2 \left(\frac{15,3}{k} \text{ kgf/mm}^2\right).$$

8.3.9 The webs of primary members are to be adequately stiffened, preferably in a direction perpendicular to the shell plating.

8.3.10 The primary members of the bow doors and hull structure in way are to have sufficient stiffness to ensure the integrity of the boundary support of the doors.

8.3.11 All load transmitting elements in the design load path, from door through securing arrangements and supporting devices into the ship structure, including welded connections, are to be to the same strength standard. These elements include pins, supporting brackets and back-up brackets. Where cut-outs are made in the supporting structure, the strength and stiffness will be specially considered.

8.3.12 For bow doors and inner doors, the distribution of forces acting on the securing devices and the supporting devices is to be supported by direct calculations taking into account the flexibility of the structure and the actual position and stiffness of the supports.

8.3.13 The buckling strength of primary members is to be specially considered.

8.4 Vehicle ramps

8.4.1 Where doors also serve as vehicle ramps, the scantlings are to be not less than would be required by 3.2.2 and 3.3.2 and where they form part of the collision bulkhead the arrangement is to be in accordance with Pt 3, Ch 3,4.5.

8.5 Arrangements for the closing, securing and supporting of doors

8.5.1 Bow doors are to be fitted with adequate means of closing, securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Maximum design clearance between securing and supporting devices is not to exceed 3 mm.

8.5.2 Securing devices are to be simple to operate and easily accessible. They are to be of a design approved by LR for the intended purpose.

8.5.3 Securing devices are to be equipped with positive locking arrangements. Arrangements are to be such that the devices are retained in the closed position within design limits of inclination, vibration and other motion-induced loads and in the event of loss of any actuating power supply.

8.5.4 Systems for door opening/closing and securing/locking are to be interlocked in such a way that they can only operate in a proper sequence. Hydraulic systems are to comply with Pt 5, Ch 14,9.

8.5.5 Means are to be provided to enable the bow doors to be mechanically fixed in the open position taking into account the self-weight of the door and a minimum wind pressure of 1,5 kN/m^2 (0,153 tonne-f/m^2) acting on the maximum projected area in the open position.

8.5.6 The spacing for side and top cleats should not exceed 2,5 m and there should be cleats positioned as close to the corners as practicable. Alternative arrangements for ensuring weathertight sealing will be specially considered.

8.5.7 Control and monitoring arrangements are to comply with Pt 6, Ch 2,19.

8.6 Design of securing and supporting devices

8.6.1 The external design forces for securing devices, supporting devices and surrounding structure are to be taken not less than P, taking the direction of the pressure into account:

$$P_x = A_x p_e$$
$$P_y = A_y p_e$$
$$P_z = A_z p_e$$

where

p_e = external sea pressure, not to be taken less than:

(a) For bow doors:

$$p_e = 0,8\,(0,15V + 0,6\sqrt{L}\,)^2 \text{ kN/m}^2$$
$$\left(0,082\,(0,15V + 0,6\sqrt{L}\,)^2 \text{ tonne-f/m}^2\right)$$

or

$$p_e = 2,75\lambda\, C_H\,(0,22 + 0,15\tan\alpha)\,(0,4V\sin\beta + 0,6\sqrt{L}\,)^2 \text{ kN/m}^2$$

or

$$\left(0,28\lambda\, C_H\,(0,22 + 0,15\tan\alpha)\,(0,4V\sin\beta + 0,6\sqrt{L}\,)^2 \text{ tonne-f/m}^2\right)$$

whichever is the greater.

(b) For inner doors:

p_e = 0,45L kN/m^2
(0,046L tonne-f/m^2)

or

p_e = 10q kN/m^2
(1,02q tonne-f/m^2)
whichever is the greater

The symbols are as defined in 8.1.1.

8.6.2 The inner door internal design pressure, considered for the scantlings of securing devices, is not to be less than 25 kN/m^2 (2,5 tonne-f/m^2).

8.6.3 For visor doors, the pivot arrangement is to be such that the visor is self-closing under external loads. The closing moment, M_c, is to be taken as:

$M_c = P_x a + 10Wc - P_z b$ kN m
($P_x a + 1{,}02Wc - P_z b$ tonne-f m)

but is not to be less than:

$$M_c = 10Wc + 0{,}1\sqrt{(a^2+b^2)(P_x{}^2+P_z{}^2)} \quad \text{kN m}$$

$$\left(1{,}02Wc + 0{,}1\sqrt{(a^2+b^2)(P_x{}^2+P_z{}^2)} \quad \text{tonne-f m}\right)$$

8.6.4 For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the permissible stresses given in 8.6.7. The opening moment M_o, to be balanced by this reaction force, is to be taken as not less than:

$M_o = 10Wd + 5A_x a$ kN m
$\left(1{,}02Wd + 0{,}51A_x a \quad \text{tonne-f m}\right)$

8.6.5 For visor type doors, the securing and supporting devices, excluding hinges, are to be capable of resisting the vertical design force (P_z – 10W) kN ((P_z – 1,02W) tonne-f), within the permissible stresses given in 8.6.7.

8.6.6 For side-opening doors, securing devices are to be provided such that in the event of a failure of any single securing device the remainder are capable of providing the full reaction force required to prevent the opening of the door. The permissible stresses given in 8.6.7 are not to be exceeded. The opening moment about the hinges to be balanced by this reaction force is not to be less than that calculated when the following loads are applied:

(a) An internal pressure of 5 kN/m^2 (0,51 tonne-f/m^2).
(b) A force of 10W kN (1,02W tonne-f) acting forward at the centroid of mass.

8.6.7 Securing devices and supporting devices are to be designed to withstand the forces given above using the following permissible stresses:

$$\tau = \frac{80}{k} \text{ N/mm}^2 \left(\frac{8{,}2}{k} \text{ kgf/mm}^2\right)$$

$$\sigma = \frac{120}{k} \text{ N/mm}^2 \left(\frac{12{,}2}{k} \text{ kgf/mm}^2\right)$$

$$\sigma_e = \frac{150}{k} \text{ N/mm}^2 \left(\frac{15{,}3}{k} \text{ kgf/mm}^2\right).$$

8.6.8 The arrangement of securing and supporting devices is to be such that threaded bolts are not to carry support forces. The maximum tensile stress in way of threads of bolts, not carrying support forces, is not to exceed:

$$\frac{125}{k} \text{ N/mm}^2 \left(\frac{12{,}7}{k} \text{ kgf/mm}^2\right).$$

8.6.9 For steel to steel bearings in securing and supporting devices, the nominal bearing pressure is not to exceed 0,8σ_y. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification. The nominal bearing pressure is to be calculated by dividing the design force by the projected bearing area.

8.6.10 The reaction forces to be applied to the effective securing and supporting devices are to be determined from the combination of external loads defined in Table 2.8.1.

Table 2.8.1 Combination of external loads

Bow door type	Combination of external loads	
	Case 1 (Head seas)	Case 2 (Quartering seas)
Visor doors, *see* Notes 1 and 2	P_x and P_z, *see* Note 3	0,7P_y acting on each side separately, together with 0,7P_x and 0,7P_z
Side opening, *see* Notes 1 and 2	P_x, P_y and P_z acting on both doors, *see* Note 3	0,7P_x and 0,7P_z acting on both doors and 0,7P_y acting on each door separately

NOTES
1. P_x, P_y and P_z are defined in 8.6.1. These forces are to be applied at the centroid of the projected areas.
2. The self-weight of the door is to be included in the combination of external loads.
3. The Case 1 forces are generally to give rise to a zero moment about the transverse axis through the centroid of area A_x, *see* Fig. 2.8.1.

8.6.11 The distribution of the reaction forces acting on the securing and supporting devices is to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports. Small and/or flexible devices, such as cleats, intended to provide load compression of the packing material are not to be included in these calculations.

8.6.12 The hinge or linking arms of a bow door and its supports are to be designed for the static and dynamic opening forces. A minimum wind pressure of 1,5 kN/m^2 (0,153 tonne-f/m^2), acting on the transverse projected area of the door is to be taken into account.

8.6.13 For side-opening doors, supporting devices are to be provided in way of girder ends at the closing of the two doors to prevent one side shifting towards the other under the effect of asymmetrical pressure. A typical arrangement is shown in Fig. 2.8.3.

8.6.14 Inner doors are to be gasketed and weathertight.

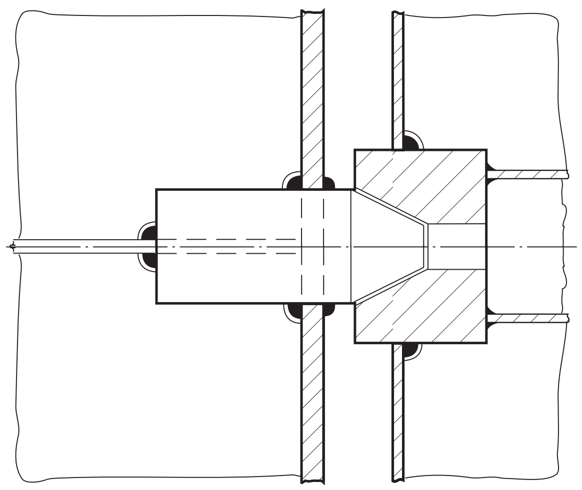


Fig. 2.8.3 Typical supporting device between doors

8.6.15 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices.

8.6.16 The number of securing and supporting devices is to be the minimum practicable whilst complying with 8.6.4 and 8.6.17 and taking account of the available space for adequate support in the hull structure.

8.6.17 The arrangement of securing devices and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces, resulting from the external loads defined in Table 2.8.1, without exceeding, by more than 20 per cent, the permissible stresses as defined in 8.6.7.

8.7 Operating and Maintenance Manual

8.7.1 An Operating and Maintenance Manual for the bow doors and inner doors is to be provided on board and is to contain the following information:

(a) main particulars and design drawings,
- special safety precautions;
- details of vessel;
- equipment and design loading for ramps;
- key plan of equipment for doors and ramps;
- manufacturers' recommended testing for equipment; and
- a description of the equipment for:
  - bow doors;
  - inner bow doors;
  - bow ramp/doors;
  - side doors;
  - stern doors;
  - central power pack;
  - bridge panel;
  - ramps leading down from the main deck;
  - engine control room panel.

(b) service conditions:
- limiting heel and trim of the ship for loading/unloading;
- limiting heel and trim for door operations;
- operating instructions for doors and ramps; and
- emergency operating instructions for doors and ramps.

(c) maintenance:
- schedule and extent of maintenance;
- troubleshooting and acceptable clearances; and
- manufacturers' maintenance procedures.

(d) register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

This Manual is to be submitted for approval, and is to contain a note recommending that recorded inspections of the door supporting and securing devices be carried out by the ship's staff at monthly intervals or following incidents that could result in damage, including heavy weather or contact in the region of the doors. Any damages recorded during such inspections are to be reported to LR.

8.7.2 Documented operating procedures for closing and securing the bow doors and inner doors are to be kept on board and posted at an appropriate place.

■ *Section 9* Subdivision structure on vehicle deck

9.1 General

9.1.1 The requirements of this Section cover subdivision structure fitted on the vehicle deck(s) of roll on–roll off passenger ships. Subdivision structure includes partition doors, bulkheads and longitudinal casings.

9.1.2 Where a ship is provided with subdivision structure that complies with the requirements of this Section, the ship will be eligible to be assigned the descriptive note **SSDS** which will be entered in column 6 of the *Register Book*.

9.1.3 The fitting of subdivision structure on the vehicle deck(s) forms one option to mitigate the stability-reducing effects of water on the vehicle deck(s) after damage. Such measures may be required by the National Administration with whom the ship is registered and/or by the National Administration within whose territorial jurisdiction the ship is intended to operate, for example *see* The Stockholm Agreement.

9.2 Design loads

9.2.1 For calculation of the design loads, an equivalent depth of water on the first vehicle deck above the design waterline, *d*, in metres, is to be derived in accordance with the requirements of the National Administration, *see* 9.1.3.

9.2.2 It is assumed that vehicles and cargo are effectively lashed and secured to prevent movement from the stowed position.

9.2.3 The design heads (*see* Fig. 2.9.1) are not to be taken less than the greater of 0,5 m and:

(a) For transverse structure more than 1,5 m away from the longitudinal boundaries of the compartment:

$$h_T = 1{,}4\sqrt{L_c\, d\, K} \quad \text{in metres, for } z < 1$$

$$= 1{,}4\sqrt{L_c\, d\, K}\ \ 1 - \left(\frac{(z-1)}{1{,}4\sqrt{L_c\, d\, K} - 1}\right)$$

in metres, for $z \geq 1$

Symbols are as defined in 9.2.4.

(b) For longitudinal structure more than $L_c/6$ away from the transverse boundaries of the compartment:

$$h_L = \sqrt{B_c\, d} \quad \text{in metres, for } z < 1$$

$$= \sqrt{B_c\, d}\ \ 1 - \left(\frac{z-1}{\left(1{,}4\sqrt{B_c\, d} - 1\right)}\right) \quad \text{in metres, for } z \geq 1$$

Symbols are as defined in 9.2.4.

(c) For structure elsewhere:

$$h_c = \frac{L_c\, K}{2} + \sqrt{R} \quad \text{in metres, for } z < 1$$

$$\left(\frac{L_c\, K}{2} + \sqrt{R}\right)\left(1 - \frac{(z-1)}{1{,}4\left(\frac{L_c\, K}{2} + R\right) - 1}\right)$$

in metres, for $z \geq 1$

Symbols are as defined in 9.2.4.

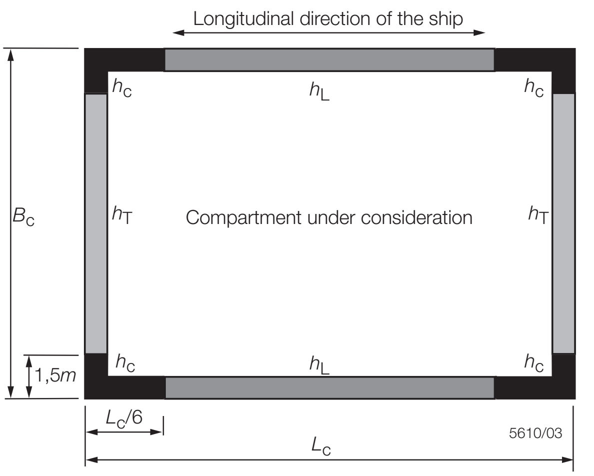


Fig. 2.9.1
Design heads for different locations in compartment

9.2.4 Symbols, as used in 9.2.3, are defined as follows:

d = equivalent depth of water on the vehicle deck, in metres, in the upright condition taking into account the volume of flooded and accumulated water on the vehicle deck calculated in accordance with the requirements of the National Administration, *see* 9.1.3 and 9.2.1

z = vertical distance, between the point under consideration and the flooded vehicle deck, in metres. For plate panels the point under consideration is to be taken as one third of the panel height above its lower edge. For stiffeners the point under consideration is to be taken as the midspan of the effective length

B_c = breadth of compartment, in metres, *see* Fig. 2.9.1

K = $0{,}21e^{(-0{,}0033 L_{pp})}$ and need not exceed 0,14

L_c = length of compartment, in metres, *see* Fig. 2.9.1

R = $B_c\, d - \dfrac{L_c^2\, K^2}{12}$ and is not to be taken less than 0

e = base of natural logarithms, 2,7183

L_{pp} = as defined in Pt 3, Ch 1,6.

9.2.5 The design heads calculated in 9.2.3 are based on the ship being in the upright condition. Where the actual damaged floating position is specified, the design heads will be specially considered taking this into account.

9.2.6 The subdivision structure, and access doors within the subdivision structure, are to be capable of withstanding the design loading applied from the side of the compartment under consideration.

9.2.7 Consideration will be given to the use of design heads agreed by the National Administration.

9.3 Height of subdivision structure

9.3.1 The height of the subdivision structure, H_D, is not to be less than:

- 4 m, or
- 8d, but not less than 2,2 m, or
- the height between the vehicle deck under consideration and the underside of the next watertight deck above,

whichever is the lesser

where

d = as defined in 9.2.4.

9.3.2 For special arrangements, such as hanging car decks or wide side casings, other subdivision structure heights may be accepted on the basis of detailed model tests in the flooded conditions under investigation by the National Administration.

9.4 Material

9.4.1 Where materials other than steel are used, the scantlings are to be specially considered.

9.5 Scantlings of subdivision structure other than doors

9.5.1 The minimum scantlings of subdivision bulkheads and casings are to be derived in accordance with Table 1.9.1 in Chapter 1 for watertight bulkheads, where h_4 is to be substituted by either of h_T, h_L or h_c, depending on the location under consideration.

9.5.2 Where a cut-out is made in the subdivision structure for the fitting of an access door, the strength and integrity of the subdivision structure are to be maintained.

9.6 Scantlings of subdivision doors

9.6.1 The plate thickness of subdivision doors of single plate construction is not to be less than the greater of:

t = $0{,}004 s\, f\, (h\, k)^{0{,}5}$ mm, or

t = 5,0 mm

where

s, k = as defined in 1.5.1

f = as defined in Table 1.9.1 in Chapter 1

h = h_T, h_L or h_c as defined in 9.2.3, as appropriate.

9.6.2 For subdivision doors of a double plate construction the plate thickness is to be specially considered.

9.6.3 The scantlings of primary and secondary stiffeners of subdivision doors are to be based on direct strength calculations.

9.6.4 The direct strength calculations are also to provide an assessment of the door, under the design load, to enable the leakage and hence the drainage requirements of 9.9 to be assessed.

9.6.5 For the purpose of the direct strength calculations, the stresses induced in the subdivision door, determined using the design loads from 9.2, are not to exceed the permissible values given in Table 2.9.1. Checks are also to be carried out to ensure that the door will not buckle under the design loads.

Table 2.9.1 Permissible stress values

Stress type	Permissible stress
Direct stress	σ_o
Shear stress	$\dfrac{\sigma_o}{3}$
Combined stress	σ_o
Symbols	
σ_o = specified minimum yield stress, in N/mm^2 (kgf/mm^2)	

9.6.6 Where a cut-out is made within the subdivision door for the fitting of an access door, the strength of the subdivision door is to be maintained.

9.7 Closing, securing and supporting of subdivision doors

9.7.1 The closing and securing devices of doors are to comply with the following requirements:

(a) Securing devices are to be simple to operate and easily accessible. They are to be of a design approved by LR for the intended purpose.

(b) Securing devices and supporting devices are to be designed to withstand the design loads calculated in 9.2.1 in association with the permissible stresses shown in Table 2.9.2.

(c) The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tensile stress in way of threads of bolts not carrying support forces is not to exceed $0{,}5\sigma_o$.

(d) For steel to steel bearings in securing and supporting devices, the bearing pressure is not to exceed $0{,}8\sigma_o$. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification. The bearing pressure is to be calculated by dividing the design force by the projected bearing area.

(e) Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included when calculating the reaction forces acting on the devices.

(f) Securing devices are to be equipped with positive locking arrangements. Arrangements are to be such that the securing devices are retained in the closed position within design limits of inclination, vibration and other motion-induced loads and in the event of loss of any actuating power supply.

(g) Hydraulic systems are to comply with Pt 5, Ch 14,9.

(h) Control and monitoring arrangements are to comply with Pt 6, Ch 2,19.

Table 2.9.2 Permissible stress values

Stress type	Permissible stress
Direct stress	$0{,}8\sigma_o$
Shear stress	$0{,}5\sigma_o$
Combined stress	$0{,}8\sigma_o$
Symbols	
σ_o = specified minimum yield stress, in N/mm^2 (kgf/mm^2)	

9.7.2 The reaction forces to be applied to the effective securing and supporting devices are to be determined using the applicable design loads calculated using the heads in 9.2 together with the weight of the door.

9.8 Access doors

9.8.1 Access doors are permitted to be fitted in subdivision doors or bulkheads in order to provide access between compartments.

9.8.2 Access doors may be manually operated.

9.8.3 The strength of access doors is to be not less than that of the surrounding structure.

9.8.4 Means are to be provided to ensure that access doors are closed and secured when not in use after the ship has left the berth.

9.8.5 A notice is to be displayed on the access doors stating that the door is to be closed and secured at all times when not in use, when the ship is under way.

9.8.6 Means are to be provided on the navigation bridge to indicate whether the access doors are open or closed.

9.9 Watertightness and drainage

9.9.1 Subdivision doors and access doors are to be fitted with gaskets in order to minimise leakage. For access doors where down flooding could result, particular attention is to be paid to drainage requirements.

9.9.2 The gasket arrangement shall provide sufficient flexibility to absorb possible racking deformation.

9.9.3 Attention is drawn to the drainage requirements of Pt 5, Ch 13,3.1 with respect to the compartments created by subdivision structures.

9.9.4 The drainage arrangement for each compartment is to have sufficient capacity to handle leakage from any adjacent flooded compartment.

9.10 Ventilation of vehicle deck spaces

9.10.1 Attention is drawn to the ventilation requirement of Pt 6, Ch 2,14.13.4, since subdivision structure could disrupt air flow.

9.11 Operating and Maintenance Manual

9.11.1 An Operating and Maintenance Manual for the subdivision doors is to be provided on board and is to contain the following:

- main particulars and design drawings,
- service conditions (e.g., service area restrictions),
- maintenance and function testing,
- register of inspections, repairs and renewals.

9.11.2 The Manual is to be submitted for approval. It is to contain a note recommending that recorded inspections of supporting and securing devices are to be carried out by the ship's staff at monthly intervals, or following incidents that could result in damage, including heavy weather or contact in the region of the subdivision doors. Any damages recorded during such inspections are to be reported to LR.

9.11.3 Documented operating procedures for closing and securing the subdivision doors are to be kept on board and posted in an appropriate place.

■ *Section 10* Masts and standing rigging

10.1 General

10.1.1 Masts are generally to be of tubular construction and may be either stayed or unstayed. Special consideration will be given to other forms of construction.

10.1.2 Masts are to be of sufficient strength to withstand the worst combination of loads from both the operational case with full sail, reduced sail configurations where applicable and survival conditions.

10.1.3 Masts are to be adequately supported using stays if necessary.

10.1.4 Drainage is to be provided to prevent the build-up of sea-water or condensation within the mast structure. Steel masts should, where possible, be coated internally with a suitable anti-corrosive preparation.

10.1.5 Openings in the masts for entry and exit of running rigging or cables should be adequately compensated with suitable insert plates or doublers.

10.1.6 Masts are to be efficiently integrated into the hull and in principle, carried through to the keel. Alternative arrangements of supporting masts will require to be specially considered.

10.1.7 Where ship response data are not available the values for roll, pitch and heave given in Table 2.10.1 should be used.

Table 2.10.1 Ship motions

Motion	Maximum single amplitude	Period, in seconds
Roll	$\phi = \sin^{-1}\theta$ degrees but need not exceed 30° and is not to be taken less than 22°	$T_r = \dfrac{0{,}7B}{\sqrt{GM}}$
Pitch	$\psi = 12e^{-0{,}0033L_{pp}}$ degrees, but need not exceed 8°	$T_p = 0{,}5\sqrt{L_{pp}}$
Heave	$\dfrac{L_{pp}}{80}$ m	$T_h = 0{,}5\sqrt{L_{pp}}$

where
L_{pp}, B as defined in Pt 3, Ch 1,6
GM = transverse metacentric height of loaded ship, in metres
$\theta = \left(0{,}45 + 0{,}1\,\dfrac{L}{B}\right)\left(0{,}54 - \dfrac{L}{1270}\right)$

10.2 Design loadings and allowable stresses

10.2.1 The mast and standing rigging design is to be considered with respect to the loads from the following conditions:

R1 – Operational case with full press of sails for the maximum operational apparent wind speed as specified by the designer.

R2 – Storm conditions with reduced sail.

R3 – Survival case with sails reefed/stowed/weather-vaning with the environmental loads resulting from the combination of a maximum wind speed of 63 m/sec and the accelerations produced by ship motions.

10.2.2 The mast section is to be designed to have a margin against failure due to column buckling using the greatest combined design axial and bending stress in both the transverse and fore and aft directions.

10.2.3 For loadcases R1 and R2 described in 10.2.1, the following condition is to be satisfied:

$$\frac{\sigma_b}{\sigma_y} + \frac{\sigma_a}{\sigma_c} \leq 0{,}67$$

For loadcase R3 the following condition is to be satisfied:

$$\frac{\sigma_b}{\sigma_y} + \frac{\sigma_a}{\sigma_c} \leq 0{,}85$$

where

σ_b is the bending stress in the mast section under consideration

σ_y is the tensile yield stress for the material

σ_a is the axial stress in the mast section under consideration

σ_c is the critical buckling stress for the mast section.

10.2.4 For thin walled masts, constructed from either flat or curved shells, calculations are to be submitted demonstrating adequate margin against local elastic instability.

10.3 Materials of mast construction

10.3.1 In general masts are to be constructed from either steel or aluminium alloy tubular members, extrusions and/or welded constructions, and are, generally, to comply with LR's *Rules for the Manufacture, Testing and Certification of Materials*, where appropriate.

10.3.2 Other materials will be specially considered.

10.4 Standing rigging

10.4.1 Standing rigging is to be so arranged such that it does not foul running rigging or interfere with the operation of the sails. Protection is to be provided against routine quay contacts.

10.4.2 Standing rigging is to be effectively attached to the masts, deck and hull structure and is to be so designed that it cannot become disconnected during operation.

10.4.3 Standing rigging is to be properly erected using tensioning devices to ensure that the correct pre-tension is applied as specified by the designer.

10.4.4 The initial pre-tension applied to standing rigging is to be measured and recorded.

10.5 Design loadings

10.5.1 The forces in the standing rigging are to be obtained by direct calculation methods for the load conditions given in 10.2.1.

10.5.2 The minimum factors of safety on the breaking strength of shrouds and stays are as follows:

Sail cases R1 and R2	3,5
Survival case R3	2,0

10.6 Shroud and stay attachment points

10.6.1 Standing rigging is to be effectively attached to the masts, ship's deck or bulwark structure. Chain plates, mast eyeplates and the structure in way are to be reinforced to withstand a load of 1,2 x breaking strength of the appropriate shroud or stay.

Generally the hull structure in way of shroud/stay attachment should be capable of withstanding the wire breaking load without permanent deformation of the structure.

10.6.2 Increased mast wall thickness, or internal or external mast stiffening rings or diaphragms are to be arranged in way of the toes of shroud and stay eyeplates to resist mast wall punching shear loads. Where additional mast stiffening rings or diaphragms are not fitted, the mast wall is not to be less than:

$$t_{wall} = \frac{2\,(h_{eye}\,B_s\,k_{mast})}{(t_{eye}\,l_{eye})} \text{ (mm)}$$

where

h_{eye} = eyeplate pin axis from mast wall, mm, *see* Fig. 2.10.1

B_s = breaking strength, in kN, of attached rigging component

k_{mast} = mast material factor, k

t_{eye} = eyeplate thickness, mm, *see* Fig. 2.10.1

l_{eye} = eyeplate length, mm, *see* Fig. 2.10.1.

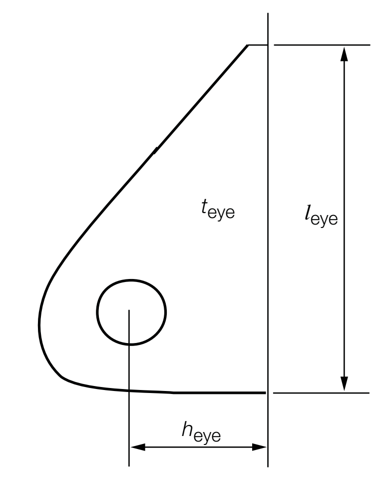


Fig. 2.10.1 Definition of h_{eye} and l_{eye}

10.6.3 The attachments of the stays and shrouds are to be efficiently integrated into the hull structure and due regard given to any attachments to the sheerstrake.

10.6.4 Where it is intended to use mechanical attachments (bolting) of running rigging or other gear to the mast walls, the number of holes are to be kept to a minimum and are to be staggered in order to maintain the structural integrity of the mast. All details are to be submitted.

10.7 Materials for rigging

10.7.1 In general, standing rigging is to be made from galvanised steel wire rope (GSWR) with galvanised steel rigging screws, shackles and terminations, and is to comply with the requirements of LR. Special consideration will, however, be given to other rigging materials.

10.7.2 Alternatively, stainless steel wire rope or solid rod rigging may be used in place of GSWR.

10.7.3 The steel wire rope, solid rods and loose fittings used for standing rigging are to be manufactured to a recognised National or International Standard and at an LR approved works.

10.7.4 Rigging components from other sources will be specially considered.

10.7.5 Where stainless steel rigging is employed, particular attention is to be given to the selection of the grade of material used as some stainless steels are prone to stress corrosion cracking and consequent fatigue failure, the onset of which is not readily observed.

10.7.6 Attention is drawn to the requirements of the Flag Administration for the vessel who may have requirements regarding the application of certain materials, systems or criteria.

10.8 Testing and certification

10.8.1 All equipment items used for standing rigging, including loose items of gear such as shackles, bottle screws, sheaves, etc., are to be tested and surveyed in accordance with LR requirements. For systems employing specialised devices or materials, individual consideration will be given to the testing and survey requirements.

10.8.2 For sailing passenger ships, the equipment requirement will be in accordance with the letter and numeral two grades higher than that corresponding to the calculated Equipment Numeral.

■ *Section 11* Miscellaneous openings

11.1 General

11.1.1 The requirements of Pt 3, Ch 11,6 are to be complied with.

11.2 Openings in main vehicle deck

11.2.1 Where the main vehicle deck is enclosed, all companionways and openings in the deck which lead to spaces below are generally to be protected by steel doors or hatch covers. Approved fire doors may be accepted in lieu of steel doors. The sills or coamings are to be not less than 230 mm above the main vehicle deck, with the exception of those leading to machinery spaces which are to have sills or coamings not less than 380 mm. Exceptionally, when such openings are to be kept closed at sea, sills or coamings may be reduced in height, provided that the sealing arrangements are adequate. In such cases, the doors or hatch covers are to be secured weathertight by gaskets and a sufficient number of clamping devices. Such items as portable plates in the main vehicle deck arranged for the removal of machinery parts, etc., may be arranged flush with the deck, provided they are secured by gaskets and closely spaced bolts at a pitch not exceeding five diameters.

11.2.2 Scuppers from vehicle or cargo spaces above the bulkhead deck fitted with an approved fixed pressure water spray fire-extinguishing system are to be led directly overboard and are to be fitted with means of preventing water from passing inboard in accordance with Pt 3, Ch 12,4.2.

11.2.3 Inboard draining scuppers do not require valves but are to be led to suitable drain tanks (not engine room or hold bilges) and the capacity of the tanks should be sufficient to hold approximately 10 minutes of drenching water. The arrangements for emptying these tanks are to be approved and suitable high level alarms provided.

11.2.4 A drainage system is to be arranged in the area between bow door and ramp, or where no ramp is fitted, between the bow door and inner door. The system is to be equipped with an audible and visual alarm function to the navigation bridge being set off when the water levels in these areas exceed 0,5 m or the high water level alarm, whichever is the lesser.

11.2.5 The drainage arrangement for each area is to have sufficient capacity to prevent accumulation of water in case of leakage. Scuppers are to be provided on both sides of the ship with a diameter not less than 50 mm and in accordance with Pt 3, Ch 12,4. Alternatively, a bilge suction should be provided.

11.2.6 If the main vehicle deck is not totally enclosed, scuppers or freeing ports are to be provided consistent with the requirements of Pt 3, Ch 8,5.3.

11.2.7 Air pipes from cofferdams or void spaces may terminate in the enclosed ‘tween deck space on the main vehicle deck provided the space is adequately ventilated and the air pipes are provided with weathertight closing appliances.

11.2.8 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room. The system must monitor the position of doors and a sufficient number of their securing devices. Special consideration is to be given for lighting and contrasting colour of objects under surveillance, *see also* 8.5.7.

11.3 Strength assessment of windows in large passenger ships

11.3.1 On windows in the second tier and higher above the freeboard deck, a glazing equivalent may be fitted in lieu of deadlights/storm covers. The thicknesses and arrangements are to be acceptable to the National Authority with whom the ship is registered and/or by the Administration within whose territorial jurisdiction the ship is intended to operate. For arrangements of glazing acceptable to LR, *see* Table 2.11.1. Alternative arrangement of glazing in lieu of deadlights/storm covers may be accepted provided details are submitted for consideration.

11.3.2 For passenger ships the design pressure, H_d, on windows is to be taken as given in Table 2.11.2, or an equivalent National or Internationally Recognised Standard.

11.3.3 The thickness, t_o, of toughened safety glass is to be taken as given in Table 2.11.3.

11.3.4 Toughened safety glass of laminated construction will also be accepted, provided the requirements of Pt 3, Ch 11,6.5.24 are complied with.

Table 2.11.2 Design pressure, H_d, on windows

Window location	Design pressure head H_d in metres
Between the design waterline and a point $Z_{1,5}$ m above the waterline	Per BS MA 25: 1973
Between a point $Z_{1,5}$ m above the waterline and the deck immediately above (at $Z_{d1,5}$)	1,5
Over the next 2 ‘tween deck heights	$1,5 - f_w\left(\frac{Z_w - Z_{d1,5}}{H_{t1} + H_{t2}}\right)$
For subsequent decks to the top of the navigation bridge	0,25 sides and aft ends 0,75 house fronts
From the top of the navigation bridge to the uppermost deck, for house fronts	0,75 at top of navigation bridge 0 at uppermost continuous deck, with linear variation between, but not less than 0,25
From the top of the navigation bridge to the uppermost deck, at sides and aft ends	0,25
Symbols	
f_w = 1,25 in way of sides and ends of superstructures = 0,75 in way of house fronts $Z_{1,5}$ = the vertical location in metres above the waterline at which the BS MA:25 pressure as given in Annex E of BS MA:25 (1973) is 1,5 t/m^2 $Z_{d1,5}$ = the vertical location in metres of the deck at which the pressure is 1,5 t/m^2 from Table 2.11.1 Z_w = the vertical location in metres above the waterline to the point under consideration $H_{t1} + H_{t2}$ = sum of the appropriate ‘tween deck heights in metres	

Table 2.11.1 Acceptable arrangements of glazing in lieu of portable storm covers/deadlights

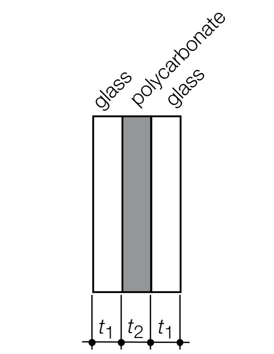
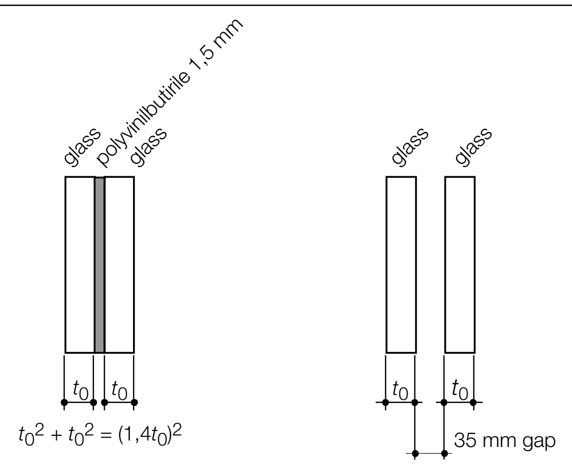
In lieu of portable storm covers	In lieu of deadlights and storm covers
 $t_1^2 + (0,77t_2)^2 + t_1^2 = (1,2t_0)^2$	 $t_0^2 + t_0^2 = (1,4t_0)^2$
Symbols	
t_0 = minimum thickness of toughened glass as calculated in Table 2.11.3	

Table 2.11.3 Thickness of toughened glass

Window type	Thickness, t_o, in mm
Rectangular	$b \sqrt{\dfrac{H_d \beta}{4000}}$
Circular	$0{,}0175\, r \sqrt{H_d}$
Semi-circular	$0{,}011 r \sqrt{H_d}$
Symbols	
b = length of shorter side of window, in mm H_d = design pressure head, in metres, as calculated in Table 2.11.2 β = $0{,}54A_R - 0{,}078A_R^2 - 0{,}17$ for $A_R \leq 3$ = 0,75 for $A_R > 3$ A_R = aspect ratio of window, in mm = a/b a = length of longer side of window, in mm r = the radius of the window, in mm	

11.4 Frame design and testing

11.4.1 **Application**. The testing requirements contained in this Section are for all exterior window and glass balustrade designs on all tiers for passenger ships regardless of length. The testing is to be carried out for characteristic window and balustrade sizes (largest, smallest) and forms (circular, semi-circular and rectangular) for each passenger ship. Window and balustrade designs, which are not covered by Type Approval Certification, will require prototype testing in order to confirm structural integrity and weather or water tightness as required. Tests are to be carried out to the satisfaction of the Surveyor.

11.4.2 **Water tightness**. A hydrostatic test is to be carried out in order to examine the water tightness of windows. This is carried out by applying the design pressure head H_d, as calculated in Section 11.3, to the external face of the window and maintained at this level for at least 15 minutes.

11.4.3 **Structural testing**. A hydrostatic test is to be carried out in order to examine the capability of the frame, mullions and glass retaining arrangements. This is carried out by applying a test pressure of $4H_d$ (H_d as calculated in Section 11.3 for windows and Section 12.3 for balustrades) to the external face of the window. Alternatively this test may be carried out using a steel plate in place of the glass. Ideally, the steel plate should be of a suitable reduced thickness in order to simulate the flexural performance of the glass.

11.4.4 Equivalent proposals for testing will be considered. Where alternative testing procedures are proposed, these are to be agreed with LR before commencement.

11.4.5 **Chemically toughened glass.**

(a) Chemically toughened glass may be used in lieu of thermally toughened glass provided it can be demonstrated the strength of the arrangement is at least equivalent in strength to that of thermally toughened glass.
(b) The glazing system is to be of laminated construction.
(c) Method of testing will be specially considered.

11.4.6 The overlap between glazing and the retaining frame is not to be less than 12 mm.

11.5 Strength of mullions

11.5.1 The section modulus of mullions is not to be less than:

$$Z = 10{,}78 H_d\, l\, A_m\, k\, 10^{-9} \text{ cm}^3$$

where

a = *see* Table 2.11.4
b = *see* Table 2.11.4
r = *see* Table 2.11.4
l = a for rectangular windows
= $2r$ for semi-circular windows
H_d = design pressure head, in metres, as calculated in 11.3.2
A_m = ab for rectangular windows
= $1{,}22r^2$ for semi-circular windows
k = as defined in 1.5.1.

11.6 Bonded windows and side scuttles

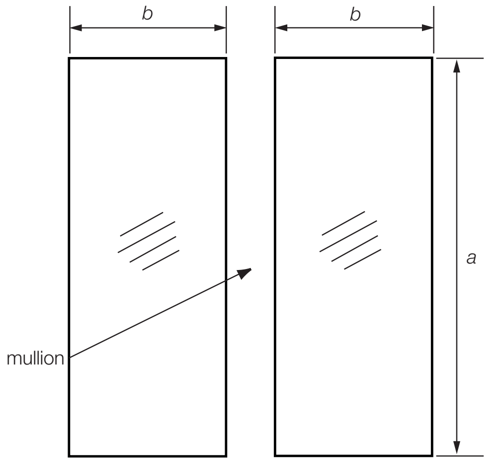
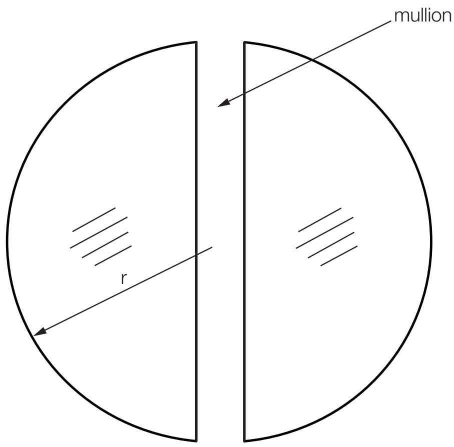
11.6.1 A 'bonded window' or 'bonded side scuttle' is one in which the glazing material is secured in its frame from outside of the ship by glue or other adhesive material. No mechanical fixing is provided for the glazing. Bonded windows and side scuttles are to comply with the requirements of Section 11. Proposals to secure glazing from the inside of the ship are to be specially considered using the requirements in this Section as a basis. It should be noted that bonding from the inside is not recommended and where it is proposed, further testing will be required. Non-load bearing secondary bonded glazing, e.g., glazing to improve thermal insulation, is not required to comply with the requirements of this sub-Section.

11.6.2 The adhesive is to be flexible enough to support the glazing without holding it firm. The glue strip is to be elastic, with width and thickness designed to allow the glazing to move in both directions in the plane of the glazing without undue forces on the bonding or the substrate. The glass is to be free to settle under-load and not to be forced to follow deflections in the supporting structure. If substantial racking of the glazing opening under-load is expected, the bonding is to be designed to accommodate such deflections.

11.6.3 Bonded windows and side scuttles may be considered as acceptable, in general, depending on their position, size of vessel and applicable statutory requirements, noting the distinction between glazing and the frame, which may have different requirements.

11.6.4 Bonded windows are not permitted in galley areas, including glazing in galley doors (internal or external). They are not permitted on escape routes and evacuation routes where a fire rating is required. The fire integrity of bulkheads is not to be impaired.

Table 2.11.4 Mullion arrangements

Rectangular windows	Semi-circular windows
	

Symbols

a = dimension parallel to mullion, in mm
b = length of shorter side of window, in mm
r = radius of the window, in mm

11.6.5 Bonded windows and side scuttles are not acceptable on fire-fighting vessels, i.e., those with a fire-fighting notation.

11.6.6 The failure of laminated glass is considered to pose a lower risk to safety than that of single pane glass. In the event of breaking, laminated glass more readily holds together and tends not to break up into large sharp pieces. Therefore, in general, laminated glazing is preferred. When laminated glass is used, the sealant is to be compatible with the interlayer. Lamination thickness is to be in accordance with Pt 3, Ch 11,6.5.24. Special consideration will be given to single pane toughened safety glass.

11.6.7 The durability of the adhesive and the sealant in the long term marine environment is to be considered in the approval process. Adhesive is to be approved in accordance with Ch 14,2.15 of the Rules for Materials. The adhesive bead is to be resistant to or protected from UV radiation, either by an optically dense area at the edges of the glazing or by overlapping trim or UV shielding tape. The adhesive bead is to be resistant to or protected from fungal attack. Arrangements are to be in accordance with the adhesive manufacturer's published guidelines and relevant LR Rules.

11.6.8 The edges of the bonding recess are to be rounded to facilitate the application of the sealant without air entrapment. The width of the gap between the flange and the glazing is to be large enough to accommodate the movement of the glazing as a result of hull deflection and thermal expansion, *see* Fig. 2.11.1. Recommended gap widths for bonded windows are to be taken as:

Gap width	Length of longest side of window
10–15 mm	<1,5 m
15–20 mm	1,5–3,0 m.

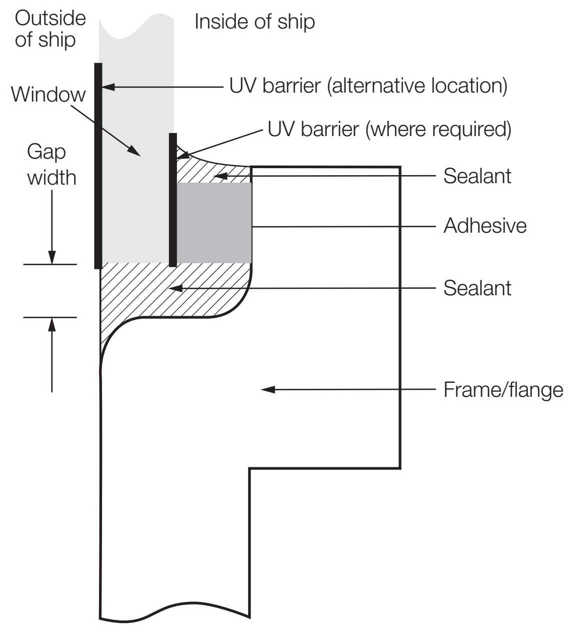


Fig. 2.11.1
Gap width between flange and window, bonded from outside of the ship

11.6.9 The minimum adhesive width and thickness are to be in accordance with the adhesive manufacturer's published guidelines.

■ *Section 12* Glass structures

12.1 General

12.1.1 The requirements of this Section apply solely to external glass balustrades, as well as glass walls and wind screens when acting as balustrades.

12.2 Top rail of balustrades

12.2.1 The minimum section modulus of the steel top rail of glass balustrades is given by:

$$Z = L_b^2 \quad \text{cm}^3$$

where

L_b = span of top rail, in metres.

12.3 Glass balustrades

12.3.1 The minimum thickness of glass balustrades is to be not less than as given by Table 2.11.3 using a design pressure as given in Table 2.11.2, provided by continuous support along all four edges. The design pressure will be specially considered if glass balustrades are fitted in lower exposed deckhouses at a location where the design pressure from Table 2.11.2 is greater than 0,25 t/m^2.

12.3.2 The glazing is to be of laminated construction.

12.3.3 Balustrades and their frames and glass retaining arrangements will require prototype testing in order to confirm structural integrity in accordance with 11.4. The use of National or Internationally recognised Standards may be considered.

■ *Section 13* Direct calculation

13.1 Application

13.1.1 Direct calculations are to be employed in derivation of scantlings where required by preceding Sections of this Chapter or by related provisions included in Part 3.

13.1.2 Direct calculation methods are also generally to be used where additional calculations are required by the Rules in respect of unusual structural arrangements.

13.2 Procedures

13.2.1 For details of LR's direct calculation procedures, *see* Pt 3, Ch 1,2. For requirements concerning use of other calculation procedures, *see* Pt 3, Ch 1,3.

Section 1 General

1.1 Application

1.1.1 Sections 1 to 8 of this Chapter apply to tugs.

1.1.2 Section 9 of this Chapter applies to tugs and offshore supply ships intended to provide escort operation.

1.1.3 The scantlings and arrangements are to be as required by Chapter 1 except as otherwise specified. The draught, *T*, used for the determination of scantlings is to be not less than 0,85*D*.

1.2 Class notations

1.2.1 Ships complying with relevant requirements will be assigned one or more of the class notations given in Table 3.1.1.

Table 3.1.1 Class notations

Class Notation	Applicable Sections
100A1 tug	Sections 1 to 8
100A1 escort tug	Sections 1 to 9, except 9.3
100A1 escort tug EPN (F,B,V,C)	Sections 1 to 9
NOTE Tugs which comply with the anchor handler requirements in Ch 4, Sections 1 to 4 and 10 will be eligible for the additional notation **anchor handler.**	

1.2.2 Tugs intended to be operated only in suitable areas or conditions which have been agreed by the Committee, as defined in Pt 1, Ch 2,2.3.6 to 2.3.10, will receive individual consideration on the basis of the Rules with respect to the environmental conditions agreed for the design basis and approval. In particular, tugs complying with the requirements of this Chapter and Pt 3, Ch 13,7 for the relevant reduced equipment requirements, will be eligible to be classed:

- **A1 tug protected waters service**; or
- **A1 escort tug protected waters service**; or
- **A1 escort tug EPN (F,B,V,C) protected waters service**, *see* Pt 1, Ch 2,2.3.6; or
- **100A1 tug with service restriction notation**; or
- **100A1 escort tug with service restriction notation**; or
- **100A1 escort tug EPN (F,B,V,C) with service restriction notation**;

whichever is applicable.

1.2.3 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2 to which reference should be made.

1.3 Information required

1.3.1 In addition to the information and plans required by Pt 3, Ch 1,5, plans covering the following items are to be submitted for approval where applicable:

- Support structure and foundations of towing equipment.
- Skegs, propeller guards and other structures which support the weight of the vessel during dry-docking.

1.3.2 The following supporting documents are to be submitted for information:

- Towing arrangements, including lines of action, magnitudes and corresponding points of application of towline pulls on towing equipment.
- Details of the breaking strength of the components of the towline system, together with maximum pull and brake holding load, or equivalent, of towing winches where applicable.

Section 2 Longitudinal strength

2.1 General

2.1.1 The longitudinal strength standard is to comply with the relevant requirements of Pt 3, Ch 4.

2.1.2 The requirements of Pt 3, Ch 4,8.3 regarding loading instruments are not applicable to tugs.

Section 3
Floors in single bottoms

3.1 Floors

3.1.1 Single bottom floors are to be in accordance with the requirements of Ch 1,7, except that floors clear of the machinery space may be flanged in lieu of a face plate being fitted.

Section 4
Panting and strengthening of bottom forward

4.1 Panting region reinforcement

4.1.1 The arrangements to resist panting required by Pt 3, Ch 5 do not apply to tugs less than 46 m in length. In tugs 46 m or more in length, additional stiffening is also to be fitted in the 'tween decks throughout the panting region.

4.2 Strengthening of bottom forward

4.2.1 The requirements for strengthening of bottom forward detailed in Pt 3, Ch 5 do not apply to tugs.

Section 5
Machinery casings

5.1 Escape hatches

5.1.1 Any emergency exit from the machinery room to the deck is to be capable of being used at extreme angles of heel, and should be positioned as high as possible above the waterline and on or near the ship's centreline. Covers to escape hatches are to have hinges arranged athwartships. Coaming heights are to be at least 600 mm above the upper surface of the deck.

Section 6
Freeing arrangements

6.1 General

6.1.1 If the only means of access to the wheelhouse is external, then stormboards, or an equivalent, are to be fitted between the deckhouse and the ship's sides forward of any deckhouse doors up to the height of the bulwark rail. A gap is to be left between the deck and the bottom board for freeing purposes.

Section 7
Towing arrangements

7.1 Towing equipment

7.1.1 For tugs which normally tow over the stern with the main towline connection to the hull ahead of the propellers, the position of towline connection is normally to be five to 10 per cent of the ship's length abaft amidships, but in no circumstances is it to be sited forward of a position, five per cent of the ship's Rule length abaft the longitudinal centre of gravity of the tug in any anticipated condition of loading.

7.1.2 The attachment of the towline to the tug is to be located as low as practicable in order to minimise heeling moments arising from working conditions. Reliable slip arrangements which facilitate towline release regardless of the angle of the towline are to be provided.

7.1.3 It is recommended that the slip arrangements should also be operable from the bridge. The arrangements should be tested to the Surveyor's satisfaction. The breaking strength of the hook, or its equivalent, should generally be 50 per cent in excess of that of the towline, *see* Pt 3, Ch 13,7.

7.2 Towing equipment foundations

7.2.1 Direct support for towing equipment by means of pillars and/or pillar bulkheads is to be arranged as far as this is practicable.

7.2.2 The design load for the support structure in way of towing equipment is to be not less than the breaking strength of the towline system. The design load is also to be taken as not less than the breaking strength of the tow hook or the brake holding load, or equivalent, of the winch, whichever is appropriate.

7.2.3 Scantlings of pillars and pillar bulkheads are to be in accordance with Ch 1,4.4.

7.2.4 Scantlings of deck girders and transverses forming the support structure of towing equipment are to be determined by direct calculations using the following stresses:

$$\tau = \left(\frac{87}{k}\ \text{N/mm}^2\right)\left(\frac{8{,}9}{k}\ \text{kgf/mm}^2\right)$$

$$\sigma = \left(\frac{150}{k}\ \text{N/mm}^2\right)\left(\frac{15{,}3}{k}\ \text{kgf/mm}^2\right)$$

$$\sigma_e = \left(\frac{213}{k}\ \text{N/mm}^2\right)\left(\frac{21{,}7}{k}\ \text{kgf/mm}^2\right)$$

where

τ = shear stress, in N/mm^2
σ = bending stress, in N/mm^2
k = material factor, *see* Pt 3, Ch 2,1.2
σ_e = equivalent stress, in N/mm^2
$\sqrt{\sigma^2 + 3\tau^2}$

7.2.5 Generally, the foundations of towing fairleads are to be carried through the deck and integrated into suitable underdeck structure.

7.2.6 On tugs which utilise an indirect method of towing, attention is drawn to the increased out-of-plane forces that occur in towing fairleads.

■ *Section 8* Fenders

8.1 Ship's side fenders

8.1.1 An efficient fender is to be fitted to the ship's side at deck level extending all fore and aft.

■ *Section 9* Escort operation, performance numeral and trials

9.1 General

9.1.1 An escort tug is a tug intended for escort operation. Escort operation is an operation in which the tug closely follows the assisted ship providing control by steering and braking, as necessary.

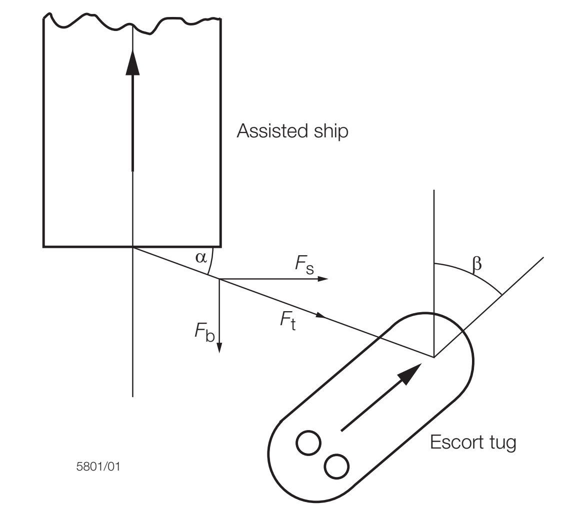
9.1.2 Escort tugs are to be capable of utilising methods of towing through which steering and braking forces are generated by a combination of propulsive and hydrodynamic forces developed by the tug, acting on the towline to the attended ship, *see* example in Fig. 3.9.1.

9.1.3 The intact stability of the tug during escort operation is to comply with a Standard recognised by the National Administration with whom the ship is registered and/or by the National Administration within whose territorial jurisdiction the tug is intended to operate, as applicable. Attention is drawn to the inherent problems relating to the quick release of the towline and the sudden loss of propulsion power during the escort operation in addition to the maximum steering and braking forces.

9.2 Towing arrangements

9.2.1 The specified breaking strength of the towline is to be at least 2,5 x maximum design towline force.

9.2.2 The towing winch is to include a system of continuous load monitoring, with a bridge readout display and an overload prevention system, which is to be operational during escort duties. The overload prevention system is to be designed with the capability to pay out the towline in a controlled manner when the load reaches the maximum design towline force, and is to be capable of alerting the Master and crew.



F_t = force exerted by the tug on the assisted ship via the towline
F_s = steering (athwartships) component of F_t
F_b = breaking (longitudinal) component of F_t
α = angle between assisted ship's transverse axis and towline
β = angle between centreline of assisted ship and centreline of tug

Fig. 3.9.1
Forces generated during a typical escort mode

9.3 Performance trials

9.3.1 Escort tugs which carry out full scale performance trials in accordance with the requirements of this Section will be eligible to have the escort performance numeral **EPN (F,B,V,C)** appended to the **escort tug** notations, *see* 1.2.1 and 1.2.2 and Ch 4,1.2.2,
where

- **F** is the maximum steering force (F_s), in tonnes, *see* Fig. 3.9.1 and 9.3.6.
- **B** is the maximum braking force (F_b), in tonnes, *see* Fig. 3.9.1 and 9.3.6.
- **V** is the speed, in knots, at which **F** and **B** are determined.
- **C** is the time, in seconds (s), required for the escort tug in manoeuvring from maintained oblique position of tug giving maximum steering force F_s on one side of assisted vessel to mirror position on the other side, *see* 9.3.6. The towline angle, α, need not be taken less than 30°, *see* Fig. 3.9.1.

9.3.2 The performance numeral may be determined with speed **V** equal to either 8 knots or 10 knots. If both sets of numerals are determined at the trials then the class notation will include them all.

9.3.3 A trials plan, which includes the estimated forces, is to be submitted and approved prior to trials being undertaken.

9.3.4 The trials of the escort tug are to be performed using a ship capable of maintaining almost constant heading and speed when subjected to the steering and braking forces from the escort tug.

9.3.5 The following trials are to be carried out in calm weather conditions and in the presence of a Lloyd's Register Surveyor:

- Steering and braking force capability test, *see* 9.3.6.
- Bollard pull test, *see* 9.3.8.

A record of the results is to be kept on board the escort tug.

9.3.6 Prior to commencing a trial, the following data are to be recorded:

- Wind speed and direction.
- Sea state.
- Current speed and direction.
- Water depth.
- The main particulars and the loading condition of the assisted ship.
- Loading condition of the escort tug.

9.3.7 **Steering and braking force capability test** is a test by which the steering force, F_s, and braking force, F_b, are determined when utilising the method, shown in Fig. 3.9.1, of towing at a range of towline angles, α, from 0 to 90 degrees and for a range of operating speeds up to and including the maximum escort speed. The following parameters are to be continuously recorded during the test:

- Position, speed and heading of the assisted ship and the escort tug.
- Towline force, F_t.
- Angle of towline, α.
- Heel angle of the escort tug.
- Direction of thrust and power absorbed by all propellers and thrusters of the tug.
- Rudder angles of the tug.

9.3.8 The length of the towline is to represent a typical operating condition and is to be recorded prior to and at the completion of the test. The steering and braking forces for a given speed and angle can be calculated by using the average values of the recorded towline force.

9.3.9 **Bollard pull test** is to be carried out in accordance with LR's *Bollard Pull Certification Procedures Guidance Information*.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to sea-going ships specially designed and constructed for the carriage of specialised stores and cargoes to mobile offshore units and other offshore installations, and also to offshore tug/supply ships which in addition to the above perform the duties of a tug.

1.1.2 The scantlings and arrangements are to be as required by Chapter 1, except as otherwise specified in this Chapter.

1.1.3 Attention is drawn to the need for Masters to be able to assess the stability of their ships quickly and accurately in all service conditions, *see* Pt 1, Ch 2,3.

1.1.4 Where towing equipment is fitted, the requirements of Ch 3,7 are to be applied.

1.2 Class notations

1.2.1 In general, ships complying with the requirements of this Chapter and relevant additional requirements will be eligible for one or a combination of the notations indicated in Table 4.1.1.

1.2.2 The following additional notations and annotations can be provided to give a further detailed description of features:

- **WDL(+)** (Weather deck load):
  If the weather deck scantlings have been approved for a loading greater than a design head of 3,5 m, the notation **WDL(+)** may be added. If requested, the maximum permissible weather deck load and extent can be identified in the notation, e.g., **WDL(5,0 t/m^2 from Aft to Fr. 26)**.
- **RD** (Relative density):
  Where a ship has tanks appraised for a maximum permissible relative density greater than 1,025, the notation **RD(specified tank names, density)** may be added, *see* Chapter 1.
- **LFPL** (Low flashpoint liquids):
  Ships intended for the carriage of liquids with flash point below 60°C (closed-cup test) in bulk are to be built and equipped in accordance with the relevant requirements of Section 8 and will be given the class notation **LFPL**. If requested, the concerned cargo, flash point (closed-cup test) and tank can be identified in the notation, e.g., **LFPL(methanol, 12°C, No. 7 centre tank)**.

1.2.3 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.3 Information required

1.3.1 In addition to the information and plans required by Pt 3, Ch 1,5, plans covering the following items are to be submitted where applicable:

- Independent cargo tanks.
- Cargo tank foundations and securing arrangements.
- Towing arrangements, including supports and foundations of towing winches.
- Arrangements for the stowage of deck cargoes (cargo containment) and details of any associated racks or other similar structures and their supports/foundations together with information to indicate design loads.
- Movable decks, including the stowing arrangements for portable components.
- Freeing arrangements.

1.4 Symbols

1.4.1 The symbols are as defined in Ch 1,1.5.

Table 4.1.1 Class notations applicable to offshore supply ships

Class notation	Requirements
100A1	Pt 1, Ch 2
Offshore supply ship	Pt 4, Ch 4, Sections 1 to 7
Supply ship	Pt 4, Ch 1
Standby ship	Pt 4, Ch 4, Sections 1 to 7 and 9
Anchor handler	Pt 4, Ch 4, Sections 1 to 7 and 10 Sections 5 to 7 need not be applied if notation for **Offshore supply ship** is not applied
Tug **Escort tug** **Escort tug EPN (F,B,V,C)**	Pt 4, Ch 3, Sections 1 to 8 Pt 4, Ch 3, except 9.3 Pt 4, Ch 3
AHTS	Pt 4, Ch 3, Sections 1 to 8; and Pt 4, Ch 4, Sections 1 to 7 and 10
Oil Recovery	Pt 7, Ch 5

NOTES
1. A ship designed to fulfil more than one function can be assigned a combination of the notations listed above, e.g.:
   - **100A1 Offshore supply ship/Standby ship**
   - **100A1 Offshore supply ship/Anchor handler**
   - **100A1 Offshore supply ship/Standby ship/Oil Recovery**
   - Any combination of the requirements listed in this Table.
2. The notation **Offshore Supply Ship** will be assigned to ships that are designed to be operated on unrestricted worldwide service.
3. The notation **Supply Ship** will be assigned to ships that are designed for operation in specified restricted locations where the environmental conditions are less severe than for unrestricted worldwide service.

■ *Section 2* Longitudinal strength

2.1 General

2.1.1 The longitudinal strength standard is to comply with the relevant requirements of Pt 3, Ch 4.

2.1.2 The requirements of Pt 3, Ch 4,8.3 regarding loading instruments are generally not applicable to offshore supply ships.

■ *Section 3* Hull envelope plating

3.1 Side shell

3.1.1 The thickness of side shell is to be that required by Ch 1,5.4 but is not to be less than given by Table 4.3.1.

3.1.2 As an alternative, where over the length of a vessel, portions of the sheerstrake that are not protected by an efficient fender, the sheerstrake is to be increased by a minimum of 5 mm thickness. The increased thickness shall extend from the deck level to not less than 600 mm below the deck level.

Table 4.3.1 Minimum side shell thickness

Ship type	Minimum thickness, mm
Offshore supply ships	9
Standby ships	8
Anchor handler	9

3.2 Weather decks

3.2.1 Where cargo is to be carried on weather decks, the scantlings are to be suitable for the specified loadings. The thickness, t, of deck plating is to be not less than the greater of:

(a) $t = 0{,}025L + 4{,}5 + t_a$ mm

(b) $t = 0{,}1 f_m s \sqrt{\dfrac{P F_D}{f_y \sigma}} + t_a$ mm

where

P = specified design load for weather deck, in tonnef/m^2

$= \dfrac{h}{1{,}39}$

h = equivalent design head, in metres, not to be taken less than 3,5 m

s = spacing of secondary stiffeners, in mm

σ = yield stress of plating, in N/mm^2

F_D = as defined in Pt 3, Ch 4,5.7

f_m = 0,75

f_y = 0,67

t_a = 2,5 mm, in general
= 1,0 mm, for ships with dedicated class notation **Standby ship**.

3.2.2 Scantlings are to be increased locally where specialised cargoes are likely to induce concentrated loads that exceed the specified design load. Acceptable stress levels are given in Ch 3,7.2.4.

3.3 Cargo containment

3.3.1 Means are to be provided to enable deck cargoes to be adequately secured and protected. In general, suitable inner bulwarks, rails, bins or storage racks of substantial construction are to be provided and properly secured to adequately strengthened parts of the hull structure. Properly designed locking equipment or efficient means of lashing containers are to be fitted where appropriate. Small hatches (including escape hatches), valve controls, ventilators, air pipes, etc., are to be situated clear of the cargo containment areas.

■ *Section 4* Hull envelope framing

4.1 General

4.1.1 The section moduli of side longitudinals, the main and 'tween deck frames are to be not less than kZ, cm^3 where

k = 1,25 in general
= 1,10 for ships with dedicated class notation **Standby ship**
Z = as required by Ch 1,6, Pt 3, Ch 5,4 and Pt 3, Ch 6,4 for the appropriate location.

4.1.2 Frames are not to be scalloped.

4.1.3 The scantlings of deck secondary stiffeners are to be in accordance with the requirements of Table 1.4.4(1) or Table 1.4.5(2) in Chapter 1, where h_2 is to be taken as the specified design loading and not less than a design head of 3,5 m.

■ *Section 5* Superstructures and deckhouses

5.1 Scantlings

5.1.1 The scantlings of deckhouses situated on the forecastle deck and above are to comply with the requirements of Table 4.5.1.

5.1.2 The scantlings of forecastle end bulkheads are to be not less than those required by Table 4.5.1 for aft ends of deckhouses or less than those required by Pt 3, Ch 8,2 for an exposed machinery casing.

Table 4.5.1 Superstructures and deckhouses on forecastle deck

Position	Thickness of plating, in mm	Modulus of stiffeners, in cm^3	Depth of stiffeners, in mm
Fronts	The greater of t = 0,012s or 8,0	$Z = 0{,}034 s l_e^2$	Not less than 100
Sides	The greater of t = 0,01s or 6,5	$Z = 0{,}027 s l_e^2$	Not less than 75
Aft ends	The greater of t = 0,008s or 6,5	$Z = 0{,}027 s l_e^2$	Not less than 65

NOTE
The ends of stiffeners are to be connected on all tiers.

■ *Section 6* Miscellaneous openings

6.1 General

6.1.1 For offshore supply ships the requirements of Pt 3, Ch 11,6 are to be complied with.

6.2 Access from freeboard deck

6.2.1 There is to be no direct access from the freeboard deck to machinery or other spaces below the freeboard deck. Indirect access may be arranged via a space or passageway fitted with an outer door having a sill not less than 600 mm high and an inner door having a sill not less than 380 mm high. The inner door is to be self-closing and gastight. The space or passageway between the two doors is to be adequately drained. It is desirable, however, that access to spaces below the freeboard deck is arranged from a position above the superstructure deck. Where it is necessary to provide an emergency escape trunk which cannot terminate within a superstructure space, the arrangements for maintaining the integrity of the hatch or outlet are to be approved by Lloyd's Register (hereinafter referred to as 'LR').

6.3 Windows and side scuttles

6.3.1 The requirements of this Section are to be applied in conjunction with Pt 3, Ch 11,6.5.

6.3.2 Windows may only be fitted in the following locations:
(a) Second tier and higher above the freeboard deck:
 (i) in the after end bulkhead of deckhouses and superstructures,
 (ii) in the sides of deckhouses and superstructures which are not part of the shell plating.
(b) Third tier and higher above the freeboard deck:
 (i) in the forward facing bulkheads of deckhouse and superstructures, except that in the first tier of the front bulkhead above the weather deck, only side scuttles will be accepted.

6.3.3 In locations not specified in 6.3.2, only side scuttles will be accepted.

6.3.4 Permanently attached deadlights are to be provided as follows:
(a) Side scuttles:
 (i) in the side shell plating,
 (ii) in the forward facing bulkheads of superstructures and deckhouses,
 (iii) in the sides of deckhouses and superstructures up to and including the third tier above the freeboard deck,
 (iv) in the after end bulkheads of superstructures, deckhouses, casings and companionways in the first and second tiers above the freeboard deck.
(b) Windows in locations permitted in 6.3.2:
 (i) in the sides of deckhouses and superstructures in the second and third tiers above the freeboard deck.
 (ii) in the after end bulkheads of superstructures, deckhouses, casings and companionways in the second tier above the freeboard deck.

6.3.5 On windows in the second tier and higher above the freeboard deck, hinged storm covers may be fitted in lieu of deadlights, provided there is safe access for closing.

6.3.6 Windows in the wheelhouse front are to have deadlights or storm covers. For storm covers, an arrangement for easy and safe access is to be provided, (e.g., gangway with railing). However, for practical purposes, the deadlights or storm covers may be portable if stowed adjacent to the window for quick fitting. At least two of the deadlights or storm covers are to have the means of providing a clear view.

6.3.7 Deadlights for side scuttles, and for windows not mentioned in 6.3.5 and 6.3.6, are to be internally hinged.

6.3.8 Side scuttles are to comply with ISO Standard 1751, as follows:
(a) Type A side scuttles in the shell plating, in the sides of superstructures and in the forward facing bulkheads of superstructures and deckhouses on the weather deck;
(b) Type B side scuttles in the after ends of superstructures and in the sides and ends of deckhouses; or
(c) an equivalent National Standard.

6.3.9 For the location of windows and side scuttles, *see* Fig. 4.6.1.

6.3.10 The thickness of the toughened safety glass for windows is to be not less than the greater of:
(a) $t = 10$ mm
(b) $t = b\sqrt{\dfrac{H_d \beta}{4000}}$ mm

where
H_d = design pressure head, in metres, as obtained from Table 4.6.1
b = length of shorter side of window, in mm
β = $0{,}54A_R - 0{,}078A_R^2 - 0{,}17$ for $A_R \le 3$
 = 0,75 for $A_R > 3$
A_R = aspect ratio of window
 = a/b
a = length of longer side of window, in mm.

Table 4.6.1 Design pressure head, H_d, on windows

	Design pressure head, in metres	
	Windows in front and side bulkheads	Windows in after end bulkheads
6th tier and above	3,0	2,5
5th tier	5,0	2,5
4th tier	8,0	2,5
3rd tier	12,5	6,25
2nd tier	14,0	8,0

6.3.11 Proposals for alternative materials will be specially considered.

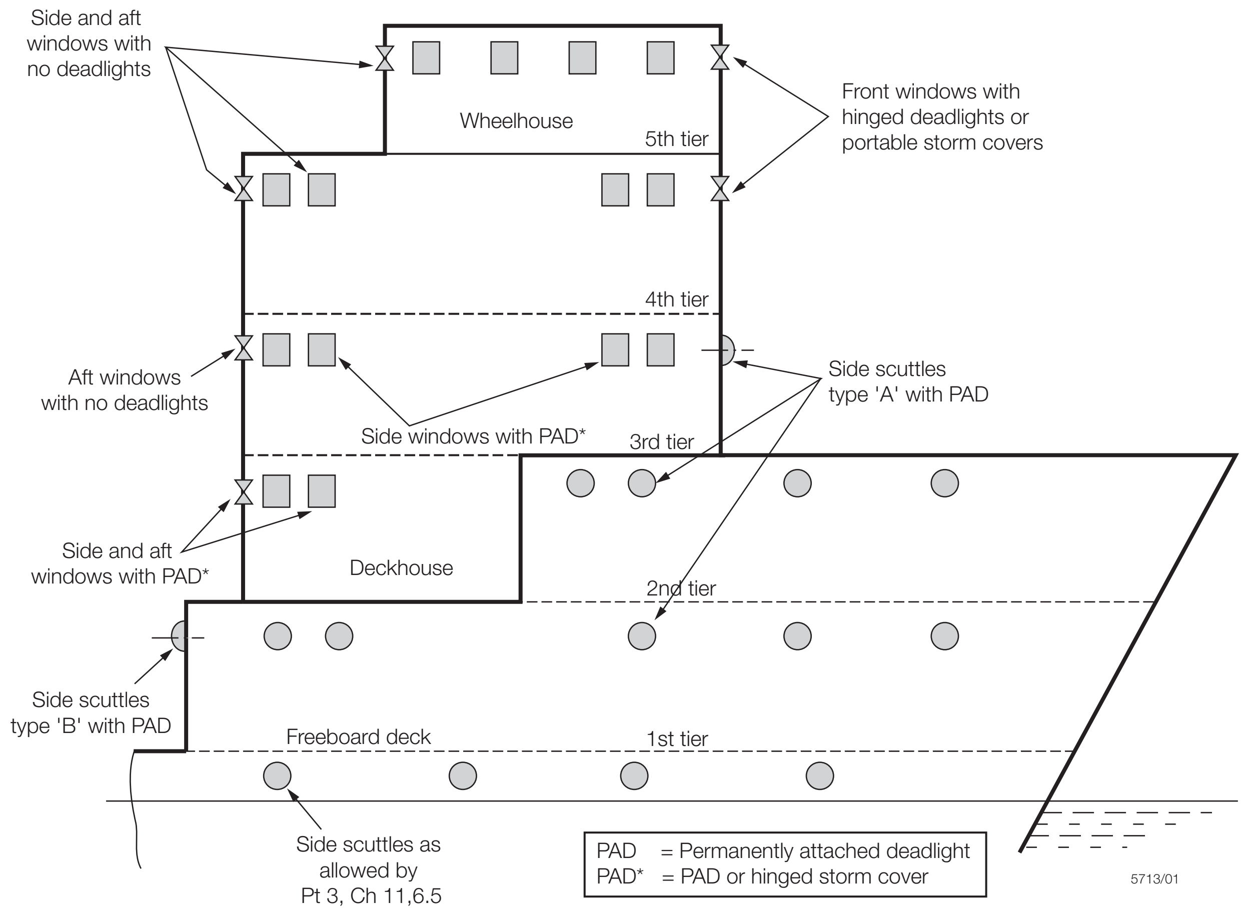


Fig. 4.6.1 Location of windows and side scuttles

■ *Section 7* Engine exhaust outlets

7.1 Location

7.1.1 Engine exhaust outlets are to be located as high as is practicable above the deck and are to be fitted with spark arresters.

■ *Section 8* Transport and handling of limited amounts of hazardous and noxious liquid substances in bulk

8.1 General

8.1.1 The requirements of this Section are, in general, to be complied with unless they are waived or substituted by requirements mandated by the Administration.

8.1.2 This Section applies to the arrangement and scantling of sea-going ships as defined in 1.1 and intended for the carriage of:

- the aggregate quantity of bulk liquids identified in 8.1.3 that is carried is any amount not exceeding a maximum which is the lesser of 800 m^3 or a volume in cubic metres equal to 40 per cent of the vessel's deadweight calculated at a cargo density of 1,0.

8.1.3 Products which may be carried are:

(a) hazardous and noxious liquids listed in Table 4.8.1 and those other products which may be assigned to Table 4.8.1 based on the following criteria:
  - products which for safety reasons may be assigned for carriage on a type 3 ship as defined by the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquid Chemicals in Bulk* (hereinafter referred to as Rules for Ships for Liquid Chemicals) and which are not required to meet the requirements for toxic products in 15.12 of the Rules for Ships for Liquid Chemicals;
  - noxious liquid substances which would be permitted for carriage on a type 3 ship;

(b) flammable liquids (liquids having a flashpoint not exceeding 60°C (closed-cup test).

Table 4.8.1 Table of permitted cargoes

Cargo	Flammability	Hazard
Oil-based mud containing mixtures of products listed in chapters 17 and 18 of the IBC Code and the MEPC.2/Circular and permitted to be carried under paragraph 8.1	No	–
Water-based mud containing mixtures of products listed in chapters 17 and 18 of the IBC Code and the MEPC.2/Circular and permitted to be carried under paragraph 8.1	No	–
Drilling Brines, including: Sodium Chloride Solution Calcium Bromide Solution Calcium Chloride Solution	No No No No	 P P P
Calcium nitrate/Magnesium nitrate/Potassium chloride solution	No	P
Calcium Nitrate Solution (50% or less)	No	P
Drilling brines (containing zinc salts)	No	P
Potassium Formate Solution	No	P
Potassium Chloride Solution	No	S/P
Ethyl Alcohol	Yes	P
Ethylene Glycol	No	P
Ethylene Glycol monoalkyl ether	Yes	S/P
Methyl Alcohol	Yes	P
Acetic acid	Yes	S/P
Formic acid	Yes	S/P
Hydrochloric Acid	No	S/P
Hydrochloric-hydrofluoric mixtures containing 3% or less Hydrofluoric acid	No	S/P
Sodium Silicate Solution	No	P
Sulphuric Acid	No	S/P
Triethylene Glycol	No	P
Toluene	Yes	P
Xylene	Yes	P
Liquid carbon dioxide	No	S
Liquid nitrogen	No	S
Noxious liquid, NF, (7) n.o.s. (trade name ..., contains ...) ST3, Cat. Y	No	P
Noxious liquid, F, (8) n.o.s. (trade name …., contains …) ST3, Cat. Y	Yes	P
Noxious liquid, NF, (9) n.o.s. (trade name …, contains …) ST3, Cat. Z	No	P
Noxious liquid, F, (10) n.o.s. (trade name …, contains …) ST3, Cat. Z	Yes	P
Noxious liquid, (11) n.o.s. (trade name …, contains …) Cat. Z	No	P
Non-noxious liquid, (12) n.o.s. (trade name …, contains …) Cat. OS	No	P

8.1.4 Carriage of products not listed in Table 4.8.1 should only be undertaken in accordance with suitable preliminary carriage conditions and the limitation referred to in 8.1.3.

8.1.5 Additives which are considered to fall outside the scope of products in 8.1.3 may be carried in limited amounts. The aggregate amount of such additives which may be transported should not exceed 10 per cent of the vessel's maximum authorised quantity of products subject to this Section. An individual tank should contain not more than 10 m^3 of these additives. The discharge of these additives into the sea from offshore support vessels is prohibited.

8.1.6 Ships complying with the requirements of this section will be eligible for the special feature notation **HNLS**.

8.2 Definitions

8.2.1 Cargo area is that part of the offshore supply ship where cargo and cargo vapours are likely to be present and includes cargo tanks, cargo pump-rooms, hold spaces in which independent tanks are located, cofferdams surrounding integral tanks and the following deck areas:

- within 3 m of a cargo tank installed on deck;
- within 3 m of a cargo tank outlet in case of independent tanks installed below deck;
- within 3 m of a cargo tank outlet in case of integral tanks installed below deck and separated from the weather deck by a cofferdam;
- the deck area above an integral tank without an overlaying cofferdam plus the deck area extending transversely and longitudinally for a distance of 3 m beyond each side of the tank;
- within 3 m of any cargo liquid or vapour pipe, flange, cargo valve, gas or vapour outlet, or entrance or ventilation opening to a cargo pump-room.

8.2.2 Deadweight means the difference in metric tons between the displacement of an offshore support vessel in water of a density of 1,025 at the load waterline corresponding to the assigned summer freeboard and the lightweight of the ship.

8.2.3 Lightweight means the displacement of an offshore support vessel in metric tons without cargo, fuel, lubricating oil, ballast water, fresh water and feed water in tanks, consumable stores, and passengers and crew and their effects.

8.2.4 Hazardous substance is any substance either listed in chapter 17 of the Rules for Ships for Liquid Chemicals or having a hazard more severe than one of the minimum hazard criteria given in criteria for hazard evaluation of bulk chemicals as approved by the Organisation.

8.2.5 Pollution hazard only substance means a substance having an entry only of 'P' in column d in chapter 17 of the Rules for Ships for Liquid Chemicals.

8.2.6 Safety hazard substance means a substance having an entry of 'S' or 'S/P' in column d in chapter 17 of the Rules for Ships for Liquid Chemicals.

8.2.7 Flammable liquid is any liquid having a flashpoint not exceeding 60°C (closed-cup test).

8.3 Cargo tank location

8.3.1 Cargo tanks should be located at least 760 mm measured inboard from the side of the vessel perpendicular to the centreline at the level of the summer load waterline.

8.4 Cargo segregation

8.4.1 Tanks containing cargo or residues of cargo should be segregated from machinery spaces, propeller shaft tunnels, if fitted, dry cargo spaces, accommodation and service spaces and from drinking water and stores for human consumption, by means of a cofferdam, void space, cargo pump-room, empty tank, oil fuel tank, or other similar space. On-deck stowage of independent tanks or installing independent tanks in otherwise empty hold spaces should be considered as satisfying this requirement.

8.4.2 Cargoes which react in a hazardous manner with other cargoes or oil fuels should:

- be segregated from such other cargoes or oil fuels by means of a cofferdam, void space, cargo pump-room, empty tank, or tank containing a mutually compatible cargo;
- have separate pumping and piping systems which should not pass through other cargo tanks containing such cargoes, unless encased in a tunnel; and
- have separate tank venting systems.

8.4.3 Cargo piping should not pass through any accommodation, service or machinery space other than cargo pump-rooms or pump-rooms.

8.4.4 Pumps, ballast lines, vent lines and other similar equipment serving permanent ballast tanks should be independent of similar equipment serving cargo tanks.

8.4.5 Bilge pumping arrangements for cargo pump-rooms or for hold spaces in which independent cargo tanks are installed should be situated entirely within the cargo area.

8.5 Segregation requirements for integral tanks

8.5.1 Where not bounded by bottom shell plating, fuel oil tanks, a cargo pump-room or a pump-room, the cargo tanks should be surrounded by cofferdams. Tanks for other purposes (except fresh water and lubricating oils) may be accepted as cofferdams for these tanks.

8.5.2 For access to all spaces, the minimum spacing between cargo tank boundaries and adjacent ship's structures should be 600 mm.

8.5.3 Cargo tanks may extend to the deck plating, provided dry cargo is not handled in that area. Where dry cargo is handled on the deck area above a cargo tank, the cargo tank may not extend to the deck plating unless a continuous, permanent deck sheathing of wood or other suitable material of appropriate thickness and construction is fitted.

8.5.4 Cargoes subject to the scope of products in 8.1.2 and 8.1.3 should not be carried in either the fore or aft peak tanks.

8.5.5 For pollution hazard only substances having a flashpoint exceeding 60°C (closed-cup test) the arrangements referred to in 8.4.1 and 8.4.3 need not be applied provided that the segregation requirements for accommodation spaces, drinking water and stores for human consumption are satisfied. Additionally, 8.5.1 and 8.5.2 need not be applied.

8.6 Accommodation, service and machinery spaces and control stations

8.6.1 Accommodation or service spaces, or control stations should not be located within the cargo area.

8.6.2 Unless they are spaced at least 7 m away from the cargo area containing flammable products, entrances, air inlets and openings to accommodation, service and machinery spaces and control stations should not face the cargo area. Doors to spaces not having access to accommodation, service and machinery spaces and control stations, such as cargo control stations and store-rooms, may be permitted within the 7 m zone specified above, provided the boundaries of the spaces are insulated to A-60 Standard and each case will be specially considered. When arranged within the 7 m zone specified above, windows and side scuttles facing the cargo area should be of a fixed type. Such side scuttles in the first tier on the maindeck should be fitted with inside covers of steel or equivalent material.

8.6.3 In order to guard against the danger of hazardous vapours, due consideration should be given to the location of air intakes and openings into accommodation, service and machinery spaces and control stations in relation to cargo piping and cargo vent systems.

8.6.4 For pollution hazard only substances having a flashpoint exceeding 60°C, the arrangements referred to in 8.6.1 to 8.6.3 may be waived.

8.7 Access to spaces in the cargo areas

8.7.1 Access to spaces within the cargo area should meet the requirements of 3.4 of the Rules for Ships for Liquid Chemicals.

8.8 Cargo tank construction

8.8.1 Cargo tanks are to be as required by the Rules for Ships for Liquefied Gases or Rules for Ships for Liquid Chemicals as applicable and for the intended cargo.

8.8.2 Instead of the use of permanently attached deck-tanks, portable tanks meeting the requirements of the International Dangerous Goods (IMDG) Code or other portable tanks specially approved may be used for cargoes indicated in 8.1.3, provided that the tanks are properly located and secured to the vessel.

8.8.3 Except for the tank connections to cargo pump-rooms, all tank openings and connections to the tank should terminate above the weather deck and should be located in the tops of the tanks. Where cofferdams are provided over integral tanks, small trunks may be used to penetrate the cofferdam.

8.8.4 The greater of the following design pressures (gauge) should be used for determining scantlings of independent pressure tanks:

- 0,07 MPa;
- the vapour pressure of the cargo at 45°C;
- the vapour pressure of the cargo at 15°C above the temperature at which it is normally carried; or
- the pressure which occurs in the tank during the loading or unloading.

The design of the tanks should comply with acceptable standards taking into account the carriage temperature and relative density of cargo. Due consideration should also be given to dynamic forces and any vacuum pressure to which the tanks may be subjected.

8.8.5 Integral and independent gravity tanks should be constructed and tested according to acceptable standards taking into account the carriage temperature and relative density of cargo.

8.8.6 For pollution hazard only substances having a flashpoint exceeding 60°C, the requirements of 8.8.3 need not be applied.

8.9 Materials of construction

8.9.1 Materials of construction for tanks, piping, fittings and pumps should be in accordance with chapter 6 of the Rules for Ships for Liquid Chemicals, or the Rules for Ships for Liquefied Gases, as applicable.

8.10 Cargo tank vent systems

8.10.1 Independent pressure tanks should be fitted with pressure relief devices that are so designed as to direct the discharge away from personnel and that have a set pressure and capacity which is in accordance with acceptable standards taking into account the design pressure referred to in 8.8.4.

8.10.2 Cargo tank vent systems of integral or independent gravity tanks should meet the requirements of the Rules for Ships for Liquid Chemicals, except that the height specified in 8.3.4 of those Rules may be reduced to 2 m.

8.10.3 The location of cargo tank vent outlets for independent pressure tanks and for cargo tanks used to carry pollution hazard only substances with a flashpoint exceeding 60°C (closed-cup test) should be to the satisfaction of LR.

8.10.4 Cargo tank vent systems of portable tanks allowed under 8.8.2 should be to the satisfaction of LR, taking into account the requirements of 8.10.

8.11 Cargo transfer

8.11.1 The cargo transfer system should comply with the requirements of chapter 5 of the Rules for Ships for Liquid Chemical, or the Rules for Ships for Liquefied Gases, when considered applicable and practical, taking into account existing industry standards and practices.

8.11.2 The remote shut-down devices for all cargo pumps and similar equipment, required by 5.6.1.3 of the Rules for Ships for Liquid Chemicals, should be capable of being activated from a dedicated cargo control location which is manned at the time of cargo transfer and from at least one other location outside the cargo area and at a safe distance from it.

8.12 Electrical installations

8.12.1 Electrical installations should meet the requirements of chapter 10 of the Rules for Ships for Liquid Chemicals.

8.13 Acid spill protection

8.13.1 Floors or decks under acid storage tanks and pumps and piping for acid should have a lining or coating of corrosion-resistant material extending up to a minimum height of 500 mm on the bounding bulkheads or coamings. Hatches or other openings in such floors or decks should be raised to a minimum height of 500 mm; however, where this height is not practicable a lesser height may be required.

8.13.2 Flanges or other detachable pipe connections should be covered by spray shields.

8.13.3 Portable shield covers for connecting the flanges of the loading manifold should be provided. Drip trays of corrosion-resistant material should be provided under loading manifolds for acids.

8.13.4 Spaces for acid storage tanks and acid pumping and piping should be provided with drainage arrangements of corrosion-resistant materials.

8.13.5 Deck spills should be kept away from accommodation and service areas by means of a permanent coaming of suitable height and extension.

8.14 Ventilation of spaces in the cargo area

8.14.1 The requirements of chapter 12 of the Rules for Ships for Liquid Chemicals are to be applied. Consideration will be given to requests for relaxation of requirements concerning the distance required in 12.1.5 of the Rules for Ships for Liquid Chemicals.

8.15 Vapour detection

8.15.1 Vapour detection for the cargoes carried should be provided in accordance with the requirements contained in the Rules for Ships for Liquid Chemicals.

8.15.2 Enclosed and semi-enclosed spaces containing installations for acid should be fitted with fixed vapour detection and alarm systems which provide visual and audible indication. The vapour detection systems should be capable of detecting hydrogen except that, in the case where only hydrochloric acid is carried, a hydrogen chloride vapour detection system should be provided.

8.15.3 At least two portable instruments for detecting flammable vapour concentrations should be provided when cargoes subject to the requirements of this Section (*see* 8.1.3) with a flashpoint not exceeding 60°C (closed-cup test) are carried.

8.15.4 At least two portable instruments suitable for measuring the concentration of oxygen in atmospheric air should be provided.

8.16 Special requirements

8.16.1 The special requirements for the cargo as referred to in chapter 17 of the Rules for Ships for Liquid Chemicals or chapter 19 of the Rules for Ships for Liquefied Gases are applicable; however, the requirement in 15.19.6 of the Rules for Ships for Liquid Chemicals for a visual and audible high-level alarm may be waived taking into account the cargo carriage arrangements and cargo loading procedures and each case will be specially considered.

8.17 Special requirements for the carriage of liquefied gases

8.17.1 Each enclosed space used for handling or storage of a liquefied gas should be fitted with a sensor continuously monitoring the oxygen content of the space and an alarm indicating low oxygen concentration. For semi-enclosed spaces portable equipment may also be acceptable.

8.17.2 Drip trays resistant to cryogenic temperatures should be provided at manifolds transferring liquefied gases or at other flanged connections in the liquefied gas system.

8.17.3 For the carriage of liquid nitrogen the requirements of 17.19 of the Rules for Ships for Liquefied Gases are to be applied.

8.17.4 The construction of cargo tanks and cargo piping systems for liquefied nitrogen and liquid carbon dioxide should be to the satisfaction of LR.

8.17.5 Emergency shut-off valves should be provided in liquid outlet lines from each liquefied gas tank. The controls for the emergency shut-off valves should meet the requirements given in 8.10.2 for remote shut-down devices.

8.18 Gauging and level detection

8.18.1 Each cargo tank should have a level gauging system in accordance with the Rules for Ships for Liquefied Gases or Rules for Ships for Liquid Chemicals as applicable.

8.19 Emergency remote shut-down

8.19.1 In the case of transfer operations involving pressures in excess of 5 MPa, arrangements for emergency depressurising and disconnection of the transfer hose should be provided. The controls for activating emergency depressurisation and disconnection of the transfer hose should meet the requirements given in 8.11.2 for remote shut-down devices.

8.20 Pollution requirements

8.20.1 Each ship certified to carry noxious liquid substances should be provided with a Cargo Record Book, a Procedure and Arrangements Manual and a Shipboard Marine Emergency Plan developed for the ship in accordance with Annex II to MARPOL 73/78 and approved.

8.20.2 Discharge into the sea of residues of noxious liquid substances permitted for the carriage in Ship Type 3, or products listed in 8.1.2 or ballast water, tank washings, or other residues or mixtures containing such substances, is prohibited. Any discharges of residues and mixtures containing noxious liquid substances should be to reception facilities in port. As a consequence of this prohibition, the requirements for efficient stripping and underwater discharge arrangements in MARPOL 73/78, Annex II may be waived.

8.20.3 In the case of cargoes regulated by MARPOL 73/78, Annex I, the requirements of that Annex should apply as appropriate.

8.21 Decontamination showers and eyewashes

8.21.1 Except in the case of pollution hazard only substances, a suitably marked decontamination shower and eyewash should be available on deck in a convenient location. The shower and eyewash should be operable in all ambient conditions.

8.22 Protective and safety equipment

8.22.1 Protective and safety equipment should be kept on board in suitable locations as required by chapter 14 of the Rules for Ships for Liquefied Gases or Rules for Ships for Liquid Chemicals for products to be carried.

■ *Section 9* Standby ship

9.1 Application and definitions

9.1.1 The requirements in this Section apply to standby ships. A standby ship is a sea-going ship designed, constructed, organised and maintained in such a way that she can give assistance in the event of an emergency on or near an offshore installation.

9.1.2 The National Authority with whom the ship is registered and/or the Administration within whose territorial jurisdiction the ship is intended to operate may have requirements for the same items as required by these Rules. In those instances the more onerous requirements are to be applied.

9.2 Configuration of standby ship

9.2.1 The main features of standby ships which dictate the structural configuration are:

(a) Designated and illuminated winching area for helicopter operations.
(b) Clearly marked and lighted rescue zone at the side of the ship.
(c) Survivors area.
(d) Fast rescue boat.

9.3 Information required

9.3.1 In addition to the information and plans required by Ch 4,1.3, details of local strengthening of the following items are to be submitted where applicable:

(a) The arrangement and integration into the hull of equipment, supports, foundations for rescue equipment, etc., in conjunction with their weight, working load and holding capability information.
(b) Support for towing arrangement as applicable.
(c) The arrangement for the fast rescue craft.

9.4 Equipment foundations

9.4.1 When considering the loads, all expected directions of operation are to be taken into account.

9.4.2 The foundation for towing equipment, if applicable, is to be in accordance with Ch 3,7.2.

9.5 Ship arrangement

9.5.1 For standby ships the rescue arrangement, accommodation and facilities for survivors and safety equipment is required to comply with a National Standard. The applicable Certificate or Statement of Compliance with a National Standard is to be issued by a National Administration, or by LR, or by an IACS member when so authorised. Where no national requirements exist for a particular vessel, LR will issue statement of compliance with UKOOA.

■ *Section 10* Anchor handler

10.1 Application and definitions

10.1.1 The requirements of this Section apply to ships specially designed, constructed and equipped for handling anchors of a floating offshore installation.

10.2 Structural configuration

10.2.1 The main features of an anchor handler which dictate the structural configurations are:

(a) The ship has a completely clear after deck in order to handle the anchors effectively.
(b) One or more winches designed for the purpose of deploying and recovering the anchors.
(c) Large horizontal stern roller, if fitted. During the anchor-handling process the ship is often required to take the anchors on board by hauling them over her stern, along with their associated chain and other fittings. For this purpose a large horizontal roller is installed in the stern, usually at deck level.
(d) A rounded form in way of the area for shipping/unshipping anchors at stern.
(e) Chain lockers under the main winch, if fitted. Anchor handlers are sometimes required to store rig or mooring chain and, for this purpose, most are fitted with chain lockers under the main winch which double as ballast or brine tanks when not in use.
(f) Equipment for temporary securing of the anchor, e.g., shark's jaw.
(g) Towing pins in way of the stern roller.
(h) High duty bollards.

10.3 Information required

10.3.1 In addition to the information and plans required by Ch 4,1.3, details of local strengthening of the following items are to be submitted where applicable:

(a) The arrangement and integration into the hull of equipment, tanks, supports, foundations, etc., in conjunction with their weight, working load and holding capability information.
(b) For unusual structural arrangement and equipment, calculations are to be submitted showing acceptable structural strength.
(c) Supports and foundations for anchor handling and laying arrangements for anchors carried as cargo.

10.4 Hull envelope plating

10.4.1 Anchor handing activities often give rise to areas of high local loads and/or frequent impacts, such as in way of stern rollers and immediately adjacent to high duty bollards. The shell in way of high loads and/or frequent impacts is to be suitably reinforced by increasing shell plate thickness, additional stiffening support or other appropriate means.

10.5 Working deck

10.5.1 Deck areas, where there are arrangements for the collection and handling of anchors and associated equipment, are to be protected by wooden sheathing. Alternatively, this can be omitted if the plate thickness is increased by 2,5 mm.

10.6 Equipment foundations

10.6.1 When considering the loads, all expected directions of operation are to be taken into account. The foundation for deck equipment (winch, stern roller, etc.) is to be in accordance with Ch 3,7.2 as applicable.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies, in general, to manned or unmanned non-self-propelled ships defined as follows:

(a) Barges for the carriage of general dry cargoes in cargo holds.
(b) Barges for the carriage of liquid cargoes in bulk.
(c) Pontoons designed specifically for the carriage of non-perishable cargo on deck.
(d) Shipborne barges for the carriage of general dry cargo in cargo holds and intended to operate afloat only within specified geographical limits, and suitable for regular carriage on board a larger ship.

1.1.2 Manned or unmanned barges for the carriage of liquid chemicals in bulk and barges for the carriage of liquefied gases will receive individual consideration on the basis of the Rules, *see* Table 5.1.1.

1.1.3 The scantlings and arrangements, except where otherwise specified in this Chapter, are to comply with the Rules as indicated in Table 5.1.1.

1.1.4 The Rules assume that the structural arrangements of barges carrying cargo in holds will generally approximate to normal ship shape and construction. Barges of this type not doing so will receive individual consideration on the basis of the Rules.

1.1.5 The Rules also assume that barges and pontoons are homogeneously loaded. Barges or pontoons with other types of loading, e.g., crane pontoon, will receive individual consideration.

1.1.6 All barges and pontoons are to be fitted with adequate arrangements for towing. In general, such arrangements are to consist of, or be equivalent to, not less than two sets of bollards, each of which shall be suitable for accepting a towline of suitable breaking strength.

Table 5.1.1 Applicable Rules

Type of barge	Applicable Rules
Barge for the carriage of general dry cargo in cargo hold	Chapter 1
Barge for the carriage of liquid cargo in bulk	Chapter 10
Pontoon designed specifically for the carriage of non-perishable cargo on deck	Chapter 1
Shipborne barges for the carriage of general dry cargo in cargo holds	Chapter 1 and this Chapter for 'extended protected water service' barges
Barge for the carriage of liquid chemicals in bulk	*Rules for Ships for Liquid Chemicals in Bulk*
Barge for the carriage of liquefied gases	*Rules for Ships for Liquefied Gases*

1.2 Class notations

1.2.1 In general, ships complying with the requirements of this Chapter will be eligible for one of the following classes:

(a) **100A1 barge**. This class will be assigned to non-self-propelled sea-going ships as defined in 1.1.1(a).
(b) **100A1 oil barge**. This class will be assigned to non-self-propelled sea-going ships as defined in 1.1.1(b).
(c) **100A1 pontoon**. This class will be assigned to non-self-propelled sea-going ships as defined in 1.1.1(c).

1.2.2 Barges and pontoons intended to be operated only in suitable areas or conditions which have been agreed by the Committee, as defined in Pt 1, Ch 2,2.3.6 to 2.3.10, will receive individual consideration on the basis of the Rules with respect to the environmental conditions agreed for the design basis and approval. In particular, shipborne barges as defined in 1.1.1(d) complying with the requirements of this Chapter will be eligible to be classed **100A1 shipborne barge extended protected water service**.

1.2.3 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.3 Information required

1.3.1 In addition to the information and plans required by Pt 3, Ch 1,5, the following are to be submitted:

- Details of structure and fittings to which deck cargo securing lashings, etc., are attached.
- Details of the bollards and their supporting structure.
- Where pusher tugs or integral tug/barge systems are proposed, full details and data of the attachment and support arrangements.
- Details of the intended service areas required for barges or pontoons designed to operate within specified geographical limits.
- Longitudinal strength and lifting arrangements for shipborne barges.

1.4 Symbols and definitions

1.4.1 The Rule length, L, for vessels with swim ends is to be measured as shown in Fig. 5.1.1. Where a swim end is arranged aft but no rudder is fitted, L need not exceed 97 per cent of the extreme length on the summer load waterline. For tugs and barge units having rigid connections, the length, L, is to be taken as the combined length of the tug and barge.

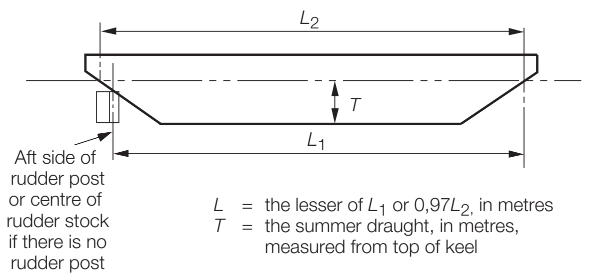


Fig. 5.1.1 Definition of Rule length

Section 2
Longitudinal strength

2.1 General

2.1.1 Longitudinal strength calculations are to be made in accordance with the requirements given in Pt 3, Ch 4, and the ship service factor, f_1, is given in Table 5.2.1.

Table 5.2.1 Ship service factor f_1

Type of ship	f_1	
	'100A1'	'100A1 extended protected water service'
Barge for the carriage of general cargo in holds and for the carriage of liquid cargoes in bulk Pontoons for the carriage of non-perishable cargoes on deck	1,0	0,80
Shipborne barges for the carriage of general cargo in holds and unmanned	—	0,70

2.1.2 The requirements of Pt 3, Ch 4,8.3 regarding loading instruments are not applicable to barges and pontoons.

2.1.3 For shipborne barges, where it is the intention to lift the barge on board ship by crane, a condition 'fully loaded barge suspended by crane' is to be submitted. For this condition the following stresses are permissible:

Bending stress σ_b = 147,2 N/mm^2 (15,0 kgf/mm^2)

Shear stress τ = 98,1 N/mm^2 (10,0 kgf/mm^2)

Section 3
Hull envelope plating

3.1 Shell and deck plating

3.1.1 The thickness of shell and deck plating is to be as necessary to give the hull section modulus required by 2.1 and to satisfy the requirements listed in Table 5.3.1.

Table 5.3.1 Shell and deck plating

Item of plating	Thickness for ships classed 100A1	Thickness for ships having extended protected water service notation
(a) Keel	The separate requirements of Chapter 1 or Chapter 10, whichever is applicable, for keel width and thickness need not be applied, except where L > 100 m and the bottom has a rise of floor	
(b) Bottom shell and bilge	In accordance with the requirements of Chapter 1 or Chapter 10, whichever is applicable	In accordance with the requirements of Chapter 1 or Chapter 10, whichever is applicable, reduced by 12,5 per cent, but is to be not less than required by (c) below
	For chines, *see* 3.1.2	
(c) Side shell from upper turn of bilge or chine to deck	The greater of the values obtained from Chapter 1 or Chapter 10, whichever is applicable, for the appropriate framing arrangement	
(d) Deck	In accordance with the requirements of Chapter 1 or Chapter 10, whichever is applicable	In accordance with the requirements of Chapter 1 or Chapter 10, whichever is applicable, reduced by 2 mm, but is to be not less than the deck basic end thickness as required by Pt 3, Ch 5 and Ch 6
	In pontoon barges with deck cargoes the deck thickness derived from (d) may be required to be increased	
(e) Swim ends	The bottom shell plating thickness is to be maintained up to the summer load waterline for the rake plating. Above this point the thickness may be tapered to that of the side shell requirements from a point not less than 1 m above the load waterline	

3.1.2 On ships with two chines each side, the bilge plating should generally be calculated from the bottom plating formulae. On hard chine ships, flanged chines will not, in general, be approved, but where a chine is formed by knuckling the shell plating, the radius of curvature, measured on the inside of the plate, is to be not less than 10 times the plate thickness. Where a solid round chine bar is fitted, the bar diameter is to be not less than three times the thickness of the thickest abutting plate. Where welded chines are used, the welding is to be built up as necessary to ensure that the shell plating thickness is maintained across the weld.

■ *Section 4* Hull envelope framing

4.1 Symbols

4.1.1 The symbols used in this Section are defined as follows:

h = head or load height, in metres, and is to be taken as:
for bottom longitudinals, frames, girders and transverses: the depth D
for side longitudinals: the distance of the longitudinal below the deck at side, but not less than $0{,}01L + 0{,}7$
for side transverses: the distance from the mid-point of span to the deck at side, but not less than $0{,}01L + 0{,}7$
for deck longitudinals and transverses: the head equivalent to cargo carried at a stowage rate of 1,39 m^3/tonne, but is not to be taken less than $0{,}01L + 0{,}7$
for side frames: the distance from the midpoint of span to the deck at the side
for deck beams and girders: the head equivalent to cargo carried at a stowage rate of 1,39 m^3/tonne, but is not to be taken less than required by Table 3.5.1 in Pt 3, Ch 3

l_e = effective length of stiffening member, in metres, *see* Pt 3, Ch 3,3

s = spacing of frames, beams or longitudinals, in mm

S = spacing or mean spacing of girders, transverses or floors, in metres

Z = section modulus of stiffening member, in cm^3, *see* Pt 3, Ch 3,3.

4.2 General

4.2.1 Bottom, side and deck transverses are to be connected in such a manner as to ensure continuity of the transverse ring system, and longitudinals are to be attached to transverses. In way of deck and bottom transverses, a deep web frame is to be fitted.

4.2.2 End connections of longitudinals at bulkheads are to provide adequate fixity and direct continuity of longitudinal strength.

4.2.3 Brackets at the top and bottom of side frames are to extend to the adjacent deck or bottom longitudinal to which they are to be attached.

4.2.4 In pontoons where truss arrangements, comprising top and bottom girders in association with pillars and diagonal bracing, are used in the support of the deck loads, the diagonal members are generally to have angles of inclination with the horizontal of about 45° and cross-sectional area of approximately 50 per cent of the adjacent pillar in accordance with Ch 1,4.4, with a head in accordance with 4.1.1.

4.2.5 Adequate support must be provided on the centreline for the loads imposed on the structure when the ship is in dry dock.

4.3 Longitudinal framing

4.3.1 The scantlings of bottom, side and deck longitudinals are to comply with the requirements of Table 5.4.1.

Table 5.4.1 Longitudinal framing

Position of longitudinals	Modulus, in cm^3
Bottom	* $Z = 11{,}0 l_e^2 sh \times 10^{-3}$
Side shell	* $Z = 8{,}0 l_e^2 sh \times 10^{-3}$
Deck	* $Z = 5{,}5 l_e^2 sh \times 10^{-3}$
	* For the requirements for barges carrying liquid cargoes in bulk *see* Chapter 10
NOTE The scantlings derived from above need not exceed the scantling requirements of Chapter 1 or Chapter 10, whichever is applicable.	

4.4 Transverse framing

4.4.1 The scantlings of bottom and side frames and deck beams are to comply with the requirements of Table 5.4.2.

Table 5.4.2 Transverse framing

Position of member	Modulus, in cm^3
Bottom and side frames	* $Z = 9{,}5 l_e^2 sh \times 10^{-3}$
Deck beams	* $Z = 4{,}5 l_e^2 sh \times 10^{-3}$
	* For the requirements for barges carrying liquid cargoes in bulk *see* Chapter 10
NOTE The scantlings derived from above need not exceed the scantling requirements of Chapter 1 or Chapter 10, whichever is applicable.	

4.5 Primary supporting structure

4.5.1 Primary supporting members are to comply with the requirements of Table 5.4.3.

Table 5.4.3 Primary supporting structure

Position of member	Modulus, in cm^3
Bottom transverse	* $Z = 11{,}0 l_e^2 Sh$
Side transverse	* $Z = 8{,}0 l_e^2 Sh$ (may be reduced by 5 per cent for vessels classed '100A1 extended protected water service')
Deck transverse	* $Z = 5{,}5 l_e^2 Sh$
Bottom girder	* $Z = 9{,}5 l_e^2 Sh$
Deck longitudinal girder	* $Z = 5{,}0 l_e^2 Sh$
	* For the requirements for barges carrying liquid cargoes in bulk *see* Chapter 10
NOTE The scantlings derived from above need not exceed the scantling requirements of Chapter 1 or Chapter 10, whichever is applicable.	

■ *Section 5*
Strengthening of bottom forward

5.1 Application

5.1.1 The requirements for strengthening of bottom forward detailed in Pt 3, Ch 5 do not apply to barges or pontoons less than 50 m in length.

■ *Section 6*
Bottom strengthening for loading and unloading aground

6.1 Application

6.1.1 For barges or pontoons intended to load or unload while aground, *see* Pt 3 Ch 9,9.

■ *Section 7*
Watertight bulkheads

7.1 Collision bulkheads

7.1.1 Barges and pontoons are to have a collision bulkhead extending intact to the strength/weather deck and, in general, this is to be positioned as detailed in Table 5.7.1.

Table 5.7.1 Collision bulkhead position

Length L, in metres	Distance of collision bulkhead aft of fore end of L, in metres, *see* Fig. 5.1.1	
	Minimum	Maximum
≤ 150	$0{,}05L$	$0{,}05L + 4{,}5$
> 150	The lesser of: $0{,}05L$ or 10	$0{,}08L$

■ *Section 8*
Void spaces

8.1 Void spaces on unmanned pontoons not fitted with auxiliary machinery

8.1.1 Drainage arrangements and air pipes are to be provided in accordance with Pt 5, Ch 13,10 and Pt 5, Ch 13,12.4.4 respectively.

8.1.2 Deck openings to allow drainage in accordance with Pt 5, Ch 13,10.1.3 are to be as small as practicable and closed by watertight gasketed covers of steel or equivalent material.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to sea-going steel trawlers, stern trawlers and fishing vessels.

1.1.2 For the purpose of this Chapter, a fishing vessel is a ship used for fishing operations, but not equipped for trawling.

1.1.3 The scantlings and arrangements are to be as required by Chapter 1 except as otherwise specified in this Chapter. Consideration will be given to proposals for modified scantlings on vessels where *L* is less than 24 m.

1.2 Assignment of load lines

1.2.1 The *International Convention on Load Lines, 1966* does not apply to trawlers and fishing vessels, but certain National Authorities may request the assignment of load lines for ships registered in their countries.

1.2.2 The Rules affecting the protection of openings and protection of crew, and particularly those contained in Pt 3, Ch 11 and Ch 12, may be modified to take account of National Regulations or practicabilities related to fishing operations.

1.3 Class notations

1.3.1 In general, ships complying with the requirements of this Chapter will be eligible for one of the following classes:

(a) **100A1 trawler**. This class will be assigned to side fishing trawlers.

(b) **100A1 stern trawler**. This class will be assigned to stern fishing trawlers.

(c) **100A1 fishing vessel**. This class will be assigned to fishing vessels, *see* 1.1.2.

1.3.2 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2 to which reference should be made.

1.4 Information required

1.4.1 In addition to the information required by Pt 3, Ch 1,5, the position and arrangement of trawl gear and deck machinery and location of insulated compartments are to be indicated.

1.5 Symbols and definitions

1.5.1 The Rule length, *L*, is the distance, in metres, on the classification waterline from the fore side of the stem to the after side of the rudder post, or to the centre of the rudder stock if there is no rudder post. *L* is to be not less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on the classification waterline.

1.5.2 Breadth *B*, is the greatest moulded breadth, in metres.

1.5.3 Depth *D*, is measured, in metres, at the middle of the length, *L* from the base line to top of the deck beam at side on the uppermost continuous deck.

1.5.4 The classification waterline in single deck ships is the waterline taken perpendicular to the plane of the transverse bulkheads located at 0,85*D* from the base line amidships, or at the maximum operational draught amidships, whichever is the greater. In two-deck ships, it is the waterline located at the maximum operational draught, but if this is unknown, it may be taken at 50 mm below the lower deck. If a load line is required by a National Authority, the classification waterline is the summer load waterline.

1.5.5 Keel line is the line parallel to the slope of the keel intersecting the top of the keel at amidships, or the line of intersection of the inside of shell plating with the keel where a bar keel is fitted.

1.5.6 Base line is a line parallel to the classification waterline and intersecting the keel line at amidships.

1.5.7 Draught *T*, is the distance in metres, between the classification waterline and the base line amidships.

1.5.8 The block coefficient C_b is to be taken at the classification waterline.

1.5.9 The following symbols are also applicable to this Chapter:

k = material factor, *see* Ch 1,1.5
l_e = effective length of stiffening member, in metres, *see* Pt 3, Ch 3,3
s = spacing of stiffeners, in mm
s_b = $470 + \frac{L}{0{,}6}$ with minimum limitation at ends as defined in Table 5.3.1 in Pt 3, Ch 5, for fore end structure and Table 6.3.1 in Pt 3, Ch 6, for aft end structure
s_1 = s, but not less than s_b
t = thickness of plating, in mm
Z = section modulus of stiffening member, in cm^3, *see* Pt 3, Ch 3,3.

Section 2
Protection

2.1 Protection of steelwork

2.1.1 Where wood sheathing is fitted, the material is to be of good quality, well seasoned and free from sapwood, and the thickness is to be not less than 65 mm. The plank widths should not normally exceed 150 mm. Thwartship planks are to be laid at the ends of deckhouses and at break of deck. Fastenings are to be sunk below the surface of the planking and covered with turned dowels, and the whole to be thoroughly bedded in a suitable composition. All weather decks are to be caulked and payed.

2.1.2 Where gutter waterways are fitted, the bar forming the inner edge of the waterway is to be not less than 7,5 mm thick.

2.1.3 Welded studs are to be not less than 9,5 mm diameter, and are to be coated with suitable composition before the planking is laid. Bolts used instead of studs may be 12,5 mm diameter galvanised. If the steel deck is penetrated for bolts, the deck is to be hose tested in accordance with Pt 3, Ch 1,8.

2.2 Protection of cargo

2.2.1 When an oil fuel bunker or double bottom carrying oil fuel, or a lubricating oil tank, is adjacent to a fish hold, the relevant requirements of Pt 6, Ch 3,4 are to be complied with.

2.2.2 Compartments used for the processing of fish, or for temporary storage during or while awaiting processing, need not comply with the requirements of 2.2.1, but the construction of the bulkheads, decks and insulation, if any, should be such as to minimise the risk of oil leakage.

Section 3
Longitudinal strength

3.1 General

3.1.1 The longitudinal strength standard is to comply with the relevant requirements of Pt 3, Ch 4.

3.1.2 The requirements of Pt 3, Ch 4,8.3 regarding loading instruments are not applicable to trawlers and fishing vessels.

Section 4
Deck structure

4.1 Deck plating

4.1.1 The thickness of deck plating is to be not less than that required by Ch 1,4. Under the trawl winch, windlass, mast, centre and side bollards and gallows, the plating thickness is to be not less than:

t = $(0{,}04L + 7{,}5)$ mm

where

L is to be taken not less than 30 m.

4.1.2 When a raised deck is fitted, adequate scarfing is to be arranged at the step.

4.2 Factory deck beams

4.2.1 The section modulus of the beams of factory decks under fish handling spaces is to be not less than that required by Table 1.4.5(2) in Chapter 1, with h_2 equal to 2 m, but extra strengthening may be required in way of heavy items of machinery or equipment.

Section 5
Shell envelope plating

5.1 Shell plating

5.1.1 The thickness of shell plating is to be not less than that required by Ch 1,5 but in no case is it to be less than the following:

For $L \le 70$ m $\quad t = (5{,}5 + 0{,}033L)\sqrt{\frac{ks_1}{s_b}}$ mm

For $L > 70$ m $\quad t = (6{,}5 + 0{,}033L)\sqrt{\frac{ks_1}{s_b}}$ mm

5.1.2 For single deck side trawlers the thickness derived from the formulae in 5.1.1 is to be increased by 10 per cent.

5.1.3 When nets or control wires are in contact with the ship's side, such as below the gallows in a side trawler, the side shell plating is to be increased by 40 per cent.

5.1.4 Where a bar keel is fitted, the breadth of the garboard strake is to be not less than 760 mm, and the thickness is to be 10 per cent greater than the bottom shell.

5.1.5 The thickness of the bottom shell plating is to be increased by 10 per cent where intercostal girders are not fitted.

5.1.6 For increase to sheerstrake at the break of a raised deck, *see* Ch 1,5.

5.1.7 Cope irons are to be fitted under gallows or any other area where excessive wear could occur.

■ *Section 6* Shell envelope framing

6.1 Transverse side framing

6.1.1 The section modulus of the side frames of single deck trawlers and fishing vessels need not be greater than 80 per cent of the modulus required by Ch 1,6, but in no case is the depth of the frame to be less than 60 mm. Where not specified the draught is to be taken as not less than 0,85D.

6.1.2 For two deck trawlers and two deck fishing vessels and all vessels requiring a load line, the requirements of Ch 1,6 are to be complied with.

6.1.3 The section modulus of frames in the fore peak is to be the greater of the following:
(a) 10 per cent greater than that required by Pt 3, Ch 5,4.
(b) $Z = (45D - 212)$ cm^3.

6.1.4 The section modulus of frames in the aft end region is to be not less than that required by Pt 3, Ch 6,3.

6.1.5 Where frames are stopped at watertight flats they are to be bracketed.

■ *Section 7* Watertight bulkheads

7.1 Collision bulkheads

7.1.1 Consideration will be given to proposals for the collision bulkhead to be positioned further aft than 0,08L from the fore end of the classification waterline, provided that bow damage will not result in excessive trim forward.

■ *Section 8* Stern ramp, and cruiser and transom sterns

8.1 Stern ramp

8.1.1 The thickness of plating of the stern ramp is to be not less than:

t = 0,025s mm or 10 mm, whichever is the greater.

8.1.2 The section modulus of stiffeners is to be not less than:

$Z = 0{,}019 s\, l_e^2$ cm^3.

8.2 Cruiser and transom sterns

8.2.1 Cruiser and transom sterns are to have frames of the size required for peaks, and are to be additionally stiffened by web frames when required. The depth of plate floors is to be not less than that given in Ch 1,7, and the floors are to be associated with a suitable system of girders.

■ *Section 9* Strengthening of bottom forward

9.1 General

9.1.1 The requirements of Pt 3, Ch 5,1 are to be applied except when the forward draught contemplated for any sea-going condition is equal to or greater than 0,03L in which case the bottom shell plating in the region to be strengthened may be taken as:

$t = 0{,}00818 s\, f\, L^{1/4} k^{1/2}$

where the symbols are as defined in Table 5,1.1 in Pt 3, Ch 5. This thickness derivation may be adopted for both longitudinal and transverse framing.

■ *Section 1* General

1.1 General

1.1.1 This Chapter applies to sea-going self propelled ships, constructed generally with single deck double bottom, hopper side tanks and topside tanks and with single or double side skin construction in the cargo length area, and intended primarily for the carriage of bulk dry cargoes.

1.1.2 A 'bulk carrier of single side skin construction' is defined as a bulk carrier where one or more cargo holds are bound by the side shell only, or by two watertight boundaries, one of which is the side shell, which are less than 1000 mm apart.

1.1.3 The term 'bulk carrier of double side skin construction' is defined as a bulk carrier where all cargo holds are bound by two watertight boundaries, one of which is the side shell, which are greater than or equal to 1000 mm apart at any location within the hold length.

1.1.4 The ShipRight Procedures for the hull construction of ships are detailed in Pt 3, Ch 16 and the classification notations and descriptive notes associated with these procedures are given in Pt 1, Ch 2,3.

1.1.5 The attention of Owners, Masters and Cargo Shippers is drawn to the IMO Code of Safe Practice for Solid Bulk Cargoes when shipping these cargoes. Attention is also drawn to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered, and any special requirements of the Port Authorities at the ports of loading and discharge.

1.1.6 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2 to which reference should be made.

1.2 Application

1.2.1 Single skin and double skin bulk carriers with length, *L*, greater than or equal to 90 m with structural configuration as shown in Fig. 7.1.1 are defined as '*CSR Bulk Carriers*' and are to comply with 1.4.

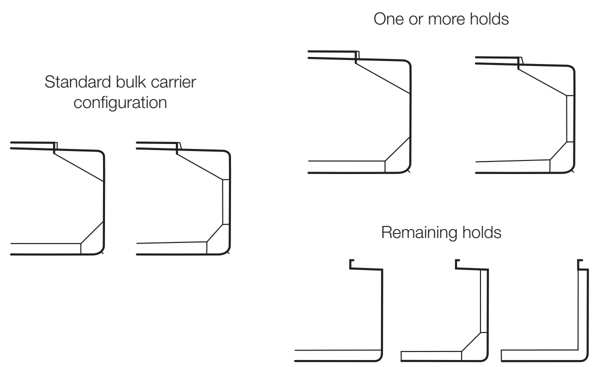


Fig. 7.1.1 CSR-BC applicability

1.2.2 Single skin and double skin bulk carriers other than those described in 1.2.1 are defined as '*Non-CSR Bulk Carriers*' and are to comply with 1.5.

1.3 General class notations

1.3.1 Class notations applicable to CSR bulk carriers are defined as follows:

- **CSR**
  Identifies the bulk carrier as being compliant with the *IACS Common Structural Rules for Bulk Carriers;*
- **ESP**
  Identifies the bulk carrier as being subject to an Enhanced Survey Programme as detailed in Pt 1, Ch 3,3 and Ch 3,6, *see also* Pt 1, Ch 2,2.3.12.

1.3.2 Class notations applicable to non-CSR bulk carriers are defined as follows:

- **Strengthened for heavy cargoes**
  For bulk carriers with scantlings complying with 8.2;
- **ESP**
  Identifies the bulk carrier as being subject to an Enhanced Survey Programme as detailed in Pt 1, Ch 3,3 and Ch 3,6, *see also* Pt 1, Ch 2,2.3.12;
- **ESN**
  Identifies the bulk carrier as having been assessed for enhanced survivability with respect to flooding. Scantlings and arrangements are to comply with 3.1.2, 8.8 and 10.4.

1.4 Class notation for CSR bulk carriers

1.4.1 In general, CSR bulk carriers less than 150 m in length are to comply with the requirements of 1.6, Pt 3, Ch 2 and the *IACS Common Structural Rules for Bulk Carriers* (CSR) and will be eligible for one of the following mandatory class notations:

(a) **100A1 bulk carrier, CSR, any holds may be empty, ESP.** This class notation is normally assigned to a ship designed to carry dry bulk cargoes of cargo density 1,0 tonne/m^3 and above, with an approved arrangement of loaded holds such that any hold may be empty at the full loaded draught.

(b) **100A1 bulk carrier, CSR, hold nos. 1, 2 ... may be empty, ESP.** This class notation is normally assigned to a ship designed to carry dry bulk cargoes of cargo density 1,0 tonne/m^3 and above with specified holds empty at maximum draught.

(c) **100A1 bulk carrier, CSR, ESP.** This class notation will be assigned to a ship designed to carry dry bulk cargoes of cargo density less than 1,0 tonne/m^3.

1.4.2 In general, CSR bulk carriers equal to or greater than 150 m in length are to comply with the requirements of 1.6, Pt 3 Ch 2 and the *IACS Common Structural Rules for Bulk Carriers* (CSR) and will be eligible for one of the following mandatory class notations:

(a) **100A1 bulk carrier, CSR, BC-A, hold nos. 1, 2 … may be empty, GRAB [X] ESP.** This class will be assigned for bulk carriers designed to carry dry bulk cargoes of cargo density 1,0 tonne/m^3 and above with specified holds empty at maximum draught.

(b) **100A1 bulk carrier, CSR, BC-B, GRAB [X], ESP.** This class will be assigned for bulk carriers designed to carry dry bulk cargoes of cargo density 1,0 tonne/m^3 and above with all cargo holds loaded.

(c) **100A1 bulk carrier, CSR, BC-C, ESP**. This class will be assigned for bulk carriers designed to carry dry bulk cargoes of cargo density less than 1,0 tonne/m^3 with all cargo holds loaded.

1.4.3 The following additional notations and annotations are to be provided giving further detailed description of limitations to be observed during operation as a consequence of the design loading condition applied during the design.

- **Notations:**
  (maximum cargo density (in tonnes/m^3)) For notations **BC-A** and **BC-B** if the maximum cargo density is less than 3,0 tonnes/m^3;
  (no MP) For all notations when the vessel has not been designed for loading and unloading in multiple ports in accordance with the conditions specified in *IACS Common Structural Rules for Bulk Carriers* (CSR) Ch 4,7.3.3;
  GRAB [X] where the net thickness of inner bottom, lower strake of hopper tank sloping plate and transverse lower stool plating comply with *IACS Common Structural Rules for Bulk Carriers* (CSR) Ch 12,1 for **BC-A** and **BC-B**, *see also* CSR Ch 1,1;
- Annotations:
  (allowed combination of specified empty holds). For notation **BC-A**.

1.4.4 The ‘Construction Monitoring’ (CM) procedures detailed in the *ShipRight Procedures Manual*, published by LR, are mandatory for bulk carriers greater than 190 m in length.

1.4.5 Optional notations indicating compliance with specific requirements of Sections 3 to 14 on a voluntary basis may also be assigned.

1.5 Class notation for non-CSR bulk carriers

1.5.1 In general, non-CSR Bulk Carriers are to comply with the requirements of 1.5.2 to 1.5.7 and will be eligible for one of the following mandatory class notations:

(a) **100A1 bulk carrier, ESP.**

(b) **100A1 bulk carrier, strengthened for heavy cargoes, ESP.** This class notation will be assigned to a ship when the double bottom structure has been specially strengthened in accordance with the requirements of Table 7.8.1.

(c) **100A1 bulk carrier, strengthened for heavy cargoes, hold nos. 1, 2 ... may be empty, ESP**. This class notation is normally assigned to a ship which has been specially strengthened for heavy cargoes, *see* (b), so as to enable the ship to be fully loaded with an approved arrangement of empty holds, *see also* 1.3.5 and 1.4.3.

(d) **100A1 bulk carrier, strengthened for heavy cargoes, any holds may be empty, ESP.** This class notation is normally assigned to a ship which has been specially strengthened for heavy and ore cargoes, with an approved arrangement of loaded holds such that any hold may be empty at the full loaded draught.

1.5.2 Plans and information are to be submitted in accordance with 1.7.

1.5.3 Requirements are also given for special strengthening for heavy cargoes, *see* 8.2.

1.5.4 The scantlings and arrangements of the cargo region are to be as specified in this Chapter in Sections 2 to 14. The requirements are intended to cover the midship region, but also apply, with suitable modification, to the taper regions forward and aft in way of cargo spaces.

1.5.5 The 'Structural Design Assessment' **(SDA)**, 'Fatigue Design Assessment' **(FDA)** and 'Construction Monitoring' **(CM)** procedures detailed in the *ShipRight Procedures Manual*, published by LR, are mandatory for non-CSR bulk carriers greater than 190 m in length and for other non-CSR bulk carriers of abnormal hull form, or of unusual structural configuration or complexity *see* 1.1.5 and Section 11.

1.5.6 Where the class notation referred to in 1.5.1(d) is assigned such that any hold may be empty at the full draught the following items are to be considered and the corresponding requirements complied with:

(a) Longitudinal strength calculations are to be carried out for all the operational fully loaded, non-homogeneous, part loaded, heavy cargo conditions, and these conditions included in the approved Loading Manual, *see* Section 3. Envelopes of the still water bending moments and the shear forces covering these conditions are also to be submitted.
(b) The double bottom structure in each hold is to satisfy the requirements of 8.4.
(c) The arrangement and scantlings of cross-deck structure between the upper deck cargo hatchways, *see* 4.1.2.
(d) Transverse bulkheads in holds, *see* 10.1.4.
(e) For main cargo hatchway openings the requirements of 4.3.1 are to be complied with.

1.5.7 Where appropriate, other cargoes or particular loading arrangements will be included in the class notation. When the class notation referred to in 1.5.1(c) is to be assigned for other combinations of empty and loaded holds, for example where it is the intention to load fully any two adjoining holds with adjacent holds empty in sea-going or short voyage conditions, the longitudinal and local strength aspects will be specially considered, *see also* 4.1.2. In addition, permissible weights of cargo in each hold or pair of adjacent holds, plotted against ship's draught likely to be incurred, are to be included in the ship's approved Loading Manual.

1.5.8 The scantlings of structural items may be determined by direct calculation.

1.5.9 The additional requirements for bulk carriers for the alternate carriage of oil cargo and dry bulk cargo are given in Ch 9,11. When complying with the requirements of this Chapter, such ships may be excluded from all requirements and notations pertaining to vessels with length, L, greater than or equal to 150 m. The requirements of 1.5.5 are however to be complied with.

1.6 Information required for CSR bulk carriers

1.6.1 In addition to the plans and documents required by the CSR the following are to be submitted:

- Ice strengthening.
- Freeboard plan or equivalent showing freeboards and items relative to the conditions of assignment.
- In addition the supporting calculations given in Pt 3, Ch 1,5.2.3 are to be submitted.

1.7 Information required for non-CSR bulk carriers

1.7.1 In addition to the information and plans required by Pt 3, Ch 1,5, the following are to be submitted:

- Cargo loadings on decks, hatchways and inner bottom if these are to be in excess of Rule, *see* Pt 3, Ch 3,5.
- The maximum pressure head in service on tanks, also details of any double bottom tanks interconnected with hopper, and topside tanks.
- Details of the proposed depths of any partial fillings where water ballast or liquid cargo is intended to be carried in the holds.
- Details of loading arrangements where combinations of empty and loaded holds are envisaged, and where it is the intention to load fully any two adjoining holds with adjacent holds empty in sea-going or short voyage conditions.

1.7.2 Additional information required for bulk carriers of length, L, 150 m or above:

- The bulk cargo density to be used in the design homogeneous loading condition at scantling draught with all holds, including hatchways, being 100 per cent full.
- The maximum bulk cargo density the ship is designed to carry.
- The maximum bulk cargo weight to be carried in each hold.
- Tables or curves indicating the change of cargo hold volume as a function of height above moulded baseline.

1.8 Symbols and definitions

1.8.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated: L, B, D, T as defined in Pt 3, Ch 1,6

k_L, k = higher tensile steel factor, *see* Pt 3, Ch 2,1
l = overall length of stiffening member, in metres, *see* Pt 3, Ch 3,3
l_e = effective length of stiffening member, in metres, *see* Pt 3, Ch 3,3
s = spacing of secondary stiffeners, in mm
t = thickness of plating, in mm
C = stowage rate, in m^3/tonne, as defined in Pt 3, Ch 3,5
I = inertia of stiffening member, in cm^4, *see* Pt 3, Ch 3,3
M_H = the actual cargo mass in a cargo hold corresponding to a homogenously loaded condition at maximum draught
M_{Full} = the cargo mass in a cargo hold corresponding to cargo with virtual density (homogenous mass/hold cubic capacity, minimum 1,0 tonne/m^3) filled to the top of the hatch coaming. M_{Full} is in no case to be less than M_H
M_{HD} = the maximum cargo mass allowed to be carried in a cargo hold according to design Loading conditions with specified holds empty at maximum draught
R = $\sin\theta$
S = spacing, or mean spacing, of primary members, in metres

Z = section modulus of stiffening member, in cm^3, *see* Pt 3, Ch 3,3
ρ = relative density (specific gravity) of liquid carried in a tank, and is not to be taken less than 1,025
θ = roll angle, in degrees

$$\sin\theta = \left(0{,}45 + 0{,}1\,\frac{L}{B}\right)\left(0{,}54 - \frac{L}{1270}\right)$$

Section 2 Materials and protection

2.1 Materials and grades of steel

2.1.1 Materials and grades of steel are to comply with the requirements of Pt 3, Ch 2.

2.2 Protection of steelwork

2.2.1 For the protection of steelwork, in addition to the requirements specified in Ch 1,2 and Pt 3, Ch 2,3 the requirements of 2.2.2 are to be complied with.

2.2.2 All internal and external surfaces of hatch coamings and hatch covers, and all internal surfaces of the cargo holds, except where excluded below, are to have an efficient protective coating (epoxy coating or equivalent) applied in accordance with the manufacturer's recommendations. In the selection of coating, due consideration is to be given to the intended cargo conditions in service. Areas which may remain uncoated are:

(a) The inner bottom plating.
(b) The hopper tank sloping plating between the intersection with the inner bottom plating and a line approximately 300 mm below the toe of the side shell frame end brackets.

2.2.3 For the notation '**strengthened for regular discharge by heavy grabs**', *see* Pt 3, Ch 9,9.

Section 3 Longitudinal strength

3.1 General

3.1.1 Longitudinal strength calculations are to be made in accordance with the requirements given in Pt 3, Ch 4 and 1.5.6 and 1.5.7 where appropriate.

3.1.2 Longitudinal strength calculations for the flooded conditions defined in 3.2 to 3.4 are to be applied for bulk carriers which satisfy all of the following criteria:

- Single skin construction, or double skin construction where any part of the longitudinal bulkhead is located within B/5 or 11,5 m, whichever is less, inboard from the ship's side at right angles to the centreline at the assigned summer load line.
- Length, L, of 150 m or above.
- Intended for the carriage of cargoes having bulk densities of 1,0 tonne/m^3 or above.

3.2 Hull vertical bending stresses for flooded conditions

3.2.1 The maximum hull vertical bending stresses in the flooded condition at deck, σ_{Df}, and keel, σ_{Bf}, for use in Pt 3, Ch 4 are given by the following, using the appropriate combination of bending moments to give sagging and hogging stresses:

$$\sigma_{Df} = \frac{|M_{sf} + 0{,}8M_w| \times 10^{-3}}{Z_D} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

$$\sigma_{Bf} = \frac{|M_{sf} + 0{,}8M_w| \times 10^{-3}}{Z_B} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

where
M_{sf} = maximum still water bending moment in the flooded condition, in kN m (tonne-f m), at the section under consideration, *see* 3.4
M_w = design hull vertical wave bending moment, in kN m (tonne-f m), as defined in Pt 3, Ch 4,5 at the section under consideration
Z_D, Z_B = actual hull section moduli, in m^3, at strength deck and keel respectively, at the section under consideration.

3.2.2 The maximum values of σ_{Df} and σ_{Bf} are to be used in Pt 3, Ch 4.

3.3 Shear stresses for flooded conditions

3.3.1 The shear stress, τ_{Af}, in the flooded condition to be used in Pt 3, Ch 4,6, is to be taken as:

$$\tau_{Af} = 100Az\,\frac{|Q_{sf}| + |0{,}8Q_w|}{I\,\delta_i} \quad \text{N/mm}^2$$

$$\left(\tau_{Af} = 10{,}2Az\,\frac{|Q_{sf}| + |0{,}8Q_w|}{I\,\delta_i} \quad \text{kgf/mm}^2\right)$$

where
Az = the first moment, in cm^3, about the neutral axis, of the area of the effective longitudinal members between the vertical level under consideration and the vertical extremity of the effective longitudinal members, taken at the section under consideration
Q_{sf} = maximum hull still water shear force, in kN (tonne-f), in the flooded condition at the section under consideration
Q_w = design hull wave shear force, in kN (tonne-f), as defined in Pt 3, Ch 4,6.3 at the section under consideration
I = moment of inertia of the hull about the horizontal neutral axis, in cm^4, at the longitudinal section under consideration
δ_i = as defined in Pt 3, Ch 4,6.5.

3.4 Flooded conditions

3.4.1 For the relevant loading conditions specified in Pt 3, Ch 4,5.3 and 5.4, each cargo hold is to be considered individually flooded up to the equilibrium waterline, except that cargo holds of double skin construction of not less than 1000 mm breadth at any location within the hold length, measured perpendicular to the side shell need not be considered flooded. The shear forces and still water bending moments are to be calculated for the most severe flooded conditions which will significantly load the ship's structure. Harbour conditions, docking conditions afloat, loading and unloading transitory conditions in port and loading conditions encountered during ballast water exchange need not be considered.

3.4.2 In calculating the weight of ingressed water into the cargo hold under consideration, the permeabilities and bulk densities given in Table 7.3.1 are to be used.

Table 7.3.1 Permeability and bulk density factors

Hold condition	Permeability (*see* Note 1)	Bulk density (tonne/m^3)
Empty cargo space	0,95	—
Volume left in loaded cargo spaces above any cargo	0,95	—
Iron ore cargo	0,3 (*see* Note 2)	3,0
Cement	0,3 (*see* Note 2)	1,3

NOTES
1. Bulk cargo permeability is defined as the ratio of the voids within the cargo mass to the volume occupied by the cargo.
2. More specific information relating to the bulk cargo may be used where available, but permeabilities are not to be less than those given above.
3. For packed cargo, the actual density of the cargo is to be used with a permeability of zero.

3.4.3 In calculating the strength of the ship's structure in the flooded condition it is to be assumed that the ship's structure will remain fully effective in resisting the applied loads.

■ *Section 4* Deck structure

4.1 General

4.1.1 Longitudinal framing is, in general, to be adopted outside line of openings. The arrangement of structure between hatches is to be such as to ensure continuity of the main deck structure to resist athwartship forces, and transverse stiffening is to be arranged. For and aft knuckles in cross deck strip plating between hatches should be arranged close to longitudinal girders or supported by brackets.

4.1.2 In the case of large bulk carriers with narrow deck strips between hatchways, or where it is the intention to load any two adjoining holds fully with adjacent holds empty for a sea-going condition or for bulk carriers to be classed 'any hold may be empty', the cross deck scantlings will be specially considered.

4.1.3 The requirements of Ch 1,4 are to be applied, together with the requirements of this Section.

4.1.4 The *ShipRight FDA Procedure, Structural Detail Design Guide* (SDDG), indicates recommended structural design configurations in critical areas, for the deck structure outside the line of openings and between hatches.

4.2 Deck plating

4.2.1 Where the difference between the thickness of plating inside and outside the line of main hatches exceeds 12 mm, a transitional plate of thickness equivalent to the mean of the adjacent plate thicknesses is to be fitted. The plate thickness outside the line of hatches is to be continued inboard between hatches beyond the end of the hatch corner curvature, to ensure that the chamfered plating is clear of the corner tangent point.

4.3 Main cargo hatchway openings

4.3.1 The following requirements apply to bulk carriers with vertically corrugated transverse bulkheads in cargo holds having one or more of the following characteristics:

(a) $B \geq 40$ m

(b) $\dfrac{b}{w} \geq 2,2$

b = breadth of deck opening
w = width of cross deck strip
B = moulded breadth of ship

(c) A structural arrangement where the hatch side coaming and deck opening are arranged inboard of the topside tank.

(d) All bulk carriers to be classed 100A1 bulk carrier, strengthened for heavy cargoes, any hold may be empty, ESP.

4.3.2 The corners of main cargo hatchways in the strength deck are to be rounded with a radius not less than $^1/_{20}$ of the breadth of the opening, with a maximum radius of 1000 mm.

4.3.3 Insert plates are to be fitted at the corners having a thickness not less than 25 per cent greater than the adjacent deck thickness outside the line of openings, with a minimum increase of 5 mm, *see also* 4.3.4. The corner inserts are to be extended transversely into the cross deck plating for a minimum distance equal to 0,075b, where b, is the breadth of deck opening.

4.3.4 For the extreme corners of the end hatchways of the cargo region furthest from amidships the thickness of the corner insert plates is to be not less than 60 per cent greater than the adjacent deck thickness outside the line of openings.

4.4 Deck supporting structure

4.4.1 For the scantlings of deck longitudinals and transverses in way of topside tanks, *see* 7.4 and 7.5, respectively.

■ *Section 5* Shell envelope plating

5.1 General

5.1.1 Longitudinal framing is, in general, to be adopted at the bottom, but special consideration will be given to proposals for transverse framing in this region. The side shell may be longitudinally or transversely framed.

5.1.2 The requirements of Ch 1,5 are to be applied together with the requirements of this Section.

5.2 Bottom shell

5.2.1 The thickness of the bottom shell plating below loaded holds may be required to be increased for local strength considerations.

5.3 Side shell

5.3.1 The thickness of the side shell plating may be required to be increased for shear forces to satisfy the requirements of 3.2.1.

5.3.2 The thickness of the side shell plating located between the hopper and topside tanks of single skin bulk carriers is to be not less than:

$t = \sqrt{L}$ mm

■ *Section 6* Shell envelope framing

6.1 Longitudinal stiffening

6.1.1 Side frames of all single skin bulk carriers with a hopper are to comply with 6.2 and 6.3.

6.1.2 Side frames and end brackets of all double skin bulk carriers are to comply with Ch 1,6.

6.1.3 Side frames and end brackets of other structural configurations will be specially considered.

6.1.4 The end connections for the longitudinal stiffening are to satisfy the requirements of Pt 3, Ch 10,3, *see also* 7.6.1 and 9.7.1.

6.1.5 The arrangements at the intersections of continuous secondary and primary members are to satisfy the requirements of Pt 3, Ch 10,5.2 and Ch 1,6.2.

6.2 Transverse stiffening

6.2.1 The modulus and inertia of main and topside tank frames in the midship region are to comply with the requirements given in Table 7.6.1. Arrangements of main frames in holds in association with web frames are not recommended in view of the vulnerability to cargo handling damage. Where such web frames are proposed the arrangements and scantlings will be specially considered.

6.2.2 Main frames in the cargo and ballast holds are to have a web thickness not less than:

- In general:

  $t_{min} = 7 + 0{,}03L$ mm or 13 mm whichever is the lesser

- In the foremost hold:

  $t_{min} = 1{,}15\,(7 + 0{,}03L)$ mm or 15 mm whichever is the lesser

where

L is the Rule length, in metres.

6.2.3 The web depth to thickness ratio of the frames is not to be greater than:

$60\sqrt{k}$, for symmetric sections

$50\sqrt{k}$, for asymmetric sections

The breadth to thickness ratio of the flange outstand is not to be greater than:

$10\sqrt{k}$.

6.2.4 The upper and lower end brackets of the main frames in the cargo and ballast holds are to satisfy the requirements of 6.2.5 to 6.2.14 inclusive, based on the mild steel section modulus Z in cm^3, derived from Table 7.6.1, or the equivalent mild steel section modulus for higher tensile steel frames.

6.2.5 The lengths of the arms of the brackets, measured as shown in Fig. 7.6.1, are not to be less than:

(a) Frame connection to hopper tank

Athwartship arm:

Dry cargo hold $l_a = 32{,}43\sqrt{Z}$ mm

Ballast hold $l_a = 32{,}43\left(\sqrt{Z} - 7{,}5\right)$ mm

Vertical arm:

Dry cargo hold $l_v = 27{,}6\sqrt{Z}$ mm

Ballast hold $l_v = 27{,}6\left(\sqrt{Z} - 9{,}0\right)$ mm

(b) Frame connection to topside tank

Athwartship arm:

Dry cargo hold $l_a = 30{,}0\sqrt{Z}$ mm

Ballast hold $l_a = 30{,}0\left(\sqrt{Z} - 9{,}0\right)$ mm

Table 7.6.1 Shell framing

Location	Modulus, in cm^3	Inertia, in cm^4
(1) Main frames in dry cargo holds	$Z = 3{,}50skh_{T1}H^2 \times 10^{-3}$	$I = \frac{3{,}2}{k}HZ$
(2) Main frames in cargo holds used for water ballast	The greater of the following: (a) Z = 1,15 x modulus given in (1) (b) $Z = 6{,}7skh_4 H^2 \times 10^{-3}$	$I = \frac{3{,}2}{k}HZ$
(3) Transverse frames in topside wing tanks	The greater of the following: (a) 1,15 x Z as given in location (1) of Table 1.6.2 in Chapter 1 (b) As required by 7.3.1 for the sloped bulkhead stiffeners	$I = \frac{3{,}2}{k}HZ$

Symbols

D, T, s, k as defined in 1.7.1

h_{T1} = head, in metres, at middle of H

$= C_w\left(1 - \frac{h_6}{D-T}\right)F_\lambda$, in metres, for frames where the mid-length of frame is above the summer load waterline, $\left(1 - \frac{h_6}{D-T}\right)$ is not to be taken less than 0,7

$= \left(h_6 + C_w\left(1 - \frac{h_6}{2T}\right)\right)F_\lambda$, in metres, where the mid-length of frame is below the summer load waterline

h_4 = head, in metres, measured from the middle of H to the deck at side, or half the distance from the middle of H to the top of the overflow, whichever is greater

h_6 = vertical distance in metres, from the summer load waterline at draught T to the mid-length of H

C_w = a wave head, in metres
$= 7{,}71 \times 10^{-2}Le^{-0{,}0044L}$
where e = base of natural logarithms 2,7183

F_λ = 1,0 for $L \le 200$ m
$= (1{,}0 + 0{,}0023(L - 200))$ for $L > 200$ m

H = length overall of frame, in metres, but is to be taken not less than 2,5 m

Vertical arm:

Dry cargo hold $l_v = 26{,}85\sqrt{Z}$ mm

Ballast hold $l_v = 26{,}85\left(\sqrt{Z} - 11{,}0\right)$ mm

In no case are the bracket arm lengths to be taken less than 0,125H, where H is as defined in Table 7.6.1.

6.2.6 The section modulus of the frame and bracket or integral bracket, and associated shell plating at the location marked Z_a in Fig. 7.6.1 is to be not less than 2,0Z.

In addition, the minimum depth of the frame and bracket or integral bracket at the location indicated in Fig. 7.6.1 is to be not less than 1,5d.

6.2.7 The upper and lower integral or separate brackets are to have a web thickness not less than the as built web thickness of the side frame. In addition, the lower bracket thickness is to be not less than:

$t = t_{min} + 2$ mm, where t_{min} is derived from 6.2.2

The toes of the brackets are to be designed to avoid notch effects by making the upper and lower toes concave or otherwise tapering them off, *see also* Pt 3, Ch 10,5.1.7.

6.2.8 Except as indicated in 6.2.9, frames are to be fabricated symmetrical sections with integral upper and lower brackets. The side frame face plate is to be curved (not knuckled) at the connection with the end brackets. The radius of curvature, r, is to be not less than:

$$r = \frac{0{,}4b_f^{\,2}}{t_f} \text{ mm}$$

where

b_f = breadth of the bracket face plate, in mm
t_f = thickness of the bracket face plate, in mm

The brackets are to be arranged with soft toes and the frame section face bar tapered symmetrically to the toes with a taper rate not exceeding 1 in 3. Where the free edge of the bracket is hollowed out, it is to be stiffened or increased in size to ensure that the section modulus of the bracket through the throat is not less than that of the required straight edged bracket.

6.2.9 In ships of length, L, less than 190 m, mild steel fabricated frames may be asymmetric and fitted with separate brackets. Brackets are to be arranged with soft toes. The free edges of the brackets are to be stiffened as follows:

(a) Where a flange is fitted, its breadth, b_f, is to be not less than:

$$b_f = 40\left(1 + \frac{Z}{1000}\right) \text{ mm}$$

or 50 mm, whichever is the greater
The flange is to be tapered at the ends with a taper rate not exceeding 1 in 3.

(b) Where the edge is stiffened by a welded face flat, the cross-sectional area of the face flat is to be not less than:
(i) $0{,}009b_f\,t$ cm^2 for offset edge stiffening
(ii) $0{,}014b_f\,t$ cm^2 for symmetrically placed stiffening
where
t = web thickness of bracket, in mm
The face plate is to be tapered at the ends with a taper rate not exceeding 1 in 3.

6.2.10 For mild steel construction with separate brackets where the frames are lapped on to the bracket, the length of the overlap is to be adequate to provide for the required area of welding to achieve equivalent strength.

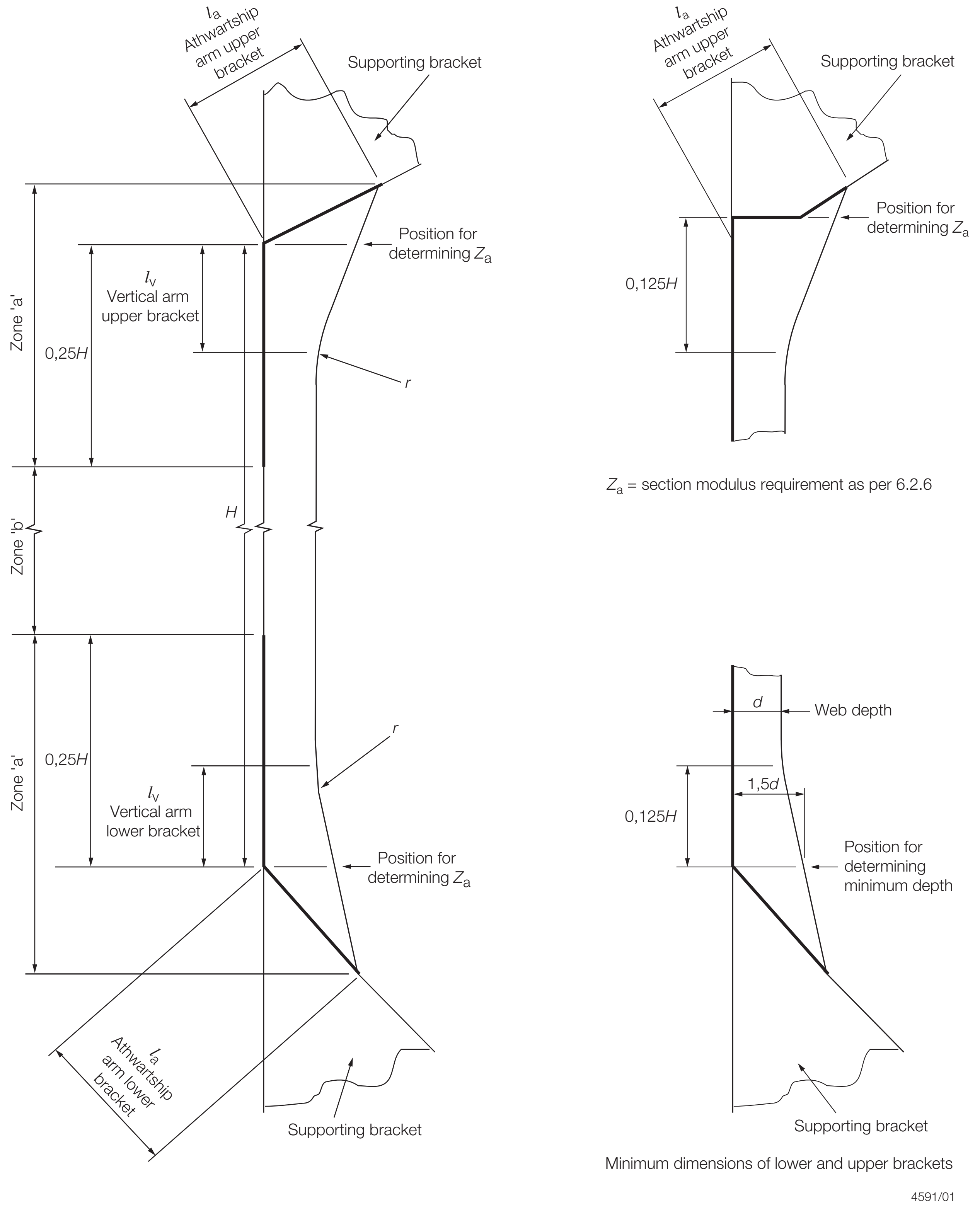


Fig. 7.6.1 Diagrammatic arrangement of end brackets

6.2.11 Double continuous welding is to be adopted for the connections of frames and brackets to side shell, hopper and topside tank plating and web to face plates. For this purpose, the following weld factors are to be adopted:

- 0,44 in Zone 'a' and
- 0,40 in Zone 'b', *see* Fig. 7.6.1.

Where the hull form is such that an effective fillet weld cannot be made, edge preparation of the web of the frame and bracket may be required, in order to ensure the required efficiency of the weld connection.

6.2.12 Continuity of the frames is to be maintained by supporting brackets, *see* Fig. 7.6.2, in the topside and hopper tanks. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint. For this purpose, in the hopper and topside tanks, the thickness of the supporting brackets (which must align with the hold main frame brackets) is to be not less than the following:

(a) Lower brackets (In hopper tank):

$t = t_{min} + 0{,}5$ mm, where t_{min} is derived from 6.2.2, or

$t = 9{,}0$ mm

whichever is the greater.

(b) Upper brackets (in topside tank):

$t = t_{min}$, where t_{min} is derived from 6.2.2, or

$t = 9{,}0$ mm

whichever is the greater.

The size and arrangement of stiffening of the supporting brackets will be specially considered. Where the toe of the hold frame bracket is situated on or in close proximity to the first longitudinal from the shell of the hopper or topside tank sloped bulkheads, the supporting brackets are to be extended to the next longitudinal. This extension is to be achieved by enlarging the supporting bracket or by fitting an intercostal flat bar stiffener the same depth as the longitudinal and connected to the webs of the longitudinals.

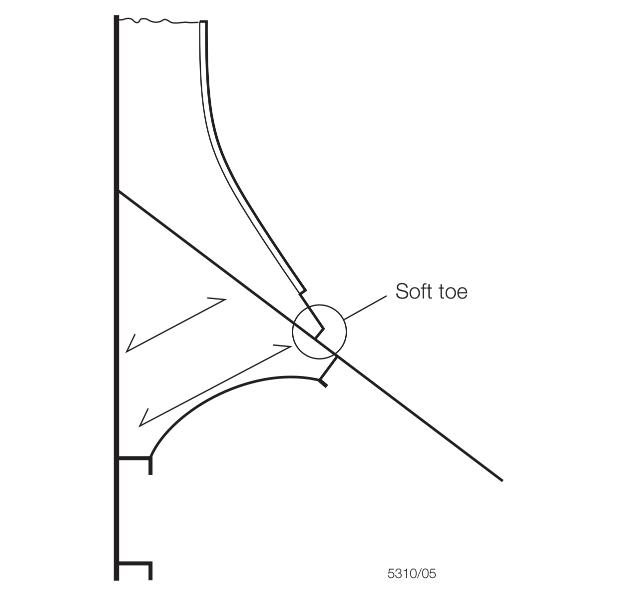


Fig. 7.6.2
Supporting brackets in topside and hopper tanks

6.2.13 The requirements are to be maintained throughout the cargo hold region. However, in the forward and aft cargo holds where the shape becomes finer because of the ship form, increased requirements may be necessary and each case will be specially considered.

6.2.14 In way of the foremost hold, side frames of asymmetric section are to be effectively supported by intercostal brackets, *see* Fig. 7.6.3.

6.2.15 The hold side shell frame adjacent to the collision bulkhead is to be suitably strengthened. As an alternative, at least two supporting structures are to be fitted which align with the forepeak stringers or flats, *see* Fig. 7.6.4. The supporting structures are to have adequate cross-sectional shear resisting area at their connections to the hold frame.

6.2.16 Detail design guidelines for connection of side shell frames to hopper and topside tank plating are shown in the *ShipRight FDA Procedure, Structural Detail Design Guide* (SDDG).

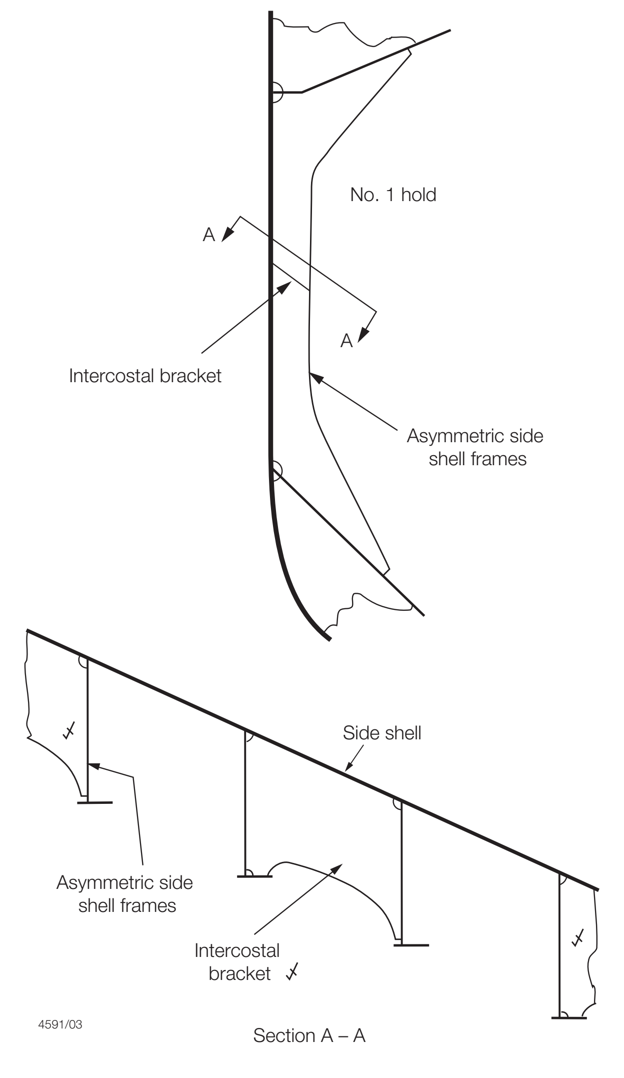


Fig. 7.6.3
Typical arrangement of intercostal brackets supporting asymmetric side shell frames in No. 1 hold

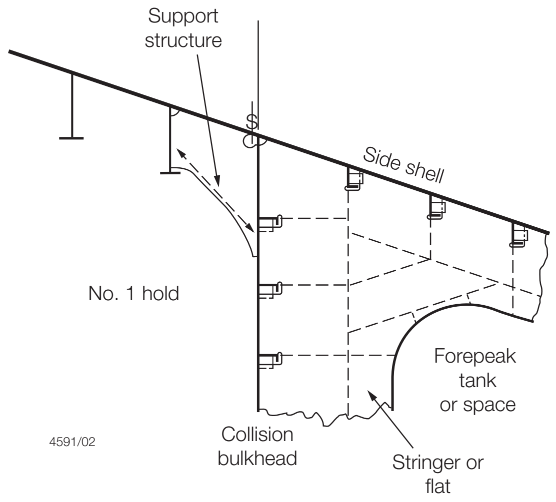


Fig. 7.6.4
Hold frame supporting structures at fore end of No. 1 cargo hold

6.3 Primary supporting structure

6.3.1 For the requirements for primary supporting structure, *see* 7.5 and 9.6.

Section 7
Topside tank structure

7.1 General

7.1.1 Requirements are given in this Section for longitudinal or transverse framing in the topside tank, but, in general, the deck is to be longitudinally framed. The sloped bulkhead is to be of plane construction with the associated stiffening arranged inside or outside the tank.

7.1.2 The buckling requirements of Pt 3, Ch 4,7 are to be satisfied.

7.1.3 Recommended examples of structural design configurations around the transverse ring web of the topside tank can be seen in the *ShipRight FDA Procedure, Structural Detail Design Guide* (SDDG).

7.2 Bulkhead plating

7.2.1 The thickness of the sloped bulkhead, tank end bulkhead, and diaphragm, if fitted, is to be the greater of the following:

(a) For watertight bulkheads, the thickness, t, as derived from Table 1.9.1 in Chapter 1 for a deep tank bulkhead using a head, h_4, in metres determined as follows:

$h_4 = h_o \cos\theta + Rb_1$ or
= the greater of the distance from a point one-third of the height of the plate above its lower edge to the top of the tank, or half the distance to the top of the overflow

whichever is the greater, or

(b) t = 7,5 mm

In no case, however, is the thickness of the sloped bulkhead and diaphragm to be taken less than:

$t = 0{,}012s$ mm, or

$$t = 0{,}012s\sqrt{\frac{F_D}{k_D}}\ \text{mm}$$

whichever is the greater

where

k_D = the higher tensile steel factor equal to k_L value for deck material
F_D = as defined in Pt 3, Ch 4,5.7
R = as defined in 1.8.1
h_o = the vertical distance, in metres, from a point one third of the height of the plate from its lower edge to the highest point of the tank excluding hatchway
b_1 = the larger horizontal distance, in metres, from the tank corner at top of tank either side to point of plate under consideration.

7.2.2 The thickness of the top strake of the sloped bulkhead, including the vertical plate attached to deck, may be required to be increased to form an effective girder below the deck. In general, this plate is to be not less in thickness than 60 per cent of the thickness of the deck plate outside the line of openings nor less than:

(a) $t = 0{,}018s$ mm, or

(b) $$t = 0{,}018s\sqrt{\frac{F_D}{k_D}}\ \text{mm}$$

whichever is the greater.

7.2.3 The thickness of the transverse wash bulkhead, where fitted, is to be not less than:

$t = 0{,}012s$ mm or 7,5 mm

whichever is the greater.

7.3 Bulkhead stiffeners

7.3.1 The section modulus of longitudinal or transverse stiffeners on the sloped bulkhead or watertight diaphragms, if fitted, is to be not less than:

$Z = 0{,}01skh_4 l_e^2$ cm^3

where

$h_4 = h_o \cos\theta + Rb_1$
= the greater of the distance, in metres, from the middle of the effective length to the top of the tank, or half the distance to the top of the overflow, or
= 1,5 m
whichever is the greatest
R = as defined in 1.7.1
h_o = the vertical distance, in metres, from the mid-point of span of the stiffener to the highest point of the tank excluding hatchway
b_1 = the larger horizontal distance, in metres, from the tank corner at top of tank, either side to midpoint of span.

7.3.2 Where the bulkhead stiffening is fitted on the hold side of the sloped bulkhead, suitable arrangements are to be made to prevent tripping.

7.3.3 The scantlings of stiffeners on tank end bulkheads are to be not less than those given in Table 1.9.1 in Chapter 1 for deep tanks, using h as defined in 7.3.1.

7.3.4 The section modulus of stiffeners of non-watertight fore and aft diaphragms, or transverse wash bulkheads is to be not less than 50 per cent of that required by 7.3.3. The stiffeners are to be bracketed at both ends.

7.3.5 Tank end bulkheads are generally to be in line with the main hold bulkheads.

7.4 Shell and deck structure

7.4.1 The scantlings of shell and deck longitudinals are to comply with 7.3.1. The scantlings must also satisfy the requirements of Chapter 1, *see also* 7.6.1.

7.4.2 The scantlings of side shell frames are to comply with 6.2.

7.5 Primary supporting structure

7.5.1 The section modulus and inertia of deck, shell and bulkhead transverses or stringers are to be not less than:

$$Z = 7{,}5\, k\, S\, h\, l_e^2 \quad \text{cm}^3$$

$$I = \frac{2{,}5}{k}\, l_e\, Z \quad \text{cm}^4$$

using h as defined in 7.3.1. The scantlings of shell and deck members must also satisfy the requirements of Chapter 1 for dry cargo holds.

7.5.2 Primary transverse members are, in general, to be spaced not more than 3,8 m apart where the length, L, is 100 m or less, and (0,006L + 3,2) m apart for lengths greater than 100 m.

7.5.3 Transverses are to be arranged in line with the primary structure at ends of hatchways, or equivalent scarfing arranged. Where the sloped bulkhead or side shell is transversely framed, arrangements are to be made to ensure effective continuity at the ends of the deck transverse.

7.5.4 Where non-watertight transverse diaphragms are arranged instead of open transverses, the thickness of plating is to be in accordance with 7.2.3. The diaphragms are to be efficiently stiffened.

7.6 Structural details

7.6.1 Bracket/diaphragm connections at the bottom of the topside tank are to be of sufficient size and thickness to provide effective rigidity, and care is to be taken to ensure alignment with brackets at the heads of the side frames in the holds, *see also* 6.2.12. The shell and sloped bulkhead longitudinals supporting the diaphragms are to be derived using the span taken between transverses.

7.6.2 For ships where $L \geq 300$ m a fore and aft diaphragm extending vertically from the deck to the sloping plating of the topside tank is to be arranged at about the half-width of the tank.

7.6.3 Where longitudinal framing is fitted to the side shell, a bracket may be required in way of a rounded gunwale, approximately halfway between transverses and extending to the adjacent shell and deck longitudinal.

■ *Section 8* Double bottom structure

8.1 General

8.1.1 The double bottom is, in general, to be longitudinally framed, but special consideration will be given to proposals for a transverse framing system.

8.1.2 The requirements of Ch 1,8 are to be applied, together with the requirements of this Section, *see also* 2.2.3.

8.1.3 Where the double bottom tanks are interconnected with double skin side tanks or combined hopper and top side tanks, the double bottom scantlings are also to satisfy the requirements of Table 7.8.1(3)(c), (3)(d), (4)(c) and (4)(d) for ballast holds, and (3)(c) and (4)(c) in way of dry cargo holds, *see also* Ch 1,6.2.

8.1.4 The requirements given in 8.8 are to be applied to bulk carriers which satisfy the following criteria:

- Single skin construction, or double skin construction where any part of the longitudinal bulkhead is located within B/5 or 11,5 m, whichever is less, inboard from the ship's side at right angles to the centreline at the assigned summer load line.
- Length, L, of 150 m or above.
- Intended for the carriage of cargoes having bulk densities of 1,0 tonne/m^3 or above.

8.1.5 For all bulk carriers where bulk cargoes are discharged by grabs the maximum recommended unladen weight of the grab corresponding to the approved inner bottom plating thickness is to be calculated using the following formulae:

$$P = \left(\frac{s}{k}\right)^2 \frac{10^d}{1{,}775} \quad \text{tonnes}$$

where

$$d = \frac{40{,}875\,(t - 1{,}5)\sqrt{k} + 344{,}5}{s} - 5{,}7633$$

P = unladen grab weight, in tonnes
s = spacing of inner bottom longitudinal, in mm
k = higher tensile steel factor as defined in 1.7.1
t = thickness of inner bottom plating, in mm

The maximum recommended unladen weight of the grab rounded up to the next tonne above, is to be recorded in the Loading Manual (*see also* Pt 3, Ch 4,8.2.4(e)) and does not preclude the use of heavier grabs. It is intended as an indication to the Builders, Owners and operators of the

Table 7.8.1 Strengthening for heavy cargo requirements

<table>
<tr><th>Symbols</th><th>Item</th><th>Requirement</th></tr>
<tr><td rowspan="4">L, l_e, D, T, s, S, k, Z, and t as defined in 1.8.1
C_1 = a factor varying from 1,0 at $\frac{D}{2}$ to $\frac{75}{225 - 150F_B}$ at base line of ship

C = stowage rate, in m^3/tonne, and is defined as the volume of the hold excluding the volume contained within the depth of the cargo hatchway divided by the weight of cargo stowed in the hold. The value is not to be taken greater than 0,865

F_B as defined in Pt 3, Ch 4,5.7

R and θ as defined in 1.8.1

H = height from tank top, at position under consideration, to deck at side amidships, in metres

Y_1 = distance from $\frac{D}{2}$ to tank top, in metres

h_o = for plating and stiffeners the vertical distance, in metres, from the inner bottom to the highest point of the tank excluding hatchway

b_1 = the larger horizontal distance, in metres, from the tank corner at top of tank either side to the point of plate or stiffener under consideration</td><td>(1) Double bottom floors</td><td>The spacing of floors, generally, is not to exceed 2,5 m. Scantlings are to comply with the requirements of Ch 1,8.5</td></tr>
<tr><td>(2) Double bottom side girders</td><td>The spacing of side girders, generally is not to exceed 3,7 m. Scantlings are to comply with requirements of Ch 1,8.3</td></tr>
<tr><td>(3) Inner bottom plating, see Note 3</td><td>The thickness of the inner bottom plating in the holds is to be not less than required by the greatest of the following:
(a) $t = 0{,}00136\,(s + 660)\,\sqrt[4]{k^2LT} + 5$ mm, or
(b) $t = 0{,}00455s\sqrt{\frac{Hk}{C}}$ mm, or
(c) Where the double bottom tanks are interconnected with double skin side tanks or combined hopper and topside tanks the scantlings are also to satisfy the requirements for deep tanks in Table 1.9.1(b) in Chapter 1, with the load head $h_4 = h_o \cos\theta + Rb_1$ m
(d) In way of ballast holds the scantlings are also to satisfy the requirements for deep tanks in Table 1.9.1 in Chapter 1, with the load head h_4, in metres, measured to the deck at centre, but see also Pt 3, Ch 9,9 if protection against heavy grabs is desired</td></tr>
<tr><td>(4) Inner bottom longitudinals, see Notes 1 and 2</td><td>The section modulus of inner bottom longitudinals is to be not less than the greatest of the following:
(a) Z = 85 per cent of the Rule value for bottom longitudinals as given in Table 1.6.1(b) in Chapter 1, or
(b) $Z = \dfrac{0{,}0083s\,l_e^2\,HC_1\,k}{\left(1 - 0{,}233\dfrac{Y_1}{D}\right)C}$ cm^3, or
(c) Where the double bottom tanks are interconnected with double skin side tanks or combined hopper and topside tanks $Z = 0{,}0073sk\,h_4\,l_e^2$ cm^3 where $h_4 = h_o \cos\theta + Rb_1$ m
Z is not to be less than the requirements for deep tanks in Table 1.9.1 in Chapter 1, with the load head h_4, in metres, measured to the highest point of the topside tank, or side tank, or
(d) In way of ballast holds the section modulus of the longitudinals is to be not less than required for deep tanks in Table 1.9.1 in Chapter 1, with the load head h_4, in metres measured to the deck at centre</td></tr>
<tr><td colspan="3">NOTES
1. If plate girders are fitted alternately with built or rolled sections, the section modulus as given in (4)(b) may be reduced by 10 per cent.
2. Consideration will be given to the fitting of struts in way of double bottom tanks in ships with homogeneous loading. The arrangement and scantlings are, in general, to be confirmed by direct calculation.
3. See also 8.1.5 for the maximum recommended unladen weight of the grab corresponding to the approved inner bottom plating thickness.</td></tr>
</table>

increased risk of local damage and the possibility of accelerated diminution of the plating thickness if grabs heavier than this are used regularly to discharge cargo.

8.1.6 Detail design guidelines for stiffeners connecting inner bottom and bottom longitudinals are shown in the *ShipRight FDA Procedure, Structural Detail Design Guide* (SDDG).

8.2 Carriage of heavy cargoes

8.2.1 When the notation 'strengthened for heavy cargoes' is to be assigned, the requirements of Table 7.8.1 are to be complied with.

8.3 Carriage of heavy cargoes with specified or alternate holds empty

8.3.1 For ships strengthened for heavy cargoes and having a class notation permitting specified or alternate holds to be empty, the requirements of 8.2.1 are to be complied with. In addition the scantlings and arrangements of the primary structure are to be confirmed by additional calculations, *see* 11.1.

8.4 Ships to be classed '100A1 bulk carrier, strengthened for heavy cargoes, any hold may be empty, ESP'

8.4.1 For ships to be classed **'100A1 bulk carrier, strengthened for heavy cargoes, any hold may be empty, ESP'**, the requirements of 8.2.1 and 8.3.1 are to be complied with. In addition the value for *C*, the stowage rate in m^3/tonne, as defined in Table 7.8.1, is not to be taken greater than 0,60 for each hold.

8.5 Ballast ducts

8.5.1 Where ballast ducts are arranged in lieu of suction and/or filling pipes, the scantlings will be approved as suitable for a specified equivalent static head of water. This head must not be exceeded in service, and details of methods to ensure this are to be submitted. The continuity of the floors is to be maintained in way of the ducts.

8.6 Structural details in way of double bottom tank and hopper tank knuckle

8.6.1 In all dry holds where the double bottom tank and hopper tank knuckle is of radiused construction and the floor spacing is 2,5 m or greater brackets as shown in Fig. 7.8.1 are to be arranged mid-length between floors in way of the intersection. The brackets are to be attached to the adjacent inner bottom and hopper longitudinals. The thickness of the brackets is to be in accordance with Ch 1,8.5.3 but need not exceed 15 mm. This requirement does not apply where the double bottom tank and hopper tank knuckle is of welded construction.

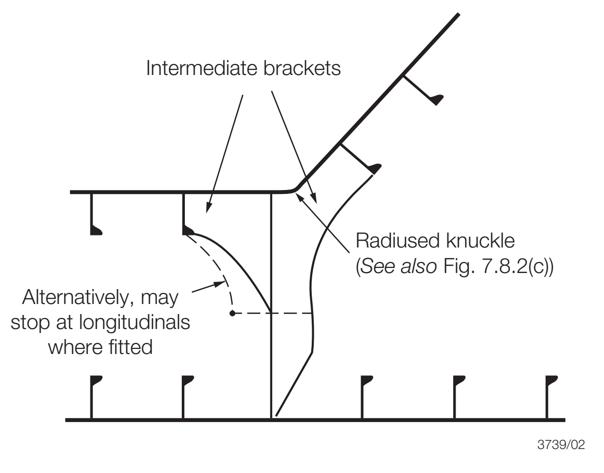


Fig. 7.8.1 Intermediate brackets at knuckle

8.6.2 In way of floodable holds, two intermediate bracket arrangements, as shown in Fig. 7.8.1, are to be provided in all cases where the hopper to double bottom knuckle is radiused and are, in general, to be located at each frame space. Where the double bottom tank and hopper tank knuckle is of welded construction, a single intermediate bracket arrangement, as shown in Fig. 7.8.1, is to be provided only when the floor spacing is greater than 2,5 m.

8.6.3 The connections at the intersection are to be as follows:

(a) Where of welded construction the corner scallops in floors and transverses are to be omitted, or closed by welded collars where arranged for purposes of construction. In such cases to ensure satisfactory welding of the collars the radius of the scallops should not be less than 150 mm, *see* Fig. 7.8.2(a). Alternatively the scallop may be retained on the hopper tank side provided gusset plates are arranged in line with the inner bottom plating, *see* Fig. 7.8.2(b).

(b) Where of radiused construction the corner scallops are to be omitted, and full penetration welding arranged locally for the connection to the inner bottom plating. The centre of the flange is not to be greater than 70 mm from the side girder, *see* Fig. 7.8.2(c).

8.6.4 Detail design guidelines for the connection of hopper tank sloping plating to inner bottom plating are shown in the *ShipRight FDA Procedure, Structural Detail Design Guide* (SDDG).

8.7 Combined double bottom/hopper tank and topside tank

8.7.1 Where a double bottom/hopper tank is inter-connected with a topside tank the dimensions of the connecting trunks or pipes, and the air/overflow pipe(s) and the type of closing appliance are to comply with the requirements of Pt 5, Ch 13,10.10.

8.8 Allowable hold loading in the flooded condition

8.8.1 The requirements of this sub-Section are to be applied as defined in 8.1.4.

8.8.2 The maximum load which may be carried in each cargo hold in combination with flood water is to be determined for the most severe homogeneous, non-homogeneous and packed cargo conditions contained in the Loading Manual. The maximum density of cargo intended to be carried in each condition is to be used.

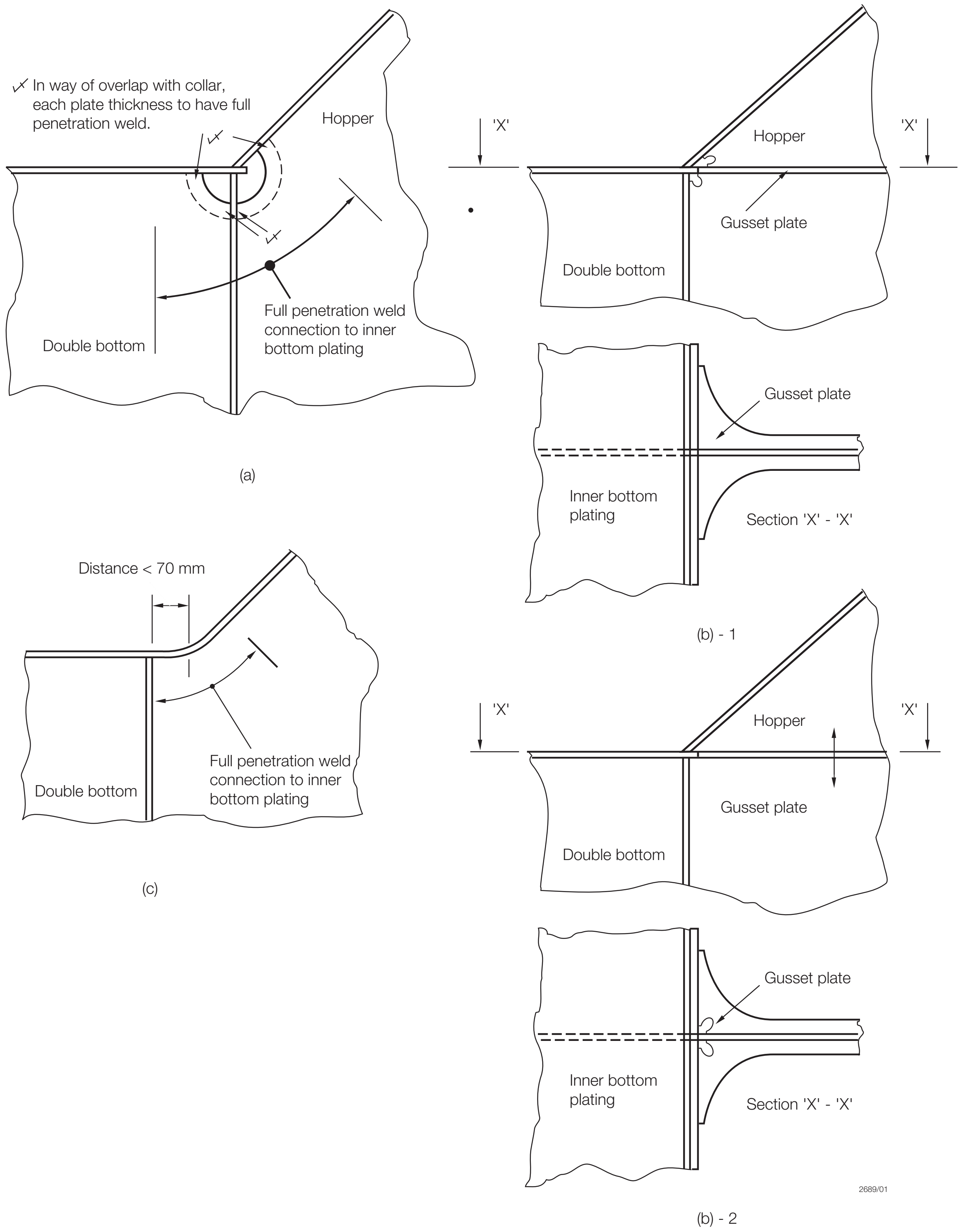


Fig. 7.8.2 Connection at intersection of double bottom and hopper

8.8.3 The ship is to be assumed immersed to the draught, T_F, in metres, in way of the flooded cargo hold under consideration. The flooding head, h_f, *see* Fig. 7.8.3, is to be taken as the distance, in metres, measured vertically with the ship in the upright position, from the inner bottom to position, d_f, in metres, from the base line given by:

(a) In general:
- (i) $d_f = D$ for the foremost hold
- (ii) $d_f = 0{,}9D$ for other holds

(b) For ships less than 50 000 tonnes deadweight with Type B freeboard:
- (i) $d_f = 0{,}95D$ for the foremost hold
- (ii) $d_f = 0{,}85D$ for other holds

where

D = distance, in metres, from the base line to the freeboard deck at side amidships.

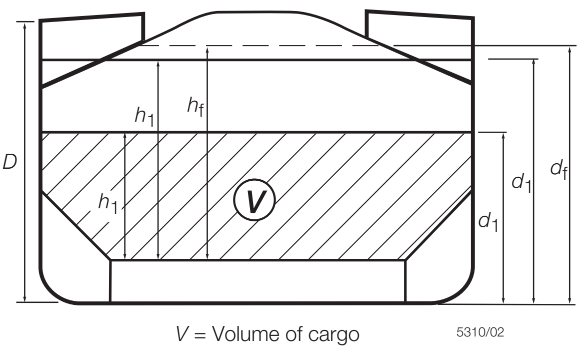


Fig. 7.8.3 Loading

8.8.4 For this application, the double bottom is defined as the structure bounded by the transverse bulkhead lower stools (or bulkhead plating if no lower stools are fitted) and the hopper sides. The floors and girders immediately in way of these structures are excluded.

8.8.5 The determination of shear strength required for the permissible load assessment in 8.8.9, is to be performed using the net plate thickness, t_{net}, for the floors and girders:

$t_{net} = t - t_c$

where

t = as built thickness, in mm

t_c = thickness deduction for corrosion, in mm, generally to be taken as 2,5 mm.

8.8.6 Shear capacity of the double bottom is defined as the sum of the shear strengths for:

(a) all the floors adjacent to both hoppers, less one half the strength of the floors adjacent to each lower stool (or transverse bulkhead if no lower stool is fitted), *see* Fig. 7.8.4, and

(b) all the girders adjacent to the lower stools (or transverse bulkheads if no lower stool is fitted).

Where a girder or floor terminates without direct attachment to the boundary stool or hopper side girder, its shear capacity is to include only that for the effectively connected end.

8.8.7 The shear strengths S_{f1}, of floors adjacent to hoppers, and S_{f2}, of floors in way of openings in bays nearest to the hoppers, are as follows:

$S_{f1} = 0{,}001\, A_f\, \tau_p/\eta_1$ kN (tonne-f)

$S_{f2} = 0{,}001\, A_{f,h}\, \tau_p/\eta_2$ kN (tonne-f)

where

A_f = net sectional area, in mm^2, of floor panel adjacent to hopper

$A_{f,h}$ = net sectional area, in mm^2, of floor panel in way of opening in the bay closest to hopper

η_1 = 1,10

η_2 = 1,20 generally
= 1,10 where appropriate reinforcement is fitted in way of the opening

σ_0 = specified minimum yield stress, in N/mm^2 (kgf/mm^2)

τ_p = permissible shear stress, to be taken equal to the lesser of:

$$\tau_0 = \frac{\sigma_0}{\sqrt{3}} \text{ N/mm}^2 \text{ (kgf/mm}^2\text{) and}$$

$$\tau_c = \frac{162\,\sigma_0^{0,6}}{\left(\dfrac{s_1}{t_{net}}\right)^{0,8}} \text{ N/mm}^2$$

$$\left(\tau_c = \frac{65\sigma_0^{0,6}}{\left(\dfrac{s_1}{t_{net}}\right)^{0,8}} \text{ kgf/mm}^2\right)$$

where

s_1 = spacing of stiffening members, in mm, for the panel under consideration

t_{net} = net thickness, in mm, of the panel under consideration

For floors adjacent to the stools (or bulkhead plating if no lower stools are fitted), τ_p may be taken as $\dfrac{\sigma_0}{\sqrt{3}}$ N/mm^2 (kgf/mm^2).

8.8.8 The shear strengths S_{g1}, of girders adjacent to transverse bulkhead lower stools (or transverse bulkheads if no lower stools are fitted), and S_{g2}, of girders in way of the largest openings in bays nearest to the lower stools (or transverse bulkheads if no lower stools are fitted), are as follows:

$S_{g1} = 0{,}001\, A_g\, \tau_p/\eta_1$ kN (tonne-f)

$S_{g2} = 0{,}001\, A_{g,h}\, \tau_p/\eta_2$ kN (tonne-f)

where

A_g = net sectional area, in mm^2, of the girder adjacent to transverse bulkhead lower stool (or transverse bulkhead, if no lower stool is fitted)

$A_{g,h}$ = net sectional area, in mm^2, of the girder in way of the largest openings in the bays closest to the transverse bulkhead lower stool (or transverse bulkhead if no lower stool is fitted)

η_1 = 1,10

η_2 = 1,15 generally
= 1,10 where appropriate reinforcement is fitted in way of the opening.

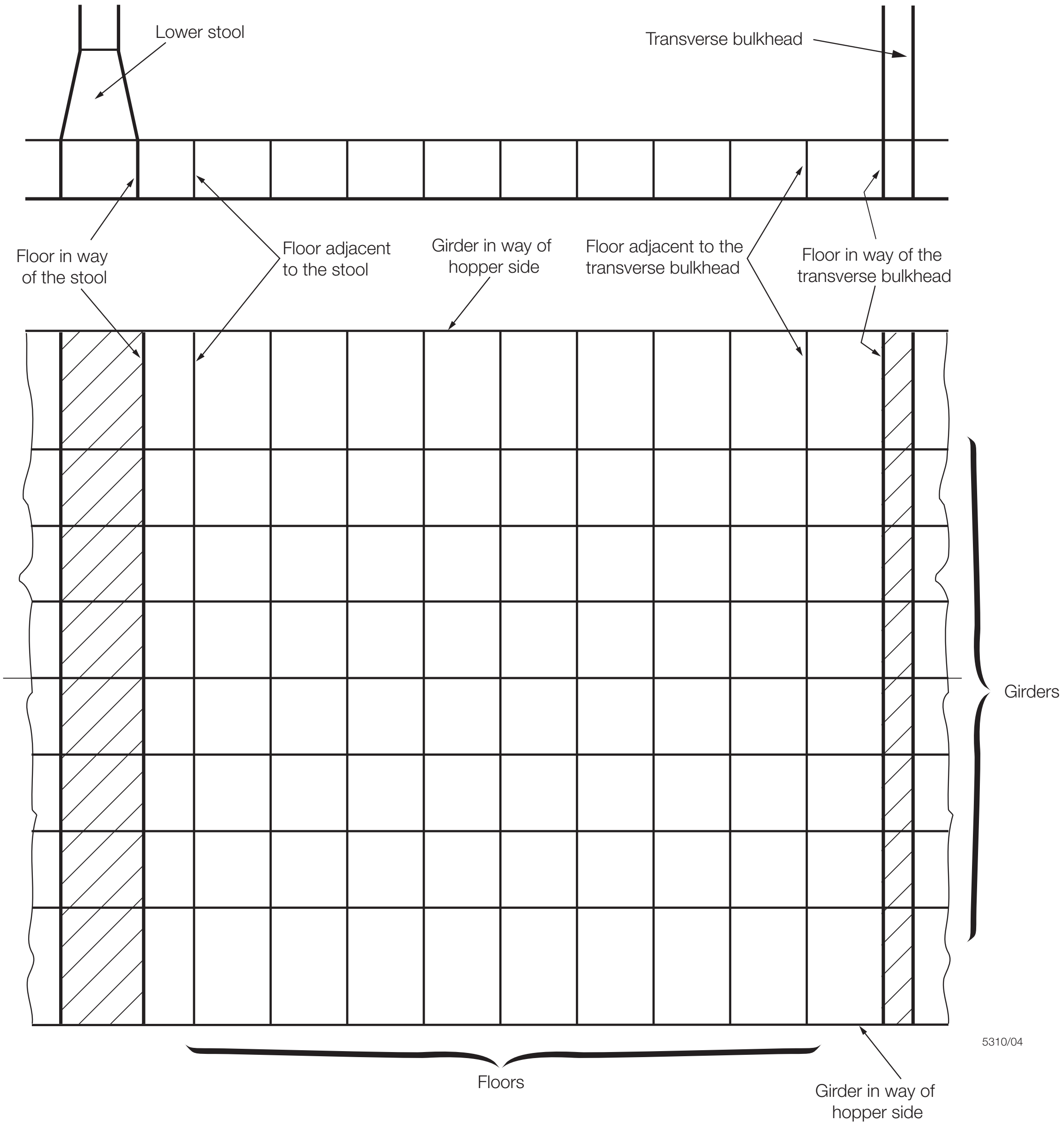


Fig. 7.8.4 Double bottom structure

8.8.9 The permissible cargo hold loading, W_p, is given by:

$W_p = g\,\rho_c\,V/F_c$ kN

($W_p = \rho_c\,V/F_c$ tonne-f)

where

d_f, D = as defined in 8.8.3

g = gravitational constant, 9,81 m/sec^2

h_f = flooding head, in metres, as defined in 8.8.3

$h_1 = \dfrac{X}{\rho_c\,g}$ where Y is in kN/m^2

$\left(h_1 = \dfrac{X}{\rho_c}\right.$ where Y is in tonne-f/m$^2\Big)$

n = number of floors between transverse bulkhead lower stools or transverse bulkheads, if no lower stools are fitted

s = spacing, in metres, of double bottom longitudinals adjacent to hoppers

$$A_{DB,e} = \sum_{i=1}^{n} S_i\,(B_{DB} - s)$$

$$A_{DB,h} = \sum_{i=1}^{n} S_i\,B_{DB,i}$$

B_{DB} = breadth of double bottom, in metres, between hoppers, *see* Fig. 7.8.5

$B_{DB,h}$ = distance, in metres, between openings, *see* Fig. 7.8.5

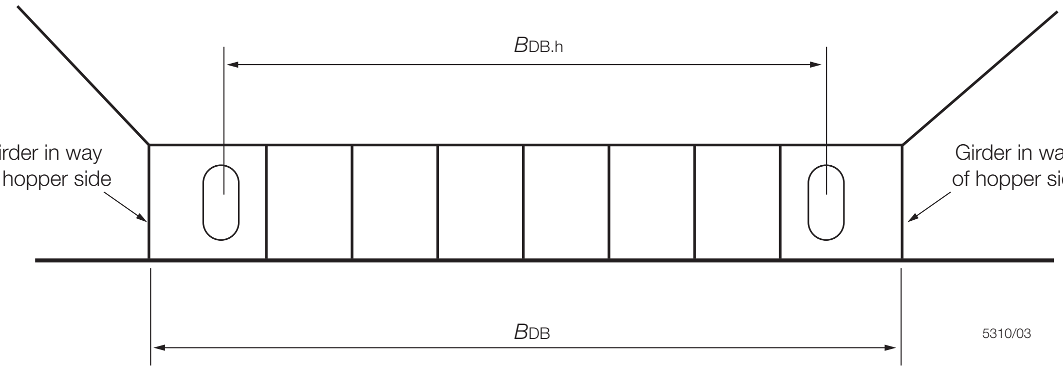


Fig. 7.8.5 Double bottom breadth

$B_{DB,i}$ = ($B_{DB} - s$) for floors where shear strength is given by S_{f1}
= $B_{DB,h}$ for floors where shear strength is given by S_{f2}
C_e = shear capacity of the double bottom, in kN (tonne-f), as defined in 8.8.6, considering for each floor, the shear strength S_{f1}, *see* 8.8.7, and for each girder, the lesser of the shear strengths S_{g1} and S_{g2}, *see* 8.8.8
C_h = shear capacity of the double bottom, in kN (tonne-f), as defined in 8.8.6, considering for each floor, the lesser of the shear strengths S_{f1} and S_{f2}, *see* 8.8.7, and for each girder, the lesser of the shear strengths S_{g1} and S_{g2}, *see* 8.8.8
F_c = 1,1 in general
= 1,05 for steel mill products
S_i = spacing of *i*th floor, in metres
T_F = $d_f - 0{,}1D$
V = volume, in m^3, occupied by cargo at a level h_1
X = the lesser of X_1 and X_2 for bulk cargoes and
X = X_1 for steel mill products
where

$$X_1 = \frac{Y + \rho\, g\,(T_F - h_f)}{1 + \left(\frac{\rho}{\rho_c}\right)(\mu - 1)} \text{ where } Y \text{ is in kN/m}^2$$

$$\left(X_1 = \frac{Y + \rho\,(T_F - h_f)}{1 + \left(\frac{\rho}{\rho_c}\right)(\mu - 1)} \text{ where } Y \text{ is in tonne-f/m}^2\right)$$

X_2 = $Y + \rho\, g\,(T_F - h_f\,\mu)$ where Y is in kN/m^2
(X_2 = $Y + \rho\,(T_F - h_f\,\mu)$ where Y is in tonne-f/m^2)
Y = the lesser of Y_1 and Y_2 given by:

$$Y_1 = \frac{C_h}{A_{DB,h}}$$

$$Y_2 = \frac{C_e}{A_{DB,e}}$$

μ = permeability of cargo but need not exceed 0,3
= 0,0 for steel mill products
ρ = density of sea water, 1,025 tonne/m^3
ρ_c = cargo density, in tonne/m^3 (bulk density for bulk cargoes and actual cargo density for steel mill products).

■ *Section 9*
Hopper side tank structure

9.1 General

9.1.1 Provision is made in this Section for longitudinal framing of the hopper side tank, but proposals for transverse framing will be specially considered.

9.1.2 Where oil cargoes are carried the scantlings of the sloped bulkhead are to comply with the requirements of 10.2.

9.1.3 For ships to be classed **'100A1 bulk carrier, strengthened for heavy cargoes, any hold may be empty, ESP'**, the requirements of 9.2, 9.3 and 9.6 are to be complied with. In addition the value for C, the stowage rate in m^3/tonne, as defined in Table 7.8.1 is not to be taken greater than 0,60 for each hold.

9.1.4 The buckling requirements of Pt 3, Ch 4,7 are also to be satisfied.

9.1.5 The *ShipRight FDA Procedure, Structural Detail Design Guide* (SDDG), indicates recommended details of structural design configurations around the transverse ring web of the hopper tank.

9.2 Sloped bulkhead plating

9.2.1 The thickness of the sloped bulkhead plating is to be as required by Ch 1,8.4.1 but based on actual spacing of sloped bulkhead stiffeners.

9.2.2 Where the ship is regularly discharged by grabs and the optional notation for heavy grabs is not desired (*see* Pt 3, Ch 9,9) the increase in thickness, as required by Ch 1,2.2, is to be tapered from the inner bottom knuckle to nil at the top corner of the tank.

9.2.3 Where a 'strengthened for heavy cargo notation' is desired, in addition to 9.2.2 the thickness of the sloped bulkhead plating is also to comply with the requirements of Table 7.8.1(3)(b) using the actual spacing of stiffeners and with *H*, in metres, measured vertically from a point one third of each plate width from its lower edge to the upper deck at side.

9.2.4 Where the hopper tanks are interconnected with the topside tanks, or in way of ballast holds, the plating is also to comply with the requirements of Table 7.8.1(3)(c) and (3)(d), whichever is appropriate.

9.3 Sloped bulkhead stiffeners

9.3.1 The scantlings of sloped bulkhead stiffeners are to be as required for inner bottom longitudinals, *see* Section 8. In ships strengthened for heavy cargoes, the scantlings of the stiffeners are to be derived from Table 7.8.1 using a head for heavy cargo measured vertically from the mid-point of the effective length to the underside of the topside tank sloped bulkhead. Where the hopper tanks are interconnected with the topside tanks, or in way of ballast holds, the scantlings of the stiffeners are also to comply with the requirements of Table 7.8.1(4)(c) and (4)(d), whichever is appropriate. For higher tensile steel longitudinals the requirements of Ch 1,6.2.3 are to be complied with where applicable, *see also* 9.7.1.

9.4 Shell and bilge stiffeners

9.4.1 The scantlings of the shell and bilge longitudinals are to comply with the requirements of Ch 1,6.

9.5 Tank end bulkheads

9.5.1 The scantlings of tank end bulkheads are to comply with the requirements for deep tanks in Table 1.9.1 in Chapter 1. Where the hopper tanks are interconnected with the topside tanks, the scantlings are to be derived, using the load head h_4, in metres, from Table 7.8.1(3)(c) and (4)(c), as appropriate.

9.6 Primary supporting structure

9.6.1 Transverses supporting longitudinal stiffening are to comply with the requirements of Table 7.9.1, and are to be in line with the double bottom floors.

9.7 Structural details

9.7.1 Bracket/diaphragms at the top of the hopper tank are to be of sufficient size and thickness to provide effective rigidity, and care is to be taken to ensure alignment with brackets at the bottom of the side frames in the holds. The shell and sloped bulkhead longitudinals supporting the diaphragms are to be derived using the span taken between transverses, *see also* 6.2.11.

Table 7.9.1 Hopper tank primary structure

Item	Modulus, in cm^3	Inertia, in cm^4
(1) Bottom and side shell transverses	$Z = 11{,}71\rho\, k\, S\, h\, l_e^2$	$I = \dfrac{2{,}5}{k} l_e Z$
(2) Sloped bulkhead transverses	The greater of: (a) $Z = 11{,}71\rho\, k\, S\, h_1\, l_e^2$ (b) $Z = 6{,}6 \dfrac{k\, S\, H_H\, l_e^2}{C}$	$I = \dfrac{2{,}5}{k} l_e Z$ $I = \dfrac{1{,}85}{k} l_e Z$

Symbols

S, k, l_e, Z, I, ρ as defined in 1.7.1

h = distance, in metres, from the mid-point of the effective length to the upper deck at side

h_1 = the greater of the distance, in metres, from the midpoint of the effective length to the top of the tank or half the distance, in metres, to the top of the overflow, or in way of cargo oil or ballast holds: the distance from the tank top to the deck at centre, or where the hopper tank is interconnected with the topside tank: the load head h_4, as derived from Table 7.8.1(4)(c), whichever is the greatest

C = stowage rate, in m^3/tonne, as defined in Table 7.8.1. For bulk carriers without the notation 'strengthened for heavy cargoes', the value to be used is 1,39 m^3/tonne. For bulk carriers with the notation 'strengthened for heavy cargoes', the actual stowage rate is to be used, but the value is not to be taken greater than 0,865 m^3/tonne

H_H = distance, in metres, measured vertically from the mid-point of the effective length to the underside of the topside tank sloped bulkhead

■ *Section 10* Bulkheads

10.1 General

10.1.1 The requirements of Ch 1,9 are to be applied, together with the requirements of this Section.

10.1.2 Where vertically corrugated transverse watertight bulkheads are fitted, the scantlings and arrangements are also to satisfy the requirements of 10.4 to 10.6. Other transverse watertight bulkhead types will be specially considered.

10.1.3 In way of ballast holds, the scantlings are to satisfy the requirements of Table 1.9.1 in Chapter 1 for deep tanks with the load head, h_4, in metres, taken to the deck at centre. This includes the scantlings of vertically corrugated and double plate transverse bulkheads supported by stools. In addition, the thickness of corrugations is to be not less than given by 10.5.8 for watertight corrugated bulkheads. Alternatively, the scantlings may be based on direct calculations which are to be submitted.

10.1.4 All bulk carriers to be classed **'100A1 bulk carrier, strengthened for heavy cargoes, any hold may be empty, ESP'** are to be arranged with top and bottom stools. The requirements of 10.2 are to be complied with as appropriate.

10.2 Bulkheads supported by stools

10.2.1 The stools are to be reinforced with plate diaphragms or deep webs, and in bottom stools the diaphragms are to be aligned with double bottom side girders. Continuity is also to be maintained between the diaphragms and the bulkhead corrugations for 90° corrugations.

10.2.2 The sloping plate of bottom stools is to be aligned with double bottom floors. Particular attention is to be given to the through-thickness properties of the inner bottom plating and continuity at the connection to the inner bottom, and to the through-thickness properties of the bottom stool shelf plate. *See* Ch 3,8 of the *Rules for the Manufacture, Testing and Certification of Materials* regarding requirements for plates with specified through-thickness properties.

10.2.3 An efficient system of reinforcement is to be arranged in line with the hold transverse bulkheads or bulkhead stools at the intersection with the sloped plating of the hopper and topside tanks. The reinforcement fitted in the tanks is to consist of girders or intercostal bulb plate or equivalent stiffeners fitted between, and connected to, the sloped bulkhead longitudinals.

10.2.4 The shelf plates of the bulkhead stools are to be arranged to align with the longitudinals in the hopper and topside tanks. Where sloping shelf plates are fitted to stools, suitable scarfing is to be arranged in way of the connections of the stools to the adjoining structures.

10.2.5 The *ShipRight FDA Procedure, Structural Detail Design Guide* (SDDG), indicates recommended structural design configurations in the critical areas of the lower stool and of the upper boundaries.

10.3 Structural details in way of holds confined to dry cargoes

10.3.1 In dry cargo holds where transverse bulkheads are arranged without bottom stools, the stiffeners and brackets of plane bulkheads, and rectangular corrugations of corrugated bulkheads, are to be aligned with floors and inner bottom longitudinals. In the case of non-rectangular corrugations, the flanges are to be aligned with floors, but consideration will be given to the fitting of a substantial transverse girder in place of one of the floors.

10.3.2 Where transverse corrugated bulkheads are arranged without top stools, transverse beams are to be arranged under the deck in way.

10.4 Vertically corrugated transverse watertight bulkheads – Application and definitions

10.4.1 Where corrugated transverse watertight bulkheads are fitted, the scantlings are to be determined in accordance with the following requirements.

10.4.2 For ships of length, L, 190 m or above, the vertically corrugated transverse bulkheads are to be fitted with a bottom stool and, generally, with a top stool below the deck. The requirements of 10.6 are to be complied with as appropriate.

10.4.3 The loads to be considered as acting on the bulkheads are those given by the combination of cargo loads with those induced by the flooding of one hold adjacent to the bulkhead under consideration. The most severe combinations of cargo induced loads and flooding loads are to be used for the determination of the scantlings of each bulkhead, depending on the specified design loading conditions:
(a) homogeneous loading conditions,
(b) non-homogeneous loading conditions (excluding part loading conditions associated with multi-port loading and unloading),
(c) packed cargo conditions (such as steel mill products).
The individual flooding of loaded and empty holds is to be considered, but the pressure used in the assessment is not to be less than that obtained for flood water alone. Holds containing packed cargo are to be treated as empty holds.

10.4.4 The cargo surface is to be taken as horizontal and at a distance d_1, in metres, from the base line, *see* Fig. 7.10.1, where d_1 is calculated taking into account the cargo properties and the hold dimensions. Unless the ship is designed to carry only cargo of bulk density greater than or equal to 1,78 tonne/m^3 in non-homogeneous loading conditions, the maximum mass of cargo which may be carried in the hold is to be taken as filling that hold to the upper deck level at centreline. A permeability, μ, of 0,3 and angle of repose, ψ, of 35° is to be assumed for this application.

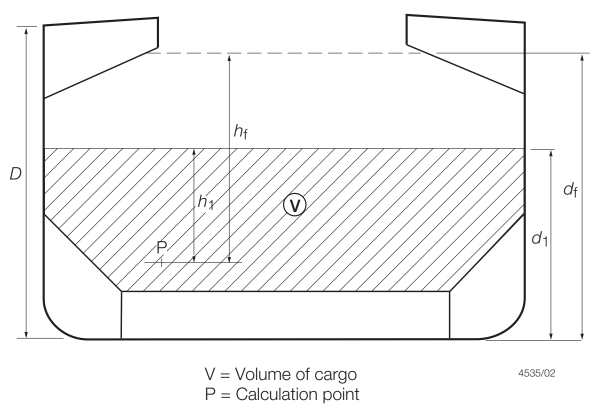


Fig. 7.10.1 Cargo hold dimensions

10.4.5 An homogeneous load condition is defined as one where the ratio between the highest and the lowest filling levels, d_1, in adjacent holds does not exceed 1,20. For this purpose, where a loading condition includes cargoes of different densities, equivalent filling levels are to be calculated for all holds on the basis of a single reference value of cargo density, which can be the minimum to be carried.

10.4.6 The permeability, μ, may be taken as 0,3 for ore, coal and cement cargoes. The bulk density and angle of repose, ψ, may generally be taken as 3,0 tonne/m^3 and 35° respectively for iron ore and 1,3 tonne/m^3 and 25° respectively for cement.

10.4.7 The flooding head, h_f, *see* Fig. 7.10.1, is the distance, in metres, measured vertically with the ship in the upright position, from the location *P*, under consideration, to a position d_f, in metres, from the base line as given in Table 7.10.1.

10.4.8 In considering a flooded hold, the total load is to be taken as that of the cargo and flood water at the appropriate permeability. Where there is empty volume above the top of the cargo, this is to be taken as flooded to the level of the flooding head.

10.4.9 Corrugations may be constructed of flanged plates or fabricated from separate flange and web plates, which may be of different thicknesses. The corrugation angle is to be not less than 55°, *see* Fig. 7.10.2.

10.4.10 The term net plate thickness is used to describe the calculated minimum thickness of plating of the web, t_w, or flange, t_f. The plate thickness to be fitted is the net plate thickness plus a corrosion addition of 3,5 mm.

10.5 Vertically corrugated transverse watertight bulkheads – Scantling assessment

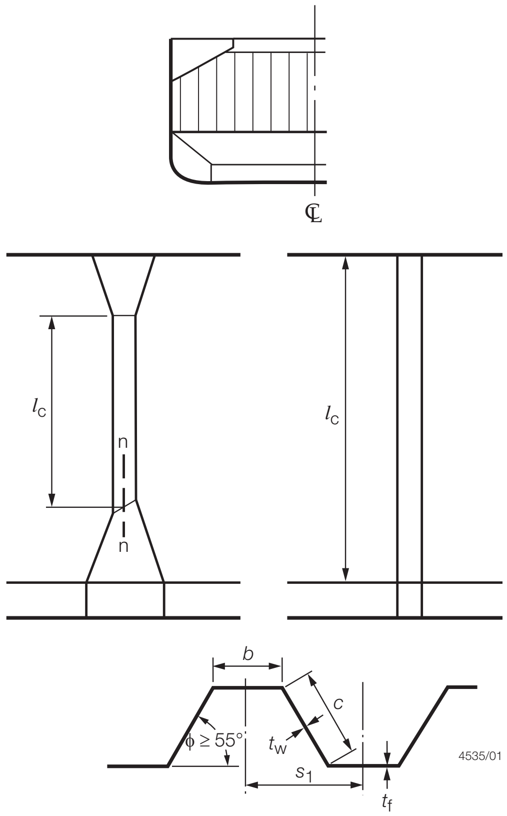
10.5.1 The bending moment *M*, in kNm (tonne-f m), for the bulkhead corrugations is given by:

$$M = \frac{F\,l}{8}$$

where

l = span of the corrugation, in metres, to be measured between the internal ends of the bulkhead upper and lower stools in way of the neutral axis of the corrugations or, where no stools are fitted, from inner bottom to deck, *see* Fig. 7.10.2 and Fig. 7.10.3. The lower end of the upper stool is not to be taken greater than a distance from the deck at the centreline equal to:
3 times the depth of the corrugation, in general, or
2 times the depth of the corrugation, for rectangular stools

F = resultant force, in kN (tonne-f), *see* Table 7.10.3.



n = neutral axis of the corrugations
s = max (b; c)

Fig. 7.10.2
Dimensions of bulkhead corrugation angles

10.5.2 The shear force, *Q*, in kN (tonne-f) at the lower end of the bulkhead corrugation is given by:

$$Q = 0{,}8F$$

where

F is defined in 10.5.1.

Table 7.10.1 Flooding head

Item	Bulkhead location	Bulk carriers with Type B freeboard and deadweight < 50 000 tonnes	Other bulk carriers
I(1)	Between holds 1 and 2	d_f = 0,95D	d_f = D
	Elsewhere	d_f = 0,85D	d_f = 0,9D
II(1)	Between holds 1 and 2	d_f = 0,9D	d_f = 0,95D
	Elsewhere	d_f = 0,8D	d_f = 0,85D

NOTES
1. Item II is to be used for non-homogeneous loading conditions where the bulk cargo density is less than 1,78 tonne/m^3. Otherwise, Item I is to be used.
2. D = distance, in metres, from the base line to the freeboard deck at side amidships, *see* Fig. 7.10.1.

Table 7.10.2 Bulkhead pressure and force

Item	Pressure, kN/m^2 (tonne-f/m^2)	Force, kN (tonne-f)
(1) In non-flooded bulk cargo holds	$p_c = g\,\rho_c\,h_1 \tan^2\theta$ $(p_c = \rho_c\,h_1 \tan^2\theta)$	$F_c = 0{,}5\,\rho_c\,g\,s_1\,(d_1 - h_{DB} - h_{LS})^2 \tan^2\theta$ $(F_c = 0{,}5\,\rho_c\,s_1\,(d_1 - h_{DB} - h_{LS})^2 \tan^2\theta)$
(2) In flooded bulk cargo holds, when $d_f \geq d_1$ (a) For positions between d_1 and d_f from base line (b) For positions at a distance lower than d_1 from base line	(a) $p_{cf} = g\,\rho\,h_f$ $(p_{cf} = \rho\,h_f)$ (b) $p_{cf} = g\,(\rho\,h_f + (\rho_c - \rho\,(1-\mu))\,h_1 \tan^2\theta$ $(p_{cf} = (\rho\,h_f + (\rho_c - \rho\,(1-\mu))\,h_1 \tan^2\theta)$	$F_{cf} = 0{,}5\,s_1\,(\rho\,g\,(d_f - d_1)^2 + (\rho\,g\,(d_f - d_1) + p_{le})\,(d_1 - h_{DB} - h_{LS}))$ $(F_{cf} = 0{,}5\,s_1\,(\rho\,(d_f - d_1)^2 + (\rho\,(d_f - d_1) + p_{le})\,(d_1 - h_{DB} - h_{LS})))$
(3) In flooded bulk cargo holds, when $d_f < d_1$ (a) For positions between d_1 and d_f from base line (b) For positions at a distance lower than d_f from base line	(a) $p_{cf} = g\,\rho_c\,h_1 \tan^2\theta$ $(p_{cf} = \rho_c\,h_1 \tan^2\theta)$ (b) $p_{cf} = g\,(\rho\,h_f + (\rho_c\,h_1 - \rho\,(1-\mu)\,h_f) \tan^2\theta)$ $(p_{cf} = (\rho\,h_f + (\rho_c\,h_1 - \rho\,(1-\mu)\,h_f) \tan^2\theta))$	$F_{cf} = 0{,}5\,s_1\,(\rho_c\,g\,(d_1 - d_f)^2 \tan^2\theta + (\rho_c\,g\,(d_1 - d_f) \tan^2\theta + p_{le})\,(d_f - h_{DB} - h_{LS}))$ $(F_{cf} = 0{,}5\,s_1\,(\rho_c\,(d_1 - d_f)^2 \tan^2\theta + (\rho_c\,(d_1 - d_f) \tan^2\theta + p_{le})(d_f - h_{DB} - h_{LS})))$
(4) In flooded empty holds	$p_f = g\,\rho\,h_f$ $(p_f = \rho\,h_f)$	$F_f = 0{,}5\,s_1\,\rho\,g\,(d_f - h_{DB} - h_{LS})^2$ $(F_f = 0{,}5\,s_1\,\rho\,(d_f - h_{DB} - h_{LS})^2)$

Symbols

d_f *see* 10.4.7
d_1 = vertical distance, in metres, from the base line to the top of the cargo, *see* Fig. 7.10.1
g = gravitational constant, 9,81 m/sec^2
h_{DB} = height of double bottom, in metres
h_f = flooding head, *see* 10.4.7
h_{LS} = mean height of lower stool, in metres
h_1 = vertical distance, in metres, from the calculation point to the top of the cargo, *see* Fig. 7.10.1
p_c, p_{cf}, p_f = pressure on the bulkhead at the point under consideration, in kN/m^2 (tonne-f/m^2)
p_{le} = pressure at the lower end of the corrugation, in kN/m^2 (tonne-f/m^2)
s_1 = spacing of the corrugations, in metres, *see* Fig. 7.10.2
ρ = density of sea water = 1,025 tonne/m^3
ρ_c = bulk cargo density, in tonne/m^3
θ = 45° – (Ψ/2)
ψ = angle of repose of the cargo, in degrees
μ = permeability of cargo, *see* 10.4.6

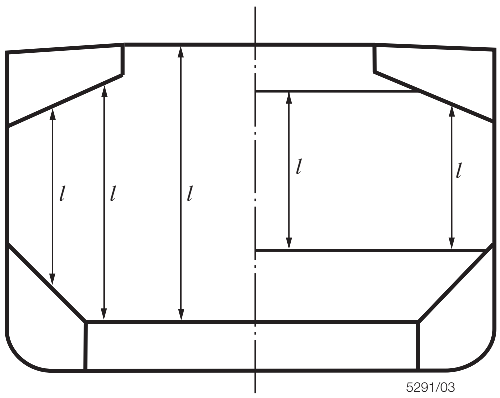


Fig. 7.10.3 Scantling assessment

10.5.3 The section modulus of the corrugations is to be calculated using net plate thicknesses. At the lower end, the following requirements apply:

(a) An effective width of compression flange, b_{ef}, not greater than given in 10.5.7, is to be used.

Table 7.10.3 Resultant pressure and force

Loading condition	Resultant pressure kN/m^2 (tonne-f/m^2)	Resultant force kN (tonne-f)
Homogeneous	$p_r = p_{cf} - 0{,}8p_c$	$F = F_{cf} - 0{,}8F_c$
Non-homogeneous	$p_r = p_{cf}$	$F = F_{cf}$
Flood water alone (adjacent holds empty)	$p_r = p_f$	$F = F_f$

NOTE
For symbols, *see* Table 7.10.2.

(b) Where corrugation webs are not supported by local brackets below the shelf plate (or below the inner bottom if no lower stool is fitted), they are to be assumed 30 per cent effective in bending. Otherwise, the full area of web plates may be used, *see also* (e).

c) Where effective shedder plates are fitted, *see* Figs. 7.10.4(a) and 7.10.4(b), the net area of the corrugation flange plates, in cm^2, may be increased by the lesser of:

$$2{,}5b\sqrt{(t_f\,t_{sh})} \text{ and } 2{,}5b\,t_f$$

where

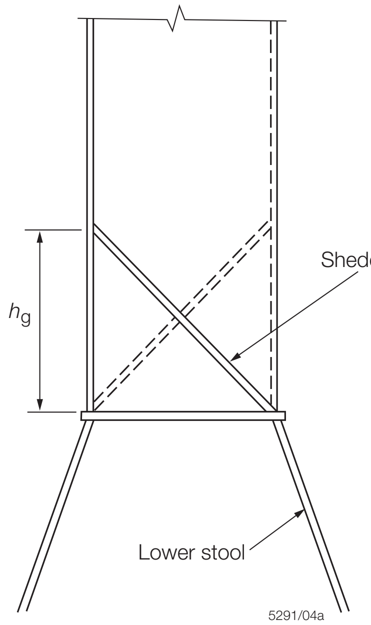


Fig. 7.10.4(a) Symmetric shedder plates

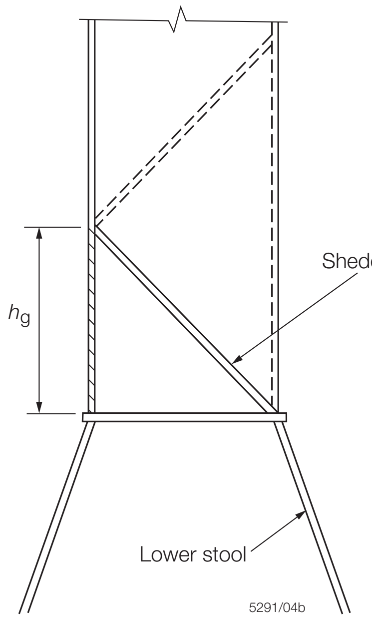


Fig. 7.10.4(b) Asymmetric shedder plates

b = width of corrugation flange, in metres, *see* Fig. 7.10.2
t_f = net flange plate thickness, in mm
t_{sh} = net shedder plate thickness, in mm

A shedder plate is considered effective when it:

- is not knuckled; and
- is welded to the corrugations and the lower stool shelf plate by one-side penetration welds or equivalent; and
- has a minimum slope of 45° and lower edges in line with the stool side plating; and
- has a thickness not less than 0,75 times the thickness of the corrugation flanges; and
- has material properties at least equal to those of the corrugation flanges.

(d) Where effective gusset plates are fitted, *see* Figs. 7.10.5(a) and (b) the net area of the corrugation flange plates, in cm^2, may be increased by:

$7h_g\, t_f$

where

h_g = height of the gusset plate, in metres, but is not to be taken greater than $\frac{10}{7}\, s_{gu}$
t_f = net flange plate thickness, in mm
s_{gu} = width of the gusset plate, in metres

A gusset plate is considered effective when it:

- is fitted in combination with an effective shedder plate as defined in (c); and
- has height not less than half the flange plate width; and
- is fitted in line with the stool side plating; and
- has thickness and material properties at least equal to those of the flanges; and
- is welded to the top of the lower stool by full penetration welds and to the corrugations and shedder plates by one-side penetration welds or equivalent.

(e) Where the corrugation is welded to a sloping stool shelf plate, set at an angle of not less than 45° to the horizontal, the corrugation webs may be taken as fully effective in bending. Where the slope is less than 45°, the effectiveness is to be assessed by linear interpolation between fully effective at 45° and the appropriate value from (b) at 0°. Where effective gusset plates are also fitted, the area of the flange plates may be increased in accordance with (d). No increase is permitted in the case where shedder plates are fitted without gussets.

10.5.4 The section modulus of corrugations at cross-sections other than the lower end is to be calculated with fully effective webs and an effective compression flange width, b_{ef} not greater than given in 10.5.7.

10.5.5 The bending capacity of the bulkhead corrugations is to comply with the following relationship:

$$\frac{1000\, M}{0{,}5 Z_{le}\, \sigma_{p,le} + Z_m\, \sigma_{p,m}} \leq 0{,}95$$

where

M = bending moment, in kNm (tonne-f m), *see* 10.5.1
Z_{le} = section modulus at the lower end of the corrugations, in cm^3
Z_m = section modulus at mid-span of the corrugations, in cm^3
$\sigma_{p,le}$ = permissible bending stress at the lower end of the corrugations, in N/mm^2 (kgf/mm^2)
$\sigma_{p,m}$ = permissible bending stress at mid-span of the corrugations, in N/mm^2 (kgf/mm^2)

In the above expression Z_{le}, in cm^3, is not to be taken greater than Z'_{le}

where

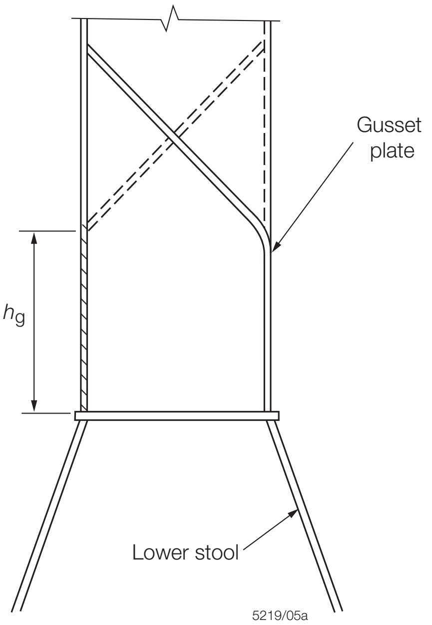


Fig. 7.10.5(a) Symmetric gusset/shedder plates

$$Z'_{le} = Z_g + \left(\frac{1000\,Q\,h_g - 0{,}5 h_g^2\,s_1\,p_g}{\sigma_{p,le}} \right)$$

and Z_m is not to exceed the lesser of $1{,}15Z_{le}$ and $1{,}15Z'_{le}$

where

h_g = height of the gusset plate, in metres

p_g = resultant pressure calculated in way of the middle of the shedder or gusset plates as appropriate, in kN/m^2 (tonne-f/m^2)

s_1 = spacing of the corrugations, in metres

Q = shear force, in kN (tonne-f), *see* 10.5.2

Z_g = section modulus of the corrugations in way of the upper end of shedder or gusset plates as appropriate, in cm^3.

10.5.6 The applied shear stress, in N/mm^2 (kgf/mm^2), is determined by dividing the shear force derived from 10.5.2 by the shear area of the corrugation, calculated using the net plate thickness. The shear area is to be reduced to account for non-perpendicularity between the corrugation webs and flanges. In general, the reduced area may be obtained by multiplying the web sectional area by sin ϕ, where ϕ is the angle between the web and the flange, *see* Fig. 7.10.2. The applied shear stress is not to exceed the permissible shear stress or the shear buckling stress given in Table 7.10.4.

10.5.7 The width of the compression flange, in metres, to be used for calculating the effective modulus is:

$b_{ef} = C_{ef}\, b$

where

$$C_{ef} = \frac{2{,}25}{\beta} - \frac{1{,}25}{\beta^2} \quad \text{for } \beta > 1{,}25$$

$$C_{ef} = 1{,}0 \quad \text{for } \beta \leq 1{,}25$$

$$\beta = 10^3 \left(\frac{b}{t_f}\right) \sqrt{\frac{\sigma_0}{E}}$$

Other symbols are as defined in Table 7.10.4.

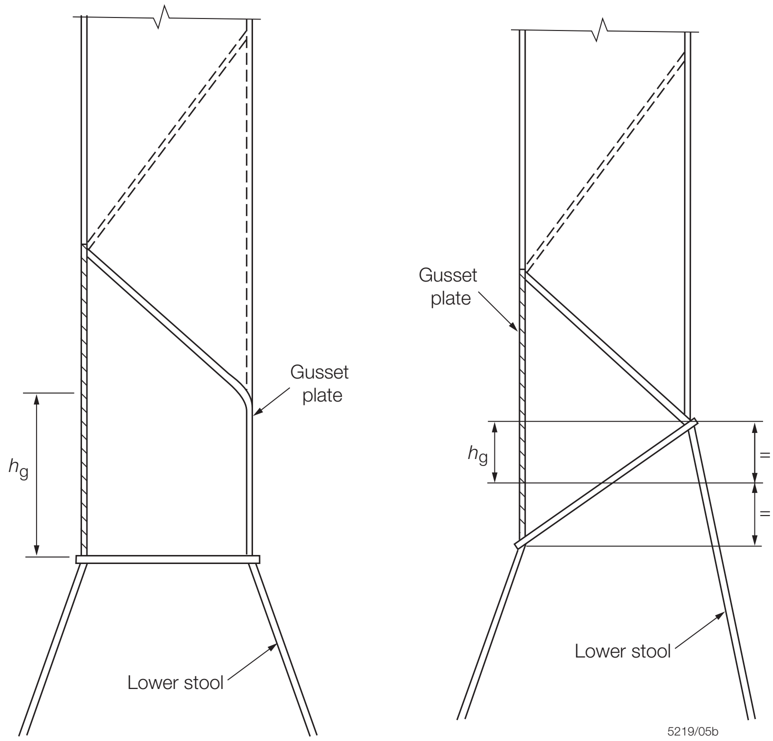


Fig. 7.10.5(b) Asymmetric gusset/shedder plates

Table 7.10.4 Permissible shear and buckling stresses

Bending, N/mm^2 (kgf/mm^2)	Shear, N/mm^2 (kgf/mm^2)	Shear buckling, N/mm^2 (kgf/mm^2)
$\sigma_p = \sigma_0$	$\tau_p = 0{,}5\sigma_0$	$\tau_{cr} = \tau_E$ when $\tau_E \le \dfrac{\tau_0}{2}$ $= \tau_0\left(1 - \dfrac{\tau_0}{4\tau_E}\right)$ when $\tau_E \le \dfrac{\tau_0}{2}$
Symbols		
b = width of corrugation flange, in metres, *see* Fig. 7.10.2 c = width of corrugation web, in metres, *see* Fig. 7.10.2 t_f = net flange plate thickness, in mm t_w = web plate net thickness, in mm E = modulus of elasticity = 206 000 N/mm^2 (21000 kgf/mm^2) σ_0 = specified minimum yield stress, in N/mm^2 (kgf/mm^2) τ_E = 5,706 $E\,(t_w/1000c)^2$ N/mm^2 (kgf/mm^2) $\tau_0 = \dfrac{\sigma_0}{\sqrt{3}}$ N/mm^2 (kgf/mm^2)		

10.5.8 The corrugation flange and web local net plate thickness are not to be less than:

$$t = 14{,}9\, s_w \sqrt{1{,}05\, \frac{p_r}{\sigma_0}} \text{ mm}$$

where

s_w = plate width, in metres, to be taken equal to the width of the corrugation flange or web, whichever is the greater

p_r = resultant pressure, in kN/m^2 (tonne-f/m^2), as defined in Table 7.10.3, at the lower edge of each strake of plating. The net thickness of the lowest strake is to be determined using the resultant pressure at the top of the lower stool, (or at the inner bottom, if no lower stool is fitted), or at the top of the shedders, if effective shedder or gusset and shedder plates are fitted

σ_0 = specified minimum yield stress of the material, in N/mm^2 (kgf/mm^2).

10.5.9 For built-up corrugations, where the thickness of the flange and of the web are different, the net thickness of the narrower plating is to be not less than:

$$t_n = 14{,}9\, s_n \sqrt{1{,}05\, \frac{p_r}{\sigma_0}} \text{ mm}$$

where

s_n = width of the narrower plating, in metres.

The net thickness, in mm, of the wider plating is not to be taken less than the greater of:

$$t_{wp} = 14{,}9\, s_w \sqrt{1{,}05\, \frac{p_r}{\sigma_0}} \text{ mm or}$$

$$t_{wp} = \sqrt{\frac{462\, s_w^2\, p_r}{\sigma_0} - t_{np}^2} \text{ mm}$$

where

t_{np} ≤ actual net thickness of the narrower plating but not greater than:

$$14{,}9\, s_w \sqrt{1{,}05\, \frac{p_r}{\sigma_0}} \text{ mm}$$

10.5.10 The required thickness of plating is the net thickness plus the corrosion addition given in 10.4.10.

10.5.11 Scantlings required to meet the bending and shear strength requirements at the lower end of the bulkhead corrugation are to be maintained for a distance of 0,15l from the lower end, where l is as defined in 10.5.1. Scantlings required to meet the bending requirements at mid-height are to be maintained to a location no greater than 0,3l from the top of the corrugation. The section modulus of the remaining upper part of the corrugation is to be not less than 0,75 times that required for the middle part, corrected for differences in yield stress.

10.6 Vertically corrugated transverse bulkheads – Support structure at ends

10.6.1 The requirements of 10.2 are to be complied with as applicable, together with the following.

10.6.2 **Lower stool**:

(a) The height of the lower stool is generally to be not less than three times the depth of the corrugations.
(b) The thickness and steel grade of the stool shelf plate are to be not less than those required for the bulkhead plating above.
(c) The thickness and steel grade of the upper portion of vertical or sloping stool side plating, within the depth equal to the corrugation flange width from the stool top, are to be not less than the flange plate thickness and steel grade needed to meet the bulkhead requirements at the lower end of the corrugation.
(d) The thickness of the stool side plating and the section modulus of the stool side stiffeners are to be not less than those required by Ch 1,9 for a plane transverse bulkhead and stiffeners using the greater of the pressures determined from the head, h_4, in Table 1.9.1 and the expressions given in Table 7.10.2.
(e) The ends of stool side vertical stiffeners are to be attached to brackets at the upper and lower ends of the stool.
(f) The width of the shelf plate is to be in accordance with Fig. 7.10.6.
(g) The stool bottom is to have a width not less than 2,5 times the mean depth of the corrugation.
(h) Scallops in the brackets and diaphragms in way of connections to the stool shelf plate are to be avoided.
(j) Where corrugations are terminated on the bottom stool, corrugations are to be connected to the stool top plate by full penetration welds. The stool side plating is to be connected to the stool top plate and the inner bottom plating by either full penetration or partial penetration welds, *see* Fig. 7.10.7. The supporting floors are to be connected to the inner bottom by either full penetration or partial penetration welds.

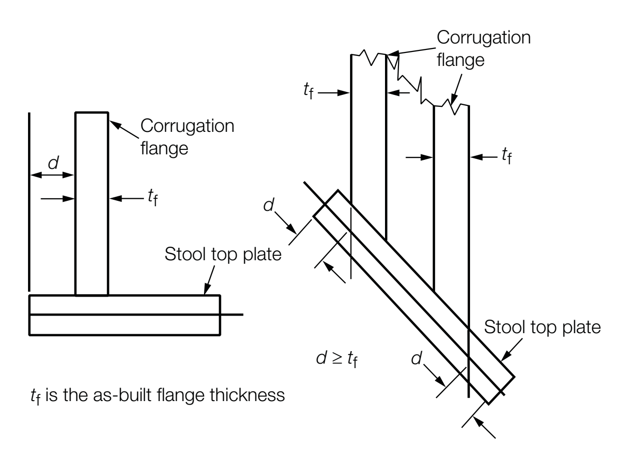


Fig. 7.10.6 Width of shelf plate

10.6.3 **Upper stool**:

(a) The upper stool, where fitted, is to have a height generally between two and three times the depth of corrugations.

(b) Rectangular stools are to have a height generally equal to twice the depth of corrugations, measured from the deck level and at hatch side girder.

(c) The upper stool is to be properly supported by girders or deep brackets between the adjacent hatch-end beams.

(d) The width of the shelf plate is generally to be the same as that of the lower stool shelf plate.

(e) The upper end of a non-rectangular stool is to have a width not less than twice the depth of corrugations.

(f) The thickness and steel grade of the shelf plate are to be the same as those of the bulkhead plating below.

(g) The thickness of the lower portion of stool side plating is to be not less than 80 per cent of that required for the upper part of the bulkhead plating where the same materials is used.

(h) The thickness of the stool side plating and the section modulus of the stool side stiffeners are to be not less than those required by Ch 1,9 for plane transverse bulkheads and stiffeners using the greater of the pressures determined from the head, h_4, in Table 1.9.1 and the expressions given in Table 7.10.2.

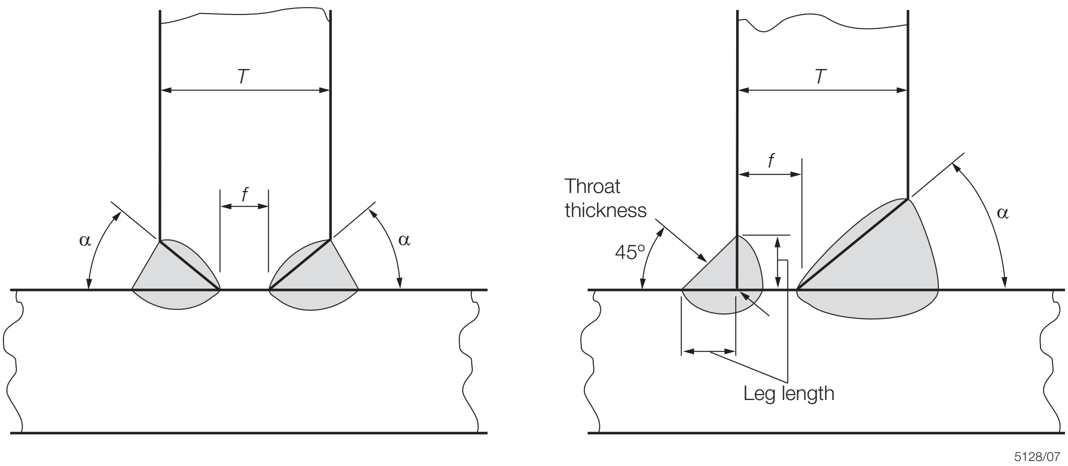
(j) Where vertical stiffening is fitted, the ends of stool side stiffeners are to be attached to brackets at the upper and lower end of the stool.

(k) Diaphragms are to be fitted inside the stool, in line with, and effectively attached to, longitudinal deck girders extending to the hatch end coaming girders for effective support of the corrugated bulkhead.

(l) Scallops in the brackets and diaphragms in way of the connection to the stool shelf plate are to be avoided.

10.6.4 If no upper stool is fitted, two transverse reinforced beams are to be fitted in line with the corrugation flanges.

10.6.5 If no bottom stool is fitted, the corrugation flanges are to be in line with the supporting floors. Corrugations are to be connected to the inner bottom plating by full penetration welds. The thickness and steel grades of the supporting floors are to be at least equal to those provided for the corrugation flanges. The plating of supporting floors is to be connected to the inner bottom by either full penetration or deep penetration welds, *see* Fig. 7.10.7. The cut-outs for connections of the inner bottom longitudinals to double bottom floors are to be closed by collar plates. The supporting floors are to be connected to each other by suitably designed shear plates. Stool side plating is to align with the corrugation flanges. Stool side vertical stiffeners and



Root face f = 3 mm to T/3 mm

Groove angle α = 40 to 60

Throat thickness = } *See* Pt 3, Ch 10
Leg length = }

Fig. 7.10.7 Partial penetration welding

their brackets in the lower stool are to align with the inner bottom longitudinals to provide appropriate load transmission between these stiffening members. The lower stool side plating is not to be knuckled.

10.6.6 Stool side plating is to align with the corrugation flanges. Stool side vertical stiffeners and their brackets in the lower stool are to align with the inner bottom longitudinals to provide appropriate load transmission between these stiffening members. The lower stool side plating is not to be knuckled.

10.6.7 The design of local details is to take into account the transfer of the bulkhead forces and moments to the boundary structures and particularly to the double bottom and cross-deck structures.

■ *Section 11* Direct calculation

11.1 Application

11.1.1 Direct calculations are to be employed in derivation of scantlings where required by the preceding Sections of this Chapter or by related provisions included in Part 3.

11.1.2 Direct calculation methods are also generally to be used where additional calculations are required by the Rules in respect of unusual structural arrangements.

11.2 Procedures

11.2.1 For details of LR's direct calculation procedures, *see* Pt 3, Ch 1,2. For requirements concerning use of other calculation procedures, *see* Pt 3, Ch 1,3.

■ *Section 12* Steel hatch covers

12.1 General

12.1.1 These requirements apply to hatch covers on exposed decks in Position 1, *see* Pt 3, Ch 1,6.5.1, and are in addition to the following requirements:

(a) Pt 3, Ch 11,4.2.14, 4.2.16, 4.2.17, 4.2.25, 4.2.27, and 4.2.29 to 4.2.33.

(b) Pt 3, Ch 11,4.2.5 for the vertical weather pressure load case and cargo load, if carried on the hatch covers.
NOTE
When cargo is carried on the hatch covers, Pt 3, Ch 11,4.2.8 to 4.2.10 are also to be complied with. Cargo loads are to be in accordance with Pt 3, Ch 11,2.3.4 and 2.3.5. Pt 4, Ch 8,11.2 is to be considered for compliance with Pt 3, Ch 11, 2.4.1, 2.4.2, 2.5.1, 2.8.1, 2.8.4, 2.8.5, 2.9.1 and 2.9.2. The vertical weather design load needs not to be combined with the cargo load.

(c) For hatch covers subject to wheel loading or helicopter landing, Pt 3, Ch 9,3 and Ch 9,5 are to be complied with.

12.1.2 The net plate thickness, t_{net}, is the calculated minimum thickness of the plating and stiffeners. The required thickness is the net thickness plus a corrosion addition, t_c, given in Table 7.12.1.

Table 7.12.1 Corrosion addition t_c

Hatch cover type	t_c , in mm
(a) Single skin	2,0
(b) Pontoon (double skin)	
(i) for the top and bottom plating	2,0
(ii) for the internal structures	1,5

12.1.3 Material for the hatch covers is to be steel according to the requirements for ship's hull.

12.2 Stiffener arrangement

12.2.1 The secondary stiffeners and primary supporting members of the hatch covers are to be continuous over the breadth and length of the hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to ensure sufficient load carrying capacity.

12.2.2 The spacing of primary supporting members parallel to the direction of secondary stiffeners is not to exceed 1/3 of the span of primary supporting members.

12.3 Closing arrangements

12.3.1 Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced alongside the coamings and between cover elements.

12.3.2 Arrangement and spacing are to be determined with due attention to the effectiveness for weather-tightness, depending upon the type and the size of the hatch cover, as well as on the stiffness of the cover edges between the securing devices.

12.3.3 The net sectional area of each securing device is not to be less than:

$$A = 1,4\, a/f \quad \text{cm}^2$$

where

a = spacing in m of securing devices, not being taken less than 2 m

f = $(\sigma_Y/235)^e$

σ_Y = specified minimum upper yield stress in N/mm^2 of the steel used for fabrication, not to be taken greater than 70 per cent of the ultimate tensile strength

e = 0,75 for $\sigma_Y > 235$
= 1,0 for $\sigma_Y \leq 235$

12.3.4 Rods or bolts are to have a net diameter not less than 19 mm for hatchways exceeding 5 m^2 in area.

12.3.5 Between cover and coaming and at cross-joints, a packing line force sufficient to obtain weathertightness is to be maintained by the securing devices. For packing line forces exceeding 5 N/mm, the cross-section area is to be increased in direct proportion. The packing line force is to be specified.

12.3.6 The cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices. The moment of inertia, I, of edge elements is not to be less than:

$$I = 6p\,a^4 \text{ cm}^4$$

where

p = packing line pressure in N/mm, minimum 5 N/mm
a = spacing in m of securing devices.

12.3.7 Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or covers. Individual securing devices on each cover are to have approximately the same stiffness characteristics.

12.3.8 Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

12.3.9 Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

12.3.10 Hatch covers are to be effectively secured, by means of stoppers, against transverse and longitudinal forces (acting on the forward end) arising from a pressure of 175 kN/m^2.

12.3.11 The equivalent stress:

- in stoppers and their supporting structures; and
- calculated in the throat of the stopper welds;

is not to exceed the allowable value of 0,8σ_Y.

12.4 Load model

12.4.1 The pressure, p, in kN/m^2, acting on the hatch covers is given by:

(a) For ships of length 100 m or greater, for hatchways located on the freeboard deck, p is to be the greater of 34,3 or the following:

$$p = 34{,}3 + \frac{p_{FP} - 34{,}3}{0{,}25}\left(0{,}25 - \frac{x}{L}\right)$$

Where a hatchway is located in position 1 and at least one superstructure standard height higher than the freeboard deck, the pressure p may be 34,3 kN/m^2.

(b) For ships less than 100 m in length, for hatchways located at the freeboard deck, p is to be the greater of 0,195L + 14,9 or the following:

$$p = 15{,}8 + \frac{L}{3}\left(1 - \frac{5}{3}\,\frac{x}{L}\right) - 3{,}6\,\frac{x}{L}$$

Where two or more panels are connected by hinges, each individual panel is to be considered separately.

where

p_{FP} = pressure at the forward perpendicular
= 49,1 + (L – 100) a
a = 0,0726 for type B freeboard ships
0,356 for ships with reduced freeboard
L = Freeboard length, in metres, as defined in Regulation 3 of Annex I to the 1966 Load Line Convention as modified by the Protocol of 1988, to be taken not greater than 340 m
x = distance, in metres, of the mid length of the hatch cover under examination from the forward end of L.

(c) For weather deck covers for holds which may be flooded and used as ballast tanks and holds in OBO, ore or oil and similar types of ship, the pressure p, in kN/m^2, due to the internal load for a member and position under consideration is to be taken as:

$$p = 5{,}53Y \sin q \quad \text{kN/m}^2$$

where

$$\sin q = \left(0{,}45 + \frac{L}{10B}\right)\left(0{,}54 - \frac{L}{1270}\right)$$

q = roll angle, in degrees, but need not exceed 25° and is not to be taken as less than 22°
Y = transverse distance, in metres, from the side coaming at the coaming top to the member and position under consideration. Both sides of roll are to be considered.
In way of holds for oil cargo, a load equivalent to the inert gas pressure is to be applied over the full breadth of the cover and added to the load corresponding to the liquid pressure. However, where the rolling angle has been determined by direct calculations, the load may be derived accordingly.

12.5 Allowable stress

12.5.1 The normal and shear stresses calculated for the net section hatch cover structures are not to exceed the values given in Table 7.12.2.

Table 7.12.2 Permissible stresses

Failure mode	Permissible stress, in N/mm^2 (kgf/mm^2)
Bending	σ_a = 0,80σ_F
Shear	τ_a = 0,46σ_F
Symbols	
σ_F = minimum upper yield stress, in N/mm^2 (kgf/mm^2)	

12.5.2 The normal stress in compression of the attached flange of primary supporting members is not to exceed 0,8 times the critical buckling stress of the structure according to the buckling check as given in 12.10, 12.11 and 12.12.

12.5.3 The stresses in hatch covers that are designed as a grillage of longitudinal and transverse primary supporting members are to be determined by a grillage or a FE analysis. When such an analysis is used the secondary stiffeners are not to be included in the attached flange area of the primary members.

12.5.4 When calculating the stresses σ and τ as defined in Table 7.12.2, the net scantlings are to be used.

12.6 Effective cross-sectional area of panel flanges for primary supporting members

12.6.1 The effective flange area, A_f, in cm², of the attached plating, to be considered for the yielding and buckling checks of primary supporting members, when calculated by means of a beam or grillage model, is obtained as the sum of the effective flange areas of each side of the girder web as appropriate:

$$A_f = \sum_{nf} (10 b_{ef} t)$$

where

nf = 2 if attached plate flange extends on both sides of girder web
= 1 if attached plate flange extends on one side of girder web only

t = net thickness of considered attached plate, in mm

b_{ef} = effective breadth of attached plate flange on each side of girder web, in metres
= b_p, but not to be taken greater than 0,165l

b_p = half distance between the considered primary supporting member and the adjacent one, in metres

l = span of primary supporting members, in metres.

12.7 Local net plate thickness

12.7.1 The local net plate thickness of the hatch cover top plating is to be not less than:

$$t = F_p \, 15{,}8s \sqrt{\frac{p}{0{,}95\sigma_F}}$$

or 1 per cent of the spacing of the stiffeners or 6 mm, whichever is greater

where

F_p = factor for combined membrane and bending response
= 1,50 in general
= 1,90σ/σ_a, where $\sigma/\sigma_a \geq 0{,}8$, for the attached plate flange of primary supporting members

s = stiffener spacing, in metres

p = pressure, in kN/m², as defined in 12.4

σ = as defined in 12.9

σ_a = as defined in 12.5.

12.7.2 For double skin hatch covers, when the lower plating is taken into account as a strength member of the hatch cover, the local net plate thickness of the hatch cover bottom plating is to be not less than:

t = 6,5s mm, or
t = 5,0 mm, whichever is the greater

where

s = stiffener spacing, in m.

12.8 Net scantlings of secondary stiffeners

12.8.1 The required minimum section modulus, Z, in cm³, of secondary stiffeners of the hatch cover top plate, based on stiffener net member thickness, is given by:

$$Z = \frac{1000 l^2 s p}{12\sigma_a}$$

where

l = secondary stiffener span, in metres, to be taken as the spacing, in metres, of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all secondary stiffener spans, the secondary stiffener span may be reduced by an amount equal to 2/3 of the minimum bracket arm length, but not greater than 10 per cent of the gross span, for each bracket

s = secondary stiffener spacing, in metres

p = pressure, in kN/m², as defined in 12.4

σ_a = as defined in 12.5.

12.8.2 The net section modulus of the secondary stiffeners is to be determined based on an attached plate width assumed equal to the stiffener spacing.

12.9 Net scantlings of primary supporting members

12.9.1 The section modulus and web thickness of primary supporting members, based on member net thickness, are to be such that the normal stress σ in both flanges and the shear stress τ, in the web, do not exceed the allowable values σ_a and τ_a, respectively, defined in 12.5.

12.9.2 The breadth of the primary supporting member flange is to be not less than 40 per cent of their depth for laterally unsupported spans greater than 3,0 m. Tripping brackets attached to the flange may be considered as a lateral support for primary supporting members.

12.9.3 The flange outstand is not to exceed 15 times the flange thickness.

12.10 Hatch cover plating

12.10.1 The compressive stress, σ, in N/mm², in the hatch cover plate panels, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, is not to exceed 0,8 times the critical buckling stress σ_{C1}, to be evaluated as defined below:

$\sigma_{C1} = \sigma_{E1}$ when $\sigma_{E1} \leq \sigma_F/2$

$= \sigma_F \, [1 - \sigma_F/(4\sigma_{E1})]$ when $\sigma_{E1} > \sigma_F/2$

where

σ_F = minimum upper yield stress, in N/mm², of the material

$$\sigma_{E1} = 3{,}6E \left(\frac{t}{1000s}\right)^2$$

E = modulus of elasticity, in N/mm²
= 2,06 x 10^5 for steel

t = net thickness, in mm, of plate panel
s = spacing of secondary stiffeners, in metres.

12.10.2 The mean compressive stress σ in each of the hatch cover plate panels, induced by the bending of primary supporting members perpendicular to the direction of secondary stiffeners, is not to exceed 0,8 times the critical buckling stress σ_{C2}, to be evaluated as defined below:

$\sigma_{C2} = \sigma_{E2}$ when $\sigma_{E2} \leq \sigma_F/2$
$= \sigma_F [1 - \sigma_F/(4\sigma_{E2})]$ when $\sigma_{E2} > \sigma_F/2$

where

σ_F = minimum upper yield stress, in N/mm^2, of the material

$$\sigma_{E2} = 0{,}9m\,E\left(\frac{t}{1000s_s}\right)^2$$

$$m = c\left[1 + \left(\frac{s_s}{l_s}\right)^2\right]^2 \frac{2{,}1}{\psi + 1{,}1}$$

E = modulus of elasticity, in N/mm^2
= 2,06 x 10^5 for steel
t = net thickness of plate panel, in mm
s_s = length of the shorter side of the plate panel, in metres
l_s = length of the longer side of the plate panel, in metres
Ψ = ratio between smallest and largest compressive stress
c = 1,3 when plating is stiffened by primary supporting members
= 1,21 when plating is stiffened by secondary stiffeners of angle or T type
= 1,1 when plating is stiffened by secondary stiffeners of bulb type
= 1,05 when plating is stiffened by flat bar.

12.10.3 The biaxial compressive stress in the hatch cover panels, when calculated by means of FEM shell element model is to comply with Pt 3, Ch 11,2.11.2, using S = 1,25.

12.11 Hatch cover secondary stiffeners

12.11.1 The compressive stress σ, in N/mm^2, in the top flange of secondary stiffeners, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, is not to exceed 0,8 times the critical buckling stress σ_{CS}, to be evaluated as defined below:

$\sigma_{CS} = \sigma_{ES}$ when $\sigma_{ES} \leq \sigma_F/2$
$= \sigma_F [1 - \sigma_F/(4\sigma_{ES})]$ when $\sigma_{ES} > \sigma_F/2$

where

σ_F = minimum upper yield stress, in N/mm^2, of the material
σ_{ES} = ideal elastic buckling stress, in N/mm^2, of the secondary stiffener
= minimum between σ_{E3} and σ_{E4}
σ_{E3} = $0{,}001E\,I_a/(A\,l^2)$
E = modulus of elasticity, in N/mm^2
= 2,06 x 10^5 for steel
I_a = moment of inertia of the secondary stiffener, including a top flange equal to the spacing of secondary stiffeners, in cm^4
A = cross-sectional area of the secondary stiffener, including a top flange equal to the spacing of secondary stiffeners, in cm^2
l = span of the secondary stiffener, in metres

$$\sigma_{E4} = \frac{\pi^2 E\,I_w}{10^4 I_p\,l^2}\left(m^2 + \frac{K}{m^2}\right) + 0{,}385E\,\frac{I_t}{I_p}$$

$$K = \frac{C\,l^4}{\pi^4 E\,I_w} 10^6 \quad m$$

m = number of half waves, given in Table 7.12.3
I_w = sectorial moment of inertia (warping constant) of the secondary stiffener about its connection with the plating, in cm^6

$$= \frac{h_w^3\,t_w^3}{36} 10^{-6} \text{ for flat bar secondary stiffeners}$$

$$= \frac{t_f\,b_f^3\,h_w^2}{12} 10^{-6} \text{ for 'Tee' secondary stiffeners}$$

$$= \frac{b_f^3\,h_w^2}{12(b_f + h_w)^2}\left[t_f\left(b_f^2 + 2b_f h_w + 4h_w^2\right) + 3t_w\,b_f\,h_w\right] 10^{-6}$$

for angles and bulb secondary stiffeners

I_p = polar moment of inertia of the secondary stiffener about its connection with the plating, in cm^4

$$= \frac{h_w^3\,t_w}{3} 10^{-4} \text{ for flat bar secondary stiffeners}$$

$$= \left(\frac{h_w^3\,t_w}{3} + h_w^2\,b_f\,t_f\right) 10^{-4}$$

for flanged secondary stiffeners

I_t = St.Venant's moment of inertia of the secondary stiffener without top flange, in cm^4

$$= \frac{h_w^3\,t_w}{3} 10^{-4} \text{ for flat bar secondary stiffeners}$$

$$= \frac{1}{3}\left[h_w\,t_w^3 + b_f\,t_f^3\left(1 - 0{,}63\,\frac{t_f}{b_f}\right)\right] 10^{-4}$$

for flanged secondary stiffeners

h_w, t_w = height and net thickness of the secondary stiffener, respectively, in mm
b_f, t_f = width and net thickness of the secondary stiffener bottom flange, respectively, in mm
s = spacing of secondary stiffeners, in metres
C = spring stiffness exerted by the hatch cover top plating

$$= \frac{k_p\,E\,t_p^3}{3s\left[1 + \dfrac{1{,}33k_p\,h_w\,t_p^3}{1000s\,t_w^3}\right]} 10^{-3}$$

Table 7.12.3 Number of half waves

K	m
$0 < K < 4$	1
$4 < K < 36$	2
$36 < K < 144$	3
$(m - 1)^2\,m^2 < K \leq m^2\,(m + 1)^2$	m

k_p = $1 - \eta_p$ to be taken not less than zero; for flanged secondary stiffeners, k_p need not be taken less than 0,1

η_p = $\dfrac{\sigma}{\sigma_{E1}}$

σ = as defined in 12.9
σ_{E1} = as defined in 12.10
t_p = net thickness of the hatch cover plate panel, in mm.

12.11.2 For flat bar secondary stiffeners and buckling stiffeners, the ratio h/t_W is to be not greater than $15k^{0,5}$
where
h, t_W = height and net thickness of the stiffener, respectively
k = $235/\sigma_F$
σ_F = minimum upper yield stress, in N/mm^2, of the material.

12.12 Web panels of hatch cover primary supporting members

12.12.1 This check is to be carried out for the web panels of primary supporting members formed by web stiffeners or by the crossing with other primary supporting members, the face plate (or the bottom cover plate) or the attached top cover plate.

12.12.2 The shear stress τ in the hatch cover primary supporting members web panels is not to exceed 0,8 times the critical buckling stress τ_C, to be evaluated as defined below:

$\tau_C = \tau_E$ when $\tau_E \le \tau_F/2$
$= \tau_F\,[1 - \tau_F/(4\tau_E)]$ when $\tau_E > \tau_F/2$

where
σ_F = minimum upper yield stress of the material, in N/mm^2

τ_F = $\dfrac{\sigma_F}{\sqrt{3}}$

τ_E = $0{,}9 k_t\, E \left(\dfrac{t_{pr,n}}{1000d}\right)^2$

E = modulus of elasticity, in N/mm^2
= $2{,}06 \times 10^5$ for steel
$t_{pr,n}$ = net thickness of primary supporting member, in mm
k_t = $5{,}35 + 4{,}0/(a/d)^2$
a = greater dimension of web panel of primary supporting member, in metres
d = smaller dimension of web panel of primary supporting member, in metres.

12.12.3 For primary supporting members parallel to the direction of secondary stiffeners, the actual dimensions of the panels are to be considered.

12.12.4 For primary supporting members perpendicular to the direction of secondary stiffeners or for hatch covers built without secondary stiffeners, a presumed square panel of dimension d is to be taken for the determination of the stress τ_C. In such a case, the average shear stress τ between the values calculated at the ends of this panel is to be considered.

12.13 Deflection limit and connections between hatch cover panels

12.13.1 Load bearing connections between the hatch cover panels are to be fitted with the purpose of restricting the relative vertical displacements.

12.13.2 The vertical deflection of primary supporting members is to be not more than $0{,}0056l$, where l is the greatest span of primary supporting members.

■ *Section 13* Hatch coamings

13.1 General

13.1.1 The height and construction of forward and side hatch coamings are to comply with the following requirements. All hatch coamings are to comply with the requirements of Pt 3, Ch 11,5.1.1, 5.1.3, 5.2.1, 5.2.2, 5.2.4 to 5.2.12, 5.2.16 to 5.2.18 and 5.4.1.

13.1.2 For the structure of hatch coamings and coaming stays, the corrosion addition t_c is to be 1,5 mm.

13.1.3 Material for the hatch coamings is to be steel according to the requirements for the ship's hull.

13.1.4 The secondary stiffeners of the hatch coamings are to be continuous over the breadth and length of the hatch coamings.

13.2 Load model

13.2.1 The pressure p_{coam}, on hatch coamings is to be taken as 220 kN/m^2.

13.3 Local net plate thickness

13.3.1 The local net plate thickness, t, in mm, of the hatch coaming plating is to be the greater of 9,5 mm or the following:

$$t = 14{,}9s \sqrt{\frac{p_{coam}}{\sigma_{a,coam}}\, S_{coam}}$$

where
s = secondary stiffener spacing, in metres
p_{coam} = pressure, in kN/m^2, as defined in 13.2.1
S_{coam} = safety factor to be taken equal to 1,15
$\sigma_{a,coam}$ = $0{,}95\sigma_F$.
σ_F = minimum upper yield stress, in N/mm^2, of the material.

13.4 Net scantlings of longitudinal and transverse secondary stiffeners

13.4.1 The required section modulus, Z, in cm^3, of the longitudinal or transverse secondary stiffeners of the hatch coamings, based on net member thickness, is given by:

$$Z = \frac{1000 S_{coam}\, l^2\, s\, p_{coam}}{m\, c_p\, \sigma_{a,coam}}$$

where

m = 16 in general
= 12 for the end spans of stiffeners sniped at the coaming corners
S_{coam} = safety factor to be taken equal to 1,15
l = span of secondary stiffeners, in metres
s = spacing of secondary stiffeners, in metres
p_{coam} = pressure in kN/m^2 as defined in 13.2.1
c_p = ratio of the plastic section modulus to the elastic section modulus of the secondary stiffeners with an attached plate breadth equal to $40t$, where t is the plate net thickness, in mm
= 1,16 in the absence of more precise evaluation
$\sigma_{a,coam}$ = $0,95\sigma_F$
σ_F = minimum upper yield stress, in N/mm^2, of the material.

13.5 Net scantlings of coaming stays

13.5.1 The required minimum section modulus, Z, in cm^3, and web thickness, t_w, in mm of coaming stays designed as beams with flange connected to the deck or sniped and fitted with a bracket (*see* Fig. 7.13.1, Type A and B) at their connection with the deck, based on member net thickness, are given by:

$$Z = \frac{1000 H_c^2\, s\, p_{coam}}{2\, \sigma_{a,coam}}$$

$$t_w = \frac{1000 H_c\, s\, p_{coam}}{h\, \tau_{a,coam}}$$

where

H_C = stay height, in metres
s = stay spacing, in metres
h = stay depth at the connection with the deck, in mm
p_{coam} = pressure, in kN/m^2, as defined in 13.2.1
$\sigma_{a,coam}$ = $0,95\sigma_F$
$\tau_{a,coam}$ = $0,5\sigma_F$
σ_F = minimum upper yield stress, in N/mm^2, of the material.

13.5.2 For calculating the section modulus of coaming stays, their face plate area is to be taken into account only when it is welded with full penetration welds to the deck plating and adequate underdeck structure is fitted to support the stresses transmitted by it.

13.5.3 For other designs of coaming stays, such as those shown in Fig. 7.13.1 Type C and D, the stress levels in 12.5 apply and are to be checked at the highest stressed locations.

13.6 Local details

13.6.1 The design of local details is to comply with Pt 3, Ch 11,5 for the purpose of transferring the pressures on the hatch covers to the hatch coamings and, through them, to the deck structures below. Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.

13.6.2 Underdeck structures are to be checked against the load transmitted by the stays, adopting the same allowable stresses specified in 13.5.1.

13.6.3 Double continuous welding is to be adopted for the connections of stay webs with deck plating and the weld throat is to be not less than $0,44t_W$, where t_W is the gross thickness of the stay web.

13.6.4 Toes of stay webs are to be connected to the deck plating with deep penetration double bevel welds extending over a distance not less than 15 per cent of the stay width.

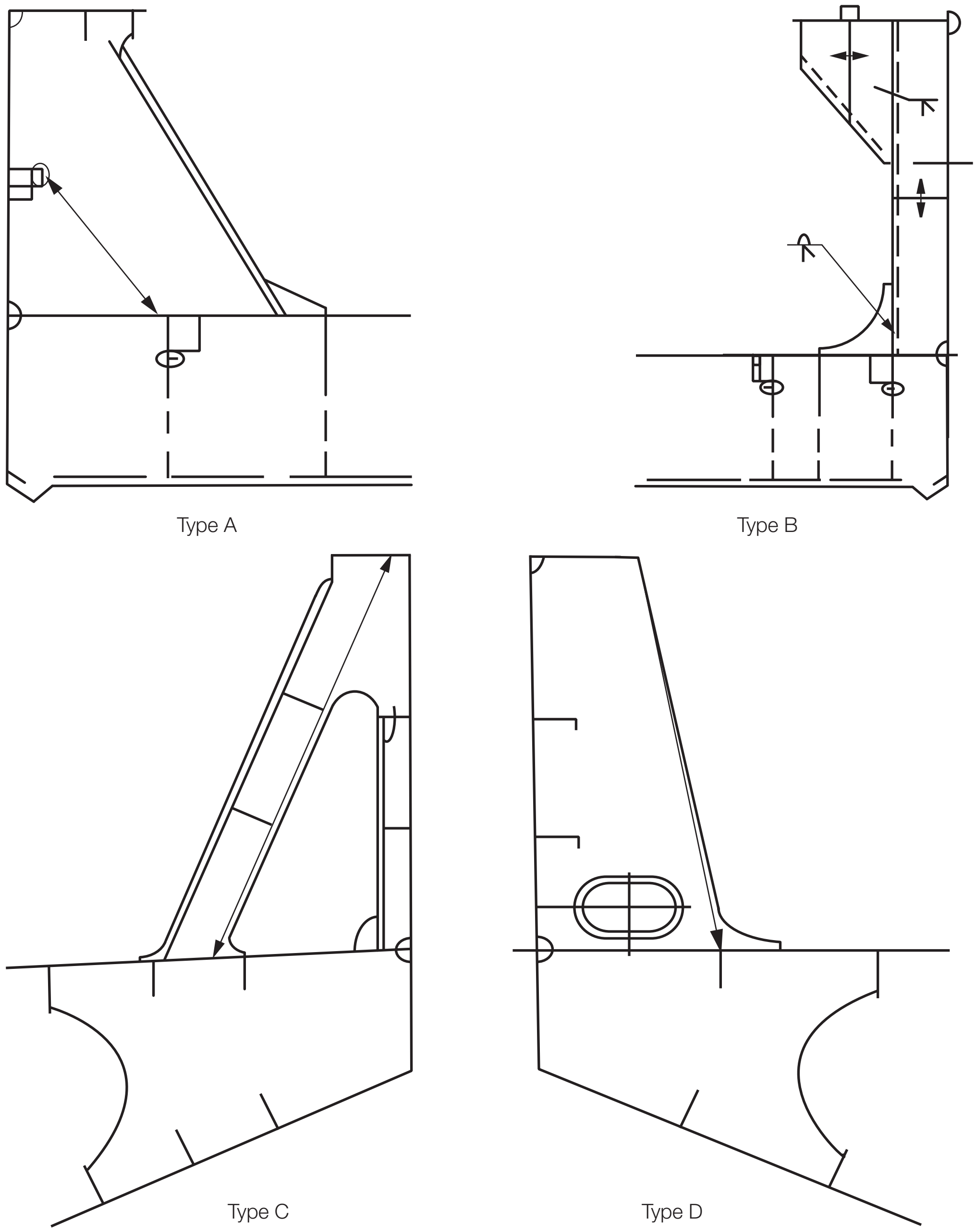


Fig. 7.13.1 Typical coaming stays

Section 14
Forecastles

14.1 Arrangement

14.1.1 An enclosed forecastle is to be fitted on the freeboard deck.

14.1.2 The aft bulkhead of the forecastle is to be fitted in way or aft of the forward bulkhead in the foremost cargo hold. *See* Fig. 7.14.1. However, if this requirement hinders hatch cover operation, the aft bulkhead of the forecastle may be fitted forward of the forward bulkhead of the foremost cargo hold provided the forecastle length is not less than 7 per cent of ship length abaft the forward perpendicular where the ship length and forward perpendicular are defined in the *International Convention on Load Lines 1966* and its Protocol of 1988.

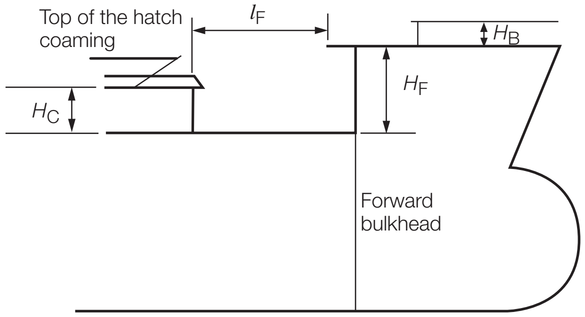


Fig. 7.14.1 Forecastle arrangement

14.1.3 The forecastle height H_F, in metres, above the main deck is to be not less than the greater of:

- the standard height of a superstructure as specified in the *International Convention on Load Lines 1966* and its Protocol of 1988; or
- H_C + 0,5 m

where

H_C = the height, in metres, of the forward transverse hatch coaming of cargo hold No.1.

14.1.4 All points of the aft edge of the forecastle deck are to be located at a distance:

$$l_f < 5 \sqrt{(H_F - H_C)}$$

from the hatch coaming, *see* Fig. 7.14.1.

14.1.5 A breakwater is not to be fitted on the forecastle deck with the purpose of protecting the hatch coaming or hatch covers. If fitted for other purposes, it is to be located such that its upper edge at centre line is not less than:

$$H_B/\tan 20°$$

forward of the aft edge of the forecastle deck.

where

H_B = the height, in metres, of the breakwater above the forecastle, *see* Fig. 7.14.1.

14.2 Construction

14.2.1 The construction of the forecastle is to comply with the requirements of Pt 3, Ch 8,4.

■ *Section 1* General

1.1 Application and definitions

1.1.1 A **container ship** is defined as a ship designed exclusively for the carriage of containers in holds and on deck. Containers in holds are normally stowed within cellular guide systems.

1.1.2 The term 'narrow side structures' applies where the breadth of hatch opening exceeds 90 per cent of the breadth of the ship.

1.1.3 Other terms used to describe the various structural components of container ships are generally indicated in LR's ShipRight FDA Procedure, *Structural Detail Design Guide*.

1.1.4 For container ships with a beam greater than 32 m, or where the structural arrangements are considered such as to necessitate it, the ShipRight notations **SDA** and **CM** are mandatory, *see* 1.3 and Section 14.

1.1.5 Scantlings of the primary structure of double bottom, side and transverse bulkheads are to be verified by direct calculation as required by 14.2.

1.1.6 Scantlings and arrangements are to be as required by Chapter 1, except as otherwise indicated in this Chapter.

1.2 Structural configuration

1.2.1 This Chapter describes a basic structural configuration as shown in Fig. 8.1.1 which includes:

(a) An efficient torsion box girder or equivalent structure at the topsides comprising strength deck, side shell, inner skin and a second deck. The space within the torsion box is often utilised as an underdeck access passageway.
(b) Single or double skin side construction with or without bilge box.
(c) Double bottom.
(d) Continuous or discontinuous hatch coamings.
(e) Optional continuous deck girders to support hatch covers.

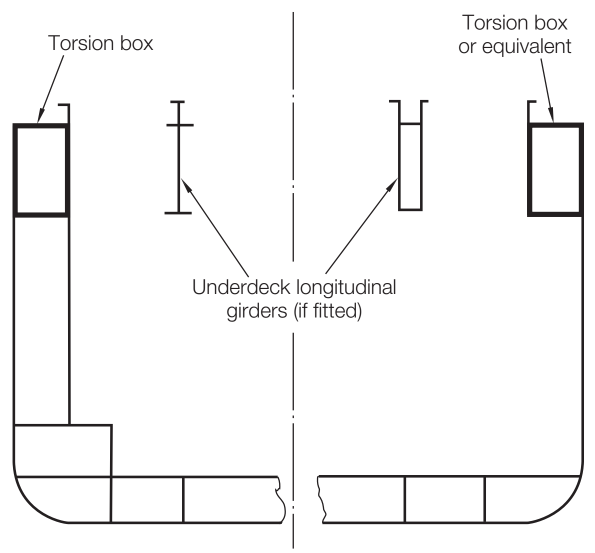


Fig. 8.1.1 Structural configuration

1.3 Class notations

1.3.1 In general, ships complying with the requirements of this Chapter will be eligible to be classed **100A1 Container Ship**.

1.3.2 The 'ShipRight Procedures' for the hull construction of ships are detailed in Pt 3, Ch 16 and the classification notations and descriptive notes associated with these procedures are given in Pt 1, Ch 2,2.

1.3.3 The notations **SDA** and **CM** are mandatory for container ships with any of the following features:

(a) beam greater than 32 m;
(b) narrow side structures;
(c) abnormal hull form; or
(d) unusual structural configuration or complexity.

1.3.4 When required, other cargoes or particular loading arrangements will be included in the class or cargo notations.

1.3.5 Reference is made to Pt 1, Ch 2 with respect to the Regulations for classification and assignment of class notations.

1.4 Information required

1.4.1 In addition to the information and plans required by Pt 3, Ch 1,5, the following are to be submitted:

(a) Details of overlap arrangement of steps in decks and longitudinal bulkheads.
(b) Details of outline stowage arrangement of containers.
(c) Details of design container stack weights.
(d) Details of cell guides and supporting structure indicating the position of guides relative to hatch corners, and attachment to structural members.
(e) Details of reinforcement to structure in way of container corners/supports.
(f) Details of reinforcement to structure in way of lashing bridges where fitted.
(g) Details showing the location of all openings in decks within the cargo holds.
(h) Details of longitudinal girders supporting hatch coamings where fitted.

1.5 Symbols and definitions

1.5.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, L_{pp}, B, D, T, V, C_b as defined in Pt 3, Ch 1,6

e = base of natural logarithms, 2,7183

k_L, k = higher tensile steel factor, *see* Pt 3, Ch 2,1

s = spacing of secondary stiffeners, in mm

s_1 = spacing of secondary stiffeners, but is not to be taken less than 470 + 1,67L mm

t = thickness of plating, in mm

L_1 = L but need not be taken greater than 190 m.

■ *Section 2* Materials

2.1 Materials

2.1.1 Materials are to comply with Pt 3, Ch 2.

2.1.2 Attention is drawn to the specific requirements for container ship hatch corners in Table 2.2.1, Note 1 in Pt 3, Ch 2.

2.2 Protection of steelwork

2.2.1 In addition to the requirements of Pt 3, Ch 2,3 the requirements of Ch 1,2.2.3 may also be applied.

2.3 Requirements for use of thick steel plates

2.3.1 This Section provides the requirements for crack arrest design to reduce the risk of brittle fractures in container ships where thick steel plates are applied for longitudinal structural members within the cargo hold region.

2.3.2 This Section is to be applied to container ships where the steel plates for longitudinal structural members exceed a thickness of 50 mm but are not greater than 100 mm. Special consideration is required for plates with a thickness exceeding 100 mm.

2.3.3 This Section applies to plates having specified minimum yield strength of 355, 390 and 460 N/mm^2. Steels and weldments are to comply with the toughness requirements of Chapters 3, 11 and 12 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.3.4 The approach in this Section generally applies to the erection block-to-block joints. Appropriate measures are to be considered to prevent large scale fracture of the hull girder in anticipation of the following:

(a) Crack initiation in the block-to-block butt weld joint in either the hatch side coaming or upper deck. Crack propagates along the butt weld joint without deviation.
(b) Crack initiation in the block-to-block butt weld joint in either the hatch side coaming or upper deck. Crack propagates away from the butt weld joint running into base metal.
(c) Crack initiation in any welded joint, for example in way of attachment welds, and deviates away from the butt weld joint running into base metal.

2.3.5 The detailed arrangements for crack arrest design are to be submitted for approval.

2.3.6 Where Measure 1 is required in Table 8.2.1, 100 per cent ultrasonic testing of all subject block-to-block welds is to be carried out in accordance with the requirements of Ch 13, 2.12 of the Rules for Materials.

2.3.7 The following are considered to be acceptable examples of brittle crack arrest design for the case given in 2.3.4(a) and (b):

(a) Where the block-to-block butt welds of the hatch side coaming and those of the upper deck are staggered, this offset is to be greater than or equal to 300 mm. Brittle crack arrest steel is to be provided for the hatch side coaming.
(b) Where crack arrest holes are provided in way of the block-to-block butt welds at the region where hatch side coaming weld meets the deck weld. The corners of the crack arrest holes located where the hatch side coaming joints meet the deck weld are to be specially assessed for fatigue strength. The fatigue strength is also to be assessed at the location where the block-to-block butt weld intersects the crack arrest hole. Brittle crack arrest

steel, as defined in 2.3.9, is to be provided for the hatch side coaming.

(c) Where higher crack arrest steel insert plates such as SUF (Surface Layer with Ultra-Fine grain) steel or equivalent, or weld metal inserts with high crack arrest toughness properties are provided in way of the block-to-block butt welds at the region where hatch side coaming weld meets the deck weld. Brittle crack arrest steel, as defined in 2.3.9, is to be provided for the hatch side coaming.

2.3.8 For the case given in 2.3.4(c), brittle crack arrest steel, as defined in 2.3.9, is to be used for the upper deck along the cargo hold region to arrest a brittle crack initiating from the coaming and propagating into the structure below.

2.3.9 Brittle crack arrest steel is defined as steel plate with measured crack arrest properties, K_{ca} 6,000 N/mm$^{3/2}$ at –10°C or other methods based on the determination of Crack Arrest Temperature (CAT). Where the thickness of the steel exceeds 80 mm the required K_{ca} value or alternative crack arrest parameter for the brittle crack arrest steel plate is to be specifically agreed with LR.

2.3.10 Where higher crack arrest steel or weld inserts are proposed, as given in 2.3.7(c), the specific properties or grades of material are to be agreed with LR.

2.3.11 As an alternative to crack arrest design, design based on crack initiation may be considered. Design based on this approach aims to prevent any defect from propagating into a brittle fracture by ensuring that no defect exists above a calculated size in the weld either during construction or subsequently in service. This size is determined by way of an Engineering Critical Assessment (ECA) which must be carried out and submitted to LR prior to construction. The ECA will determine the minimum acceptable defect size from both fatigue crack growth and fracture mechanics calculations. The detectability of such a defect in the structure will also need to be proven to LR. This can only be achieved through assessment of the non-destructive examination techniques and procedures to be applied. It is anticipated that, for this approach to be successful, the application of advanced NDT, such as the Time of Flight Diffraction (TOFD) Technique, will be necessary. The approach will also need to include a programme of non-destructive testing during the lifetime of the ship to ensure that growth of a defect does not exceed the limits of the ECA.

2.3.12 Table 8.2.1 summarises a selection of measures aimed at mitigating the risk of uncontrolled brittle fracture in way of deck and hatch coaming structure. A range of thickness is shown for the different strength grades of steel; where the maximum as-built thickness falls within this range, measures are to be selected as shown in the Table. If the as-built thickness of the hatch coaming structure is below the values contained in the Table, additional measures are not necessary.

Table 8.2.1 Preventive measures to be used in design and construction

Nominal yield strength (N/mm^2)	Thickness (mm)	Measure		
		1	2 (*see* Note 1)	3 (*see* Note 1)
355	$50 < t \leq 85$	Not required	Not required	Not required
	$85 < t \leq 100$	Required	Not required	Not required
390	$50 < t \leq 85$	Required	Not required	Not required
	$85 < t \leq 100$	Required	Required (*see* Note 2)	Required
460	$50 < t \leq 85$	Required	Required (*see* Note 2)	Required
	$85 < t \leq 100$	Required	Required (*see* Note 2)	Required

Key to measures:

Measure 1: This measure is mandatory where required is shown. 100% ultrasonic testing in accordance with Ch 13,2.12 of the Rules for Materials, both application and acceptance criteria, is to be carried out on all block-to-block butt joints of all upper flange longitudinal structural members in the cargo hold region. Upper flange longitudinal structural members include the topmost strakes of the inner hull/bulkhead, the sheerstrake, main deck, coaming plate, coaming top plate, and all attached longitudinal stiffeners

Measure 2: Design based on crack arrest, *see* 2.3.7 and 2.3.8

Measure 3: Design based on crack initiation, *see* 2.3.11

NOTES

1. Measure 2 or Measure 3 is to be applied where 'required' is shown.
2. Brittle crack arrest steel to be applied for upper deck along the cargo hold region to prevent crack propagation from the coaming into lower structure.

Section 3
Longitudinal strength

3.1 General

3.1.1 Longitudinal strength calculations are to be carried out in accordance with 3.2 and 3.3.

3.1.2 Alternatively the values and distributions of wave induced loads may be derived by direct calculation in accordance with LR's ShipRight Procedure *Guidance Notes on the Assessment of Global Design Loads of Large Container Ships and Other Ships Prone to Whipping and Springing*.

3.1.3 For ships of abnormal hull form, or for ships of unusual structural configuration or complexity, the values and distributions of wave induced loads are to be agreed with LR.

3.2 Longitudinal strength

3.2.1 Longitudinal strength calculations are to be made in accordance with the requirements of Pt 3, Ch 4 and the additional notes contained in this Section and Section 14.

3.2.2 The design vertical wave bending moments and design wave shear forces are to be determined in accordance with Ch 2,2.4 and Ch 2,2.5 and are to be used in Pt 3, Ch 4.

3.2.3 The values of sagging f_{fS} and hogging f_{fH} correction factors due to non-linear effects of the hull shape are to be derived by non-linear ship motion analysis based on equivalent design sea state methods where the following condition applies:

L > 300 m and one or more of
(i) $|f_{fS}|$> 1,4 or
(ii) RA_{BF} > 0,2 or
(iii) RA_{BFU} > 0,2

where

f_{fS} and f_{fH} are defined in Ch 2,2.4.1
RA_{BF} is the bow flare area ratio for the lower region just above the still waterline

$$= \left(\frac{A_{BF}}{0,1LB_{WL}}\right)$$

RA_{BFU} is the bow flare area ratio for the upper region near the deck

$$= \left(\frac{A_{BFU}}{0,1LB_{WL}}\right)$$

A_{BF}, B_{WL} are defined in Ch 2,2.4.1
A_{BFU} is the bow flare area in m^2 for the region from a waterline of $T_{C,U}$ to $T_{C,2U}$, calculated in the same way as A_{BF} *see* Ch 2, 2.4.1
$T_{C,2U} = T + C_1$ m or the local deck edge height if this is lower
C_1 is defined in Table 4.5.1 in Pt 3, Ch 4

The methodology to calculate the non-linear ship motion wave loads is given in LR's ShipRight Procedure *Guidance Notes on the Assessment of Global Design Loads of Large Container Ships and Other Ships Prone to Whipping and Springing*.

3.3 Combined longitudinal and torsional strength

3.3.1 The strength of the ship to resist a combination of longitudinal and torsional loads is to be determined in accordance with 15.1.

Section 4
Deck structure

4.1 General

4.1.1 The requirements of Ch 1,4 are to be complied with as modified by this Section.

4.1.2 The strength deck is to be longitudinally framed throughout the region of container holds for ships where $L \geq 100$ m.

4.1.3 Lower decks/side stringers are to be efficiently scarfed into the machinery space, and the fore end and aft end structure.

4.1.4 The ShipRight FDA Procedure, *Structural Detail Design Guide (SDDG)*, indicates recommended examples of structural design configurations in critical areas of deck structures.

4.2 Primary supporting structure

4.2.1 Where decks form part of the primary support structures described in 6.2 and 9.2 the scantlings of the decks are to be verified by direct calculation procedures in accordance with 14.2.

4.3 Deck plating and stiffeners

4.3.1 Strength/weather deck scantlings outside the line of hatch openings are to satisfy the requirements of Section 3 and 4.2, and are to be not less than required by Ch 1,4.2 and Ch 1,4.3.

4.3.2 Within the cargo holds, strength/weather/second deck scantlings inside the line of hatch openings are to satisfy the requirements of Sections 3, 4.2 and 4.4.

4.3.3 Other deck scantlings are to satisfy the requirements of Sections 3, 4.2 and Ch 1,4 as appropriate.

4.4 Cross decks

4.4.1 The width and scantlings of cross-deck strips are to satisfy the requirements of 4.2. The thickness, t, of cross-deck strips is to comply with the requirements of Table 8.4.1.

Table 8.4.1 Cross deck plating

Location	Minimum thickness, in mm
At strength deck	The greater of the following: (a) $t = 0{,}012s_1$ (b) $t = 10 + 0{,}01L_1$
At second deck	The greater of the following: (a) $t = 0{,}012s_1$ but need not exceed 12 (b) $t = 8{,}0$
Symbols	
s_1 and L_1 as defined in 1.5.1	

4.4.2 The thickness may require to be increased locally in way of access openings.

4.4.3 Where the difference between the thickness of plating inside and outside the line of main hatchway openings exceeds 25 mm, a single transition plate is to be fitted at the end of the cross-deck strip. The thickness of the transition plate is to be equal to the mean of the adjacent plate thicknesses.

4.4.4 The scantlings of cross-deck stiffeners are to comply with Ch 1,4.

4.4.5 For initial design purposes the width of the cross deck strips, *w*, forming a transverse bulkhead top box (or equivalent) can be estimated according to the following formula:

$w = 32{,}5B + 400$, or 1000 mm, whichever is the greater

where *B* is given in 1.5.1.

4.5 Deck openings

4.5.1 The corners of main hatchway openings are generally to be rounded. However, corners with negative radii, or parabolic or elliptic profiles will be specially considered.

4.5.2 The design of hold corners including deck thickness and corner profile is to comply with either 4.5.3 or 4.5.4.

4.5.3 The design of hatch corners is to be verified by direct calculations, *see* 14.1.1.

4.5.4 Alternatively, where the design of hatch corners has not been verified by direct calculations:

(a) The outboard radius of main hatchway openings at strength deck level is, in general, to be not less than 35 per cent of the width of the cross-deck strip indicated in 4.4.5 with a minimum of 300 mm.

(b) The radius of the hatch corners of the main hatchway openings adjacent to the engine room is to be made as large as practicable, with a radius of approximately 40*B* mm.

(c) Insert plates at main hatch corners are to have an increased thickness above the adjacent plating outside the line of hatchways of 15 per cent in way of the container holds, and 25 per cent in container holds at engine room bulkheads. The minimum increase is to be not less than 4,0 mm, nor need exceed 7,0 mm, and the minimum fore and aft extent is to be 1,0 m from the edge of the openings.

4.6 Local reinforcement

4.6.1 Attention is to be paid to structural continuity, and abrupt changes of shape, section or plate thickness are to be avoided, particularly in highly stressed areas. Arrangements in way of openings are to be such as to minimise the creation of stress concentrations.

4.6.2 In general, large access openings are not to be arranged in the strength deck outside the line of main hatchways in the region of container holds.

4.6.3 Small openings, such as those for ventilation pipes or scuppers, are to be kept clear of hold corners, ends of longitudinal hatch coamings, ends of cross-deck strips and other critical locations.

4.7 Support for container corner seats

4.7.1 In general, local stiffening is to be fitted under seats for container supports.

4.7.2 The design of attachments to the strength deck is to minimise the effects of stress concentration, and consideration is to be given to the strength and grade of welding consumable used, *see* Ch 13,2.2.2 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

4.7.3 The strength of support arrangements is to be verified in accordance with Pt 3, Ch 14,4.

4.7.4 Doubler plates are not to be utilised in connections subject to tensile loads.

■ *Section 5* Shell envelope plating

5.1 General

5.1.1 The requirements of Ch 1,5 are to be applied, together with the requirements of this Section.

5.1.2 The bottom shell is, in general, to be longitudinally framed for ships where $L >= 100$ m.

5.1.3 The side shell may be longitudinally or transversely framed, except in way of the topside torsion box which is, in general, to be longitudinally framed.

5.2 Bottom shell and bilge

5.2.1 The thickness of the bottom shell plating is to satisfy the requirements of Section 3 and 7.2 and is to be not less than required by Ch 1,5.3.

5.2.2 In regions where transverse framing is adopted, particularly towards the end of the ship, the buckling stability of the plating will be specially considered.

5.3 Side shell and sheerstrake

5.3.1 The thickness of the side shell and sheerstrake plating is to satisfy the requirements of Section 3 and 6.2 and is to be not less than required by Ch 1,5.4.

5.3.2 At positions where high shear forces are present, local increases in thickness may be required.

5.3.3 The difference in thickness between the sheerstrake and shell plating below is not to exceed 25 mm.

■ *Section 6* Shell envelope framing

6.1 General

6.1.1 The requirements of Ch 1,6 are to be applied, together with the requirements of this Section.

6.1.2 The ShipRight FDA Procedure, *Structural Detail Design Guide (SDDG)* indicates recommended examples of configurations for end connections of shell envelope longitudinals.

6.2 Side shell primary supporting structure

6.2.1 A primary supporting structure for side shell envelope framing is to be provided of either single or double skin construction. This normally consists of a combination of vertical transverse webs and horizontal side stringers/decks.

6.2.2 Transverse webs supporting side shell envelope framing are to be arranged in line with the floors in the double bottom to ensure continuity of transverse strength.

6.2.3 The scantlings of double skin primary structure, including thickness of side shell envelope plating, are to be verified by direct calculations in accordance with 14.2.

6.2.4 The scantlings of single skin primary structure are to comply with Ch 1,6.4. Alternatively the scantlings are to be verified by direct calculations in accordance with 14.2.

6.3 Side stringers in double skin construction

6.3.1 The scantlings of side stringers are to satisfy the requirements of Sections 3, 6.2 and 6.5.

6.3.2 In addition, the scantlings of watertight side stringers are to satisfy the requirements of Ch 1,9.

6.4 Transverse webs in double skin construction

6.4.1 The scantlings of transverse webs are to satisfy the requirements of 6.2 and 6.5.

6.4.2 Transverse webs are to be efficiently stiffened, and the thickness increased locally where necessary on account of high shear stress.

6.4.3 Where, towards the end of the ship, the width of transverse webs reduces from that assumed in the direct calculations, the thickness may require to be increased locally.

6.5 Minimum thickness of transverse webs/side stringers in double skin construction

6.5.1 Transverse webs and side stringers are to have a thickness, t, not less than:

t = 7,5 + 0,015L or 9 mm whichever is the lesser.

■ *Section 7* Double bottom structure

7.1 General

7.1.1 The double bottom is, in general, to be longitudinally framed for ships where $L \geq 100$ m.

7.1.2 Longitudinally framed double bottoms are to comply with Ch 1,8.2 and the contents of this Section.

7.1.3 Transversely framed double bottoms are to comply with Ch 1,8.

7.1.4 The ShipRight FDA Procedure, *Structural Detail Design Guide (SDDG)*, indicates recommended examples of structural design configurations in critical areas of the double bottom.

7.2 Double bottom primary supporting structure

7.2.1 The primary supporting structure formed by the double bottom comprises inner bottom plating, floors, longitudinal girders and bottom shell plating.

7.2.2 The scantlings of this primary structure are to be verified by direct calculations in accordance with 14.2.

7.2.3 Where, towards the end of the ship, the depth of double bottom structure webs is reduced from that assumed in the direct calculations, the thickness may require to be increased locally.

7.2.4 Where mid-hold or quarter-length-of-hold supports for the double bottom structure are arranged, these are to

take the form of an efficiently stiffened transverse box or open section structure, *see* 9.4.

7.3 Inner bottom plating and stiffening

7.3.1 The scantlings of the inner bottom are to satisfy the requirements of Section 3 and 7.2 and are to be not less than required by Ch 1,8.4 as modified by this sub-Section.

7.3.2 The requirements of Ch 1,8.4.2 need not be applied to container ships.

7.3.3 In applying Ch 1,8.4.5, the Rule value of bottom longitudinals may be calculated assuming F_{sb} = 1,05.

7.4 Girders

7.4.1 Girders are, in general, to be arranged under container corner seatings.

7.4.2 The scantlings of watertight centreline/side girders are to satisfy the requirements of Section 3 and 7.2 and are to be not less than required by Ch 1,8.3.

7.4.3 The scantlings of non-watertight centreline/side girders are to satisfy the requirements of Section 3 and 7.2.

7.4.4 For double bottoms having a depth greater than 1,6 m, additional longitudinal stiffening may have to be introduced in order to ensure the buckling stability of the girders.

7.5 Floors

7.5.1 Plate floors are to be fitted under watertight bulkheads, non-watertight bulkheads/mid-hold supports, under container corners at hold quarter length locations and at other locations to ensure that the maximum spacing does not, in general, exceed 3,8 m. Proposals for floor spacings greater than 3,8 m are to be supported by direct calculations agreed with LR.

7.5.2 The scantlings of watertight floors are to satisfy the requirements of 7.2 and are to be not less than required by Ch 1,8.5.

7.5.3 The thickness, t, of non-watertight floors is to satisfy the requirements of 7.2 and is to be not less than:

t = $6 + 0{,}03L$ or 12 mm, whichever is the lesser.

7.5.4 Non-watertight floor stiffeners are to be fitted at approximately the same spacing as the bottom longitudinals. The scantlings are to satisfy the requirements of Pt 3, Ch 10.

7.5.5 Docking brackets, or equivalent, are to be fitted in accordance with Ch 1,8.5.3.

7.6 Support for containers

7.6.1 In general, local stiffening is to be fitted to double bottom floors or girders under container corner seatings in order to ensure the effective transmission of load.

7.6.2 Such stiffening normally takes the form of additional brackets with suitable extensions to adjacent stiffening members. The scantlings of the adjacent stiffening members may require to be increased depending on the arrangements proposed.

7.6.3 Attention is drawn to the benefit of direct support in order to minimise the effect of eccentric loading on the support brackets.

7.6.4 The scantlings of these arrangements may be determined utilising simple beam models to verify the shear and bending strength. Based on static container loads, the stresses induced in the structure are not to exceed the permissible values stated in Table 8.7.1. Alternative more complex assessment methods are to be agreed with LR.

Table 8.7.1 Permissible stress values

	Permissible stress, N/mm^2 (kgf/mm^2)
Normal stress (bending, tension, compression)	$0{,}67\sigma_o$
Shear stress	$0{,}4\sigma_o$
Combined stress	$0{,}86\sigma_o$
Symbols	
σ_o = specified minimum yield stress, in N/mm^2 (kgf/mm^2)	

7.6.5 In general, doubling members or equivalent structures are to be attached to the inner bottom to distribute the load from container corners into the supporting structure. Doubler plates are to have well-rounded corners.

■ *Section 8*
Longitudinal bulkheads

8.1 General

8.1.1 The requirements of Ch 1,9 are to be applied, together with the requirements of this Section.

8.1.2 Longitudinal bulkheads may be transversely or longitudinally framed, except in way of the topside torsion box which is, in general, to be longitudinally framed.

8.1.3 Longitudinal bulkheads are to be maintained continuous in way of the machinery space where this is situated between container holds and as far forward and aft as practicable.

8.1.4 The scarfing arrangements in way of the steps are to be sufficient to ensure an efficient overlap of the inner skin bulkheads.

8.1.5 The ShipRight FDA Procedure, *Structural Detail Design Guide (SDDG)*, indicates recommended examples of structural design configurations in critical areas of the double side skin structures.

8.2 Side shell primary supporting structure

8.2.1 Where the longitudinal bulkhead forms the inner skin of the side shell primary supporting structure the thickness of longitudinal bulkhead plating is to be verified by direct calculations as described in 14.2.

8.3 Plating and stiffeners

8.3.1 The scantlings of longitudinal bulkheads are to satisfy the requirements of Section 3 and 8.2 and are to be not less than required by Ch 1,9.

8.3.2 Openings in the upper parts of longitudinal bulkheads are to have shapes which minimise stress concentrations and are to be framed to ensure adequate buckling stability.

8.3.3 The difference in thickness between the top strake and the bulkhead plating below is not to exceed 25 mm.

8.4 Support for container corner seats

8.4.1 Where direct support for 20 ft containers by the longitudinal bulkhead is required at the mid length of a cell arranged for 40 ft containers, adequate stiffening is to be fitted in order to ensure the effective transmission of load.

8.4.2 The strength of these arrangements is to be verified in accordance with Pt 3 Ch 14,4.

■ *Section 9* Transverse bulkheads

9.1 General

9.1.1 The requirements of Ch 1,9 are to be applied, together with the requirements of this Section.

9.1.2 Watertight transverse bulkheads may be vertically or horizontally framed.

9.1.3 The ShipRight FDA Procedure, *Structural Detail Design Guide (SDDG)*, indicates recommended examples of structural design configurations in critical areas of transverse bulkhead structures.

9.2 Transverse watertight/non-watertight bulkhead primary supporting structure

9.2.1 The primary supporting structure of transverse bulkheads normally comprises a grillage of vertical webs and horizontal stringers/decks.

9.2.2 Vertical webs are to be fitted in line with double bottom girders.

9.2.3 The scantlings of transverse bulkhead primary structure including bulkhead plating are to be verified by direct calculations as described in 14.2.

9.2.4 The scantlings are to be adequate for the static and dynamic loads imposed on the structure by the container stowage arrangements.

9.3 Transverse watertight bulkheads

9.3.1 The thickness of the transverse bulkhead plating is to satisfy the requirements of 9.2 and is to be not less than required by Ch 1,9.2 for watertight bulkheads.

9.3.2 In general, a transverse box structure or equivalent is to be arranged at upper deck level.

9.3.3 In certain cases, a transverse box structure at the inner bottom may also be required.

9.4 Transverse non-watertight mid-hold bulkheads

9.4.1 Where non-watertight bulkheads are arranged in conjunction with the double bottom mid-hold support, a transverse box is to be arranged at strength deck level.

9.4.2 Non-watertight bulkhead scantlings are to satisfy the requirements of 9.2 and Ch 1,4.4 for a non-watertight pillar bulkhead.

■ *Section 10* Hatch coamings and support for hatch covers

10.1 Hatch coamings

10.1.1 Scantlings of hatch coamings are to comply with Pt 3, Ch 11,5 in addition to the requirements of this Section.

10.1.2 Continuous side coamings are to be effectively scarfed into the deckhouse structure or gradually tapered at ends, as applicable. The scantlings are also to satisfy the requirements of Section 3.

10.1.3 The scantlings of transverse hatch coamings forming part of a transverse bulkhead top box are also to satisfy the requirements of 9.2.

10.1.4 The ShipRight FDA Procedure, *Structural Detail Design Guide* (SDDG), indicates examples of recommended structural design configurations in critical areas of the hatch side coamings.

10.2 Support for inboard edges of hatch covers by girders

10.2.1 Where longitudinal underdeck girders are fitted at deck level to support the hatch covers the requirements of this sub-Section are to be complied with.

10.2.2 The girders may take the form of open or closed box sections and these should align with webs on the transverse bulkheads to form a continuous ring structure.

10.2.3 The girders are, in general, to be continuous throughout the container hold area, including the engine room where this is situated between container holds.

10.2.4 Special attention is to be given to the intersection of the girders with transverse box girders and the integration into the fore end, aft end and machinery space structures.

10.2.5 Where girders are integrated into the cross-deck strips, inserts plates with integral gussets are to be incorporated. The inserts are to have a thickness not less than that of the girder top and bottom plates, as appropriate. The radius of main hatchway openings in way of ends of hatch girders at upper deck level is, in general, to be not less than 20 per cent of the width of the cross-deck strip indicated in 4.4.5 with a minimum of 250 mm.

10.2.6 Scantlings of girders are to comply with the requirements of Ch 1,4.

10.3 Support for hatch cover fittings

10.3.1 The width of hatch coaming top plates is to be suitable to accommodate the hatch covers and associated fittings.

10.3.2 Local stiffening is to be fitted below hatch cover supporting devices and in some cases the thickness of the coaming in way may need to be increased, (*see also* Pt 3, Ch 11,4.2.3 and 5.2.12).

■ *Section 11* Hatch covers

11.1 General

11.1.1 The requirements of Pt 3, Ch 11 are to be complied with in addition to the requirements of this Section.

11.1.2 The primary structure of hatch covers normally consists of an arrangement of deep beams and girders including hatch cover top plating.

11.1.3 For hatch covers subjected to point loads from containers, the primary structure scantlings are to be verified by direct calculation in accordance with 11.2.

11.1.4 Local stiffening is to be arranged below container corners. The substructures of container foundations are to be designed for cargo and container loads according to Pt 3, Ch 11,2.3, applying the permissible stresses according to Pt 3, Ch 11,2.4.1.

11.2 Direct calculations

11.2.1 Direct calculations are to be based on 2D or 3D finite element analysis. Simplified boundary constraints may be applied in the modelling, provided this does not compromise the overall structural response.

11.2.2 Where containers are stowed on hatch covers, the following loads due to heave, pitch, and the ship's rolling motion are to be considered, *see* Fig. 8.11.1:

$$A_z = 9{,}81 \frac{M}{2} (1 + a_v)\left(0{,}45 - 0{,}42 \frac{h_m}{b}\right) \text{ kN}$$

$$B_z = 9{,}81 \frac{M}{2} (1 + a_v)\left(0{,}45 + 0{,}42 \frac{h_m}{b}\right) \text{ kN}$$

$$B_y = 2{,}4M \text{ kN}$$

The loads due to single forces resulting from heave and pitch are also to be considered, as defined in Pt 3, Ch 11,2.3.5, where

a_v = acceleration addition according to Pt 3, Ch 11,2.3.4
b = distance between foot points, in metres
h_m = designed height of centre of gravity of stack above hatch cover supports, in metres
A_z, B_z = support forces in z-direction at the forward and aft stack corners, in kN
B_y = support force in y-direction at the forward and aft stack corners, in kN
M = maximum designed mass of container stack, in *t.*

For M and h_m, it is recommended to apply those values which are used for the calculations of cargo securing (container lashing). If different assumptions are made for M and h_m, the designer is to ensure that, in the calculation model, the hatch cover structure is not loaded by less than those values recommended.

When the strength of the hatch cover structure is assessed by FE analysis according to the ShipRight procedure *Assessment of Steel Hatch Covers using Finite Element Analysis*, h_m may be taken as the designed height of centre of gravity of stack above the hatch cover top plate. Values of M and h_m applied for the assessment of hatch cover strength are to be shown in the drawings of the hatch covers.

11.2.3 The forces acting on hatch covers when container stacks are secured to lashing bridges or carried in cell guides will be specially considered.

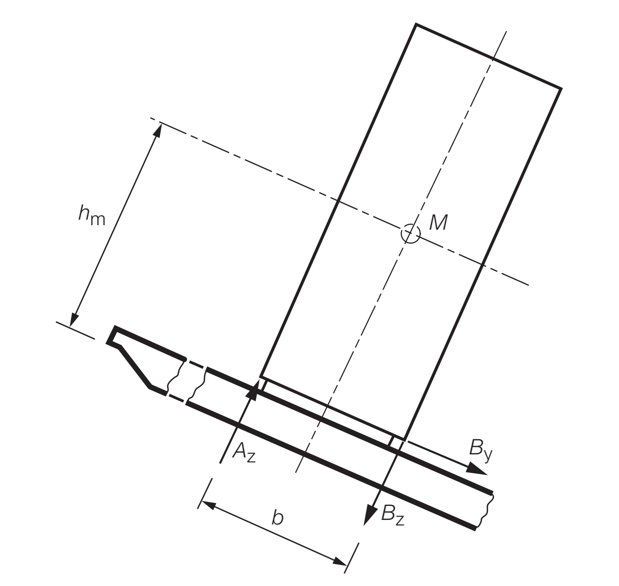


Fig. 8.11.1 Forces due to container loads

11.2.4 A load case with partial non-homogeneous loading is also to be considered, e.g., where specified container stack places are empty. This may be evaluated using a simplified approach, where the hatch cover is loaded without the outermost stacks, *see* Fig. 8.11.2.

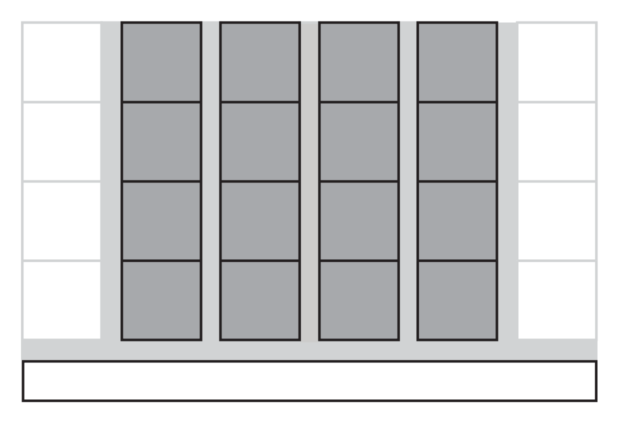


Fig. 8.11.2
Partial loading of a container hatch cover

11.2.5 The securing devices of hatch covers, onto which cargo is to be lashed, are to be designed for the lifting forces resulting from loads according to 11.2.2, *see* Fig. 8.11.3. Unsymmetrical loadings, which may occur in practice, are to be considered. Under these loadings, the equivalent stress in the securing devices is not to exceed:

$$\sigma_v = \frac{150}{k_1} \text{ in N/mm}^2$$

Special consideration may be given for the omission of anti-lifting devices for non-weathertight hatch covers.

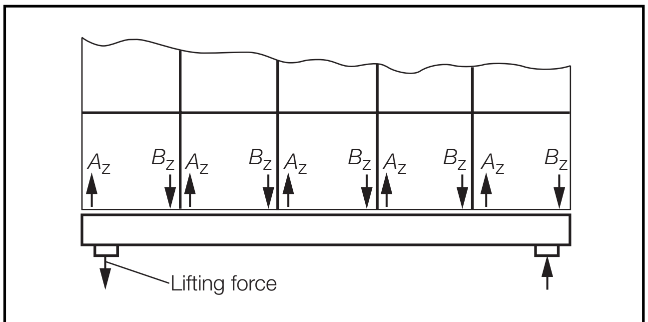


Fig. 8.11.3 Lifting forces at a hatch cover

11.2.6 Where hatch covers are arranged for carrying containers and mixed stowage is allowed, i.e., a 40' container stowed on top of two 20' containers, particular attention is to be paid to the deflections of hatch covers. Furthermore, the possible contact of deflected hatch covers with in-hold cargo is to be considered.

11.3 Dispensation of weathertight gaskets

11.3.1 For hatch covers of cargo holds solely for the transport of containers, upon request by the Owners and subject to compliance with the requirements of this Section, the fitting of weathertight gaskets according to Pt 3, Ch 11,4.4 may be dispensed with.

11.3.2 The hatchway coamings are not to be less than 600 mm in height.

11.3.3 The exposed deck on which the hatch covers are located is situated above a depth $H(x)$. $H(x)$ is to be shown to comply with the following criteria:

$$H(x) \geq T_{fb} + f_b + h, \text{ in metres}$$

where

T_{fb} = draught, in metres, corresponding to the assigned summer load line

f_b = minimum required freeboard, in metres, determined in accordance with ICLL Reg. 28 as modified by further regulations, as applicable

h = 4,6 m for $\frac{x}{L} \leq 0{,}75$

= 6,9 m for $\frac{x}{L} > 0{,}75$.

11.3.4 Labyrinths, gutter bars or equivalents are to be fitted proximate to the edges of each panel in way of the coamings. The clear profile of these openings is to be kept as small as possible.

11.3.5 Where a hatch is covered by several hatch cover panels, the clear opening of the gap in between the panels is to be not wider than 50 mm.

11.3.6 The labyrinths and gaps between hatch cover panels shall be considered as unprotected openings with respect to the requirements of intact and damage stability calculations.

11.3.7 Bilge alarms are to be provided in each hold fitted with non-weathertight covers.

11.3.8 Furthermore, Chapter 3 of IMO MSC/Circ.1087 is to be referred to concerning the stowage and segregation of containers containing dangerous goods.

11.4 Omission of hatch covers

11.4.1 Proposals for the omission of hatch covers will be specially considered. Such proposals are to include details, established by model tests or alternative means, of the quantity of water likely to ingress the cargo holds under the worst sea-going and weather conditions, and the means by which it is to be efficiently and safely discharged. The proposals will also require to be agreed by the National Authority in order that an exemption from the Load Line Convention requirements for hatch covers may be obtained.

■ *Section 12* Strengthening for wave impact loads

12.1 General

12.1.1 The scantlings of plating, stiffeners of forward and after portions of the hull are to be increased for protection against bow flare and wave impact pressure in accordance with Ch 2,4.3 and 5.2.

12.1.2 The scantlings of the primary support structure are to be adequate to resist the application of the Rule slamming load, P_{bf}, as defined in Ch 2,4.2.1, over an area A_{sl}, as shown in Fig. 2.5.2 in Chapter 2. The loaded area, A_{sl}, is a rectangle with a horizontal extent, g_{bfh}, and vertical extent, g_{bfv}, taken as follows:

$$g_{bfh} = 4 \text{ m}$$

$$g_{bfv} = \frac{8}{\sin\beta_p \sqrt{8K_{bf}}} \text{ m}$$

where

K_{bf} and β_p are given in Ch 2,4.2.1.

12.1.3 To satisfy 12.1.2, the scantlings of web frames supporting side longitudinals or side stringers supporting transverse frames are to comply with the following:

(a) Section modulus not to be less than:

$$Z = 3{,}75 f_{rpc}\, \gamma_Z\, k\, h_s\, q\, v\, l_e^2 \quad \text{cm}^3$$

(b) Web area not to be less than:

$$A = 0{,}20 f_{rpc}\, \gamma_A\, k\, h_s\, q\, v\, l_e \quad \text{cm}^2$$

where

h_s = wave impact head, in metres, as defined in Ch 2,4.3.2.

and

$$f_{rpc} = \frac{P}{3{,}05V^3}$$

$$= \left(\frac{H}{2{,}27V^3}\right)$$

P is the maximum propulsion shaft power in kW for which the machinery is classed, *see* Pt 5, Ch 1,3

H is the maximum propulsion shaft power in HP for which the machinery is classed, *see* Pt 5, Ch 1,3

V is the speed, in knots as defined in Pt 3, Ch 1,6

γ_A and γ_Z are strength factors dependent on the load position:

for $q < 1$: $\gamma_A = q^3 - 2q^2 + 2$ and $\gamma_Z = 3q^3 - 8q^2 + 6q$

for $q = 1$: $\gamma_A = 1 \gamma_Z = 1$

$$q = \frac{u}{l_e} \text{ but} \le 1$$

for web frames

u is the minimum of g_{bfv} or l_e

v is the minimum of g_{bfh} or S_{cm}

for side stringers

u is the minimum of g_{bfh} or l_e

v is the minimum of g_{bfv} or S_{cm}

l_e is the effective length of the primary member, in metres

S_{cm} is the mean spacing between primary members along the plating, in metres, *see* Fig. 2.5.2 in Chapter 2

g_{bfv} and g_{bfh} are defined in 12.1.2

(c) Web plating is to be adequately stiffened to resist shear buckling as required by Table 8.12.1.

Table 8.12.1 Critical shear buckling stress for web plating of primary support structure

$\tau_A \le \tau_{CRB}$

where

$\tau_{CRB} = \tau_E$ N/mm² (kg-f/mm²) when $\tau_E \le \dfrac{\tau_0}{2}$

$\tau_{CRB} = \tau_0 \left(1 - \dfrac{\tau_0}{4\tau_E}\right)$ N/mm² (kg-f/mm²) when $\tau_E > \dfrac{\tau_0}{2}$

where

$$\tau_E = 3{,}6 \left[1{,}335 + \left(\frac{s}{1000S}\right)^2\right] E \left(\frac{t_p}{s}\right)^2 \text{ N/mm}^2 \text{ (kg-f/mm}^2\text{)}$$

Symbols

τ_A	=	design shear stress for the web panel in N/mm² (kgf/mm²) corresponding to the worst combination of application of the slamming load P_{bf} on the patch area A_{sl}
τ_{CRB}	=	critical buckling stress in shear, N/mm² (kgf/mm²) corrected for yielding effects
τ_0	=	$\dfrac{\sigma_o}{\sqrt{3}}$
σ_o	=	specified minimum yield stress, in N/mm² (kgf/mm²)
τ_E	=	elastic critical buckling stress in shear, in N/mm² (kgf/mm²)
s	=	length of longer panel edge, in mm (generally the spacing of web stiffeners)
S	=	length of smaller panel edge, in metres (generally the web depth)
E	=	modulus of elasticity, in N/mm² (kgf/mm²)
	=	206000 N/mm² (21000 kgf/mm²) for steel
τ_p	=	as built thickness of primary member web plating, in mm

Section 13
Container stowage systems

13.1 Cell guide systems

13.1.1 Where cell guide systems are fitted to support containers in holds or on deck, they are to comply with the requirements of Pt 3, Ch 14,7.

13.2 Stowage on decks/hatch covers

13.2.1 Strength of support structures for pads/pedestals under container corners, lashing equipment and lashing bridges is to comply with Pt 3, Ch 14,4.

Section 14
Direct calculation

14.1 Procedures for calculation of combined longitudinal and torsional strength

14.1.1 For container ships as defined in 1.3.3(b), (c) and (d) or with beam greater than 33 m, longitudinal strength calculations are to be made in accordance with Parts A and B of LR's ShipRight SDA Procedure for container ships, *see also* Table 8.14.1.

14.1.2 The global, primary and local structure scantlings are to be assessed using the vertical and horizontal wave bending moments and shear forces and torsional wave moments derived using non-linear ship motion analysis based on equivalent design sea state methods where one or more of the following conditions applies:
(a) $B > 60$ m
(b) $L > 350$ m
The methodology to calculate the non-linear ship motion wave loads is given in LR's ShipRight Procedure *Guidance Notes on the Assessment of Global Design Loads of Large Container Ships and Other Ships Prone to Whipping and Springing*.

14.2 Procedures for verification of primary structure scantlings

14.2.1 For container ships as defined in 1.3.3, the strength of the ship's primary structure scantlings of double bottom, side and transverse bulkheads is to be assessed in accordance with Part C of LR's ShipRight SDA Procedure for container ships. The wave loads to be applied in this assessment are to be calculated in accordance with 3.2.

14.2.2 For other container ships the method for analysis of primary structure of double bottom, side structure and transverse bulkheads is to be agreed with LR.

14.3 Procedures for verification of structural response due to whipping, springing and fatigue

14.3.1 The ultimate strength of the hull girder of container ships is to be assessed against the extreme wave bending moments including whipping and wave impact loads in accordance with LR's ShipRight Procedure *Guidance Notes on the Assessment of Global Design Loads of Large Container Ships and Other Ships Prone to Whipping and Springing* where one or more of the following conditions applies:
(a) $L > 350$ m
(b) $L > 300$ m and one or more of
  (i) $|f_{fS}| > 1,4$ or
  (ii) $RA_{BF} > 0,2$ or
  (iii) $RA_{BFU} > 0,2$
(c) Use of HT47 or above for the deck or hatch side coaming
(d) Use of HT36 or above for the bottom shell
where
  f_{fS} is defined in Ch 2, 2.4.1
  RA_{BF} and RA_{BFU} are defined in 3.2.3
  See Table 8.14.1.

14.3.2 The fatigue assessment of container ships including hull girder springing is to be assessed where one or more of the following conditions applies, *see* Table 8.14.1:
(a) $L > 350$ m
(b) $L > 250$ m and $f_c > f_{sp}$
(c) Use of HT47 or above for the deck or hatch side coaming
(d) Use of HT36 or above for the bottom shell
where
  f_c is a wave encounter frequency at which it is expected that springing will become important

$$= \frac{1,4}{2\pi}\left(1 + \frac{1,4V}{2g}\right) \text{Hz}$$

  f_{sp} is the natural frequency of the 2 node hull girder vertical bending mode in Hz. This can be very approximately calculated as:

$$= \left(\frac{1,1}{\pi L^2}\right)\sqrt{\frac{EI10^5}{1,8\, B\, T_d\, C_b}} \text{ Hz}$$

V = speed in knots as defined in Pt 3, Ch 1,6.1.10
E = Young's modulus in N/mm^2
  = 206000 N/mm^2 for steel
I is the midship moment of inertia in m^4, *see* Pt 3, Ch 4
T_d is the design (normal standard operating) draught, in metres
C_b, L, and B are given in Pt 3, Ch 1,6.
The fatigue assessment is to be carried out in accordance with LR's ShipRight Procedure *Guidance Notes on the Assessment of Global Design Loads of Large Container Ships and Other Ships Prone to Whipping and Springing*, which also makes reference to LR's ShipRight FDA procedures.

Table 8.14.1 Summary of direct calculation analysis requirements for container ships

Rule requirement *See* Note 1	Rule reference	ShipRight notation	Application criteria. If any of the following criteria apply then the appropriate analysis is required					
			Length criteria	Any of $\lvert f_{fS}\rvert > 1,4$ or $RA_{BF} > 0,2$ or $RA_{BFU} > 0,2$	$f_c > f_{sp}$	Deck or hatch side coaming steel grade >= HT47	Bottom steel grade >= HT36	Breadth criteria
Part C of LR's ShipRight SDA Procedure for container ships	1.1.5	SDA	—	—	—	—	—	$B > 32$
Parts A and B of LR's ShipRight SDA Procedure for container ships	14.1.1	SDA	—	—	—	—	—	$B > 33$
Non-linear ship motion analysis to calculate hogging and sagging factors	3.2.3	—	—	$L > 300$	—	—	—	—
Non-linear ship motion analysis to calculate combined vertical, horizontal and torsional loads	14.1.2	—	$L > 350$	—	—	—	—	$B > 60$
Fatigue assessment	14.3.2	FDA (*see* Note 3)	$L > 350$	—	$L > 250$	Yes	Yes	—
Whipping assessment	14.3.1	—	$L > 350$	$L > 300$	—	Yes	Yes	—
Springing assessment See Note 2	14.3.2	—	$L > 350$	—	$L > 250$	Yes	Yes	—

NOTES
1 The stated rule requirements may be deemed applicable to ships that do not meet the application criteria but where the structural configuration is such as to necessitate them.
2 The results of the springing assessment may also need a fatigue assessment procedure to be undertaken.
3 If ShipRight notation **FDA** is to be assigned, the requirements of LR's ShipRight FDA procedure are to be complied with; this may require calculations additional to those implied by 14.3.2.

■ *Section 15* Combined stress calculations

15.1 Application

15.1.1 The combined stresses due to vertical bending moment, horizontal bending moment and torque are to be calculated as described in this Section.

15.2 Symbols and definitions

15.2.1 The following symbols and definitions are applicable to this Section unless otherwise stated:

Z_Y = actual hull section modulus about the transverse neutral axis at the position considered, in m^3

Z_Z = actual hull section modulus about the vertical neutral axis at the position considered, in m^3

ε = maximum shear centre distance below baseline of the ship in the midship region, in metres. ε is taken as positive where the shear centre is below the baseline

M_s = design still water bending moment at the section under consideration, in kN m (tonne-f-m)

σ_c = combined stress at the position considered.

15.3 Design loadings

15.3.1 The design vertical wave bending moment, M_{WC}, at any position along the ship is defined as:

M_{WC} = $0,0505 C_1 L^2 B (C_b + 0,7) C_3$ kN m
= $(0,0052 C_1 L^2 B (C_b + 0,7) C_3$ tonne-f m)

C_3 = vertical wave bending moment distribution coefficient depending on the length L_{pp} as defined in Table 8.15.1

C_1 is given in Table 4.5.1 in Pt 3, Ch 4.
L, B, C_b are given in Pt 3, Ch 1,6.
The sign convention is given in Fig. 8.15.1.

15.3.2 The design horizontal wave bending moments, M_{HC1} and M_{HC2}, at any position along the ship are defined as:

M_{HC1} = $0,2063 C_1 C_{41} L^2 T (C_b + 0,7)$ kN m
= $(0,0210 C_1 C_{41} L^2 T (C_b + 0,7)$ tonne-f-m)

M_{HC2} = $0,2063 C_1 C_{42} L^2 T (C_b + 0,7)$ kN m
= $(0,0210 C_1 C_{42} L^2 T (C_b + 0,7)$ tonne-f-m)

C_{41}, C_{42} = horizontal wave bending moment distribution coefficient depending on the length, L_{pp}, as defined in Table 8.15.2
C_1 is given in Table 4.5.1 in Pt 3, Ch 4
L, B, T, C_b are given in Pt 3, Ch 1,6.
The sign convention is given in Fig. 8.15.1.

15.3.3 The design hydrodynamic torques, M_{WTC1} and M_{WTC2}, at any position along the ship are defined as:

M_{WTC1} = $M_{WTCB1} + M_{WTCQ1}$
M_{WTCB1} = $0{,}0764 C_1\ C_{51}\ L\ B^2\ (C_b + 0{,}7)$ kN m
= $(0{,}0078 C_1\ C_{51}\ L\ B^2\ (C_b + 0{,}7)$ tonne-f-m)
M_{WTCQ1} = $-(0{,}65T + f_3\ \varepsilon)\ Q_{HC1}$ kN m (tonne-f-m)
M_{WTC2} = $M_{WTCB2} + M_{WTCQ2}$
M_{WTCB2} = $0{,}0764 C_1\ C_{52}\ L\ B^2\ (C_b + 0{,}7)$ kN m
= $(0{,}0078 C_1\ C_{52}\ L\ B^2\ (C_b + 0{,}7)$ tonne-f-m)
M_{WTCQ2} = $-(0{,}65T + f_3\ \varepsilon)\ Q_{HC2}$ kN m (tonne-f-m)
C_{51}, C_{52} = hydrodynamic torque distribution coefficient depending on the length, L_{pp}, as defined in Table 8.15.2
C_1 is given in Table 4.5.1 in Pt 3, Ch 4

f_3 = shear centre distribution factor, to be taken as:
–1,0 at the aft end of L_{pp}
1,0 between $0{,}15L_{pp}$ and $0{,}80L_{pp}$ from aft
–1,0 at the forward end of L_{pp}

Intermediate values are to be determined by linear interpolation:

Q_{HC1} = $0{,}8683 C_1\ K_{31}\ L\ T\ (C_b + 0{,}7)$ kN
= $(0{,}0886 C_1\ K_{31}\ L\ T\ (C_b + 0{,}7)$ tonne-f)
Q_{HC2} = $0{,}8683 C_1\ K_{32}\ L\ T\ (C_b + 0{,}7)$ kN
= $(0{,}0886 C_1\ K_{32}\ L\ T\ (C_b + 0{,}7)$ tonne-f)
K_{31}, K_{32} = horizontal wave shear force distribution coefficient depending on the length, L_{pp}, as defined in Table 8.15.2
L, B, T, C_b are given in Pt 3, Ch 1,6.
ε is given in 15.2.1
The sign convention is given in Fig. 8.15.1.

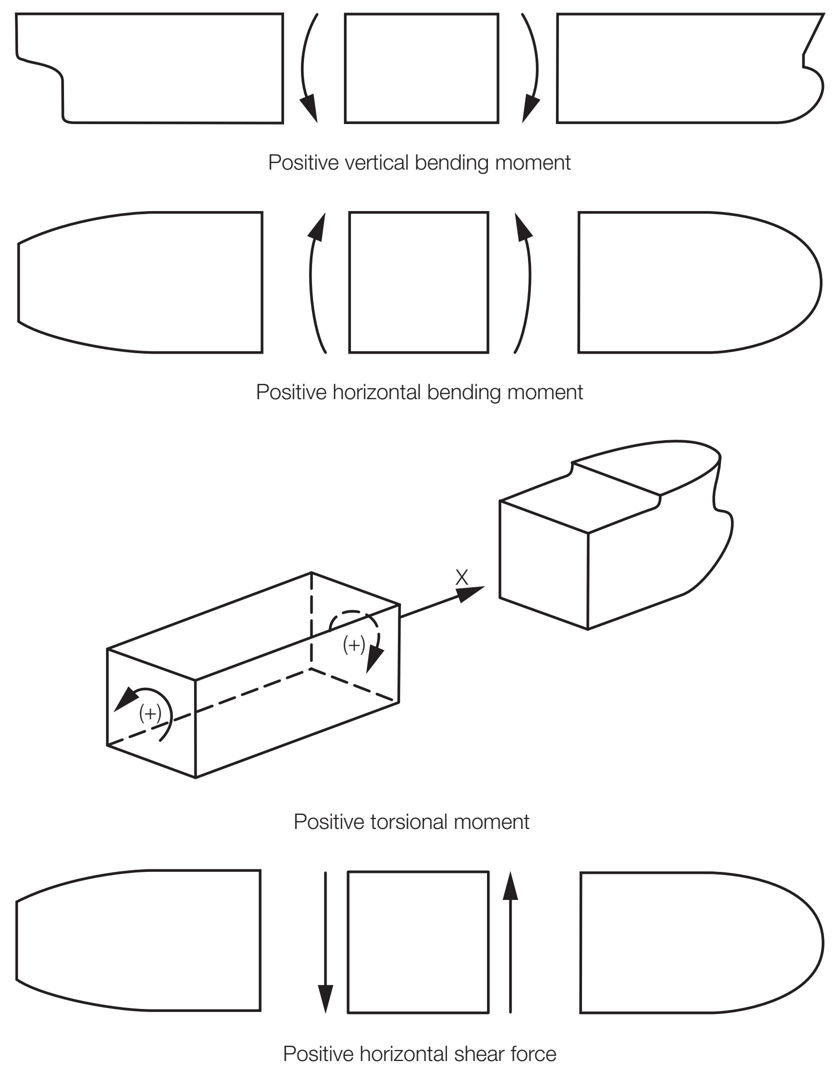


Fig. 8.15.1 Sign conventions for hull girder loads

Table 8.15.1 Distribution of wave bending moments

Position		C_3
Station	0 (A.P.)	0,000
	1	0,065
	2	0,159
	3	0,305
	4	0,464
	5	0,626
	6	0,769
	7	0,889
	8	0,966
	9	1,000
	10 (mid – L_{pp})	0,988
	11	0,919
	12	0,796
	13	0,648
	14	0,489
	15	0,344
	16	0,225
	17	0,142
	18	0,093
	19	0,060
	20 (F.P.)	0,000

NOTE
Intermediate values are to be determined by linear interpolation.

15.3.4 The design value of static cargo torque, M_{STC}, at any position along the ship is defined as:

M_{STC} = $15,7C_6\,B\,(\eta_s\,\eta_t + 0,7N_{sd}\,N_{td})$ kNm

= $(1,6C_6\,B\,(\eta_s\,\eta_t + 0,7N_{sd}\,N_{td})$ tonne-f/m)

η_s = the maximum number of stacks of containers over the breadth of the cargo hold

η_t = the maximum number of tiers of containers in the cargo hold amidships, excluding containers above the main deck or on the hatch covers

C_6 = distribution coefficient depending on the length, L_{pp}, as defined in Table 8.15.3

N_{sd} = the maximum number of stacks of containers over the breadth, B, on hatch covers or above the main deck

N_{td} = the number of tiers of containers on hatch covers or above the main deck amidships, excluding containers in cargo holds

B is given in Pt 3, Ch 1,6.

Table 8.15.3 Static cargo torque distribution factor

Position		Factor C_6
Station	0 (A.P.)	0,0
	5	1,0
	15	1,0
	20 (F.P.)	0,0

NOTE
Intermediate values are to be determined by linear interpolation.

15.4 Combined stresses

15.4.1 Combined stress calculations are to be carried out at least at the following positions along the length of the ship:

(a) At the forward and aft ends of the engine room.
(b) At the forward and aft ends of the deck-house for multi-island designs.
(c) At the forward and aft transverse bulkhead positions of each cargo bay.
(d) At the forward and aft transverse bulkhead of fuel oil deep tanks.
(e) At any other sections where there are significant changes in cross-section properties.

Table 8.15.2 Distribution of horizontal wave bending moments and hydrodynamic torques

Position		C_{41}	C_{42}	C_{51}	C_{52}	K_{31}	K_{32}
Station	0 (A.P.)	0,000	0,000	0,000	0,000	0,000	0,000
	1	–0,016	0,010	–0,289	0,235	0,101	–0,113
	2	–0,046	0,046	–0,456	0,525	0,211	–0,304
	3	–0,097	0,119	–0,455	0,754	0,276	–0,486
	4	–0,154	0,228	–0,342	0,910	0,277	–0,659
	5	–0,208	0,369	–0,184	0,988	0,214	–0,804
	6	–0,242	0,533	–0,022	1,000	0,089	–0,860
	7	–0,247	0,699	0,169	0,944	–0,083	–0,801
	8	–0,217	0,846	0,323	0,851	–0,268	–0,662
	9	–0,153	0,948	0,439	0,727	–0,422	–0,404
	10 (mid – Lpp)	–0,072	0,997	0,522	0,585	–0,485	–0,090
	11	0,014	0,985	0,562	0,443	–0,447	0,232
	12	0,087	0,915	0,544	0,288	–0,338	0,483
	13	0,136	0,802	0,472	0,111	–0,227	0,734
	14	0,158	0,657	0,260	–0,011	–0,094	0,913
	15	0,151	0,502	–0,074	–0,121	0,067	0,998
	16	0,123	0,349	–0,366	–0,082	0,185	0,952
	17	0,083	0,214	–0,385	0,039	0,245	0,821
	18	0,043	0,106	–0,198	0,062	0,220	0,627
	19	0,013	0,034	–0,075	0,052	0,133	0,326
	20 (F.P.)	0,000	0,000	0,000	0,000	0,000	0,000

NOTE
Intermediate values are to be determined by linear interpolation.

15.4.2 The combined stress, σ_c, is to be taken as σ_{chog}, calculated as:

$$\sigma_{chog} = \sqrt{(\sigma_{HC1} + \sigma_{WTC1})^2 + (\sigma_{HC2} + \sigma_{WTC2})^2} + |f_{fH}\,\sigma_{WC}| + |\sigma_{STC}| + |\sigma_{SC}|$$

σ_{SC} = longitudinal stress due to hogging or sagging design still water bending moment M_s

σ_{WC} = longitudinal stress due to vertical wave bending moment

σ_{HC1}, σ_{HC2} = longitudinal stress due to horizontal wave bending moment

σ_{STC} = warping stress due to static cargo torque

σ_{WTC1}, σ_{WTC2} = warping stress due to hydrodynamic torque

f_{fH} = hogging vertical bending moment correction factor calculated in accordance with Ch 2,2.4

other symbols are as defined in 15.3 and 15.4.

15.4.3 For ships with a beam greater than or equal to 33 m, longitudinal stresses are to be calculated using a finite element model of the entire hull in accordance with Part A of the LR's ShipRight SDA procedure for container ships.

15.4.4 For ships with a beam less than 33 m, the longitudinal stresses may be obtained as follows:

$$\sigma_{SC} = \frac{M_s}{Z_y} \times 10^{-3} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

$$\sigma_{WC} = \frac{M_{WC}}{Z_y} \times 10^{-3} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

$$\sigma_{HC1} = C_7 \frac{M_{HC1}}{Z_z} \times 10^{-3} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

$$\sigma_{HC2} = C_7 \frac{M_{HC2}}{Z_z} \times 10^{-3} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

σ_{WTC1}, σ_{WTC2} and σ_{STC} are to be evaluated by approved calculation procedures.

C_7 = coefficient for shear lag depending on vertical location of the point under consideration
= 0,6 at inboard edge of strength deck
= 1,0 at base line
= intermediate positions by interpolation

Z_y and Z_z are given in 15.2.1.

15.4.5 At each section the stresses are to be calculated on the port and starboard sides, at:

(a) the inboard edge of the strength deck;
(b) the point on the bilge where the combined stress is greatest; and
(c) the top of continuous hatch coaming (where fitted).

15.4.6 Where the ship's length is greater than 350 m or the ship's beam is greater than 60 m, the vertical wave bending moments, horizontal wave bending moments and hydrodynamic torques are to be obtained from a direct calculation method. Alternatively, the hull stresses may be obtained using a probabilistic approach response-based analysis method considering the ship's responses in wave environment. The analysis method is to be agreed with LR.

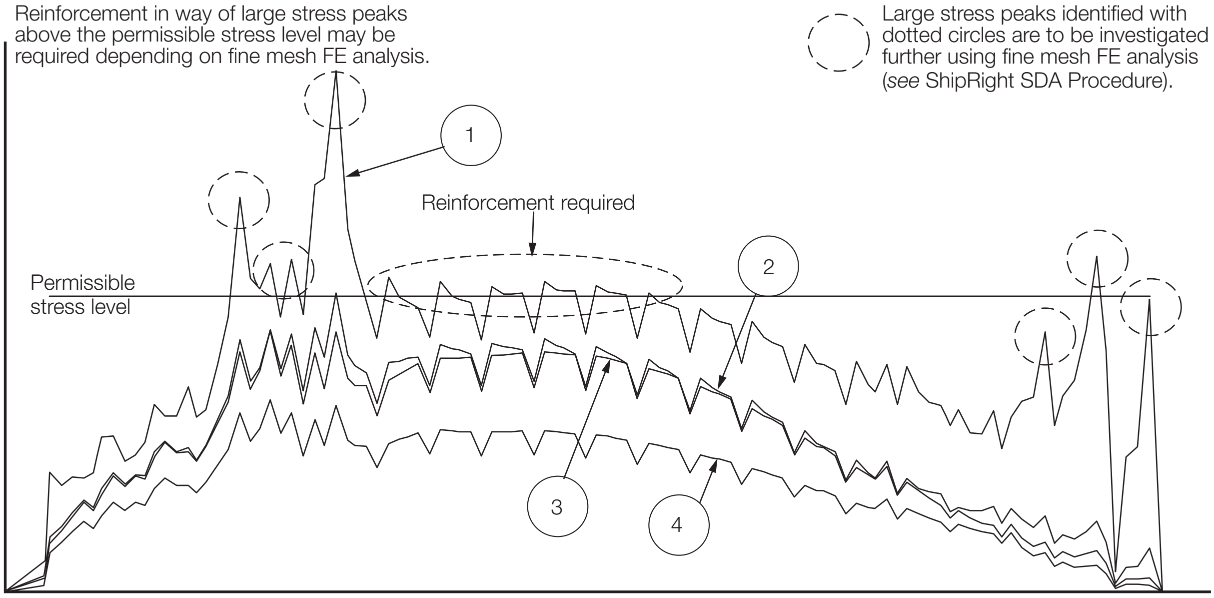
15.5 Permissible stress

15.5.1 The maximum tensile or compressive combined stress σ_c at any position along the length is not to be more than indicated in Table 8.15.4.

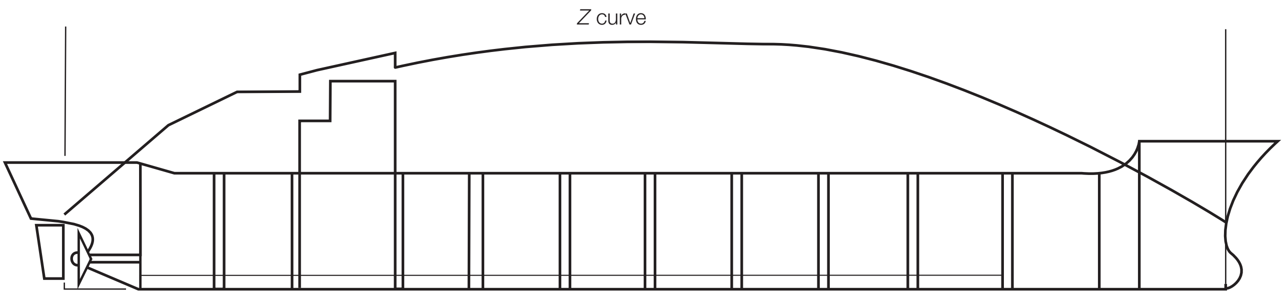
Table 8.15.4 Permissible stress

Position	Permissible combined stress, N/mm^2 (kgf/mm^2)
Shear strake, upper deck, top strake of longitudinal bulkheads, longitudinal hatch coaming side and top	$\sigma_c = \dfrac{190}{k_L} \left(\dfrac{19,37}{k_L}\right)$
Elsewhere	$\sigma_c = \dfrac{175}{k_L} \left(\dfrac{17,84}{k_L}\right)$

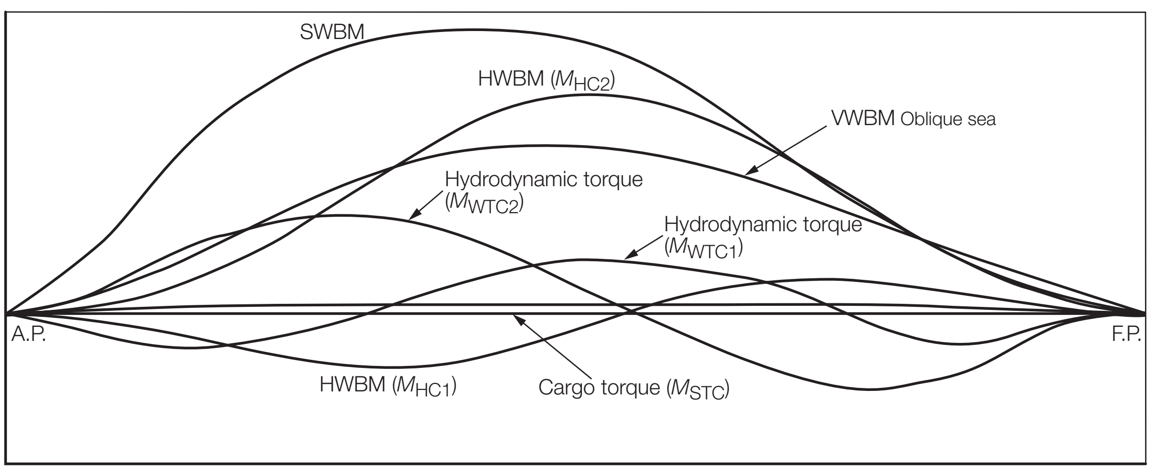
15.5.2 The assessment of combined stress may conveniently be presented in the form of combined stress diagrams as indicated in Fig. 8.15.2.



(a) Longitudinal stress distributions at top of hatch coaming showing contributions from:
1) still water bending moment + vertical wave bending moment + static cargo torque + horizontal wave bending moment and hydrodynamic torque
2) still water bending moment + vertical wave bending moment + static cargo torque
3) still water bending moment + vertical wave bending moment
4) still water bending moment



(b) Ship Profile and Section modulus



(c) Oblique Sea longitudinal distribution of vertical and horizontal bending moments and torques

NOTES
1. These diagrams are for illustration only and are not to scale.
2. A similar diagram is to be prepared for the bottom structure.

Fig. 8.15.2 Combined stress diagram for deck — Oblique sea

■ *Section 1* General

1.1 General

1.1.1 This Chapter applies primarily to the arrangements and scantlings within the cargo tank region of sea-going tankers having integral cargo tanks, for the carriage of oil having a flash point not exceeding 60ºC (closed-cup test), in association with the class notation indicated in 1.3.1 or 1.4.1. Except as indicated in 1.1.2, 1.1.3 and 1.1.4, the cargo spaces are to be bounded by side and bottom dedicated water ballast tanks or void spaces constituting a double hull for the ship, *see* Table 9.1.1.

1.1.2 Double side tanks may be dispensed with for tankers of less than 5000 tonnes deadweight where each cargo tank capacity does not exceed 700 m^3, *see* Table 9.1.1.

1.1.3 Double bottom tanks may be dispensed with for tankers of 5000 tonnes deadweight or greater subject to compliance with the requirements of 1.2.18.

1.1.4 Double bottoms and double sides may be dispensed with for vessels less than 600 tonnes deadweight, *see* Table 9.1.1.

1.1.5 Where only oils having flash points exceeding 60ºC are to be carried, the Rule requirements and class notation will be modified accordingly the additional class notation '**F.P.** exceeding 60ºC' will be entered in the *Register Book*.

1.1.6 Oil cargoes listed in Table 9.1.2 are those which are generally envisaged as being carried in ships classed in accordance with this Chapter.

1.1.7 The scantlings and arrangements of tankers intended for cargoes other than oil will be specially considered in relation to the characteristics of the cargo, and the class notation will be modified accordingly. A full list of such cargoes for a particular ship, with special requirements as applicable, can be provided by Lloyd's Register (hereinafter referred to as 'LR') on application. Chemical cargoes listed in Chapter 18 of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquid Chemicals in Bulk* (hereinafter referred to as the Rules for Ships for Liquid Chemicals) may be carried in ships for which the arrangements, scantlings and materials comply with the requirements of that Chapter. Special consideration will also be given to the carriage of cargoes with a relative density greater than 1,025, *see also* 1.3 and 1.4.

1.1.8 The Regulations for classification and assignment of the above notations and other notations, as appropriate to the arrangements, scantlings and service are provided for in Pt 1, Ch 2,2.

1.2 Application and ship arrangement

1.2.1 Double hull tankers with length, *L*, greater than or equal to 150 m with structural configuration as shown in Table 9.1.3 are defined as 'CSR Oil Tankers' and are to comply with 1.3.

1.2.2 The applicable Rules for double hull tankers with length, *L*, greater than or equal to 150 m of unusual hull form or structural arrangements will be specially considered.

1.2.3 Double hull tankers with length, *L*, less than 150 m are defined as 'Non-CSR Oil Tankers' and are to comply with 1.4.

1.2.4 Any dry tanks, or tanks intended for water ballast and thus empty in the loaded condition, are to be so arranged that they cannot be used for any other purpose.

1.2.5 Cofferdams are to be provided at the forward and after ends of the oil cargo spaces; cofferdams are to be at least 760 mm in length and are to cover the whole area of the end bulkheads of the cargo spaces.

1.2.6 A pump-room, oil fuel bunker or water ballast tank will be accepted in lieu of a cofferdam.

Table 9.1.1 Cargo tank boundary requirements

Deadweight (DWT) tonnes	Minimum double side width (d_s) metres	Minimum double bottom depth (d_b) metres
DWT ≥ 5000	$d_s = 0{,}5 + \frac{DWT}{20\,000}$ or $d_s = 2{,}0$ whichever is the lesser, but not less than 1,0	$d_b = \frac{B}{15}$ or $d_b = 2{,}0$ whichever is the lesser, but not less than 1,0
600 ≤ DWT < 5000	$d_s = 0{,}4 + \frac{2{,}4\,DWT}{20\,000}$ or $d_s = 0{,}76$ whichever is the greater, *see* Note 2	$d_b = \frac{B}{15}$ or $d_b = 0{,}76$ whichever is the greater
DWT < 600	$d_s = 0$	$d_b = 0$

NOTES
1. The symbols *DWT*, d_s and d_b are defined in 1.5.
2. Where each cargo tank capacity does not exceed 700 m^3, the value of d_s is taken as 0 and the inner bottom line is to run parallel to the line of the midship flat of bottom as shown in Fig. 9.1.2.
3. Where the double bottom tank is fitted, the centre girder depth is to be not less than as required by 9.3.3.

Table 9.1.2 Oil cargoes suitable for carriage in oil tankers, *see* Note 1

Asphalt solutions
(*see* Note 2)
Blending Stocks
Roofers Flux
Straight Run Residue

Oils
Clarified
Crude Oil
Mixtures containing crude oil
Diesel Oil
Fuel Oil No. 4
Fuel Oil No. 5
Fuel Oil No. 6
Residual Fuel Oil
Road Oil
Transformer Oil
Lubricating Oils and
Blending Stocks
Mineral Oil
Motor Oil
Penetrating Oil
Spindle Oil
Turbine Oil

Distillates
Straight Run
Flashed Feed Stocks

Gas Oil
Cracked

Gasoline Blending Stocks
Alkylates - fuel
Reformates
Polymer - fuel

Gasolines
Casinghead (natural)
Automotive
Aviation
Straight Run
Fuel Oil No. 1 (Kerosene)
Fuel Oil No. 1-D
Fuel Oil No. 2
Fuel Oil No. 2-D

Jet Fuels
JP-1 (Kerosene)
JP-3
JP-4
JP-5 (Kerosene, Heavy)
Turbo Fuel
Kerosene
Mineral Spirit

Naphtha (*see* Note 3)
Solvent
Petroleum
Heartcut Distillate Oil

NOTES
1. This list of oils is taken from Appendix 1 to Annex 1 of the MARPOL Convention. Special consideration will be given to the carriage of oil cargoes not included in the above list.
2. Asphalt solutions, *see* Chapter 18 of the Rules for Ships for Liquid Chemicals.
3. For naphtha coal tar and naphthalene molten, *see* Chapter 17 of the Rules for Ships for Liquid Chemicals.

1.2.7 Where the lower portion of the pump-room is recessed into the machinery space, the height of the recess is not, in general, to exceed one-third of the moulded depth above the keel, *see also* Pt 5, Ch 15,1.

1.2.8 Where a compartment or tank, such as a fore peak tank, forms a cofferdam, access is to be from the open deck. Alternatively, any space through which it is necessary to pass in order to obtain access is to conform to the requirements of Pt 6, Ch 2,14. Oil engine or electrically driven pumps are not to be sited in the space containing the access to such cofferdams.

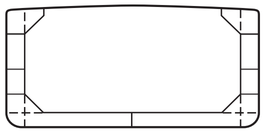
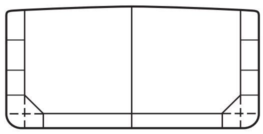
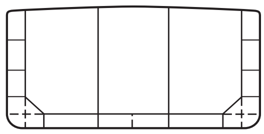
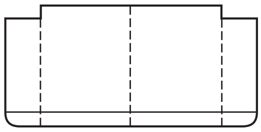
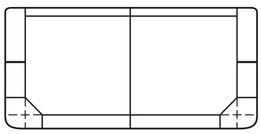
1.2.9 A cofferdam is also to be arranged between a cargo oil tank and accommodation spaces, and between cargo oil tanks and spaces containing electrical equipment, other than spaces where the only items of electrical equipment are lighting fittings complying with Pt 6, Ch 2,14. Where a corner-to-corner situation occurs, protection may be formed by a diagonal plate across the corner. The scantlings and testing arrangements are to comply with Rule requirements for cofferdam bulkheads, and arrangements are to be made to enable the space to be filled with water ballast to assist in gas freeing, *see also* Pt 5, Ch 15,3. Suitable corrosion protection, drainage and gas-freeing arrangements are to be provided to such spaces.

1.2.10 Passages or tunnels passing through, or adjacent to, a cargo oil tank and not separated from it by a cofferdam, are to be provided with mechanical ventilation, and any access is to be from the open deck.

1.2.11 Arrangements are to be provided to enable double bottom and vertical wing tanks to be filled with water ballast to assist in gas freeing these tanks, *see* Pt 5, Ch 15,3.

1.2.12 Fittings within cargo tanks and pump-rooms are to be securely fastened to the structure.

Table 9.1.3 Structural arrangement

Arrangement	Typical configuration	$L < 150$	$L \geq 150$
No longitudinal bulkhead		Non CSR	CSR (specially considered)
One or two longitudinal bulkhead(s)	 	Non CSR	CSR
Trunk deck in association with longitudinal bulkhead(s) (*see* Ch 10,6)		Non CSR	CSR
Double deck in association with a centreline bulkhead		Non CSR	CSR (specially considered)
Mid-deck in association with a centreline bulkhead or centreline girders	 	Non CSR	CSR (specially considered)

1.2.13 Accommodation, control and service spaces are to be located clear of the cargo tank region such that a single failure of deck or bulkhead will not allow cargo fumes into these spaces. Navigation positions, where fitted above the cargo tank region, are to be separated from the cargo tank deck by means of an open space with a height of at least 2,0 m.

1.2.14 Where spill retainment flats are fitted at the sides of the weather deck, separate arrangements are to be provided for freeing the deck of oil and water respectively, *see also* Pt 3, Ch 10,5.1.1.

1.2.15 Alternative arrangements which are proposed as being equivalent to the Rules will receive individual consideration, taking into account any relevant National Authority requirements.

1.2.16 Reference should also be made to the relevant Regulations of the *International Convention for the Safety of Life at Sea, 1974* and applicable amendments.

1.2.17 Cargo spaces are to be bounded by double bottom and double side tanks or void spaces such that the distance between the cargo tank boundary and the shell plating is not less than that given in Table 9.1.1 and Fig. 9.1.1, except as otherwise specified in 1.2.18 and 1.2.19. Cargo or oil fuel are not to be carried in double bottom or double side tanks.

1.2.18 Where $DWT \geq$ 5000 tonnes, double bottom tanks as required by 1.2.17 may be dispensed with, provided the following requirements are complied with:

(a) The cargo height, h_c, in contact with the bottom shell plating is to be not greater than:

$$h_c = \frac{1{,}025T_m - 10{,}2P_v}{1{,}1\rho}$$

where the symbols are defined in 1.6.

(b) Where a mid-deck dividing the cargo oil tanks into upper and lower spaces is arranged, it is to be located at a height of not less than the lesser of $\frac{B}{6}$ or 6 m, but not more than 0,6D, above the base line.

(c) Below a level 1,5d_b above the base line, the cargo tank boundary line may be vertical down to the bottom shell plating as shown in Fig. 9.1.3.

1.2.19 Alternative arrangements which are equivalent to 1.2.17 will receive individual consideration, taking into account any relevant National Authority requirements.

1.2.20 The length of each cargo tank is not to exceed 10 m or the appropriate value obtained from Table 9.1.4, whichever is the greater.

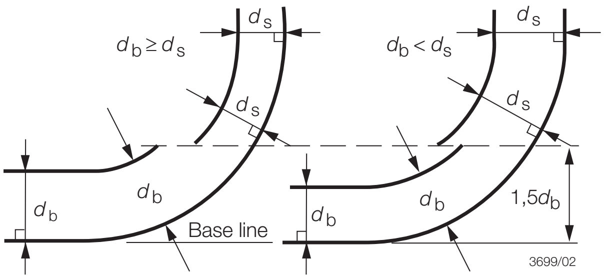


Fig. 9.1.1
Cargo tank boundary lines for oil tankers having double bottom and double side tank arrangements (*See* Table 9.1.1)

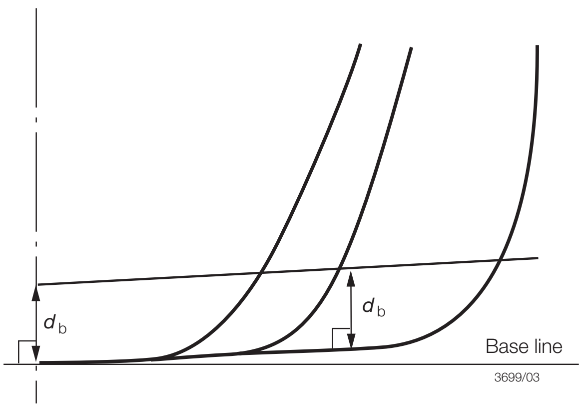


Fig. 9.1.2
Cargo tank boundary lines for oil tankers having double bottom arrangement (*See* Table 9.1.1)

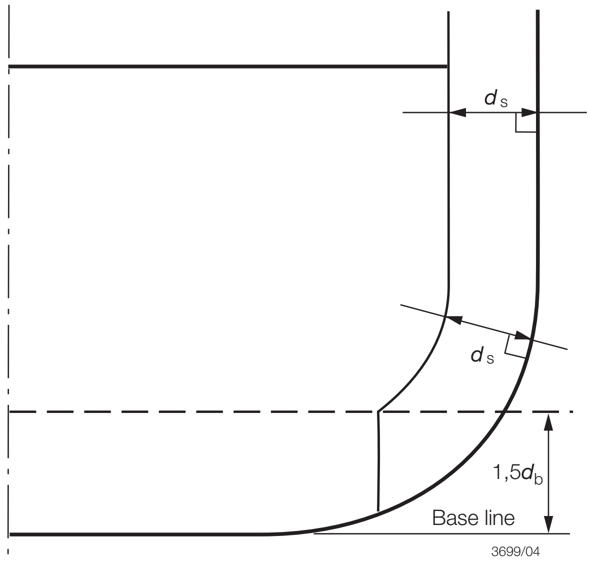


Fig. 9.1.3
Cargo tank boundary lines for oil tankers having mid-deck arrangement (*See* 1.2.18)

1.2.21 Where DWT ≥ 5000 tonnes, the cargo pump-room shall be provided with a double bottom such that at any cross-section the depth of each double bottom tank or space shall be such that the distance d_c, as defined in 1.5, is not less than the lesser of $\frac{B}{15}$ m and 2 m

d_c is in no case to be less than 1 m.
In the case of cargo pump-rooms whose bottom plate is located above the base line by at least the minimum height required, there will be no need for a double bottom construction in way of the cargo pump-room.

1.2.22 Notwithstanding the requirements of 1.2.21, above, where the flooding of the cargo pump-room would not render the ballast or cargo pumping system inoperative, a double bottom need not be fitted.

Table 9.1.4 **Permissible length of cargo tanks**, *see* 1.2.20

Number of longitudinal bulkheads inside cargo tanks		One (on centreline)	Two	Three (one on centreline)	Where no longitudinal bulkhead is arranged or where longitudinal bulkheads are perforated across breadth of cargo tanks
Length of wing cargo tank		$\left(0{,}25\,\frac{b_i}{B} + 0{,}15\right) L_L$	$0{,}2L_L$	$0{,}2L_L$	$\left(0{,}5\,\frac{b_i}{B} + 0{,}1\right) L_L$ or $0{,}2L_L$ whichever is the lesser
Length of centre tank	$b_i \geq 0{,}2B$	—	$0{,}2L_L$	$0{,}2L_L$ port and starboard	
	$b_i < 0{,}2B$	—	$\left(0{,}5\,\frac{b_i}{B} + 0{,}1\right) L_L$	$\left(0{,}25\,\frac{b_i}{B} + 0{,}15\right) L_L$ port and starboard	

NOTE
The symbols L_L, B and b_i are defined in 1.5.

1.3 Class notation and applicable Rules for CSR Double Hull Oil Tankers

1.3.1 In general, CSR Double Hull Oil Tankers are to comply with 1.3.2 to 1.3.8 and the *IACS Common Structural Rules for Double Hull Oil Tankers* (*CSR*) for the draught required and will be eligible to be classed **100A1 Double Hull Oil Tanker CSR, ESP**.

1.3.2 Class notations applicable to CSR double hull oil tankers are defined as follows:

- **CSR**
  Identifies the double hull oil tanker as being compliant with the *IACS Common Structural Rules for Double Hull Oil Tankers*
- **ESP**
  Identifies the double hull oil tanker as being subject to an Enhanced Survey Programme as detailed in Pt 1, Ch 3,3 and Ch 3,7, *see also* Pt 1, Ch 2,2.3.12.

1.3.3 Materials are to comply with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). Corrosion protection is to comply with Pt 3, Ch 2,3.

1.3.4 The rudder and rudder stock are to comply with Pt 3, Ch 13,2.

1.3.5 Ice strengthening is to be in accordance with Part 8.

1.3.6 The 'Construction Monitoring' (CM) procedures detailed in the *ShipRight Procedures Manual*, published by LR, are mandatory for oil tankers greater than 190 m in length and for other tankers of abnormal hull form, or of unusual structural configuration or complexity.

1.3.7 The 'ShipRight Procedures' for the hull construction of ships are detailed in Pt 3, Ch 16 and the classification notations and descriptive notes associated with these procedures are given in Pt 1, Ch 2,2.

1.3.8 Ships intended to carry heated cargoes are to comply with Section 12.

1.4 Class notation and applicable Rules for non-CSR Double Hull Oil Tankers

1.4.1 In general, non-CSR Double Hull Oil Tankers are to comply with 1.4.2 to 1.4.7 for the draught required and will be eligible to be classed **100A1 Double Hull Oil Tanker, ESP**.

1.4.2 The notation **ESP** serves to identify the ship as being subject to an Enhanced Survey Programme as detailed in Pt 1, Ch 3,3 and Ch 3,7, *see also* Pt 1, Ch 2,2.3.12.

1.4.3 At the Owner's request, the notation **MARPOL 20.1.3** may be appended to the notation **100A1 Double Hull Oil Tanker** for vessels not meeting the minimum double side width (d_s) requirements of Table 9.1.1 but which comply with MARPOL Annex I, Regulation 20.1.3.

1.4.4 At the Owner's request, the notation **MARPOL 21.1.2** may be appended to the notation **100A1 Double Hull Oil Tanker** for vessels of less than 5000 tonnes deadweight which have a complete double hull in accordance with MARPOL Annex I, Regulation 21.1.2.

1.4.5 Where the length of the ship is greater than 190 m, or where the structural arrangements are considered such as to necessitate it, the scantlings of the primary supporting structure are to be assessed by direct calculation and the ShipRight notations **SDA**, **FDA** and **CM** are mandatory, *see* 1.4.6 and Section 14.

1.4.6 The 'ShipRight Procedures' for the hull construction of ships are detailed in Pt 3, Ch 16 and the classification notations and descriptive notes associated with these procedures are given in Pt 1, Ch 2,2.

1.4.7 The disposition of transverse bulkheads is to comply with the requirements of Pt 3, Ch 3,4, as applicable to ships with machinery located aft.

1.4.8 Arrangements and scantlings forward and aft of the cargo tank region are to comply with Pt 3, Ch 5, Ch 6 and Ch 7. The remaining requirements of Part 3 are also to be complied with as appropriate to the intended arrangements.

1.4.9 Arrangements pertaining to gangways, bulwarks and rails are to comply with the requirements of Pt 3, Ch 8.

1.4.10 The structural configurations may include one or more of the arrangements shown in Table 9.1.3. these provisions do not preclude the fitting of additional bulkheads or the perforation of longitudinal bulkheads.

1.4.11 The bottom shell, inner bottom and deck are generally to be framed longitudinally in the cargo tank region where the ship length, *L*, exceeds 75 m. However, consideration will be given to alternative proposals for ships of special design.

1.4.12 The side shell, inner hull bulkheads and longitudinal bulkheads are generally to be longitudinally framed where the ship length, *L*, exceeds 150 m, but alternative proposals, taking account of resistance to buckling, will be considered.

1.4.13 Where the side shell is longitudinally framed, the inner hull bulkheads are to be similarly constructed.

1.4.14 Provided the ship length, *L*, does not exceed 200 m the longitudinal bulkheads may be horizontally corrugated. Vertically corrugated centreline bulkheads may also be considered on the basis of direct calculations.

1.4.15 In general, the primary member scantlings will require to be determined by direct calculation, *see also* 9.1.3.

1.4.16 Alternative arrangements, which are proposed as being equivalent to the Rules, will receive individual consideration. Particular attention is to be paid to deflection of members and to the ability of the structure to resist buckling. Where necessary, additional calculations will be required.

1.4.17 For additional requirements for single hull oil tankers, *see* Chapter 10.

1.4.18 The scantlings of structural items may be determined by direct calculation.

1.5 General definitions and symbols

1.5.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, L_L, B, D, T as defined in Pt 3, Ch 1,6.

d_c = the height between the ship's base line and the bottom of the cargo pump-room, in metres

DWT = deadweight, in tonnes, at the summer load waterline

b = the width of plating supported by the primary or secondary member, in metres or mm respectively

b_e = the effective width, in metres, of end brackets as determined from Pt 3, Ch 3,3

b_i = minimum distance from side shell to inner hull/outer longitudinal bulkhead of the tank in question measured inboard at right angles to the centreline at the summer load waterline, in metres, *see* Table 9.1.4

d_b = the distance, in metres, between the bottom of the cargo tanks and the moulded line of the bottom shell plating measured at right angles to the bottom shell plating as shown in Fig. 9.1.1 and Fig. 9.1.2

d_s = the distance, in metres, between the cargo tank boundary and the moulded line of the side shell plating measured at any cross-section at right angles to the side shell as shown in Fig. 9.1.1 and Fig. 9.1.3

h = the load height applied to the item under consideration, in metres

k_L, k = higher tensile steel factors. For the determination of these factors, see Pt 3, Ch 2,1. For mild steel, k_L, k may be taken as 1,0

l_e = effective length, in metres, of the primary or secondary member, measured between effective span points. For determination of span points, *see* Pt 3, Ch 3,3

s = spacing of secondary members, in mm

t = thickness of plating, in mm

I = the moment of inertia, in cm^4, of a primary or secondary member, in association with an effective width of attached plating determined in accordance with Pt 3, Ch 3,3

L_1 = length of ship, in metres, but need not be taken greater than 190 m

P_v = pressure/vacuum relief valve positive setting, in bar

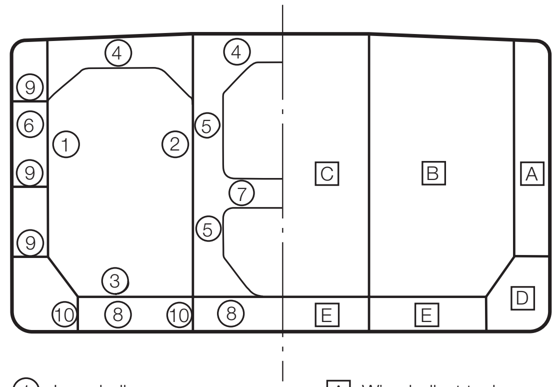
T_m = minimum operating moulded draught of the ship at amidships under any expected cargo loading condition, in metres

Z = the section modulus, in cm^3, of the primary or secondary member, in association with an effective width of attached plating determined in accordance with Pt 3, Ch 3,3

ρ = maximum cargo density, in t/m^3.

1.5.2 Where symbols not defined in 1.5.1 are used these are defined at the head of the Section concerned.

1.5.3 For oil tankers of double hull configuration the main structural and spatial terminology within the cargo length, as used in this Chapter, is shown in Fig. 9.1.4.



1 Inner hull
2 Longitudinal bulkhead
3 Inner bottom
4 Deck transverse
5 Vertical web on longitudinal bulkhead
6 Vertical web in wing ballast tank
7 Cross tie
8 Floor
9 Horizontal girder in wing ballast tank
10 Double bottom girder

A Wing ballast tank
B Wing cargo tank
C Centre cargo tank
D Hopper tank
E Double bottom ballast tank

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Fig. 9.1.4 Structural and spatial terminology

1.5.4 The expression 'primary member' as used in this Chapter is defined as a girder, floor, transverse, vertical web, stringer, cross-tie or buttress. 'Secondary members' are supporting members other than primary members.

1.6 Information required for CSR Double Hull Oil Tankers

1.6.1 In addition to the plans required by *IACS Common Structural Rules for Double Hull Oil Tankers (CSR)* the following additional plans and information is to be submitted.

- Rudder, stock and tiller;
- Ice Strengthening.
- Freeboard plan or equivalent showing freeboards and items relative to the conditions of assignment.

1.7 Information required for non-CSR Double Hull Oil Tankers

1.7.1 In addition to the plans required by Pt 3, Ch 1,5, plans showing the connections for all longitudinals and other framing members and arrangements at intersections of transverse and longitudinal framing are also to be submitted.

1.7.2 Any dry tanks, or tanks for water ballast only, are to be indicated on the principal structural and arrangement plans.

1.7.3 The information required by Pt 3, Ch 4,4 is to be forwarded as soon as possible and preferably when the midship section is submitted.

1.7.4 A docking plan is to be submitted for consideration of strength requirements in association with the intended docking condition.

1.7.5 A plan showing the location of all openings in the deck is to be submitted. Where it is intended to provide holes in the deck for staging wires, these holes are also to be shown. Full particulars of the proposed closing arrangements for all deck openings are to be submitted.

1.7.6 Information is required indicating the equipment provided for the acceptable means of access to meet the minimum requirements for Close-up Surveys, *see also* 13.2.8, 13.2.9 and Pt 1, Ch 3,7.

1.7.7 A diagrammatic plan verifying compliance with the requirements of 1.2.17 or 1.2.18 as appropriate is to be submitted.

■ *Section 2* Materials and protection

2.1 General

2.1.1 Materials, grades of steel and protection of materials are to comply with the requirements of Pt 3, Ch 2 and the Rules for Materials.

2.2 Corrosion protection coatings for salt-water ballast spaces

2.2.1 The requirements of Pt 3, Ch 2,3.6 are to be complied with.

2.3 Aluminium structure, fittings and paint

2.3.1 Aluminium may, under certain circumstances give rise to incendive sparking on impact with steel, the following requirements are therefore to be complied with:

(a) Aluminium fittings in tanks used for the carriage of oil and in cofferdams and pump-rooms are to be avoided wherever possible.
(b) Where fitted, aluminium fittings, units and supports, in tanks used for the carriage of oil, cofferdams and pump-rooms are to satisfy the requirements specified in Pt 3, Ch 2,3 for aluminium anodes.
(c) The danger of mistaking aluminium anodes for zinc anodes must be emphasised. This gives rise to increased hazard if aluminium anodes are inadvertently fitted in unsuitable locations.
(d) The underside of heavy portable aluminium structures such as gangways, etc., is to be protected by means of hard plastic or wood cover in order to avoid the creation of smears when dragged or rubbed across steel, which if subsequently struck, may create an incendive spark. It is recommended that such protection be permanently and securely attached to the structures.

2.3.2 For permissible locations of aluminium anodes, *see* Pt 3, Ch 2,3.4.

2.3.3 Paint containing aluminium should not be used in positions where cargo vapours may accumulate unless it has been shown by appropriate tests that the paint to be used does not increase the incendive sparking hazard. Tests need not be performed for coatings containing less than 10 per cent aluminium by weight.

2.4 Other materials

2.4.1 The suitability of coatings and their compatibility with intended cargoes are the responsibility of the Builder and the Owner. LR will, however, require the confirmation of the coating manufacturers that coatings which are used to protect the cargo tank structure are in order for the list of defined cargoes. A copy of the coating manufacturer's product resistance list is to be placed on board.

2.4.2 Attention is drawn to the requirements of Pt 3, Ch 11,7.1.4 in respect of compatibility of cargoes and hatch packing materials. The packing material is to be resistant to both the liquids and vapours to which it is exposed.

2.4.3 Some plastics and rubbers are unsuitable for certain cargoes other than oil. In such cases the manufacturer's advice should be sought.

2.4.4 Some materials or their alloys are unsuitable for certain cargoes other than oil. Where such cargoes are to be carried, the use of these materials is not permitted in locations where they may come into contact with the cargo or its vapours, *see also* 1.1.7.

■ *Section 3* Longitudinal strength

3.1 General

3.1.1 The longitudinal strength standard is to comply with the relevant requirements of Pt 3, Ch 4.

3.1.2 The readout points for loading instruments, fitted in accordance with the requirements of Pt 3, Ch 4,8.3, are to be positioned at the transverse bulkheads. In general, except when the instrument calculates the maximum values between readout points, the spacing of readout points within the cargo tank length is not to exceed five per cent of the ship length with intermediate points arranged between bulkheads as necessary.

3.2 Symbols

3.2.1 The symbols used in this Section are defined in 1.5.

3.3 Loading conditions

3.3.1 The loading conditions which are to be included in the Loading Manual and examined for longitudinal strength are given in Pt 3, Ch 4,5.

3.3.2 The Loading Manual is to contain the calculated still water bending moments and shear forces for the conditions proposed and the maximum permissible values calculated in accordance with Pt 3, Ch 4.

3.3.3 The strengthening of bottom forward derived in accordance with the requirements of Pt 3, Ch 5,1 is to be based on the minimum draught forward obtained using segregated ballast tanks only, without recourse to ballasting of cargo tanks.

3.3.4 Where bottom forward strengthening has not been arranged, at least one ballast departure and one ballast arrival condition providing for a forward draught of at least 0,045*L* is to be included in the Loading Manual, *see also* Pt 3, Ch 5,1.5.

3.3.5 Where part-load conditions are proposed with a forward draught less than that for which the bottom forward arrangements and scantlings have been approved, the Loading Manual is to provide for the addition of ballast in segregated ballast tanks only as necessary to attain the required draught in heavy weather.

3.3.6 Conditions which provide for wing and centre cargo tanks abreast to be filled, with adjacent wing and centre cargo tanks empty, should, in general, be avoided. Similarly, conditions which provide for differential loading of port and starboard wing cargo tanks with centre cargo tanks empty should also be avoided. Where such conditions are contemplated, they will be subject to special consideration which may involve additional calculation in respect of the resultant effects on transverse strength and centre tank cross-tie.

3.3.7 Where a double bottom tank is omitted in accordance with 1.3.7 a minimum operating draught T_m is to be indicated on the midship section plan, the Loading Manual and Loading Instrument.

3.3.8 Tanks intended for water ballast are to be indicated in the Loading Manual.

3.3.9 Where loading conditions having partially filled tanks are contemplated, attention is drawn to the need to ensure that the scantlings of the boundary bulkheads are capable of withstanding the loads imposed by the movement of liquid in the tanks, *see* 6.1.2, 7.1.2 and 14.2.2.

■ *Section 4*
Hull envelope plating

4.1 General

4.1.1 The thickness of hull envelope plating amidships is to be as necessary to comply with the hull section modulus, shear strength and buckling requirements of Pt 3, Ch 4, but is to be not less than as shown in Table 9.4.1 for the parts itemised in Fig. 9.4.1. Panel stability is also to be confirmed by direct calculation taking account of shear stress and direct stresses derived from both transverse and longitudinal strength investigation.

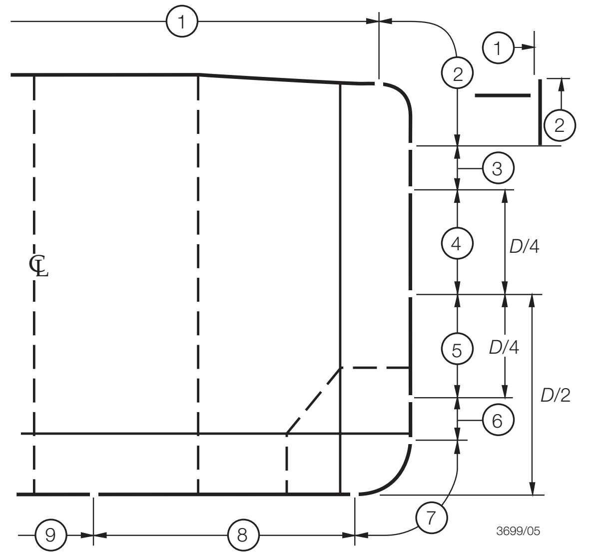


Fig. 9.4.1
Hull envelope plating – Itemisation of parts
(*See* Table 9.4.1)

4.1.2 For requirements in respect of structural details, bilge keels, attachments, etc., *see* Pt 3, Ch 10. In addition the *ShipRight FDA Procedure, Structural Detail Design Guide* (SDDG), indicates recommended structural design configurations for double hull tanker structural details to assess and improve the relative fatigue life performance of the details in critical areas.

Table 9.4.1 Hull envelope plating – minimum thickness, in mm

Hull envelope plating – minimum thickness, in mm			
Longitudinally framed	Item	Item No. *see* Fig. 9.4.1	Transversely framed, *see* 1.3 for limits of application
$t = \frac{s}{J} + 2{,}0$ *see* Note 1	Deck	1	*see* 1.3
$t = \frac{s}{J} + 2{,}0$ or $t = 0{,}0042s\sqrt{h_{T1}k}$ whichever is the greater *see* Note 1	Sheerstrake and gunwale	2	$t = \dfrac{0{,}00085s}{1 + \left(\frac{s}{S}\right)^2}(0{,}083L_1 + 10)\sqrt{\dfrac{F_D}{k_L}}$ *see* Note 6 or $t = 0{,}0042s\sqrt{h_{T1}k}$ whichever is the greater *see* Note 1
$t = 0{,}001s\,(0{,}059L_1 + 7)\sqrt{\dfrac{F_D}{k_L}}$ *see* Notes 6 and 7 or $t = 0{,}0042s\sqrt{h_{T1}k}$ whichever is the greater *see* Note 1	Side shell above mid-depth	3	$t = \dfrac{0{,}00085s}{1 + \left(\frac{s}{S}\right)^2}(0{,}083L_1 + 10)\sqrt{\dfrac{F_D}{k_L}}$ *see* Notes 6 and 7 or $t = 0{,}0042s\sqrt{h_{T1}k}$ whichever is the greater *see* Note 1
		4	$t = 0{,}001s\,(0{,}059L_1 + 7)\sqrt{\dfrac{F_M}{k_L}}$ *see* Notes 6 and 7 or $t = 0{,}0051s\sqrt{h_{T1}k}$ whichever is the greater *see* Note 1
$t = 0{,}001s\,(0{,}059L_1 + 7)\sqrt{\dfrac{F_B}{k_L}}$ *see* Notes 6 and 7 But not less than: (a) $t = 0{,}0042s\sqrt{h_{T1}k}$ at mid-depth (b) $t = 0{,}0054s\sqrt{\dfrac{h_{T2}k}{2 - F_B}}$ at upper turn of bilge *see* Notes 1 and 2 } Intermediate thickness by interpolation	Side shell below mid-depth	5	
		6	$t = \dfrac{0{,}00085s}{1 + \left(\frac{s}{S}\right)^2}(0{,}083L_1 + 10)\sqrt{\dfrac{F_B}{k_L}}$ *see* Notes 2, 6 and 7 or $t = 0{,}0056s\sqrt{\dfrac{h_{T2}k}{1{,}8 - F_B}}$ whichever is the greater *see* Note 1
$t = \frac{s}{J} + 2{,}0$ or $t = 0{,}0052s\sqrt{\dfrac{h_{T2}k}{1{,}8 - F_B}}$ mm whichever is the greater *see* Note 1	Bilge (*see* Note 4)	7	$t = \dfrac{0{,}00085s}{1 + \left(\frac{s}{S}\right)^2}(0{,}083L_1 + 10)\sqrt{\dfrac{F_B}{k_L}}$ *see* Notes 6 and 7 or $t = 0{,}0063s\sqrt{\dfrac{h_{T2}k}{1{,}8 - F_B}}$ mm whichever is the greater *see* Note 1
	Bottom shell	8	*see* 1.3
As for item 8, +2 mm, but need not exceed $25\sqrt{k}$ mm	Keel	9	

NOTES
1. The thickness is also to satisfy the buckling requirements of Pt 3, Ch 4,7.
2. The thickness of side shell plating need not exceed that which would be required for the bottom shell using the spacing of the side shell longitudinals.
3. In no case is the plating thickness to be less than the cargo tank minimum value given in Section 10, or the basic shell end thickness for taper given in Pt 3, Ch 5 and Ch 6.
4. *See also* 4.6.2 concerning plating thickness where longitudinal framing is fitted at bottom and side, but omitted in way of bilge.
5. Keel thickness is in no case to be less than that of the adjacent bottom shell plating.
6. Where separate maximum sagging and hogging still water bending moments are assigned, F_D may be based on the sagging moment and F_B on the hogging moment.
7. Outside the Rule minimum region of higher tensile steel as defined in Pt 3, Ch 3,2.6.1 the value of k_L may be taken as 1,0.

4.2 Symbols

4.2.1 The symbols used in this Section are defined as follows:

F_D, F_B = as defined in Pt 3, Ch 4,5.7

F_M = the greater of F_D or F_B

$$J = 1720{,}5\sqrt{\frac{1-\frac{1}{\alpha}}{\sigma_o}} \quad \text{for } \alpha \le 2$$

$$\left(J = 549{,}3\sqrt{\frac{1-\frac{1}{\alpha}}{\sigma_o}} \quad \text{for } \alpha \le 2\right)$$

$$J = 860{,}7\sqrt{\frac{\alpha}{\sigma_o}} \quad \text{for } \alpha > 2$$

$$\left(J = 274{,}8\sqrt{\frac{\alpha}{\sigma_o}} \quad \text{for } \alpha > 2\right)$$

s = spacing, in mm, of longitudinals or transverse frames. Except where indicated in the text, s is not to be taken less than:

$$470 + \frac{L}{0{,}6} \text{ mm}$$

or 700 mm whichever is the lesser

For limitations in end regions, *see* Pt 3, Ch 5,3 and Ch 6,3

C_w = a wave head, in metres

= $7{,}71 \times 10^{-2} L e^{-0{,}0044L}$

where

e = base of natural logarithms 2,7183

R_B = bilge radius, in mm, as defined in Table 1.5.2 in Chapter 1

S = overall span of frame, in mm, measured between deck and bottom support points or to, or between, stringers, where fitted

T_1 = T but to be taken not less than 0,05L m

$$\alpha = \frac{\sigma_o}{\sigma_c}$$

σ_c = maximum compressive hull vertical bending stress, in N/mm^2 (kgf/mm^2) given by σ_D and σ_B as defined in Pt 3, Ch 4,5.6.1 as appropriate

For ships of normal design, not exceeding 90 m in length, the value of maximum compressive hull vertical bending stress may be determined as follows:

at strength deck

$$\sigma_D = 654LB \frac{Z_{min}}{Z_D} \sigma \times 10^{-6} \text{ N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

at keel

$$\sigma_B = 654LB \frac{Z_{min}}{Z_B} \sigma \times 10^{-6} \text{ N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

where Z_{min}, Z_D, Z_B and σ are in accordance with Pt 3, Ch 4,5.

σ_o = specified minimum yield stress, in N/mm^2 (kgf/mm^2)

h_{T1} = $T + C_w$ m but need not be taken greater than 1,36T

h_{T2} = $T + 0{,}5C_w$ m but need not be taken greater than 1,2T

For longitudinally framed bottom and bilge plating T is to be taken as T_1

Other symbols are defined in 1.5.

4.3 Deck plating

4.3.1 The midship thickness of deck plating is to be maintained for 0,4L amidships and tapered outside this region in association with the deck longitudinals in accordance with 5.5. The midship thickness may, however, be required over an increased extent if it is shown to be necessary by the bending moment curves. Where partial filling of the tanks is contemplated the deck plating is also to comply with the requirements of 6.1.2.

4.3.2 For ships not exceeding 200 m in length, the deck thickness outside 0,4L amidships is to be not less than $\frac{s}{80}$ at any point within the cargo tank region. For lengths of 250 m and over, the thickness is to be not less than $\frac{s}{70}$. Intermediate values are to be obtained by interpolation. For the purpose of this paragraph, the minimum value of s given in 4.2.1 is not to be applied.

4.3.3 The plating thickness outside 0,4L amidships is to be not less than:

$$t = \frac{s}{J} + 2{,}0 \text{ mm}$$

where J is defined in 4.2.1, using σ_o of the plating at the location under consideration.

4.4 Sheerstrake

4.4.1 The midship sheerstrake thickness is to be maintained for 0,4L amidships and tapered outside this region as provided for in Pt 3, Ch 5 and Ch 6. In the taper region, however, the sheerstrake thickness need not exceed the adjacent deck or shell thickness, whichever is the greater.

4.4.2 The width of sheerstrake for 0,4L amidships is to be not less than that required by Table 2.2.1 in Pt 3, Ch 2.

4.4.3 Where a rounded sheerstrake is incorporated, the radius is not, in general, to be less than 15 times the thickness. The radius is to be made by careful cold rolling or bending.

4.5 Shell plating

4.5.1 The midship thicknesses of side and bottom shell plating are to be maintained for 0,4L amidships and tapered outside this region as provided for in Pt 3, Ch 5 and Ch 6. The midship thicknesses may be required over an increased extent if it is shown to be necessary by the bending moment or shear force curves.

4.5.2 The requirements of Pt 3, Ch 5 are to be complied with in respect of the thickness of bottom shell forward.

4.6 Bilge plating

4.6.1 The midship thickness of the bilge plating is to be maintained for 0,4*L* amidships and tapered outside this region as provided for in Pt 3, Ch 5 and Ch 6.

4.6.2 Where longitudinal bottom and side framing is adopted, but longitudinals are omitted between the upper and lower extremities of the bilge radius, the bilge thickness is to be not less than $\dfrac{R_B F_B}{165 k_L}$ in addition to the required minimum thickness derived from Table 9.4.1. The spacing of transverse supports associated with such an arrangement is to comply with the requirements of 5.4.

4.6.3 Where bilge longitudinals are omitted, the plating thickness outside 0,4*L* amidships will be considered in relation to the support derived from the hull form and internal stiffening arrangements. Due regard will be taken of the possibility of increased loading in the forward region.

4.7 Keel

4.7.1 The midship keel thickness is to be maintained throughout the cargo tank region, except as required by Table 9.4.1, Note 5.

4.7.2 The width of the keel over the cargo tank region is to be not less than:

70*B* mm but need not exceed 1800 mm and is to be not less than 750 mm.

4.8 Taper of higher tensile steel

4.8.1 Where higher tensile steel is used amidships and mild steel at the ends, the thickness of bottom shell, bilge and sheerstrake is to be tapered as provided for in Pt 3, Ch 3, Ch 5 and Ch 6.

4.8.2 Higher tensile steel deck plating is to be tapered in association with attached longitudinals as provided for in 5.5.

4.9 Thicknesses at ends of erections

4.9.1 The deck plating thickness at the poop front is to extend into the poop for a distance at least equal to one-third of the breadth, *B*.

4.9.2 If the poop front extends to within 0,25*L* of amidships, the sheerstrake and the stringer plate at the break are to be increased by 20 per cent. No increase is required if the poop front is 0,3*L* from amidships or greater. The increase at intermediate lengths is to be obtained by interpolation and is to be applied to the tapered thickness of the sheerstrake and stringer plate.

4.9.3 Where the poop extends to within 0,3*L* of amidships and the enclosed machinery opening extends to within $\dfrac{B}{3}$ of the poop front and has a width exceeding one half of the breadth of the ship at the poop front, the thickness of deck plating may require to be increased. The forward corners of the casing opening are to be well rounded.

4.10 Deck openings

4.10.1 Openings in the deck are to be kept to the minimum number consistent with operational requirements.

4.10.2 Plate panels in which openings are cut are to be adequately stiffened, where necessary, against compression and shear buckling.

4.10.3 The corners of all openings are to be well rounded, and the edges smooth.

4.10.4 Where the stress concentration factor in way of the opening exceeds 2,4, edge reinforcement is generally to be fitted. This is normally to be in the form of a spigot of adequate dimensions, but alternative arrangements will be considered.

4.10.5 Alternatively, the shape of the opening is to be such that a stress concentration factor of 2,4 is not exceeded.

4.10.6 In this respect, reinforcement will not, in general, be required in way of:

(a) elliptical openings having their major axis fore and aft and ratios of length to breadth not less than 2 to 1, or
(b) openings of other shapes, provided it has been shown by suitable tests that the stress concentration factor does not exceed 2,4.

4.10.7 Circular openings of diameter up to 325 mm will also be accepted, provided that they are situated at such a distance from any other opening that there is an intervening width of plating of not less than five times the diameter of the smaller of the two openings.

4.10.8 Where within 0,4*L* amidships deck openings have a total breadth or shadow area breadth in one transverse section that exceeds the limitation given in Pt 3, Ch 3,3.4.4 and 3.4.5, compensation will be required to restore the excess. This is generally to be arranged by increasing the deck plate thickness, but other proposals will be considered.

4.10.9 Where a deck longitudinal is cut in way of an opening, within 0,4*L* amidships, compensation is to be arranged to ensure full continuity of area.

4.10.10 The area of any edge reinforcement which may be required is not to be taken into account in determining the required sectional area of compensation unless such reinforcement is designed to absorb the loadings from cut longitudinals in way of opening.

4.10.11 Increased scantlings and/or compensation may also be required for large openings outside 0,5L amidships, or where openings are close to breaks of superstructure or other areas of high stress in any location on the ship.

4.10.12 Where small diameter threaded openings for staging wires are arranged on the upper deck, they are to be located clear of the other openings and similar areas of stress concentration. Care is to be taken to ensure a gradual transition at the thread ends and the edges of the holes are to be smooth. The closing arrangements are to be as required by Section 13.

4.11 Shell openings

4.11.1 Sea inlets in pump-rooms situated within 0,4L amidships, are, if practicable, to be fitted clear of the bilge radius. All openings are to be arranged so as to minimise discontinuity of transverse frames, longitudinals or bilge keels. Compensation is to be provided for all openings within 0,4L amidships and may also be required for openings in the vicinity of the poop front. The compensation should, if possible, take the form of an insert plate rather than a doubler.

4.11.2 If openings are not circular or oval, the corners are to be rounded with as large a radius as practicable.

4.12 Superstructures

4.12.1 The thickness of plating forming the deck and sides of forecastles and poops is to be as required by Pt 3, Ch 5, Ch 6 and Ch 8.

■ *Section 5* Hull framing

5.1 General

5.1.1 In the cargo tank region, the scantlings of deck, bottom and side longitudinals, and of transverse side framing, where fitted, are to be in accordance with the requirements of this Section.

5.1.2 Longitudinal and transverse framing members outside the cargo tank region are to comply with the requirements of Pt 3, Ch 5,4, Ch 6,4, and Ch 7, as appropriate to their location.

5.1.3 Outside the cargo tank region the structure is to be scarfed into the end structure as provided for in Pt 3, Ch 5, Ch 6 and Ch 7.

5.2 Symbols

5.2.1 The symbols used in this Section are defined as follows:

b_f = the width of the face plate, in mm, of the side longitudinal under consideration, *see* Fig. 9.5.1

b_{f1} = the minimum distance, in mm, from the edge of the face plate of the side longitudinal under consideration to the centre of the web plate, *see* Fig. 9.5.1

b_1 = the value as defined in Table 9.5.3

$c_1 = \dfrac{60}{225 - 165F_D}$ at deck

$= 1{,}0$ at $\dfrac{D}{2}$

$= \dfrac{75}{225 - 150F_B}$ at base line of ship

intermediate values of c_1 by interpolation

$c_2 = \dfrac{165}{345 - 180F_D}$ at deck

$= 1{,}0$ at $\dfrac{D}{2}$

$= \dfrac{165}{345 - 180F_B}$ at base line of ship

intermediate values of c_2 by interpolation

d_w = depth of web, in mm

h = distance of longitudinal below deck at side, in metres. For deck longitudinals, $h = 0$

h_0 = the distance, in metres, from the mid-point of span of the stiffener to the highest point of tank, excluding hatchway

$h_1 = \left(h_0 + \dfrac{D_1}{8}\right)$, but in no case to be taken less than $\dfrac{L_1}{56}$ m or $(0{,}01L_1 + 0{,}7)$ m, whichever is the greater, and need not be taken greater than $\left(0{,}75D + \dfrac{D_1}{8}\right)$, for bottom longitudinals

h_2 = distance, in metres, from mid-point of span of transverse side frame to deck at side measured at mid-length of tank, but to be taken not less than 2,5 m

$h_3 = h_0 + Rb_1$, but need not be taken greater than $(0{,}75D + Rb_1)$ for bottom longitudinals

l_e = effective length, in metres, of longitudinals measured between span points, but to be taken not less than 1,5 m in double bottom and 2,5 m elsewhere. For determination of span points, *see* Pt 3, Ch 3,3.

t_f = thickness of flange, in mm

t_s = thickness of the bilge shell plating, in mm

t_w = thickness of web, in mm

D_1 = D, in metres, but is to be taken not less than 10 and need not be taken greater than 16

F_B = as defined in Pt 3, Ch 4,5.7

F_D = as defined in Pt 3, Ch 4,5.7

F_1 = a factor determined from Table 9.5.1

F_2 = a factor determined from Table 9.5.2

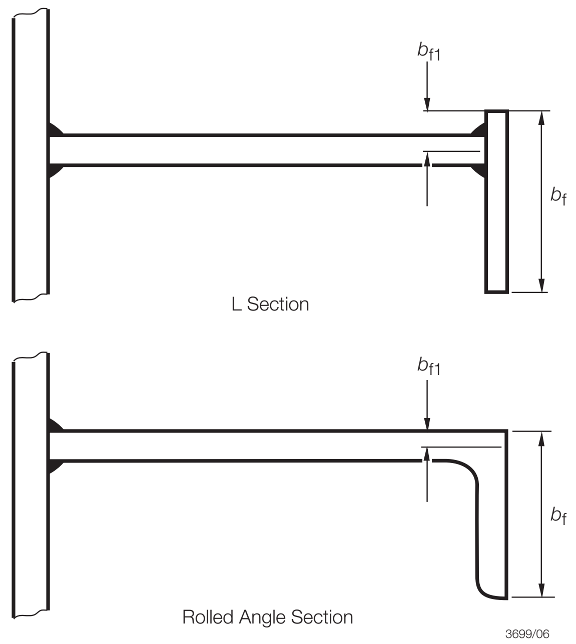


Fig. 9.5.1 Definition of b_f and b_{f1}

R = $\sin\theta$
where θ is the roll angle, in degrees
and $\sin\theta = \left(0{,}45 + 0{,}1\dfrac{L}{B}\right)\left(0{,}54 - \dfrac{L}{1270}\right)$

R_B = bilge radius, in mm, as defined in Table 1.5.2 in Chapter 1.

Other symbols are defined in 1.5.

Table 9.5.1 Values of F_1

Item	F_1
Deck longitudinals and side longitudinals above $\dfrac{D}{2}$	$\dfrac{Dc_1}{4D + 20h}$
Side longitudinals and bottom longitudinals below $\dfrac{D}{2}$	$\dfrac{Dc_1}{25D - 20h}$
NOTE Minimum F_1 = 0,12	

Table 9.5.2 Values of F_2

Item	F_2
Deck longitudinals and side longitudinals above $\dfrac{D}{2}$	$\dfrac{Dc_2}{D + 2{,}18h}$
Side longitudinals and bottom longitudinals below $\dfrac{D}{2}$	$\dfrac{Dc_2}{3{,}18D - 2{,}18h}$
NOTE Minimum F_2 = 0,73	

Table 9.5.3 Determination of b_1

Item No.	Structural arrangement	Location	Value of b_1, metres
1	Where wing and double bottom ballast tanks port and starboard are interconnected	(a) Bottom longitudinals	The greater horizontal distance from ship side to the longitudinal
		(b) Side longitudinals	Breadth of ship
		(c) Deck longitudinals	(i) In way of cargo tanks and inboard ballast tanks, the greater horizontal distance from tank corner at top of tank to longitudinal, either side (ii) In way of wing ballast tanks, the greater horizontal distance from ship side to longitudinal, either side
2	Where wing ballast tanks port and starboard are separate	(a) Bottom longitudinals	The horizontal distance from ship side to longitudinal
		(b) Side longitudinals	Width of wing ballast tank

5.3 Deck, side and bottom longitudinals

5.3.1 The modulus of longitudinals within the cargo tank region, except as provided for in 5.3.2 and 5.5 is to be not less than the greater of the following:

(a) $Z = 0{,}056 s\, k\, h_1\, l_e^2\, F_1\, F_s$ cm^3, or

(b) $Z = 0{,}0051 s\, k\, h_3\, l_e^2\, F_2$ cm^3

where F_1 and F_2 values are as given in Tables 9.5.1 and 9.5.2 and F_s is a fatigue factor to be taken as follows:

$$F_s = \frac{1{,}1}{k}\left[1 - \frac{2b_{f1}}{b_f}(1-k)\right] \text{ at } 0{,}6D \text{ above the base line}$$

$= 1{,}0$ at upper deck at side and at the base line, intermediate values by linear interpolation

For flat bars and bulb plates $\dfrac{b_{f1}}{b_f}$ may be taken as 0,5

The modulus of side longitudinals need not exceed that of a bottom longitudinal having the same spacing and configuration.

5.3.2 The modulus of bottom longitudinals is to satisfy the requirements of 5.3.1 or Table 1.6.1(3) in Chapter 1, whichever is the greater.

5.3.3 The section modulus given is that of the longitudinal and associated plating, for the extent of the associated plating, *see* Pt 3, Ch 3,3.2.3. The webs and flanges are to comply with the minimum thickness requirements of Section 10.

5.3.4 Where the spacing of transverses exceeds 5,5 m, the scantlings of side and bottom longitudinals in way of bulkheads and primary members, including end connections, are to be verified by direct calculation.

5.3.5 The side and bottom longitudinal scantlings derived from 5.3.1 and 5.3.2, using the midship thickness of plating, are to extend throughout the cargo tanks. Where the shell plating is inclined at an angle to the horizontal longitudinal axis of greater than 10°, the span of the longitudinals is to be measured along the member. Where the shell plating is inclined at an angle to the vertical axis of greater than 10°, the spacing of longitudinals is to be measured along the chord between members. Where the angle of attachment of side longitudinals clear of amidships varies by 20° or more from a line normal to the plane of the shell, the properties of the section are to be determined about an axis parallel to the attached plating. Angles of slope greater than 40° are to be avoided.

5.3.6 Fabricated longitudinals having the face plate welded to the underside of the web, leaving the edge of the web exposed, are not recommended for shell, inner hull or longitudinal bulkhead longitudinals. Where it is proposed to fit such sections, a symmetrical arrangement of connection to transverse members is to be incorporated. This can be achieved by fitting backing brackets on the opposite side of the transverse web or bulkhead. The primary member web stiffener and backing bracket are to be lapped to the longitudinal. Recommended examples of such backing structure can be seen in the *ShipRight FDA Procedure, Structural Detail Design Guide* (SDDG).

5.3.7 Where partial filling of the tanks is also contemplated the deck longitudinals are to comply with the requirements of 6.1.2.

5.3.8 Stiffeners and brackets on vertical webs in wing ballast tanks, where fitted on one side and connected to higher tensile steel longitudinals between the base line and 0,8*D* above the base line, are to have their heels well radiused to reduce stress concentrations. Where a symmetrical arrangement is fitted, i.e., bracket or stiffening on both sides, and they are connected to higher tensile steel longitudinals, the toes of the stiffeners or brackets are to be well radiused. Alternative arrangements will be considered if supported by appropriate fatigue life assessment calculations.

5.3.9 Where higher tensile steel side longitudinals pass through transverse bulkheads in the cargo area, well radiused brackets of the same material are to be fitted on both the fore and after side of the connection between the upper turn of bilge and 0,8*D* above the base line. Particular attention should be given to ensuring the alignment of these brackets. Alternative arrangements will be considered if supported by appropriate fatigue life assessment calculations.

5.4 Bilge longitudinals and brackets

5.4.1 The scantlings of bilge longitudinals are to be graduated between those required for the bottom and lowest side longitudinals.

5.4.2 Where bilge longitudinals are omitted, the spacing of transverses or equivalent bilge brackets must not exceed:

$$8 \times 10^6 \frac{t_s^2}{DR_B}\sqrt{\frac{t_s}{R_B}} \text{ mm}$$

Where no intermediate brackets are fitted between transverses, the spacing between the two outermost bottom longitudinals and between the two lowest side longitudinals is not to exceed one-third of the bilge radius or 40 times the local shell thickness, whichever is the greater.

5.4.3 Attention is drawn to 4.6.2 and 4.6.3 concerning bilge plating thickness where longitudinals are omitted.

5.5 Deck longitudinals outside 0,4*L* amidships

5.5.1 Within the cargo tank region, deck longitudinals may be gradually tapered outside 0,4*L* amidships in association with the deck plating, on the basis of area and modulus. For the requirements, *see* Pt 3, Ch 3,2.5 and Table 3.2.1, *see also* 5.3.5.

5.5.2 The midship spacing of longitudinals is, in general, to be maintained throughout the cargo tank region. The plating thickness and longitudinal depth and thickness are not to be increased at any point in the direction of the taper of area towards the ends of the ship, other than as may be required for compensation for openings. Changes of longitudinal section are, in general, to be avoided.

5.5.3 Attention is also drawn to 5.3.3, which is to be complied with, where necessary, by maintaining a constant deck plating thickness in way of the ends of the cargo tank region.

5.5.4 Where the spacing of transverses in cargo tanks is not constant and variations in longitudinal scantlings are contemplated to suit differing spans, individual consideration will be given to the taper arrangements.

5.6 Stability of longitudinals

5.6.1 The lateral and torsional stability of longitudinals together with web and flange buckling criteria are to be verified in accordance with Pt 3, Ch 4,7.

5.6.2 In addition, the following requirements are to be satisfied:

(a) Flat bar longitudinal

(i) when continuous at bulkheads

$$\frac{d_w}{t_w} \leq 18\sqrt{k_L}$$

(ii) when non-continuous at bulkheads

$$\frac{d_w}{t_w} \leq 15\sqrt{k_L}$$

(b) Built sections

(i) $\dfrac{d_w}{t_w} \leq 60\sqrt{k_L}$

(ii) $\dfrac{b_f}{t_f} \leq 15$ for asymmetric sections

(iii) $\dfrac{b_f}{t_f} \leq 30$ for symmetric sections.

5.7 Connections of longitudinals

5.7.1 Connections of longitudinals to bulkheads are to provide adequate fixity and continuity of longitudinal strength. *See also* the *ShipRight FDA Procedure, Structural Detail Design Guide* (SDDG), for recommended design details in critical areas.

5.7.2 Where the length of the ship exceeds 150 m, the longitudinals within 0,1*D* of the bottom and deck are to be continuous through the transverse bulkheads. Higher tensile steel longitudinals are to be continuous irrespective of ship length. Alternative arrangements will be individually considered.

5.7.3 Longitudinals are to be connected to transverse primary members as required by Pt 3, Ch 10,5.2.

5.8 Openings in longitudinals

5.8.1 In general, closely spaced scallops are not permitted in longitudinals within the range of cargo tanks except in way of ballast pipe suctions, reinforcement in these areas will be specially considered.

5.8.2 Small air and drain holes, cut-outs at erection butts and similar widely spaced openings are, in general, to be not less than 200 mm clear of the toes of end brackets, intersections with primary supporting members and other areas of high stress. All openings are to be well rounded with smooth edges.

5.8.3 Drain holes in higher tensile steel longitudinals attached to higher tensile steel plating are to be elliptical in shape or of equivalent design to minimise stress concentrations. The opening is generally to be located clear of the welded connection to the plating, but where a flush opening is essential for drainage the weld connection is to end in a soft toe.

5.8.4 Small circular air holes may be arranged in higher tensile steel deck longitudinals.

5.8.5 Isolated openings spaced greater than 1 metre apart need not be taken into account in calculating the section modulus of the longitudinal, provided that the depth does not exceed 10 per cent of the web depth, or 75 mm, whichever is the greater, but in no case more than 25 per cent of the depth of the longitudinal.

5.8.6 Where the depths given in 5.8.5 are exceeded, the arrangements are to be such as will minimise resultant stress concentration.

5.9 Transverse side frames

5.9.1 For limits of application of transverse side framing, *see* 1.3.

5.9.2 The section modulus of transverse side frames is to be not less than:

$Z = 0{,}01025k\, s\, h_2\, l_e^2$ cm^3, where side webs are fitted;

or

$Z = 0{,}012k\, s\, h_2\, l_e^2$ cm^3, where side webs are not fitted.

5.9.3 The size of the frame is to be governed by the maximum modulus derived from the appropriate formula in 5.9.2, and is to be maintained for the full depth of the ship.

5.9.4 The section modulus given is that of the frame and associated side shell plating. The frame is to comply with the minimum thickness requirements of Section 10.

5.9.5 The inertia of transverse side frames is to be not less than:

In the forward 0,15*L*: $I = 3{,}5 l_e Z$ cm^4

Elsewhere: $I = 3{,}2 l_e Z$ cm^4.

Section 6
Inner hull, inner bottom and longitudinal oiltight bulkheads

6.1 General

6.1.1 The inner hull, inner bottom and longitudinal bulkheads are generally to be longitudinally framed. Longitudinal bulkheads may be plane or horizontally corrugated. Centreline longitudinal bulkheads may also be vertically corrugated, *see* 1.4.14. Scantlings of inner hull and longitudinal oiltight bulkheads are to be in accordance with Table 9.6.1 and panel stability is also to be confirmed from primary structure direct calculations. The calculation is to take account of the shear stress and direct stresses derived from both the transverse and longitudinal strength investigations.

6.1.2 Where tanks are intended to be partially filled, the scantlings and structural arrangements of the boundary bulkheads are to be capable of withstanding the loads imposed by the movement of liquid in the tanks. The magnitude of the predicted loadings, together with the scantling calculations, may require to be submitted.

6.2 Symbols

6.2.1 The symbols used in this Section are defined as follows:

b_1 = the greater horizontal distance in metres, from a point one third of the height of the strake above its lower edge or mid-point of the stiffener span, to the corners at the top of the tank on either side. Where the angle α is less than $\left(32,5 - \dfrac{L}{20}\right)$ degrees, the distance is measured to the widest point of the tank, *see* Fig. 9.6.1.

α = angle, in degrees, as indicated in Fig. 9.6.1.

$c_1 = \dfrac{60}{225 - 165F_D}$ at deck

$= 1,0$ at $\dfrac{D}{2}$

$= \dfrac{75}{225 - 150F_B}$ at base line of ship

intermediate values of c_1 by interpolation

$c_2 = \dfrac{165}{345 - 180F_D}$ at deck

Table 9.6.1 Inner hull and longitudinal oiltight bulkhead scantlings

Item	Horizontally stiffened/Vertically stiffened
(1) Plating thicknesses including corrugations (mm) *See* Notes 1 and 7	(a) Within 0,1*D* of the deck: $t = t_0$ (b) Within 0,1*D* of the bottom shell: $t = \dfrac{t_0}{\sqrt{2 - F_B}}$ (but not less than t_1) (c) Elsewhere: $t = t_1$ *see* Note 6 (d) But not less than $t = 0,0009s\,(0,059L_1 + 7)$
(2) Stiffener modulus (cm^3) *See* Notes 3 and 4	(a) Horizontally stiffened: (i) $Z = 0,056k\,h_2\,s\,l_e^2\,F_1$ (ii) $Z = 0,0051k\,h_4\,s\,l_e^2\,F_2$ whichever is the greater (b) Vertically stiffened: $Z = 0,0067ks\,l_e^2 h_5$
(3) Corrugation properties *See* Note 7	(a) Modulus (cm^3): $Z = 0,0085p\,h_5\,l_e^2\,k$ (b) Inertia (cm^4): $I = 0,032p\,h_5\,l_e^3$

NOTES
1. The plating thicknesses are not to be less than as necessary to comply with the buckling requirements of Pt 3, Ch 4,7.
2. The section modulus given by the formula is that of the stiffener and associated plating or of the corrugation over pitch, *p*.
3. For vertical stiffeners, the ratio of web depth to web thickness is not to exceed $60\sqrt{k}$ for stiffeners with flanges or face plates, and $18\sqrt{k}$ for flat bars. Horizontal stiffeners are to comply with 5.6.
4. The minimum thickness criteria given in Section 10 are also to be complied with and the stiffener web thickness is to be sufficient to withstand the imposed shear forces.
5. The minimum moment of inertia represented by item 3(b) of the Table is not to be reduced on account of higher tensile steel being incorporated.
6. In applying item 1(c) of the Table, it is necessary to calculate values of t_0 for plate panels within 0,4*D* each side of mid-depth, take the minimum value, t_m, and then determine value of t_1.
7. For vertically corrugated centreline longitudinal bulkheads *see also* Table 1.9.2 in Chapter 1 for deep tanks.

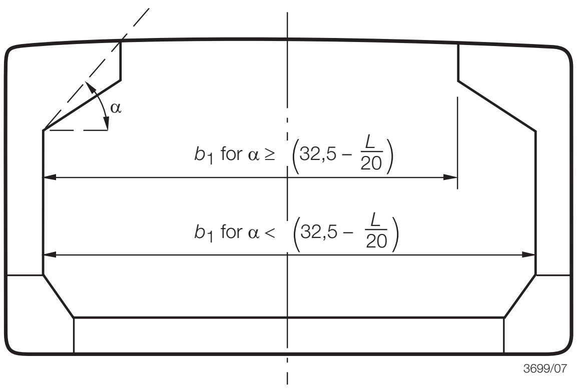


Fig. 9.6.1 Illustration of b_1 determination

= 1,0 at $\frac{D}{2}$

= $\frac{165}{345 - 180F_B}$ at base line of ship

intermediate values of c_2 by interpolation

h = load height, in metres measured vertically as follows:

(a) For bulkhead plating, the distance from a point one third of the height of the plate panel above its lower edge to the highest point of the tank, excluding hatchway

(b) for bulkhead stiffeners or corrugations, the distance from the mid-point of span of the stiffener or corrugation to the highest point of the tank, excluding hatchway

h_1 = $\left(h + \frac{D_1}{8}\right)$, but not less than 0,72 ($h + Rb_1$)

h_2 = $\left(h + \frac{D_1}{8}\right)$, in metres, but in no case to be taken less than $\frac{L_1}{56}$ m or ($0,01L_1 + 0,7$) m whichever is the greater

h_3 = distance of longitudinal below deck at side, in metres, but is not to be less than 0

h_4 = $h + R\,b_1$

h_5 = h_2 but is to be not less than $0,55h_4$

l_e = effective length, in metres, of longitudinals measured between span points, but is not to be taken less than 2,5 m. For determination of span points, *see* Pt 3, Ch 3,3

p = pitch of symmetrical corrugations, in mm

s = spacing, in mm, of bulkhead stiffeners for plane bulkheads. In case of symmetrical corrugations, s is to be taken as b or c in Fig. 3.3.1 in Pt 3, Ch 3, whichever is the greater

t_0 = $0,005s\sqrt{kh_1}$

t_1 = $t_0\left(0,84 + 0,16\left(\frac{t_m}{t_0}\right)^2\right)$

t_m = minimum value of t_0 within $0,4D$ each side of mid-depth of bulkhead

D_1 = D, in metres, but is to be taken not less than 10 and need not be taken greater than 16

F_B = as defined in Pt 3, Ch 4,5.7

F_D = as defined in Pt 3, Ch 4,5.7

F_1 = a factor determined from Table 9.6.2

F_2 = a factor determined from Table 9.6.3

R = sin θ

where θ is the roll angle, in degrees

and $\sin\theta = \left(0,45 + 0,1\frac{L}{B}\right)\left(0,54 - \frac{L}{1270}\right)$

Other symbols are defined in 1.5.

Table 9.6.2 Values of F_1

Longitudinal bulkhead longitudinals	F_1
Above $\frac{D}{2}$	$\frac{Dc_1}{4D + 20h_3}$
Below $\frac{D}{2}$	$\frac{Dc_1}{25D - 20h_3}$
NOTE Minimum F_1 = 0,12	

Table 9.6.3 Values of F_2

Longitudinal bulkhead longitudinals	F_2
Above $\frac{D}{2}$	$\frac{Dc_2}{D + 2,18h_3}$
Below $\frac{D}{2}$	$\frac{Dc_2}{3,18D - 2,18h_3}$
NOTE Minimum F_2 = 0,73	

6.3 Inner hull and longitudinal bulkheads

6.3.1 Inner hull and longitudinal bulkheads are to extend as far forward and aft as practicable and are to be effectively scarfed into the adjoining structure.

6.3.2 Longitudinal bulkheads only may be perforated provided suitable account is taken of the applied shear forces. Proposals to fit perforated longitudinal bulkheads in cargo tanks will be individually considered. *See also* 7.1 concerning penetration of pump-room, cofferdam and cargo tank bulkheads.

6.3.3 The thickness of inner hull and longitudinal bulkhead plating required by Table 9.6.1 is to be maintained throughout the cargo tank length, with the exception of item (1)(a) which may be gradually tapered outside $0,4L$ amidships to cargo tank minimum thickness or as required by item (1)(c), whichever is the greater, at $0,075L$ from the ends.

6.3.4 The bulkhead plating thicknesses throughout the cargo tank length are to be increased as necessary to attain compliance with the shear strength requirements of Pt 3, Ch 4,6.

6.3.5 For conditions which provide for wing and centre cargo tanks abreast to be filled, with adjacent cargo tanks fore and aft empty, the thickness of longitudinal bulkheads is to comply with the requirements of 8.3.2(d) and (e), *see also* 3.3.6.

6.3.6 Where bulkheads are penetrated by cargo or ballast piping, the structural arrangements in way are to be capable of withstanding the loads imparted to the bulkheads by the hydraulic forces in the pipes. The requirements for cargo and ballast piping is given in Pt 5, Ch 15,2.5 and Ch 15,3.

6.3.7 Openings in horizontal stiffeners are to comply with the requirements of 5.8.

6.4 Longitudinal corrugated bulkheads

6.4.1 Where horizontally corrugated bulkheads are adopted the angle of corrugation is to be not less than 40°.

6.4.2 In ships exceeding 150 m in length the upper and lower strakes of the longitudinal bulkhead are to be plane for a distance of 0,1*D* from the deck and bottom.

6.4.3 Corrugations are to be aligned, and stiffening arrangements on plane members are to be arranged to give adequate support in way of flanges of abutting corrugations. Where both the longitudinal and transverse bulkheads are horizontally corrugated, the arrangements at intersections are to be designed to facilitate attachment and maintain continuity.

6.4.4 Where asymmetrical girders or webs are fitted to corrugated bulkheads, the angle of corrugation is not to exceed 60°.

6.5 Inner bottom

6.5.1 The inner bottom is to be longitudinally framed and the inner bottom plating thickness is to be not less than the greater of:

(a) $t = \dfrac{t_0}{\sqrt{2 - F_B}}$ mm , or

(b) deep tank requirements of Table 1.9.1 in Chapter 1.

6.5.2 The section modulus of inner bottom longitudinals is to be in accordance with Table 9.6.1(2) or deep tank requirements of Table 1.9.1 in Chapter 1, whichever is the greater, and the unsupported span may extend to the spacing between plate floors.

6.5.3 Buckling resistance to longitudinal and transverse stresses in the inner bottom is to be confirmed by direct calculation, *see also* Pt 3, Ch 4,7.

6.5.4 Transverse continuity of inner bottom is to be maintained outboard of inner hull, *see* 6.6.3. Recommended details are shown in the *ShipRight FDA Procedure, Structural Detail Design Guide* (SDDG).

6.5.5 Particular attention is to be given to the through-thickness properties and continuity at the connection of bulkhead stools to the inner bottom. For requirements for plates with specified through-thickness properties, *see* Ch 3,8 of the Rules for Materials.

6.5.6 Connection of inner bottom longitudinals to plate floor is to satisfy the requirements given in Pt 3, Ch 10,5.2.

6.6 Hopper side tank

6.6.1 Where a hopper side tank is fitted the sloping bulkhead plating and attached longitudinals are to be as required by Table 9.6.1.

6.6.2 A transverse is to be arranged in the hopper tank in line with each double bottom plate floor, to ensure continuity of transverse strength.

6.6.3 Particular attention is to be paid to the continuity of the inner bottom plating into the hopper side tank. Scarfing brackets are to be fitted in the hopper in line with the inner bottom at each transverse. These brackets are to be arranged each side of the transverse.

6.6.4 Knuckles in the hopper tank plating are to be supported by side girders and stringers or by a deep longitudinal.

6.6.5 Detail design guidelines for connections in way of hopper tank knuckles are shown in the *ShipRight FDA Procedure, Structural Detail Design Guide* (SDDG).

6.7 Connections

6.7.1 Horizontal and vertical stiffeners are to be connected to supporting primary members as required by Pt 3, Ch 10,5.2.

6.7.2 Stiffeners are to be bracketed or otherwise efficiently connected at their ends to provide adequate fixity, as required by Pt 3, Ch 10.

6.7.3 Connections of horizontal stiffeners to transverse bulkheads are to provide adequate fixity and continuity of longitudinal strength. Horizontal stiffeners are to be continuous through bulkheads as required by 5.7, for longitudinals.

6.7.4 Where inner hulls, longitudinal and transverse bulkheads are horizontally stiffened, consideration will be given to the stability of the arrangements at intersections. Additional calculations may be required.

■ *Section 7* Transverse oiltight bulkheads

7.1 General

7.1.1 Transverse oiltight bulkheads may be plane or with corrugations arranged horizontally or vertically. Scantlings are to be in accordance with Table 9.7.1, except as otherwise provided for in this Section. The arrangement of stiffening is to be such as will efficiently support loads transmitted by end connections of inner hull, longitudinal bulkhead, shell and deck longitudinals. The thickness of bulkhead plating is also to be confirmed by direct calculation in respect of panel stability. The calculation is to take account of the shear stresses and direct stresses derived from both the transverse and longitudinal strength investigations.

7.1.2 Where tanks are intended to be partially filled, the scantlings and structural arrangements of the boundary bulkheads are to be capable of withstanding the loads imposed by the movement of liquid in the tanks. The magnitude of the predicted loadings, together with the scantling calculations, may require to be submitted.

7.1.3 The scantlings of water ballast tank and cofferdam bulkheads not forming the boundary of a cargo tank are to be as required by Ch 1,9 for deep tanks. Where the bulkheads are boundaries of 'U' shaped tanks, the scantlings are also to be confirmed by the requirements of this Section.

7.1.4 Where the pump-room acts as a cofferdam, a bulkhead which does not form part of the boundary of a cargo tank or an oil fuel bunker may be of watertight bulkhead scantlings in accordance with the requirements of Ch 1,9 provided that an inert gas system is fitted in the cargo tanks, and the corresponding notation provided for in Pt 1, Ch 2,2 is assigned.

7.1.5 Where penetration of the cofferdam or pump-room bulkheads is permitted by the Rules, the integrity of the bulkhead is to be maintained, *see also* Pt 5, Ch 13,2, Ch 15,3 and Pt 6, Ch 2,14.

7.1.6 Where bulkheads are penetrated by cargo or ballast piping, the structural arrangements in way are to be capable of withstanding the loads imparted to the bulkheads by the hydraulic forces in the pipes.

7.1.7 Special consideration will be given to any proposals to fit permanent repair/maintenance access openings with oiltight covers in cargo tank bulkheads. Attention is drawn to the existence of National Authority Regulations concerning load line and oil outflow aspects of such arrangements.

7.2 Symbols

7.2.1 The symbols used in this Section are defined as follows:

a = the lesser dimension of an unstiffened plate panel, in mm

b = the greater dimension of an unstiffened plate panel, in mm

b_1 = the greater horizontal distance, in metres, from the centre of the plate panel or mid-point of the stiffener span to the corners at the top of the tank on either side

Table 9.7.1 Transverse oiltight bulkhead scantlings

Item	Horizontally stiffened	Vertically stiffened
(1) Plating thickness (mm) (a) Generally, including corrugations *see also* item 3	$t = 0{,}0044sf\sqrt{kh_1}$	
(b) But not less than: (i) For the upper 3/4 of the bulkhead *see* Note 5	$t = \dfrac{a}{\left(95 + 20\,\dfrac{a}{b}\right)\sqrt{k}}$	$t = \dfrac{a}{\left(85 + 30\left(\dfrac{a}{b}\right)^2\right)\sqrt{k}}$
(ii) For the lower 1/4 of the bulkhead *see* Note 5	$t = \dfrac{a}{\left(80 + 20\,\dfrac{a}{b}\right)\sqrt{k}}$	$t = \dfrac{a}{\left(73 + 27\left(\dfrac{a}{b}\right)^2\right)\sqrt{k}}$
(2) Stiffener modulus (cm^3)	$Z = 0{,}0067ksS_1^2\,h_2$	
(3) Corrugation properties (a) Modulus (cm^3) (b) Inertia (cm^4) *see* Note 4	$Z = 0{,}0085ph_2\,l_e^2k$ $I = 0{,}032ph_2\,l_e^3$	

NOTES
1. The section modulus given by the formula is that of the stiffeners and associated plating or of the corrugation over pitch p.
2. The ratio of web depth to web thickness is not to exceed $60\sqrt{k}$ for stiffeners with flanges or face plates and $18\sqrt{k}$ for flat bars.
3. The minimum thickness criteria given in Section 10 are also to be complied with, and the stiffener web thickness is to be sufficient to withstand the imposed shear forces.
4. The minimum moment of inertia required by item 3(b) of the Table is not to be reduced on account of higher tensile steel being incorporated.
5. For vertically corrugated bulkheads, *see* Table 1.9.2 in Chapter 1 for deep tanks.

f = $1,1 - \dfrac{s}{2500S_1}$ but not to be taken greater than 1,0

h = load height, in metres measured vertically as follows:

(a) for bulkhead plating, the distance from a point one-third of the height of the plate panel above its lower edge to the highest point of the tank, excluding hatchway

(b) for bulkhead stiffeners or corrugations, the distance from the mid-point of span of the stiffener or corrugation to the highest point of the tank, excluding hatchway

h_1 = $h + \dfrac{D_1}{8}$ but not less than 0,72 ($h + Rb_1$)

h_2 = $h + \dfrac{D_1}{8}$ but not less than 0,55 ($h + Rb_1$)

p = pitch of symmetrical corrugations, in mm

s = spacing, in mm, of bulkhead stiffeners or the breadth, in mm, of flange or web, whichever is the greater, of symmetrical corrugations

D_1 = D, in metres, but is to be taken not less than 10 and need not be taken greater than 16

R = $\sin\theta$

where θ is the roll angle, in degrees

and $\sin\theta = \left(0,45 + 0,1\dfrac{L}{B}\right)\left(0,54 - \dfrac{L}{1270}\right)$

S_1 = spacing of primary members, in metres. For the span at top, span may be reduced by the depth of deck longitudinal.

Other symbols are defined in 1.5.

7.3 Corrugated bulkheads

7.3.1 Where corrugated bulkheads are adopted the angle of corrugation is to be not less than 40°, *see* Fig. 3.3.1 in Pt 3, Ch 3.

7.3.2 Where transverse bulkheads are vertically corrugated, adequate resistance to transverse compressive forces is to be provided by horizontal stringers or equivalent.

7.3.3 Where transverse bulkheads are horizontally corrugated, the span of the corrugations should not, in general, exceed 5,0 m. Consideration is to be given to providing an efficient connection between the corrugations and the inner hull and longitudinal bulkhead stiffeners including local reinforcement where necessary.

7.3.4 Corrugations are to be aligned and stiffening arrangements on plane members are to be arranged to give adequate support in way of flanges of abutting corrugations. Where both the longitudinal and transverse bulkheads are horizontally corrugated, the arrangements at intersections are to be designed to facilitate attachment and maintain continuity.

7.3.5 Where asymmetrical girders or webs are fitted to corrugated bulkheads, the angle of corrugation is not to exceed 60°.

7.3.6 Where corrugated bulkheads on stools are adopted, attention is to be paid to the design of end connection. The arrangements are to be in accordance with the requirements of 7.4.

7.3.7 Where vertically corrugated bulkheads are proposed without stools both flanges are to be adequately supported at deck and inner bottom. Proposals will be specially considered. Particular attention is to be given to the through-thickness properties of the inner bottom plating and continuity at the connection to the inner bottom. For the requirements for plates with specified through-thickness properties, *see* Ch 3,8 of the Rules for Materials.

7.4 Bulkheads supported by stools

7.4.1 The scantlings of vertically corrugated and double plate bulkheads supported by stools are generally to be confirmed by direct calculations which are to be submitted.

7.4.2 In addition the scantlings are to be determined in accordance with the requirements of Ch 1,9.2.1 for deep tank bulkheads with the load head h_4, in metres, measured to the highest point of the tank, excluding hatchway, but is not to be taken less than 0,44 ($h_4 + Rb_1$).

7.4.3 The sloping stool plate thickness adjacent to the corrugation is to be not less than the thickness of the corrugation flange at mid span as required by 7.4.1 and 7.4.2. Where the plate thickness is increased locally, the vertical extent is to be not less than the width of the flange of the corrugation.

7.4.4 The stools are to be reinforced with plate diaphragms or deep webs, and in bottom stools the diaphragms are to be aligned with double bottom side girders. Continuity is also to be maintained between the diaphragms and the webs of bulkhead corrugations as far as practicable.

7.4.5 Additional double bottom girders are to be arranged extending at least to the first plate floor adjacent to the bulkhead each side and, in general, are to be spaced not more than 3,8 m apart.

7.4.6 The sloping plate of bottom stools is to be aligned with double bottom floors. Particular attention is to be given to the through-thickness properties of the inner bottom plating and continuity at the connection to the inner bottom, and to the through-thickness properties of the bottom stool shelf plate. For requirements for plates with specified through-thickness properties, *see* Ch 3,8 of the Rules for Materials.

7.4.7 An efficient system of reinforcement is to be arranged in line with the tank transverse bulkheads or bulkhead stools at the intersection with the sloped plating of the double bottom hopper tanks and topside tanks. The reinforcement fitted in the tanks is to consist of girders or intercostal bulb plate or equivalent stiffeners fitted between and connected to the sloped bulkhead longitudinals.

7.4.8 The shelf plates of the bulkhead stools are to be arranged to align with the longitudinals in the double bottom hopper tank and topside tanks. Where sloping shelf plates are fitted to stools suitable scarfing is to be arranged in way of the connections of the stools to the adjoining structures.

7.4.9 The arrangement of stools and adjacent structure common with the cargo tank is to be designed to avoid pockets in which gas could collect.

7.5 Connections

7.5.1 Horizontal and vertical stiffeners are to be connected to supporting primary members as required by Pt 3, Ch 10,5.2.

7.5.2 Stiffeners are to be bracketed or otherwise efficiently connected at their ends to provide adequate fixity.

7.5.3 Arrangements and scantlings of end brackets for vertical stiffeners are to be as required by Pt 3, Ch 10.

7.5.4 Horizontal stiffener end brackets are generally to satisfy the requirements of Pt 3, Ch 10. However, the length of the bracket arm at the side shell, inner hull and longitudinal bulkhead longitudinals is, in general, not to exceed the depth of the longitudinal. In order to provide the necessary weld connection, consideration may require to be given to fitting brackets on both sides of the bulkhead or to welding the stiffener to the longitudinal. The arrangements are also to be such as to maintain transverse continuity at intersections. Examples can be seen in the *ShipRight FDA Procedure, Structural Detail Design Guide* (SDDG).

■ *Section 8*
Non-oiltight bulkheads

8.1 General

8.1.1 The requirements of this Section are applicable to longitudinal and transverse wash bulkheads, where fitted. Proposals to fit perforated longitudinal bulkheads in cargo tanks will be individually considered, *see also* 1.3.

8.1.2 Wash bulkheads are generally to be of plane construction, horizontally or vertically stiffened, having an area of perforations not less than 10 per cent of the total area of the bulkhead. The perforations are to be so arranged that the efficiency of the bulkhead as a support is not impaired.

8.1.3 Where tanks are intended to be partially filled, the scantlings and structural arrangements of the wash bulkheads are to be capable of withstanding the loads imposed by the movement of liquid in the tanks. The magnitude of the predicted loads, together with the scantling calculations, may require to be submitted.

8.2 Symbols

8.2.1 The symbols used in this Section are defined as follows:

a = the horizontal length of the plate panel, in mm

a_T = the cross-sectional area of the vertical web on longitudinal bulkhead and associated bulkhead plating over one transverse space, in cm^2

b_i = half the distance, in metres, between members supporting floors as shown in Fig. 9.8.1

b_L = half the distance, in metres, between members supporting horizontal girder, adjacent to the bulkhead under consideration, as shown in Fig. 9.8.1

b_T = overall breadth of tank, in metres

D_1 = D, in metres, but is to be taken not less than 10 and need not be taken greater than 16

D_L = the depth of the longitudinal bulkhead, including double bottom girder, in metres

d_L = the distance, in metres, from the top of the longitudinal bulkhead to the centre of the plate panel under consideration and need not be taken greater than the distance to the bracket toe of the double bottom transverse primary member

h = the distance, in metres, from the centre of the load on the horizontal girder to $\dfrac{D_1}{8}$ m above the highest point of the tank, excluding the hatchway

d_H = the mean depth of horizontal girders at the longitudinal bulkhead, in metres, including the depth of the end brackets as shown in Fig. 9.8.1

l_G = the distance, in metres, from the horizontal girders to the adjacent horizontal primary member below

t_3 = $\dfrac{Q_{SL} + Q_{SW}}{D_L\,\tau}$ mm

Q_s, Q_w = as defined in Pt 3, Ch 4,6.1

τ = $\dfrac{110}{k_L}$ N/mm^2 $\left(\dfrac{11,2}{k_L}\text{ kgf/mm}^2\right)$

Q_{SL} = the maximum still water shear force on the longitudinal bulkhead, in kN (tonne-f), of the loading condition in question.
Where two longitudinal bulkheads are fitted, Q_{SL} may be taken as:
$Q_{SL} = 0{,}34Q_S$
Where one longitudinal bulkhead is fitted, Q_{SL} may be taken as:
$Q_{SL} = 0{,}40Q_S$
Q_{SL} may also be derived by direct calculation to determine the distribution of shear force between the shell, inner hull and longitudinal bulkheads.

Q_{SW} = design wave shear force on the longitudinal bulkhead, in kN (tonne-f).
Where two longitudinal bulkheads are fitted, Q_{SW} may be taken as:
$Q_{SW} = 0{,}20Q_w$
Where one longitudinal bulkhead is fitted, Q_{SW} may be taken as:
$Q_{SW} = 0{,}28Q_w$

l_T = overall length of tank, in metres

$F_d = W_h\, S\, b_i\, \dfrac{d_L}{D_L}$

l_b = the distance between the transverse bulkheads (oiltight or non-oiltight) adjacent to the bulkhead under consideration, in metres

S = spacing of the double bottom transverse primary members, in metres

T_p = the maximum operating draught of ship, in metres, where the tank with non-oiltight bulkhead is empty.

$W_h = T_p + 0{,}023Le^{-0{,}0044L}$

$\alpha = \dfrac{s}{a}$, but not to be taken greater than 1,0

Other symbols are defined in 1.5.

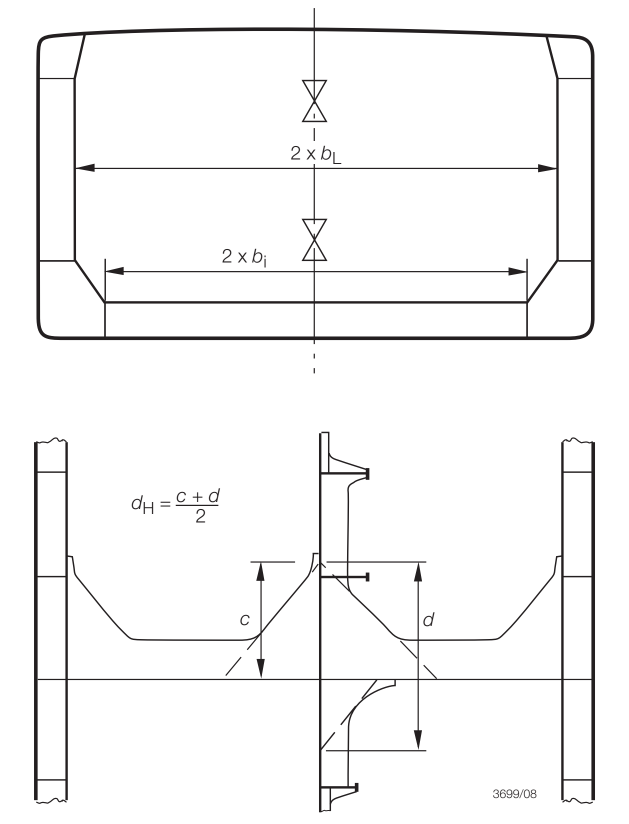


Fig. 9.8.1 Horizontal girder

8.3 Scantlings

8.3.1 The thickness of plating may be the compartment minimum, *see* Section 10, except as given in 8.3.2 and 8.3.4.

8.3.2 Where non-oiltight **longitudinal** wash bulkheads support a bottom primary member, the following additional requirements are to be met:

(a) The area of perforation is to be not greater than 25 per cent of the total area of the bulkhead, and consideration is to be given to the disposition and geometry of the perforations so that the shear rigidity of the bulkhead is a maximum.

(b) The net section area of the bulkhead is to be not less than $0{,}135 l_T\, b_T\, D$ cm^2.

(c) The plating thickness is to comply with Table 9.6.1(1)(d).

(d) The thickness of longitudinal bulkhead plating and web plating of the vertical web on longitudinal bulkhead is generally to be not less than:

$$t = 0{,}026\, \frac{s}{1+\alpha^2} \sqrt{\frac{F_d}{a_T}} \text{ mm.}$$

(e) The thickness of the longitudinal bulkheads supporting a transverse bulkhead horizontal girder is in general to be not less than:

(i) $$t = \frac{0{,}0437\, h l_G\, b_L k}{d_H} + \frac{0{,}892\, t_3 k}{k_L} \text{ mm}$$

(ii) $$t = 0{,}0011s\,(0{,}059L_1 + 7) \text{ mm}$$

whichever is the greater.

The thickness is also to satisfy the buckling requirements of Pt 3, Ch 4,7.

The increased thickness is to extend over the end bracket and buttress of the horizontal girder down to a distance of $0{,}5l_G$.

8.3.3 The section modulus of longitudinal wash bulkhead stiffeners is to be not less than, *see also* Pt 3, Ch 4,7:

$$Z = 0{,}0036\left(0{,}54 - \frac{L}{1270}\right) b_T\, k\, s\, S^2 \text{ cm}^3.$$

8.3.4 Where non-oiltight **transverse** wash bulkheads support a primary fore and aft bottom centreline girder, the following additional requirements are to be met:

(a) The area of perforation is to be not greater than 25 per cent of the total area of the bulkhead, and consideration is to be given to the disposition and geometry of the perforations so that the shear rigidity of the bulkhead is a maximum.

(b) The net section area of the bulkhead is to be not less than $0{,}135 l_b\, b_T\, D$ cm^2.

(c) The plating thickness is to comply with Table 9.7.1(1)(b). In no case is either panel dimension to exceed 180 times the thickness required by this sub-paragraph or by 8.3.1, whichever is the greater.

8.3.5 The section modulus of transverse wash bulkhead stiffeners is to be not less than:

$$Z = 0{,}1215k\, s\, l_e^2\, \frac{l_b}{L} \text{ cm}^3.$$

8.4 Connections

8.4.1 Stiffeners are to be bracketed or otherwise efficiently connected at their ends and to primary supporting members, in accordance with the requirements of Pt 3, Ch 10.

■ *Section 9* Primary members supporting longitudinal framing

9.1 General

9.1.1 These requirements are applicable to ships having structural arrangements in accordance with 1.4.

9.1.2 The minimum thickness and constructional detail requirements of Section 10 are also to be complied with.

9.1.3 The scantlings of primary members are, in general, to be determined from direct calculations carried out in accordance with the requirements of Section 14 or in accordance with the requirements of this Section or the relevant Sections of Chapter 10. The direct calculations are to be submitted with the plans for confirmatory purposes, *see also* 1.4.5.

9.2 Symbols

9.2.1 The symbols used in this Section are defined as follows:

b_{e1}, b_{e2} = effective end bracket leg length, in metres, at each end of the member, *see* Pt 3, Ch 3,3

d_{DB} = Rule depth of centre girder, in mm

h_c = vertical distance from the centre of the cross-ties to deck at side amidships, in metres

h_s = distance between the lower span point of the vertical web and the moulded deck line at centreline, in metres

l_b = the distance, in metres, between the transverse bulkheads (oiltight or non-oiltight) adjacent to the bulkhead under consideration

l_c = one half the vertical distance, in metres, between the centres of the adjacent cross-ties or between the centre of the adjacent cross-tie and the centre of the adjacent bottom or deck transverse, or double bottom, *see* Fig. 9.9.1

s = spacing of transverses, in metres

A_c = cross sectional area of the cross-tie material which is continuous over the span of the cross-tie in cm^2

I_c = least moment of inertia of the cross-tie in cm^4

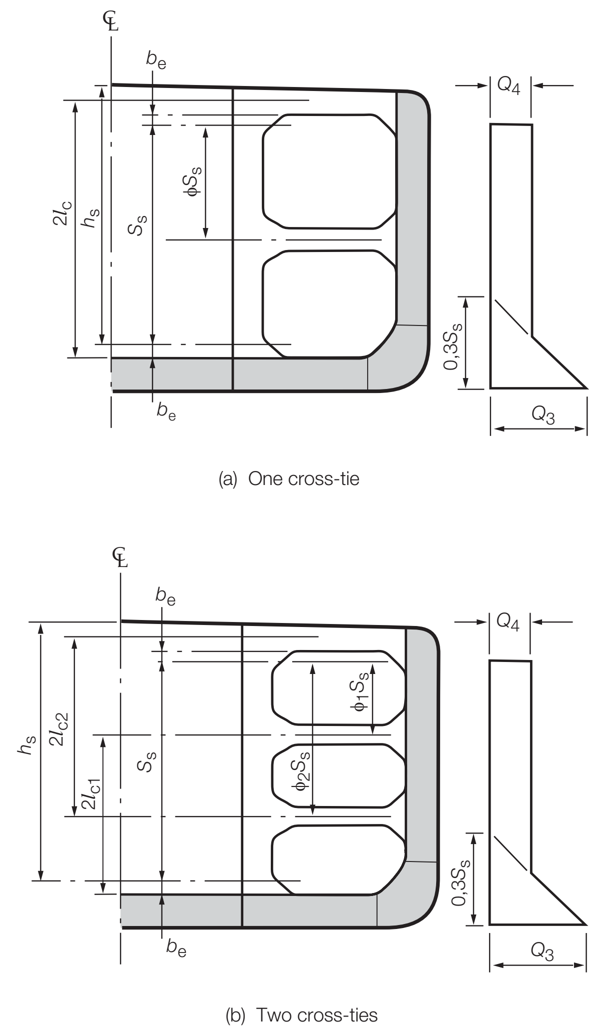
S_c = length of cross-tie, in metres, measured as follows:

(a) For centre tank cross-ties: S_c is the distance between the face plates of the vertical webs on the longitudinal bulkheads.

(b) For wing tank cross-ties: S_c is the distance between the face plate of the vertical web on the longitudinal bulkhead and the inner hull.

S_s = span of the vertical web, in metres, and is to be measured between end span points, *see* Fig. 9.9.1.

Other symbols are defined in 1.5.



NOTE: $Q_3 = 9{,}81 K_4\, h_s\, s\, S_s$ kN
($Q_3 = K_4\, h_s\, s\, S_s$ tonne-f)

$Q_4 = 9{,}81 K_5\, h_s\, s\, S_s$ kN
($Q_4 = K_5\, h_s\, s\, S_s$ tonne-f)

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Fig. 9.9.1 Wing tank construction

9.3 Girders and floors in double bottom

9.3.1 Girders are to be arranged at the centreline or duct keel, at the hopper side and in way of longitudinal bulkheads and bulkhead stools. Plate floors are to be arranged in way of transverse bulkheads and bulkhead stools.

9.3.2 In way of vertically corrugated transverse bulkheads supported by stools, additional girders are to be arranged extending at least to the first plate floor adjacent to the bulkhead each side and spaced not more than 3,8 m apart, *see* 7.4.5.

9.3.3 The centre girder is to have a depth of not less than that given by:

$d_{DB} = 28B + 205\sqrt{T}$ mm

The height of the double bottom is also to satisfy the requirements given in 1.3.

9.3.4 Thickness of floors and girders is to be confirmed by means of a direct calculation. Due account is to be taken of access and other openings. The minimum thickness however, is to be not less than that given by:

(a) Centre girder or duct keel:

$t = (0{,}008 d_{DB} + 1{,}0)\sqrt{k}$ mm

(b) Floors and side girders:

$t = (0{,}007 d_{DB} + 1{,}0)\sqrt{k}$ mm but need not exceed $12{,}0\sqrt{k}$ mm.

9.3.5 The scantlings of plating and stiffeners of longitudinal girders are not to be less than necessary to comply with the buckling requirements of Pt 3, Ch 4,7.

9.3.6 Floors and girders forming the boundaries of tanks are also to satisfy the requirements of tank bulkheads given in Ch 1,9.

9.3.7 Provision is to be made for the free passage of air and water from all parts of the tanks to the air pipes and suctions, account being taken of the pumping rates required. Adequate access is also to be provided to all parts of the double bottom. The edges of all openings are to be smooth. The size of the opening should not, in general, exceed 50 per cent of the double bottom depth, unless edge reinforcement is provided. In way of ends of floors and fore and aft girders at transverse bulkheads, the number and size of openings are to be kept to a minimum, and the openings are to be circular or elliptical. Edge stiffening may be required in these positions.

9.3.8 For ships intended to load or unload while aground, *see* Pt 3, Ch 9,9.

9.3.9 The structure of girders and duct keels is to be sufficient to withstand the forces imposed by dry-docking the ship, *see also* 10.10.

9.4 Vertical webs and horizontal girders in wing ballast tanks and hopper spaces

9.4.1 The width of the double skin side structure is to comply with the requirements given in 1.3.

9.4.2 Vertical webs are to be arranged in line with the floors in the double bottom to ensure continuity of transverse strength.

9.4.3 A horizontal girder is to be arranged at the top of the hopper space and is to be located close to the knuckle between the hopper and inner hull. Where additional longitudinal girders are provided to satisfy access requirements in accordance with 13.2.8, these are to be arranged in line with horizontal girders on the transverse bulkhead and wing tank cross-ties where these are fitted.

9.4.4 The scantlings of vertical webs and horizontal girders are to be determined by means of direct calculations and due account is to be taken of openings in the structure, *see also* the buckling requirements in Pt 3, Ch 4,7 for horizontal girders.

9.4.5 Access openings are to be kept clear of other small openings and are to have smooth edges. Edge stiffening is also to be arranged in regions of high shear stress.

9.5 Deck transverses and girders

9.5.1 Deck transverses are to be arranged in line with the vertical webs at the side and vertical transverses at longitudinal bulkheads, where fitted, to ensure continuity of transverse structure.

9.5.2 Deck girders are to be supported at transverse bulkheads by vertical webs or equivalent.

9.5.3 The scantlings of deck transverses and girders are to be determined by means of direct calculations or, alternatively, in accordance with the requirements of Ch 10,2.8 and 2.9.

9.6 Cross-ties

9.6.1 Cross-ties, where fitted, may be of plate or sectional material and are to have an area and least moment of inertia to satisfy the following:

$$A_c \geq \frac{0{,}765\, l_c\, h_c\, sk}{\left(1 - \dfrac{0{,}45 S_c}{r\sqrt{k}}\right)} \text{ cm}^2$$

where $r = \sqrt{\dfrac{I_c}{A_c}}$ cm

(As a first approximation the area and inertia of the cross-tie may be calculated in accordance with Ch 10,2.10.1.)

9.6.2 The scantlings of the webs and flanges of cross-ties are also to be confirmed by means of direct calculation.

9.6.3 Design of end connections is to be such that the area of the welding, including vertical brackets, where fitted, is to be not less than the minimum cross-sectional area of the cross-tie derived from 9.6.1. To achieve this, full penetration welding may be required and thickness of brackets may require further consideration. Attention is to be given to the full continuity of area of the backing structure on the vertical webs and within the wing ballast tank. Particular attention is also to be paid to the welding at the toes of all vertical end brackets on the cross-tie.

9.7 Primary members supporting oiltight bulkheads

9.7.1 The scantlings of primary members supporting oiltight bulkheads are, in general, to be determined by means of direct calculation, *see also* 9.7.4 and 9.7.5.

9.7.2 Alternatively, the scantlings of vertical webs and horizontal girders on transverse bulkheads are to be determined in accordance with the requirements of Ch 10,4.

9.7.3 Where longitudinal oiltight bulkheads are fitted, vertical webs are to be arranged in line with the deck transverses and the double bottom floors. Particular attention is to be paid to the alignment of the bulkhead web end brackets with the double bottom floors.

9.7.4 The section modulus of vertical webs on longitudinal bulkheads in ships with one or two longitudinal bulkheads is to be not less than:

$$Z = K_3 s h_s S_s^2 k \quad \text{cm}^3$$

where

K_3 is given in Table 9.9.1.

9.7.5 In ships with two longitudinal bulkheads, the net sectional area of the web at any section is not to be less than:

$$A = 0{,}12 Q_x k \quad \text{cm}^2$$

$$\left(A = \frac{Q_x k}{0{,}85} \quad \text{cm}^2\right)$$

where Q_x is calculated from shear force diagrams constructed as shown in Fig. 9.9.1. For this purpose the values of K_4 and K_5 and the range of application are given in Table 9.9.1.

9.7.6 The moment of inertia of vertical webs on longitudinal bulkheads is to be not less than:

$$I = \frac{7{,}5}{k} S_s Z \quad \text{cm}^4.$$

9.7.7 Where horizontal girders and vertical webs on transverse bulkheads do not form part of a ring structure, they are to be arranged with substantial end brackets forming a buttress extending to the adjacent vertical web or transverse. The shear and combined stresses in the buttress arrangements are to be examined.

9.7.8 Where the cross-ties are omitted from the transverse ring in the wing or centre tanks adjacent to the transverse bulkhead, the design of the horizontal girder, end buttress and vertical webs is to take account of the loads imposed and the deflection of the structure.

Table 9.9.1 Vertical web on longitudinal bulkhead coefficient

Number of cross-ties	K_3	K_4	K_5	Range of application
1	2,16	0,455 – 0,316ϕ	0,103	0,5 ≤ ϕ ≤ 0,7
2	1,88	0,441 – 0,267ϕ_1	0,498ϕ_2 – 0,249	0,4 ≤ ϕ_1 ≤ 0,5 0,65 ≤ ϕ_2 ≤ 0,8

9.7.9 Where, in ships exceeding 150 m in length, the longitudinal bulkhead is corrugated, the transverses are generally to be symmetrical on both sides of the bulkhead, and the scantlings may require to be increased to limit deflection.

9.8 Primary members supporting non-oiltight bulkheads

9.8.1 These requirements are applicable to primary members supporting non-oiltight transverse bulkheads. Where non-oiltight longitudinal bulkheads are proposed, the requirements for primary members will be individually considered.

9.8.2 Direct calculation procedures will generally be required where non-oiltight bulkhead primary members will interact with, or tend to support, the primary bottom, longitudinal bulkhead or side structure, and in other cases where warranted by structural design features. In general the section modulus of horizontal girders is to be not less than:

$$Z = 145 k\, b\, l_e^2 \frac{l_b}{L} \quad \text{cm}^3.$$

9.8.3 When determining the width of plating supported and the effective breadth for calculating the section modulus, no deduction is to be made on account of perforations.

■ *Section 10*
Construction details and minimum thickness

10.1 Symbols

10.1.1 The symbols used in this Section are defined as follows:

For the primary member:

d_w = depth of member web, in mm
s_t = spacing of tripping or docking brackets on the web of the member, in metres
t_w = thickness of member web, in mm
S_w = spacing of members, in metres

For the primary member web stiffener:

d = depth of web plate panel, in mm
l_s = span of stiffeners between effective support points, in metres
s = spacing of stiffeners on the web, in mm
A_s = cross-sectional area of the web stiffener and associated web plating, in cm^2
I_s = moment of inertia of the web stiffener and associated web plating, in cm^4

For the primary member end bracket, *see* Fig. 9.10.2:

d_b = arm length, in metres
l_b = effective length of the free edge, in metres
t_b = thickness of the end bracket plating, in mm
A_b = cross-sectional area of the end bracket edge stiffeners and associated plating, in cm^2
I_b = moment of inertia of the end bracket edge stiffeners and associated plating, in cm^4

Other symbols are defined in 1.5.

10.2 Compartment minimum thickness

10.2.1 Within the cargo tank region, including wing ballast tanks and cofferdams at the ends of or between cargo tanks, the thickness of primary member webs and face plates, hull envelope and bulkhead plating is to be not less than:

$t = 2{,}15L^{0{,}3}$ mm, or

$t = 7{,}5$ mm

whichever is the greater.

10.2.2 The minimum thickness of secondary members is to be determined as above, but need not exceed 11,0 mm.

10.2.3 In pump-rooms the minima apply to shell, deck, longitudinal bulkhead and associated longitudinals. For other items solely within the pump-room, including transverse bulkheads separating the adjacent machinery spaces from the pump-room, the minima may be reduced by 1,0 mm, subject to a lower limit of 7,5 mm.

10.2.4 Within the fore peak tank, minimum thicknesses are to be in accordance with 10.2.1 and 10.2.2 reduced by 1,0 mm but are to be not less than 7,5 mm.

10.3 Geometric properties and proportions of members

10.3.1 The depth of the web of any primary member is to be not less than 2,5 times the depth of the cut-outs for the passage of secondary members, except where compensation is arranged to provide satisfactory resistance to deflection and shear buckling in the web.

10.3.2 The area of material in the face plate of any primary member structure is not to exceed:

$0{,}00667 d_w t_w$ cm^2

nor is it to be less than:

$0{,}00417 s_t d_w$ cm^2.

10.3.3 The geometric properties of rolled stiffeners and built sections are to be calculated in association with an effective width of attached plating in accordance with Pt 3, Ch 3,3.

10.4 Continuity of primary members

10.4.1 Primary members are to be so arranged as to ensure effective continuity of strength throughout the range of tank structure. Abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead or on other members, arrangements are to be made to ensure that they are in alignment.

10.4.2 The members are to have adequate end fixity, lateral support and web stiffening, and the structure is to be arranged to minimise hard spots or other sources of stress concentration. Openings are to have well rounded corners and smooth edges and are to be located having regard to the stress distribution and buckling strength of the plate panel.

10.5 Primary member web plate stiffening

10.5.1 The webs of primary members are to be supported and stiffened in accordance with the following requirements, which are designated as requirements 'A', 'B', 'C', 'D' and 'E'. The application of these requirements is detailed in 10.7, and the corresponding locations indicated in Fig. 9.10.1. Where webs are slotted for the passage of secondary members, the web stiffeners are to be arranged to provide adequate support for the loads transmitted, *see* Pt 3, Ch 10,5.2. Where direct calculations are carried out in accordance with 1.1.8 and Section 14, other stiffening arrangements will be accepted subject to compliance with the maximum permissible stress and plate panel buckling criteria given in the *ShipRight SDA Procedure, Guidance Notes on Direct Calculations: Primary Structure of Tankers*.

10.5.2 Where higher tensile steel is used for the primary members, the maximum spacing of stiffeners given in this Section is to be multiplied by $\sqrt{k}$.

10.5.3 In addition to these stiffeners, tripping brackets as required by 10.11 are also to be fitted.

10.5.4 For requirement 'A' stiffening:

(a) The thickness, t_w of the web is to be not less than $\dfrac{s}{80}$

(b) Stiffening is generally to be fitted normal to the face plate of the member, but the stiffeners parallel to the face plate will be required when the web depth, d_w, exceeds a value, d_{max} which is to be taken as:

for $s \le 55t_w$ $d_{max} = 3s$

for $s > 55t_w$ $d_{max} = \dfrac{45s\, t_w}{s - 40t_w}$

(c) Where stiffening parallel to the face plate is required, the distance from the face plate of the member to the nearest stiffener is not to exceed $65t_w$. Further stiffeners are to be fitted at similar spacing so that the distance between the last stiffener and the shell or bulkhead plating does not exceed d_{max}. In way of end brackets to transverse bulkhead primary structure, stiffeners are to be fitted normal to the face plate of the member so that web plate panel dimensions parallel to the face plate do not exceed $80t_w$.

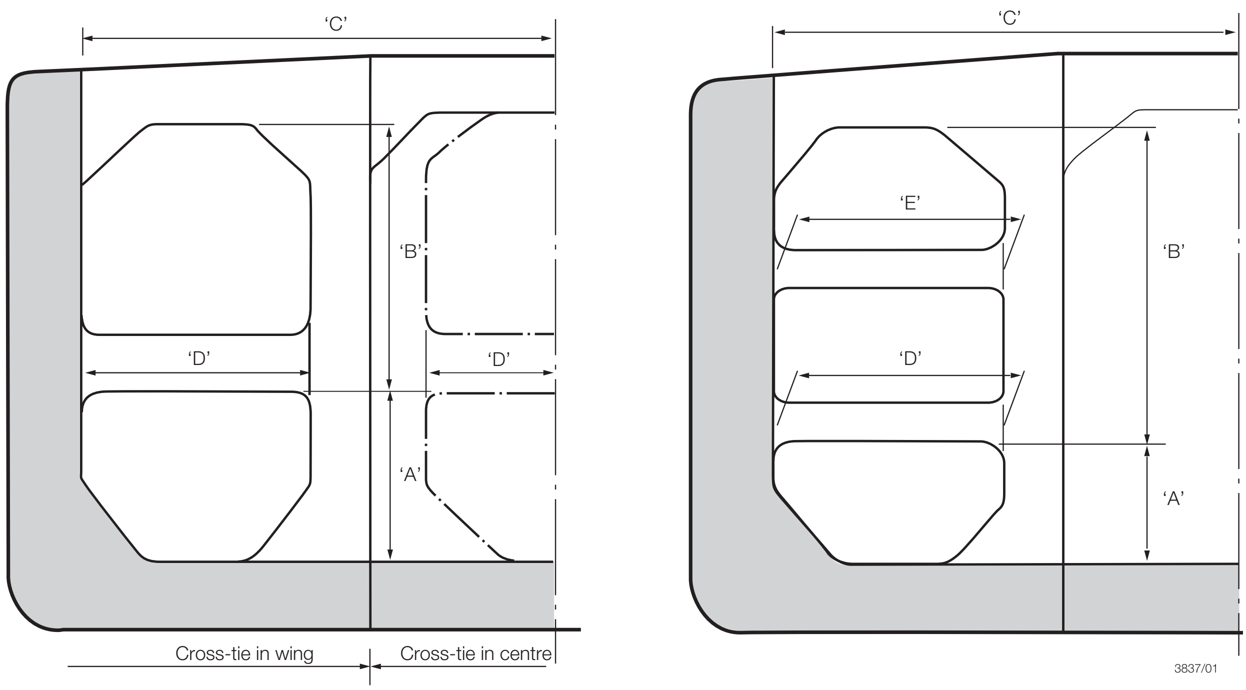


Fig. 9.10.1 Key to application requirements

10.5.5 For requirement 'B' stiffening:

(a) The thickness, t_w of the web is to be not less than $\frac{s}{85}$

(b) Stiffening is generally to be fitted normal to the face plate of the member, but stiffeners parallel to the face plate will be required when the web depth, d_w, exceeds a value d_{max}, which is to be taken as:
for $s \leq 70t_w$ $\quad d_{max} = 3s$
for $s > 70t_w$ $\quad d_{max} = \dfrac{48s\,t_w}{s - 54t_w}$

(c) Where stiffening parallel to the face plate is required, the distance from the face plate of the member to the nearest stiffener is not to exceed $80t_w$. Further stiffeners are to be fitted at similar spacing so that the distance between the last stiffener and the shell or bulkhead plating does not exceed d_{max}.

10.5.6 For requirement 'C' stiffening:

(a) Stiffening is generally to be fitted normal to the face plate of the member in line with alternate secondary members, but stiffeners parallel to the face plate will be required, when the web depth, d_w exceeds a value, d_{max} which is to be taken as:
for $s \leq 76t_w$ $\quad d_{max} = 3s$
for $s > 76t_w$ $\quad d_{max} = \dfrac{48s\,t_w}{s - 60t_w}$

(b) Where stiffening parallel to the face plate is required, the distance from the face plate of the member to the nearest stiffener is not to exceed $90t_w$. Further stiffeners are to be fitted at similar spacing so that the distance between the last stiffener and the deck plating does not exceed d_{max}.

10.5.7 For requirement 'D' stiffening:

(a) Stiffening parallel to the face plate will be required such that the distance between the stiffener and face plate, or between two stiffeners, does not exceed:
$80t_w$ where $L \leq 90$ m
$55t_w$ where $L \geq 190$ m
with intermediate values by interpolation.

(b) Brackets are to be fitted to support the face plates and stiffeners.

10.5.8 For requirement 'E' stiffening:

(a) Stiffening parallel to the face plate will be required such that the distance between the stiffener and face plate, or between two stiffeners, does not exceed:
$85t_w$ where $L \leq 90$ m
$60t_w$ where $L \geq 190$ m
with intermediate values by interpolation.

(b) Brackets are to be fitted to support the face plates and stiffeners.

10.6 Inertia and dimensions of stiffeners

10.6.1 The moment of inertia is to be not less than:

(a) For stiffeners normal to the primary member face plate:

$I_s = p s t_w^3 \times 10^{-4}$ cm^4

where

t_w need not be greater than the values in Table 9.10.1 and

p is to be obtained from Table 9.10.2.

(b) For stiffeners parallel to the primary member face plate:

On transverses, webs and stringers

$I_s = 2 l_s^2 A_s$ cm^4

On longitudinal deck, side and double bottom girders, *see also* Pt 3, Ch 4,7

$I_s = 2{,}85 l_s^2 A_s$ cm^4

Table 9.10.1 Maximum web thickness for stiffener inertia

Requirement	Web thickness t_w, in mm
'A'	$\frac{s}{55}$
'B' and 'C'	$\frac{s}{70}$
'D'	$\frac{s}{80}$ where $L \le 90$ m; $\frac{s}{55}$ where $L \ge 190$ m (*see* Note)
'E'	$\frac{s}{85}$ where $L \le 90$ m; $\frac{s}{60}$ where $L \ge 190$ m (*see* Note)

NOTE
Intermediate values by interpolation.

10.6.2 Where stiffeners are fitted in both directions, the inertia of the stiffeners parallel to the face plate of the member is to be not less than that of the stiffeners fitted normally.

10.6.3 The depth of web stiffeners is to be not less than 75 mm.

10.6.4 Where flat bar stiffeners are used, the ratio of depth to thickness is not to exceed $18\sqrt{k}$.

10.7 Application of stiffening requirements

10.7.1 The requirements as detailed in 10.5 and 10.6 are to be applied in the following locations, *see also* Fig. 9.10.1.

(a) For transverses at longitudinal bulkhead:
Requirement 'A' stiffening is to extend at least as far as the lower surface of the lower cross-tie. Elsewhere, requirement 'B' stiffening is to be fitted.

(b) For deck transverses:
Requirement 'C' stiffening is to be fitted.

(c) For stringers and horizontal girders on bulkheads:
Requirement 'A' stiffening is to extend for a distance from each end of 20 per cent of the span of the stringer or girder, but at least beyond the toes of the end brackets. Elsewhere, requirement 'B' stiffening is to be fitted.

(d) For cross-ties:
Cross-ties are to be suitably stiffened to prevent buckling and twisting. Requirement 'D' stiffening is to be fitted to the lower or to a single cross-tie. Requirement 'E' stiffening is to be fitted to the upper cross-ties where two cross-ties are arranged.

(e) For shell stringers and vertical webs in fore peak:
Requirement 'A' stiffening is to extend the full length of the member.

10.7.2 The application of stiffening requirements to transverse structures where no cross-ties are fitted and within double hull structures are to be based on the results of direct calculation and will be specially considered.

10.8 Stiffening of continuous longitudinal girders

10.8.1 The webs of continuous longitudinal deck and double bottom girders are to be stiffened longitudinally. Particular attention is to be given to the stiffening of docking girders, *see also* the buckling requirements in Pt 3, Ch 4,7.

10.8.2 The stiffeners on deck girders are to be spaced not more than $55t_w$ mm apart except in way of vertical webs and end brackets, where the spacing is not to exceed $45t_w$ mm. Alternatively, a combination of parallel stiffeners at $55t_w$ mm spacing and normal stiffeners at $45t_w$ mm spacing may be adopted. Particular attention is to be given to the stiffening of the docking girder.

10.8.3 The application of stiffening requirements to girders within double hull structures is to be based on the results of direct calculation, *see also* 10.10.1.

Table 9.10.2 Coefficients for stiffener inertia

Aspect ratio of plate panel, $\frac{s}{d}$	1,0 or more	0,9	0,8	0,7	0,6	0,5	0,4	0,3 or less
p	1,5	2,1	2,9	4,2	6,1	9,2	14,6	30,0

NOTES
1. Intermediate values by interpolation.
2. The depth of panel, d, used in calculating aspect ratio may be measured from the face of the secondary member to which the primary member web stiffener is attached.

10.8.4 The moment of inertia of the stiffeners is to comply with 10.6.

10.9 Stiffening of vertical webs on transverse bulkheads

10.9.1 Vertical webs are to be fitted with stiffeners parallel to the face plate of the web and spaced not more than $60t_w$ mm apart. Stiffeners normal to the face plate are to be fitted when a vertical web supports horizontal stiffeners on transverse bulkheads. The length of stiffener is to be sufficient to distribute the load transmitted, and the connection between web stiffener and bulkhead stiffener is to comply with the relevant requirements of Pt 3, Ch 10,5.2.

10.9.2 The moment of inertia of the stiffeners is to comply with 10.6.

10.10 Double bottom girders in way of docking supports

10.10.1 Additional vertical stiffeners may be required on the bottom panels of the girder to resist docking pressures.

10.11 Lateral stability of primary members

10.11.1 Tripping brackets are generally to be fitted close to the toes of end brackets, in way of cross-ties and elsewhere, so that the spacing between brackets does not exceed the lesser of 4,5 m or 15 times the width of the face plate (20 times in the case of deck transverses). Arrangements in way of the intersections of primary members are to be such as to prevent tripping. A closer spacing of brackets may be required to be adopted with asymmetrical face plates.

10.11.2 To maintain continuity of strength, substantial horizontal and vertical brackets are to be fitted to transverses or stringers at ends of cross-ties. Horizontal brackets are to be aligned with the cross-tie face plates, and vertical end brackets are to be aligned with the cross-tie web.

10.11.3 Wide face plates may require additional support between brackets.

10.11.4 In the fore peak tank, if the angle between the normal to the shell plating and the vertical webs exceeds 20°, tripping brackets are to be fitted at the toes of end brackets and elsewhere, such that their spacing does not exceed 3 m.

10.12 Openings in web plating

10.12.1 Where openings are cut in the webs of primary supporting members, the greatest dimension of the opening is not to exceed 20 per cent of the web depth. The openings are to be kept equidistant from the corners of notches for frames and stiffeners. In the case of webs supporting single skin structures the openings are to be located so that the edges are not less than 40 per cent of web depth from the face plate. Openings are to be suitably framed where required.

10.12.2 In way of cross-ties and their end connections lightening holes are not to be cut in horizontal girders on the ship's side and longitudinal bulkheads, in symmetrical webs nor in vertical webs on longitudinal bulkheads and wing ballast tanks.

10.12.3 Holes cut in primary longitudinal members within 0,1*D* of the deck and bottom are, in general, to be reinforced as required by 4.10. Access holes may be cut in deep transverses and girders with suitable compensation to provide satisfactory resistance to deflection and shear buckling in the web.

10.12.4 All holes are to have smooth edges and are to be kept well clear of notches and the toes of brackets.

10.12.5 Small air and drain holes cut in primary members are to be kept clear of the toes of brackets and are to be well rounded with smooth edges. Where holes are cut in primary longitudinal members in areas of high stress, or where primary members are of higher tensile steel, they are to be elliptical, or equivalent, to minimise stress concentration.

10.12.6 Where holes are cut for heating coils, the lower edge of the hole is to be not less than 100 mm from the inner bottom. Where large notches are cut in the transverses for the passage of longitudinal framing, adjacent to openings for heating coils, the longitudinal notches are to be collared. Examination of the buckling strength of the web plate panel between notches for longitudinals may be required.

10.13 Brackets connecting primary members

10.13.1 The arm length of brackets connecting primary supporting members should, in general, be not less than the depth of the member web, nor exceed 1,5 times the web depth. The two arms should be of approximately equal lengths.

10.13.2 In a ring system where the end bracket is integral with the webs of the members, and the face plate is carried continuously along the edges of the members and the bracket, the full area of the largest face plate is to be maintained to the mid-point of the bracket and gradually tapered to the smaller face plates. Butts in face plates are to be kept well clear of the toes of brackets. Where a wide face plate abuts on a narrower one, the taper is generally not to exceed 1 in 4. Where a thick face plate abuts against a thinner one, if the difference in thickness exceeds 3 mm, the taper on thickness is not to exceed 1 in 3.

10.13.3 The thickness of separate end brackets is generally to be not less than that of the thicker of the primary member webs being connected, but may be required to be increased locally at the toes. The bracket is to extend to adjacent tripping brackets, stiffeners or other support points. Bracket toes are to be well radiused. Where the bracket is attached to a corrugated bulkhead, suitable arrangements are to be made to dissipate the load at the bracket toe. Details of the welding to be used in way of toes of separate brackets are to be submitted, *see also* Pt 3, Ch 10,5.1.7.

10.13.4 Brackets are to be fitted with suitable face plates and stiffeners. The maximum distance from the face plate to the first parallel stiffener is to be $30t_b$. Subsequent stiffeners lying parallel to the face may be spaced not more than $45t_b$ apart. The maximum arm length for an unstiffened triangular panel is $100t_b$, *see* Fig. 9.10.2. The depth of stiffeners is to be not less than 75 mm, and their moment of inertia is to comply with 10.6.

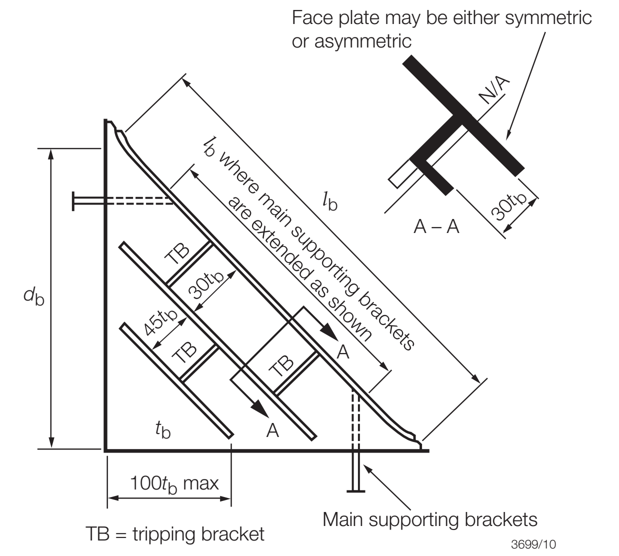


Fig. 9.10.2 Primary member end brackets

10.13.5 The area of discontinuous face plates is generally to be about 80 per cent of the area of the face plates of the adjacent members. However, where the stiffener adjacent to the face plate is of increased size, consideration will be given to the face area required. In addition, the following expression is to be satisfied:

$$\sqrt{\frac{I_b}{A_b}} \geq 2\, l_b.$$

10.13.6 The ends of discontinuous face plates are to be well tapered. The taper may be 1 in 3, but where the width of the face plate exceeds 500 mm, a taper not less than 1 in 4 is generally to be adopted. Stiffeners adjacent to the face plate should be tapered 1 in 2, and other stiffeners may be cut at 45°.

10.13.7 Face plates and web stiffeners are to be suitably supported against tripping, *see* Fig. 9.10.2.

10.13.8 In the case of very large brackets with heavy face plates, it is recommended that the effective span, l_b, be reduced by extending the primary member main supporting brackets to provide lateral stability to the face plate, *see* Fig. 9.10.2.

10.14 Arrangements at intersections of continuous secondary and primary members

10.14.1 For details and connections of collars, *see* Pt 3, Ch 10,5.2.

■ *Section 11*
Ships for alternate carriage of oil cargo and dry bulk cargo

11.1 Application

11.1.1 The requirements of this Section apply to ships intended to carry oil in bulk with a flash point not exceeding 60°C (closed-cup test) or dry bulk cargo alternatively.

11.1.2 In addition to this Chapter the requirements of Chapter 7 and Chapter 11 are also to be complied with as applicable. Particular attention is drawn to the minimum thickness requirements of Section 10.

11.2 Class notations

11.2.1 Ships complying with the requirement of this section will be eligible for one of the following class notations, as applicable.

(a) **100A1 Oil or Bulk Carrier, ESP**
(b) **100A1 Oil or Bulk Carrier strengthened for heavy cargoes, holds ... may be empty, ESP**
(c) **100A1 Oil or Bulk Carrier strengthened for heavy cargoes, any hold may be empty, ESP**
(d) **100A1 Ore or Oil Carrier, ESP**.

11.2.2 The notation **ESP** serves to identify the ship as being subject to an Enhanced Survey Programme as detailed in Pt 1, Ch 3,3 and Ch 3,6 and Ch 3.7, *see also* Pt 1, Ch 2,2.3.12.

11.2.3 The above notations assume that dry cargoes and oil cargoes will not be carried simultaneously. However, oil may be retained in slop tanks when the ship is carrying dry cargo, provided that these tanks comply with the requirements of the Rules. Gas freeing, inerting, and isolating by approved arrangements of the remaining tanks and holds before loading ore or other dry cargoes is the responsibility of the Owner and is to be accordance with National and Port Authority requirements.

11.2.4 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2 to which reference should be made.

11.3 Structural configuration and ship arrangement

11.3.1 The requirements contained in this Section apply to the following ship types:

(a) Oil or bulk carrier with a basic structural configuration having a single deck hull and which includes, a double skin side structure, double bottom, hopper side tanks and topside tanks fitted below the upper deck. A typical cross-section is indicated in Fig. 9.11.1(a). However, consideration will be given to other arrangements on the basis of the requirements of this Section. The requirements of Chapter 7 are to be applied.

(b) Ore or oil carrier with a basic structural configuration having a single deck hull and which includes, a double skin side structure, two longitudinal bulkheads, and a double bottom throughout the centre hold and wing tanks. A typical cross-section is indicated in Fig. 9.11.1(b). The requirements of Chapter 11 are to be applied.

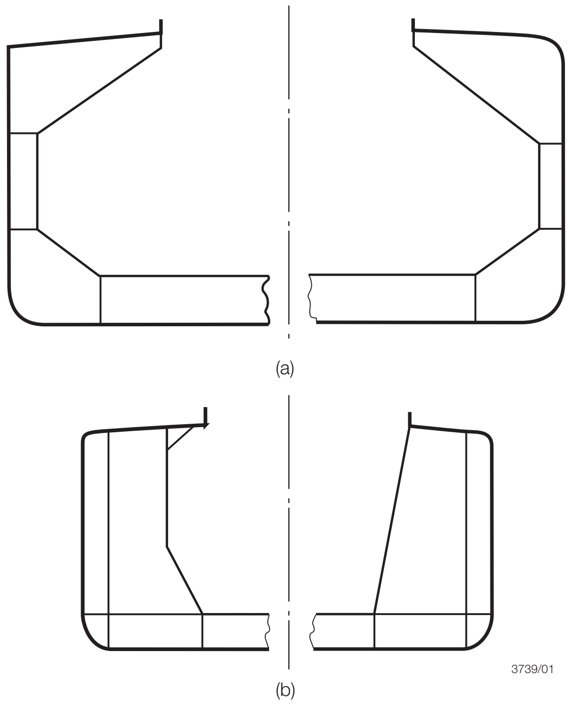


Fig. 9.11.1 Structural configuration

11.3.2 Where oil residues are to be retained on board, slop tanks of sufficient capacity to meet MARPOL requirements are to be provided and are to be separated from adjacent spaces by cofferdams which are to be capable of being flooded, except where the adjacent space is used as a pump-room, ballast tank, or an oil fuel bunker tank, *see also* 1.2.2, Pt 5, Ch 15,1.9, and SOLAS Reg. II-2/D, 56.4.

11.3.3 Arrangements are to be provided for the mechanical ventilation of cargo spaces and any enclosed spaces adjacent to cargo spaces, *see* Pt 5, Ch 15,3. Similar arrangements are to be provided for cargo oil ducts which are used as pipe tunnels when the ship is carrying dry cargo, *see also* 11.3.5.

11.3.4 Openings which may be used for cargo operations, for example in the bottom of topside tanks, are not permitted in bulkheads and decks separating oil cargo spaces from other spaces not designed and equipped for the carriage of oil cargoes unless such openings are equipped with alternative approved means to ensure equivalent integrity.

11.3.5 For the requirements of ducts for cargo oil lines below decks on ore or oil carriers, *see* Pt 5, Ch 15,3.3.

11.3.6 For the requirements for access arrangements to pipe tunnels and spaces in the cargo area, *see* Section 13.

11.4 Bulkheads in way of dry/oil cargo holds

11.4.1 In way of cargo oil holds, the scantlings of the cargo space boundaries are to comply with 11.4.2 and 11.4.6.

11.4.2 The scantlings of vertically corrugated and double plate transverse bulkheads supported by stools are to be determined in accordance with the requirements of 7.4.1, 7.4.2 and Ch 7,10.2. In general, the bulkheads are to have stiffening or corrugations arranged vertically, supported by top and bottom end stools. Alternative arrangements will, however, be considered.

11.4.3 The longitudinal bulkheads including bulkhead forming inner hull, and the sloped bulkheads of the topside and double bottom tanks are to comply with Section 6. However, in way of cargo holds b_1 is to be taken as the horizontal distance from the plate or longitudinal under consideration to the vertical projection of the hatch side furthest away from the bulkhead. For longitudinal framing the determination of the span point may be in accordance with Pt 3, Ch 3,3. The scantlings of the sloped bulkhead of the double bottom hopper tanks in way of the dry cargo holds are to be not less than the requirements of Ch 7,9.

11.4.4 The arrangement of stools and adjacent structure common with dry cargo holds is to be designed to avoid pockets in which gas could collect.

11.4.5 Where the form of construction used for transverse bulkheads in wing tanks is different from that used in centre holds, arrangements are to be made to ensure continuity of transverse strength through the longitudinal bulkhead.

11.4.6 Where partial filling of centre holds with liquid is contemplated, the scantlings and structural arrangements of the boundary bulkheads are to be capable of withstanding the loads imposed by the movement of liquid in the holds. The magnitude of the predicted loadings, together with the scantling calculations, may require to be submitted.

11.5 Bulkheads in wing tanks of ore or oil carriers

11.5.1 Oiltight bulkheads in wing tanks of ore or oil carriers, *see* 11.3.1(b), are to comply with the requirements for transverse oiltight bulkhead plating, stiffening and primary structure given in Sections 7 and 9.

11.5.2 Non-oiltight bulkheads in wing tanks are to comply with the requirements given in Sections 8 and 9. The bulkhead plating is to be suitably reinforced in way of double bottom scarfing arrangements and the ends of centre hold deck transverses. Openings in wing tank bulkheads are to be kept clear of these areas.

11.6 Cofferdam bulkheads

11.6.1 The scantlings of cofferdam bulkheads not forming the boundary of a cargo space are to be as required by Section 7.

11.7 Hatchways

11.7.1 The scantlings of the cargo hold hatch coamings are to comply with Pt 3, Ch 11,5 and the cargo hold hatch covers with Pt 3, Ch 11,2 and Pt 4, Ch 7,12.

11.7.2 Where cargo holds are intended to be partly filled the hatch covers may require to be additionally strengthened, *see also* 11.4.6.

11.7.3 Slop tank hatches and cleaning openings are only permitted on open deck. Unless these openings are closed with a watertight bolted plate, the locking arrangements are to be under the control of a responsible officer.

11.8 Hatch coamings

11.8.1 The height and construction of hatch coamings are to comply with Pt 3, Ch 11,5 and Pt 4, Ch 7,13.

■ *Section 12* Cargo temperatures

12.1 General

12.1.1 This Section applies to the carriage of heated and low temperature cargoes in vessels having a structural configuration as shown in Table 9.1.3 and Fig. 9.11.1.

12.2 Carriage of heated cargoes

12.2.1 Where cargoes are to be carried at temperatures above *T* during the voyage, temperature distribution investigations and thermal stress calculations are to be submitted. These are to be carried out using the actual temperature of the cargo during the voyage and compared with calculations carried out for a cargo temperature of *T*. For the purpose of these calculations, *T* is to be taken as follows:

(a) Where longitudinal framing is adopted, T = 65°C.
(b) Where transverse framing is adopted for the longitudinal bulkhead, inner hull and side shell, T = 80°C.

12.2.2 The calculations are to give the resultant stresses on the hull structure, based on a sea temperature of 0°C and an air temperature of 5°C. Any proposals for reinforcement of the hull structure and/or limitation of the still water bending moment for heated cargo conditions are to be submitted.

12.2.3 Submitted proposals are to take account of non-uniform loading patterns with resultant variations in temperature distribution, where applicable.

12.3 Loading of hot oil cargoes

12.3.1 Hot oil cargoes may be loaded at the permitted carriage temperature in 12.2.1 or the temperature given below, whichever is the greater, without the need for temperature distribution and thermal stress calculations, providing the temperature specified in 12.2.1(a) and (b) is not exceeded during the voyage:

(a) 65°C for sea temperatures of 0°C and below.
(b) 75°C for sea temperatures of 5°C and above.
(c) By linear interpolation between (a) and (b) above, for sea temperatures between 0°C and 5°C.

12.4 Low temperature cargoes

12.4.1 The hull structural and engineering systems permit cargoes to be loaded down to –10°C. For low temperature operations, *see* Part 8 and the *Provisional Rules for the Winterisation of Ships.*

■ *Section 13* Access arrangements and closing appliances

13.1 General

13.1.1 For requirements in respect of coamings and closing of deck openings, *see* Pt 3, Ch 11,7.

13.1.2 Openings in cargo oil tanks are not to be located in enclosed spaces.

13.1.3 Ladders and platforms in cargo tanks, pumprooms and cofferdams are to be securely fastened to the structure, *see also* 2.3.

13.2 Access to spaces in the cargo area

13.2.1 Access to cofferdams, vertical wing and double bottom ballast tanks, cargo tanks and other spaces in the cargo area shall be direct from the open deck and such as to ensure their complete inspection. Access to double bottom tanks in way of cargo oil tanks, where wing ballast tanks are omitted, is to be provided by trunks from the exposed deck led down the bulkhead. Alternative proposals will, however, be considered provided the integrity of the inner bottom is maintained. Access to double bottom spaces may also be through a cargo pump-room, pump-room, deep cofferdam, pipe tunnel or similar compartments, subject to consideration of ventilation aspects.

13.2.2 Where a duct keel or pipe tunnel is fitted, and access is normally required for operational purposes, access is to be provided at each end and at least one other location at approximately mid-length. Access is to be directly from the exposed deck. Where an after access is to be provided from the pump-room to the duct keel, the access manhole from the pump-room to the duct keel is to be provided with an oiltight cover plate. Access is not to be via the engine room. Mechanical ventilation is to be provided and such spaces are to be adequately ventilated prior to entry. A notice-board is to be fitted at each entrance to the pipe tunnel stating that before any attempt is made to enter, the ventilating fan must have been in operation for an adequate period. In addition, the atmosphere in the tunnel is to be sampled by a reliable gas monitor, and where an inert gas system is fitted in cargo tanks, an oxygen monitor is to be provided.

13.2.3 In ships for the alternate carriage of oil cargo and dry bulk cargo where the boundary of a slop tank is part of a cargo pump-room bulkhead, any openings from the cargo pump-room to the double bottom, pipe tunnel or other enclosed space are to be provided with a gastight bolted cover.

13.2.4 Every double bottom space is to be provided with separate access without passing through other neighbouring double bottom spaces.

13.2.5 Where the tanks are of confined or cellular construction, two separate means of access from the weather deck are to be provided, one to be provided at either end of the tank space.

13.2.6 For access through horizontal openings, hatches or manholes, the dimensions are to be sufficient to allow a person wearing a self-contained air-breathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening is to be not less than 600 mm x 600 mm.

13.2.7 At least one horizontal access opening of 600 mm x 800 mm clear opening is to be fitted in each horizontal girder in the vertical wing ballast space and weather deck to assist in rescue operations.

13.2.8 For access through vertical openings, or manholes providing passage through the length and breadth of the space, the minimum clear opening is to be not less than 600 mm x 800 mm at a height of not more than 600 mm from the bottom shell plating unless gratings or other footholds are provided.

13.2.9 For oil tankers of less than 5000 tonnes DWT smaller dimensions may be approved by the National Administration concerned in special circumstances, if the ability to traverse such openings or to remove an injured person can be proved to the satisfaction of the Administration.

13.2.10 In double hull construction with the wing ballast tanks having restricted access through the vertical transverse webs, permanent arrangements are to be provided within the tanks to permit access for inspection at all heights in each bay. These arrangements which should comprise fixed platforms or other means are to provide sufficiently close access to carry out Close-Up Surveys as defined in Pt 1, Ch 3,7, using limited portable equipment where appropriate. Details of these arrangements are to be submitted for approval.

13.2.11 On very large tankers it is recommended that consideration be given to providing permanent facilities for staging the interior of cargo tanks situated within the cargo tank region and of large tanks elsewhere. Suitable provisions would be:

- Staging which can be carried on board and utilised in any tank, including power-operated lift or platform systems.
- Enlargement of structural members to form permanent, safe platforms, e.g., bulkhead longitudinals widened to form stringers (in association with manholes through primary members).
- Provision of inspection/rest platforms at intervals down the length of access ladders.
- Provision of manholes in upper deck for access to staging in cargo tanks.

13.2.12 Attention is drawn to 7.1.7, concerning provision of manholes in transverse bulkheads.

■ *Section 14* Direct calculations

14.1 Application

14.1.1 Direct calculations are to be carried out for the derivation of scantlings where they are required by the preceding Sections of this Chapter or by related provisions included in Part 3.

14.1.2 Direct calculation methods are also generally to be used where additional calculations are required by the Rules in respect of unusual structural arrangements.

14.2 Procedures

14.2.1 For details of LR's direct calculation procedures, *see* Pt 3, Ch 1,2. For requirements concerning use of other calculation procedures, *see* Pt 3, Ch 1,3.

14.2.2 Details of direct calculation procedures for determining the scantlings of boundary bulkheads for partially filled tanks are given in *ShipRight SDA Procedure, Sloshing loads and Scantling Assessment*.

■ *Section 1* General

1.1 Application

1.1.1 The requirements specified in Chapter 9 are applicable to small conventional single hull oil tankers where relevant, together with the additional requirements of this Chapter.

1.1.2 For tankers intended to load or unload whilst aground, *see* Pt 3, Ch 9,9.

1.2 Class notations

1.2.1 Sea-going ships complying with the requirements of Chapter 9, where relevant, together with the additional requirements of this Chapter will be eligible to be classed **100A1 Oil Tanker, ESP**.

1.2.2 The Notation **ESP** serves to identify the ships as being subject to an Enhanced Survey Programme as detailed in Pt 1, Ch 3,3 and Ch 3,7, *see also* Pt 1, Ch 2,2.

■ *Section 2* Primary members supporting longitudinal framing

2.1 General

2.1.1 These requirements are applicable to the following structural arrangements for ships with two longitudinal bulkheads:

(a) Centre tank structure:
- (i) Primary supporting centreline girder between oiltight transverse bulkheads, in association with up to five transverses.
- (ii) Bottom transverses spanning between longitudinal bulkheads in association with a non-primary centreline docking girder.
- (iii) Double bottom.

(b) Wing tank structure:
- (i) Transverse ring structure consisting of bottom, side shell, longitudinal bulkhead and deck transverses and incorporating one cross-tie or no cross-ties in tankers not exceeding 75 m in length.
- (ii) Double bottom.

2.1.2 The requirements are also applicable to structural arrangements incorporating a single longitudinal bulkhead located on the ship's centreline without cross-ties, for tankers not exceeding 75 m in length.

2.1.3 The minimum thickness and constructional detail requirements of Section 7 are to be complied with. Particular attention is to be paid to the design of end connections between primary members and buttresses. The shear and combined stress levels in these connections are to be examined and should be within the limits specified in *ShipRight SDA Procedure, Guidance Notes on Direct Calculations*.

2.2 Symbols

2.2.1 The symbols used in this Section are defined as follows:

b_{e1}, b_{e2} = effective end bracket leg length, in metres, at each end of the member, *see* Pt 3, Ch 3,3

b_T = overall breadth of tank, in metres

h_b = $0{,}75D + 2{,}45$ m

h_c = vertical distance from the centre of the cross-tie to deck at side amidships, in metres

h_s = distance between the lower span point of the side transverse and the moulded deck line at side, in metres

l_c = one-half the vertical distance, in metres, between the cross-tie and the centre of the adjacent bottom or deck transverse, or double bottom, *see* Fig. 10.2.3

l_T = overall length of tank, in metres

s = spacing of transverses, in metres

A = net sectional area of the web including end bracket where applicable, in cm^2

I_G = moment of inertia of the girder, in cm^4

I_T = moment of inertia of the transverse, in cm^4

Q_x = shear force at the actual section under consideration, obtained from shear force diagrams constructed as indicated, in kN (tonne-f)

S_c = length of cross-tie between the face plates on the vertical transverse webs at the cross-ties, in metres

S_G = span of girder, in metres, and is in no case to be taken less than (l_T – 1,8s) metres

S_s = span of the side transverses, in metres, and is to be measured between end span points, *see* Fig. 10.2.3

S_T = span of transverses, in metres.

2.2.2 Other symbols are defined in Ch 9,1.6.

2.3 Structural arrangements

2.3.1 The spacing of transverses is not to exceed 3,6 m.

2.3.2 Where a trunk is fitted, the scantlings of primary members are to be modified as required by Section 6.

2.4 Bottom structure coefficients

2.4.1 Where a primary supporting bottom centreline girder is fitted, in a single bottom, the requirements for the girder and transverses may be derived using bending moment and shear force coefficients K_1 and K_2 determined from Table 10.2.1. To obtain the coefficients, the following factors are required:

$$\alpha = \frac{I_T - S_G}{2s}$$

$$\beta = \frac{S_G^3\, I_T}{S_T^3\, I_G}$$

Initially, an estimated value of the ratio $\dfrac{I_T}{I_G}$ may be used, and an iterative process adopted to obtain the final required values.

2.4.2 Where bottom transverses are fitted in association with a non-primary centreline girder the coefficients for the transverse are to be taken as:

K_1 = 0,083

K_2 = 0,50

For the requirements for the non-primary girder, *see* 2.6.

2.4.3 In ships with one longitudinal bulkhead, the coefficient for the bottom transverse is to be taken as:

K_1 = 0,177.

2.5 Bottom transverses

2.5.1 The section modulus of bottom transverses is to be not less than:

$$Z = 62K_1\, s\, h_b\, S_T^2\, k \quad \text{cm}^3$$

2.5.2 In ships with two longitudinal bulkheads, the depth of the bottom transverse web plate is to be not less than $0{,}2S_T$ and the net sectional area of the web at any section, including vertical end connections, is to be not less than:

$$A = 0{,}12Q_x\, k \quad \text{cm}^2$$

$$\left(A = \frac{Q_x\, k}{0{,}85} \quad \text{cm}^2\right)$$

where

Q_x is calculated from shear force diagrams constructed as shown in Fig. 10.2.1. For end connections, Q_x is to be determined by projection of the shear force diagram as indicated.

2.5.3 The moment of inertia of bottom transverses is to be not less than:

$$I = \frac{10{,}5}{k}\, S_T\, Z \quad \text{cm}^4$$

2.6 Bottom girders

2.6.1 The section modulus of the primary centreline bottom girder, where fitted, is to be not less than:

$$Z = 31K_1\, b_T\, S_G\, h_b\, s\, k \quad \text{cm}^3$$

2.6.2 The net sectional area of the web at any section, including vertical end connections, is to be not less than:

$$A = 0{,}12Q_x\, k \quad \text{cm}^2$$

$$\left(A = \frac{Q_x\, k}{0{,}85} \quad \text{cm}^2\right)$$

where

Q_x is calculated from a shear force diagram constructed as shown in Fig. 10.2.2. For end connections, Q_x is to be determined by projection of the shear force diagram as indicated.

2.6.3 In a single bottom the section modulus and web area of a non-primary centreline docking girder are to be not less than:

$$Z = 3{,}6b_T\, D\, s^2\, k \quad \text{cm}^3$$

$$A = 0{,}3b_T\, D\, s\, k \quad \text{cm}^2.$$

The scantlings of this girder may, however, be required to be increased, depending upon the docking condition and support arrangements, details of which are to be submitted. Consideration may be required to be given to restricting the level of ballast tank filling for docking purposes. The loads are to be specially considered when wing tanks are ballasted for docking.

2.6.4 Consideration will be given to alternative methods of stiffening in way of the keel blocks when accompanied by supporting calculations.

2.6.5 In way of the vertical centreline web and centreline supports to horizontal girders of transverse bulkheads, the docking girder is to be increased in depth and scantlings as necessary to provide an effective support.

2.7 Side transverses

2.7.1 The section modulus of side transverses in ships with one or two longitudinal bulkheads is to be not less than:

$$Z = K_3\, s\, h_s\, S_s^2\, k \quad \text{cm}^3$$

where

K_3 is given in Table 10.2.2.

Table 10.2.1 Bottom structure coefficients (*see continuation*)

(a) 1 GIRDER, 2 TRANSVERSES

β	Girder											
	K_1						K_2					
	α						α					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,210	0,210	0,195	0,175	0,125	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,04	0,210	0,210	0,195	0,175	0,125	0,0	0,960	0,960	0,980	1,000	1,000	1,000
0,06	0,210	0,210	0,195	0,170	0,125	0,0	0,940	0,940	0,960	0,980	1,000	1,000
0,08	0,205	0,205	0,190	0,167	0,125	0,0	0,920	0,920	0,940	0,970	1,000	1,000
0,10	0,200	0,200	0,185	0,165	0,125	0,0	0,900	0,900	0,920	0,960	0,990	1,000
0,20	0,180	0,180	0,170	0,150	0,120	0,0	0,800	0,820	0,860	0,920	0,980	1,000
0,40	0,150	0,150	0,150	0,135	0,115	0,0	0,670	0,730	0,760	0,840	0,950	1,000
0,60	0,130	0,130	0,135	0,125	0,110	0,0	0,580	0,630	0,690	0,790	0,910	1,000
0,80	0,120	0,120	0,120	0,120	0,105	0,0	0,520	0,540	0,630	0,730	0,880	1,000
1,00	0,100	0,100	0,115	0,115	0,100	0,0	0,460	0,500	0,580	0,680	0,850	1,000
	Transverses											
0,02	0,022	0,022	0,022	0,022	0,021	0,020	0,255	0,255	0,255	0,255	0,250	0,250
0,04	0,023	0,023	0,023	0,022	0,021	0,020	0,263	0,263	0,257	0,255	0,250	0,250
0,06	0,025	0,025	0,023	0,022	0,021	0,020	0,265	0,265	0,263	0,260	0,250	0,250
0,08	0,026	0,026	0,024	0,023	0,021	0,020	0,270	0,270	0,267	0,260	0,253	0,250
0,10	0,027	0,027	0,025	0,023	0,022	0,020	0,275	0,275	0,270	0,263	0,255	0,250
0,20	0,033	0,033	0,029	0,026	0,023	0,020	0,300	0,300	0,285	0,272	0,257	0,250
0,40	0,041	0,041	0,036	0,032	0,025	0,020	0,330	0,330	0,307	0,287	0,265	0,250
0,60	0,047	0,047	0,041	0,036	0,026	0,020	0,355	0,355	0,325	0,302	0,273	0,250
0,80	0,051	0,051	0,045	0,038	0,028	0,020	0,370	0,370	0,342	0,315	0,278	0,250
1,00	0,054	0,054	0,048	0,041	0,030	0,020	0,385	0,385	0,355	0,327	0,285	0,250

(b) 1 GIRDER, 3 TRANSVERSES

β	Girder											
	K_1						K_2					
	α						α					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,290	0,290	0,290	0,270	0,200	0,120	1,400	1,400	1,500	1,500	1,500	1,500
0,04	0,290	0,290	0,290	0,270	0,200	0,120	1,400	1,400	1,500	1,500	1,500	1,500
0,06	0,290	0,290	0,290	0,260	0,200	0,120	1,380	1,400	1,500	1,500	1,500	1,500
0,08	0,280	0,280	0,280	0,250	0,195	0,115	1,340	1,370	1,470	1,470	1,480	1,500
0,10	0,275	0,275	0,275	0,240	0,190	0,115	1,320	1,340	1,420	1,440	1,460	1,480
0,20	0,245	0,245	0,245	0,220	0,175	0,105	1,180	1,210	1,280	1,330	1,380	1,450
0,40	0,200	0,200	0,200	0,185	0,160	0,090	0,970	1,030	1,080	1,200	1,280	1,420
0,60	0,170	0,170	0,170	0,170	0,145	0,080	0,840	0,900	0,960	1,110	1,210	1,380
0,80	0,150	0,150	0,150	0,150	0,135	0,075	0,740	0,800	0,870	1,040	1,150	1,330
1,00	0,135	0,135	0,135	0,135	0,125	0,070	0,680	0,740	0,810	0,960	1,100	1,300
	Transverses											
0,02	0,025	0,025	0,024	0,023	0,022	0,022	0,258	0,258	0,257	0,252	0,252	0,252
0,04	0,026	0,026	0,025	0,024	0,023	0,023	0,267	0,267	0,267	0,262	0,262	0,260
0,06	0,028	0,028	0,026	0,026	0,025	0,024	0,275	0,275	0,275	0,270	0,270	0,265
0,08	0,030	0,030	0,028	0,028	0,026	0,026	0,285	0,285	0,280	0,272	0,272	0,272
0,10	0,032	0,032	0,029	0,029	0,028	0,027	0,292	0,292	0,287	0,277	0,275	0,275
0,20	0,040	0,040	0,037	0,035	0,033	0,032	0,325	0,325	0,315	0,310	0,300	0,282
0,40	0,052	0,052	0,049	0,046	0,041	0,039	0,372	0,372	0,360	0,345	0,332	0,320
0,60	0,059	0,059	0,057	0,054	0,048	0,045	0,405	0,405	0,392	0,375	0,357	0,342
0,80	0,065	0,065	0,063	0,059	0,053	0,049	0,425	0,425	0,415	0,390	0,377	0,360
1,00	0,069	0,069	0,066	0,063	0,056	0,052	0,440	0,440	0,432	0,415	0,395	0,375

Table 10.2.1 Bottom structure coefficients (*conclusion*)

(c) 1 GIRDER, 4 TRANSVERSES

β	Girder											
	K_1						K_2					
	α						α					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,370	0,350	0,330	0,315	0,275	0,215	1,890	1,890	1,920	1,940	1,960	1,990
0,04	0,370	0,350	0,330	0,315	0,275	0,215	1,870	1,870	1,900	1,930	1,940	1,960
0,06	0,360	0,350	0,330	0,310	0,270	0,205	1,820	1,820	1,870	1,890	1,920	1,940
0,08	0,350	0,340	0,320	0,300	0,260	0,200	1,760	1,800	1,820	1,840	1,880	1,920
0,10	0,340	0,330	0,315	0,290	0,255	0,195	1,700	1,750	1,790	1,830	1,860	1,900
0,20	0,300	0,300	0,275	0,260	0,230	0,180	1,500	1,580	1,630	1,700	1,780	1,820
0,40	0,240	0,240	0,230	0,220	0,200	0,155	1,240	1,300	1,400	1,540	1,620	1,700
0,60	0,200	0,200	0,200	0,200	0,175	0,135	1,060	1,120	1,250	1,400	1,500	1,600
0,80	0,175	0,175	0,175	0,175	0,165	0,120	0,940	1,000	1,150	1,270	1,420	1,520
1,00	0,150	0,150	0,150	0,150	0,150	0,105	0,850	0,920	1,050	1,200	1,340	1,460
	Transverses											
0,02	0,025	0,025	0,024	0,024	0,023	0,023	0,255	0,255	0,255	0,255	0,253	0,250
0,04	0,027	0,026	0,026	0,025	0,025	0,024	0,272	0,270	0,268	0,266	0,260	0,255
0,06	0,029	0,029	0,028	0,027	0,026	0,025	0,282	0,280	0,275	0,272	0,270	0,263
0,08	0,031	0,031	0,030	0,028	0,028	0,027	0,292	0,287	0,285	0,280	0,275	0,270
0,10	0,033	0,033	0,032	0,030	0,029	0,028	0,300	0,295	0,290	0,285	0,280	0,275
0,20	0,042	0,041	0,039	0,037	0,035	0,033	0,335	0,325	0,320	0,313	0,307	0,300
0,40	0,053	0,051	0,050	0,047	0,044	0,041	0,380	0,372	0,362	0,352	0,342	0,330
0,60	0,061	0,059	0,057	0,054	0,050	0,047	0,412	0,405	0,387	0,376	0,365	0,355
0,80	0,066	0,065	0,062	0,058	0,054	0,051	0,435	0,425	0,412	0,400	0,382	0,370
1,00	0,070	0,068	0,065	0,062	0,058	0,055	0,450	0,437	0,427	0,412	0,395	0,385

(d) 1 GIRDER, 5 TRANSVERSES

β	Girder											
	K_1						K_2					
	α						α					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,455	0,440	0,410	0,380	0,345	0,300	2,330	2,350	2,370	2,400	2,420	2,450
0,04	0,445	0,430	0,410	0,380	0,345	0,300	2,310	2,340	2,360	2,380	2,410	2,440
0,06	0,430	0,415	0,395	0,370	0,340	0,295	2,250	2,290	2,300	2,340	2,380	2,400
0,08	0,415	0,400	0,385	0,365	0,330	0,290	2,180	2,230	2,280	2,290	2,340	2,360
0,10	0,400	0,390	0,375	0,355	0,320	0,280	2,110	2,170	2,200	2,240	2,300	2,320
0,20	0,345	0,340	0,330	0,315	0,285	0,250	1,840	1,920	2,000	2,040	2,130	2,180
0,40	0,270	0,265	0,265	0,265	0,235	0,200	1,500	1,600	1,700	1,790	1,900	1,970
0,60	0,220	0,220	0,220	0,220	0,200	0,165	1,280	1,380	1,500	1,610	1,650	1,840
0,80	0,185	0,185	0,185	0,185	0,175	0,140	1,140	1,230	1,370	1,500	1,620	1,740
1,00	0,165	0,165	0,165	0,165	0,160	0,125	1,040	1,140	1,280	1,420	1,540	1,650
	Transverses											
0,02	0,025	0,025	0,025	0,024	0,024	0,023	0,265	0,265	0,263	0,260	0,257	0,255
0,04	0,028	0,028	0,028	0,027	0,026	0,025	0,280	0,280	0,275	0,270	0,267	0,265
0,06	0,031	0,031	0,030	0,029	0,028	0,027	0,290	0,287	0,284	0,280	0,277	0,275
0,08	0,034	0,034	0,033	0,032	0,031	0,030	0,303	0,300	0,295	0,290	0,287	0,283
0,10	0,037	0,036	0,036	0,034	0,033	0,032	0,312	0,309	0,305	0,300	0,297	0,292
0,20	0,046	0,046	0,045	0,043	0,043	0,041	0,352	0,349	0,343	0,337	0,330	0,325
0,40	0,060	0,058	0,057	0,055	0,054	0,053	0,405	0,402	0,393	0,383	0,378	0,375
0,60	0,068	0,067	0,065	0,064	0,063	0,061	0,435	0,432	0,426	0,417	0,412	0,407
0,80	0,073	0,072	0,071	0,069	0,068	0,067	0,455	0,452	0,446	0,440	0,436	0,432
1,00	0,077	0,076	0,074	0,073	0,071	0,070	0,470	0,467	0,461	0,455	0,450	0,445

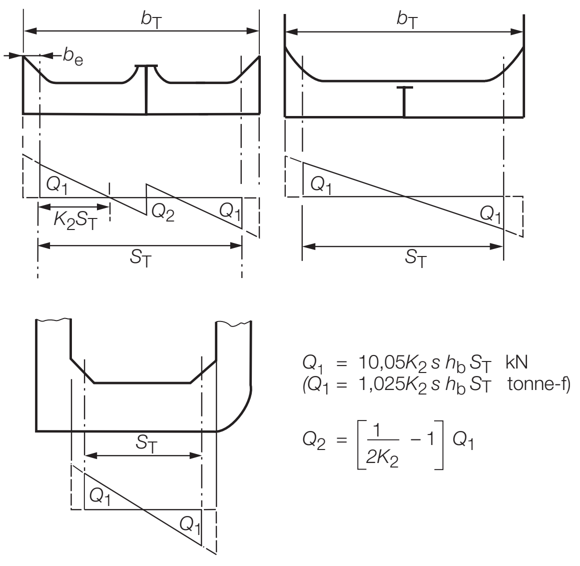


Fig. 10.2.1 Bottom transverses

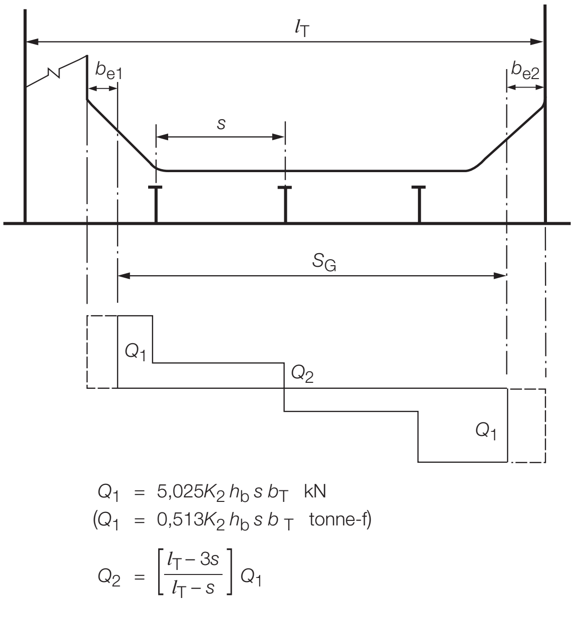


Fig. 10.2.2 Bottom centreline girder

2.7.2 In ships with two longitudinal bulkheads, the net sectional area of the web at any section is to be not less than:

$$A = 0{,}12 Q_x k \quad \text{cm}^2$$

$$\left(A = \frac{Q_x k}{0{,}85} \quad \text{cm}^2\right)$$

where

Q_x is calculated from shear force diagrams constructed as shown in Fig. 10.2.3. For this purpose the values of K_4 and K_5 and the range of application is given in Table 10.2.2.

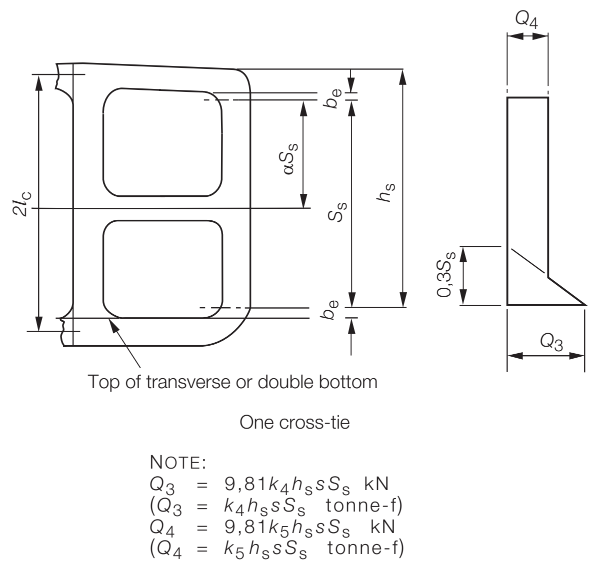


Fig. 10.2.3 Wing tank construction

2.7.3 The moment of inertia of side transverses is to be not less than:

$$I = \frac{7{,}5}{k} S_s Z \quad \text{cm}^4$$

2.8 Deck transverses

2.8.1 The section modulus of deck transverses is to be not less than:

$$Z = 53{,}75\,(0{,}0269 sL + 0{,}8)\,(S_T + 1{,}83)\,k \quad \text{cm}^3$$

Where a continuous deck girder is fitted, the term S_T in the above formula is to be replaced by $\frac{S_T}{2}$.

Table 10.2.2 Side transverse coefficients

Number of cross-ties	K_3	K_4	K_5	Range of application
0	8	Not applicable		$L \leq 75$ m, *see* 2.3
1	2,16	0,455 – 0,316α	0,103	$0{,}5 \leq \alpha \leq 0{,}7$

2.8.2 The net sectional area of the web is to satisfy the requirements of 2.5.2 using a head, $h_b = \dfrac{L_1}{56}$ m.

2.8.3 The moment of inertia of the transverses is to be not less than:

$$I = \frac{7{,}5}{k} S_T Z \quad \text{cm}^4$$

2.9 Deck girders

2.9.1 Where a continuous deck centreline girder supporting deck transverses is fitted, it is to have a section modulus not less than:

$$Z = 0{,}0476 S_G{}^2 b_T L k \quad \text{cm}^3$$

2.9.2 The net sectional area of the web is to satisfy the requirements of 2.6.2 using a head, $h_b = \dfrac{L_1}{56}$ m.

2.9.3 In way of the vertical centreline web on transverse bulkheads, the continuous deck girder is to be increased in depth and scantlings as necessary to provide an effective support.

2.9.4 Where an intercostal deck girder is fitted, it is to have a depth not less than 50 per cent of the depth of the deck transverse and the area of the face flat is to be not less than that of the transverse.

2.9.5 In way of the vertical centreline web and centreline supports to horizontal girder on transverse bulkheads, the intercostal deck girder may be required to be increased in depth and scantlings to provide an effective support.

2.10 Cross-ties

2.10.1 Cross-ties, where fitted, may be of plate or sectional material and are to have an area and least moment of inertia not less than:

$$A = (64 + 1{,}035 l_c h_c s) k \quad \text{cm}^2$$

$$I = 2{,}45 l_c h_c s S_c{}^2 \quad \text{cm}^4$$

2.10.2 Design of end connections is to be such that the area of the welding, including vertical brackets, where fitted, is to be not less than the minimum cross-sectional area of the cross-tie derived from 2.10.1. To achieve this full penetration may be required and thickness of brackets may require further consideration. Attention is to be given to the full continuity of area of the backing structure on the transverses. Particular attention is also to be paid to the welding at the toes of all vertical end brackets on the cross-tie.

2.11 Double bottom girders and floors

2.11.1 The scantlings of girder and floors are to satisfy the requirements of Ch 1,8.3 and Ch 1,8.5 respectively for longitudinally framed ships.

■ *Section 3* Primary members supporting transverse side framing

3.1 General

3.1.1 The requirements of this Section are applicable to side stringers and transverse webs associated with transverse framing.

3.1.2 The minimum thickness and constructional detail requirements of Section 7 are to be complied with.

3.2 Symbols

3.2.1 The symbols used in this Section are defined as follows:

h_1 = head, in metres, from stringer to highest point of tank excluding hatchway, but not less than 2,5 m

Q_x = shear force at the actual section under consideration, obtained from shear force diagrams constructed as indicated, in kN (tonne-f)

S_1 = span, in metres, of the horizontal girder measured between span points, but to be taken not less than the lesser of (1,2 + 0,02*L*) m or 3 m.

3.2.2 Other symbols are defined in Ch 9,1.6.

3.3 Structural arrangements

3.3.1 Side shell stringers are to be fitted as required by Table 10.3.1. Alternatively, the number of stringers may be derived by direct calculation, particular regard being given to secondary bending effects on the frames supported.

Table 10.3.1 Requirements for stringers

Ship depth, in metres	Number of stringers
$D \leq 6{,}0$	0
$6{,}0 < D \leq 7{,}5$	1
$7{,}5 < D \leq 11{,}0$	2

3.3.2 Where the spacing of bulkheads (oiltight or non-oiltight) exceeds 15 m, side transverses are to be fitted in line with each bottom transverse.

3.3.3 Where side transverses are not required, bottom transverses are to be adequately supported at the side shell and longitudinal bulkhead, and the lower side stringer is to be suitably buttressed from the bottom transverse.

3.3.4 Cross-ties, where fitted, are to comply with the requirements of 2.10 and are, in general, to be aligned with the stringers.

3.3.5 Where the ship is fitted with a trunk, the scantlings as given in this Section are to be modified as required by Section 6.

3.4 Scantlings

3.4.1 The section modulus of side stringers is to be not less than:

$Z = 10b\, h_1\, S_1^2\, k$ cm^3

3.4.2 The net sectional area of the web at any section is to be not less than:

$A = 0{,}12 Q_x\, k$ cm^2

$\left(A = \dfrac{Q_x\, k}{0{,}85} \text{ cm}^2\right)$

where

Q_x is calculated from a shear force diagram constructed using the shear force at the span point, Q_1 given by the following:

$Q_1 = 5{,}03 s\, h_1\, S_1$ kN

$(Q_1 = 0{,}513 s\, h_1\, S_1$ tonne-f)

3.4.3 The moment of inertia of the stringer is to be not less than:

$$I = S_1 Z \frac{7{,}5}{k} \text{ cm}^4$$

3.4.4 Where side transverses supporting side stringers are fitted, they are to have a section modulus not less than that required by 2.7. Where the side transverse does not support side stringers, the section modulus required by 2.7 may be reduced by 20 per cent.

■ *Section 4* Primary members supporting oiltight bulkheads

4.1 General

4.1.1 These requirements are applicable to ships having two longitudinal bulkheads, and to ships not exceeding 75 m in length having one longitudinal bulkhead located on the centreline of the ship.

4.1.2 The minimum thickness and construction detail requirements of Section 7 are to be complied with. Particular attention is to be paid to the design of end connections between primary members and buttresses. Where considered necessary, the shear and combined stresses in the connections may require to be examined and the scantlings and stiffening increased.

4.2 Symbols

4.2.1 The symbols used in this Section are defined as follows:

h = the distance from the centre of the load on the member to a point 2,45 m above the highest point of the tank, excluding the hatchway, in metres

Q_x = shear force at the actual section under consideration, obtained from shear force diagrams constructed as indicated, in kN (tonne-f).

4.2.2 Other symbols are defined in Ch 9,1.6.

4.3 Structural arrangements

4.3.1 Where horizontal girders and vertical webs do not form part of a ring structure, they are to be arranged with substantial end brackets forming a buttress extending to the adjacent vertical web or transverse.

4.3.2 Where the cross-ties are omitted from the transverse ring in the wing tank adjacent to the bulkhead, the design of the horizontal girder, of the end buttress and of the transverse is to take account of the loads imposed and the deflection of the structure.

4.3.3 The spacing of transverses on longitudinal bulkheads is not to exceed 3,6 m.

4.3.4 Where, on ships with transverse side framing, transverses are required by Section 3, vertical webs are also to be fitted in line on the longitudinal bulkhead. Where such vertical webs are not required the lower horizontal girder on the bulkhead is to be suitably buttressed from the bottom transverses.

4.4 Scantlings

4.4.1 The scantlings of vertical webs on longitudinal bulkheads are to be as required for side transverses by Section 2.

4.4.2 The section modulus of vertical webs on transverse bulkheads and of horizontal girders is to be not less than:

$Z = 8b\, h\, l_e^2 k$ cm^3

4.4.3 The net sectional area of the web at any section is to be not less than:

$A = 0{,}12 Q_x\, k$ cm^2

$\left(A = \dfrac{Q_x\, k}{0{,}85} \text{ cm}^2\right)$

where Q_x is the shear force at the section. For the horizontal girders on ships with two longitudinal bulkheads, Q_x is calculated from shear force diagrams as shown in Fig. 10.4.1. For end connections, Q_x is to be determined by projection of the shear force diagrams as indicated.

4.4.4 The moment of inertia of vertical webs and horizontal girders is to be not less than:

$$I = \frac{10{,}5}{k} l_e Z \text{ cm}^4$$

4.4.5 For the calculation of section modulus, the minimum span of horizontal girders on longitudinal bulkheads is to be taken as not less than the lesser of (1,2 + 0,02L) m or 3 m.

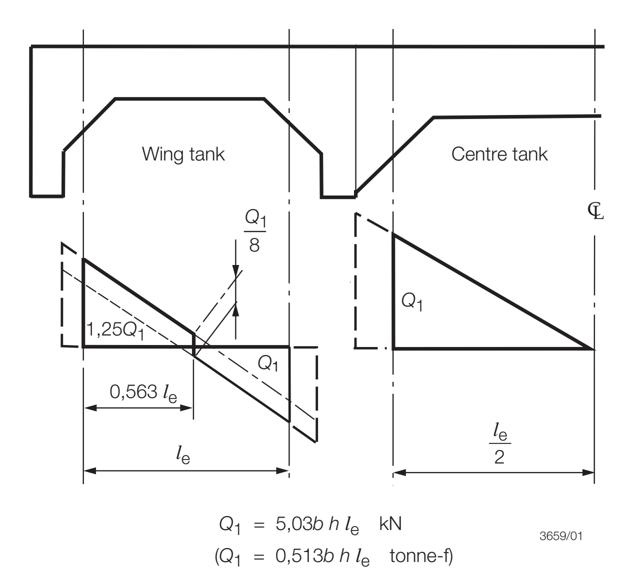


Fig. 10.4.1 Horizontal girders

4.4.6 Where a trunk is fitted, the scantlings of primary members are to be modified as required by Section 6.

Section 5 **Primary members supporting non-oiltight bulkheads**

5.1 General

5.1.1 These requirements are applicable to primary members supporting non-oiltight transverse bulkheads. Where non-oiltight longitudinal bulkheads are proposed, the requirements for the primary members will be individually considered.

5.1.2 The minimum thickness and constructional detail requirements of Section 7 are to be complied with.

5.2 Symbols

5.2.1 The symbol, l_b, used in this Section is defined as follows:

l_b = the distance, in metres, between the transverse bulkheads (oiltight or non-oiltight) adjacent to the bulkhead under consideration.

5.2.2 Other symbols are defined in Ch 9,1.6.

5.3 Direct calculations

5.3.1 Direct calculation procedures will generally be required where the non-oiltight bulkhead primary members will interact with, or tend to support, the primary bottom, longitudinal bulkhead or side structure, and in other cases where warranted by structural design features.

5.4 Scantlings and arrangements

5.4.1 The section modulus of vertical webs is to be not less than that required for a vertical web on an oiltight transverse bulkhead in the same position, *see* Section 4 multiplied by the factor $\left(0,3 + 2\ \frac{l_b}{L}\right)$.

5.4.2 The section modulus of horizontal girders is to be not less than:

$$Z = 145k\ b\ l_e^2\ \frac{l_b}{L} \quad \text{cm}^3$$

5.4.3 When determining the width of plating supported and the effective breadth for calculating the section modulus, no deduction is to be made on account of perforations.

Section 6 **Trunked construction**

6.1 General

6.1.1 The requirements of this Section are additional to those of Sections 1 to 5.

6.1.2 Where a trunk is fitted it is to extend over the full length of the cargo tanks and is to be effectively scarfed into the main hull structure.

6.1.3 The minimum thickness and constructional detail requirements of Section 7 are also to be complied with.

6.2 Symbols

6.2.1 The symbols used in this Section are defined as follows:

b_t = breadth of trunk, in metres

h_t = height of trunk, in metres, above the deck at the trunk side. Where the trunk top has excess camber, the value of h_t will be considered

D_1 = equivalent depth of ship and is to be taken as:

$D + 0,6\ \frac{b_t h_t}{B}$ where $\frac{b_t}{B} \leq 0,8$ and

$D + h_t\left(2,6\ \frac{b_t}{B} - 1,6\right)$, where $\frac{b_t}{B} > 0,8$

(*see* Fig. 10.6.1).

6.2.2 Other symbols are defined in Ch 9,1.6.

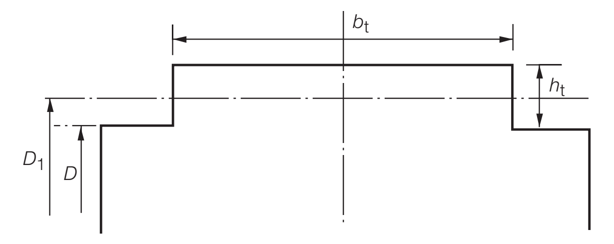


Fig. 10.6.1 Equivalent depth

6.3 Structural arrangements

6.3.1 The trunk deck and sides are to be longitudinally framed, and the transverse primary members are to be aligned with the deck transverses.

6.3.2 Particular attention is to be given to the arrangements in way of the connection of the trunk side to the deck at side. The construction is to be such as to ensure adequate rigidity and continuity of strength.

6.3.3 Typical arrangements of primary structure are shown diagrammatically in Fig. 10.6.2, which also indicates the effective spans to be used in the determination of scantlings.

6.3.4 Where the trunk primary stiffening is fitted externally, individual consideration will be given to the arrangement and scantlings.

6.3.5 Where longitudinal stiffening is fitted externally to the trunk, tripping brackets are to be fitted to maintain lateral stability in way of transverse bulkheads and elsewhere as necessary.

6.3.6 Extension brackets and web stiffeners or equivalent arrangements are to be provided at the forward and after ends of the trunk to ensure full continuity of strength from the trunk into hull and superstructures.

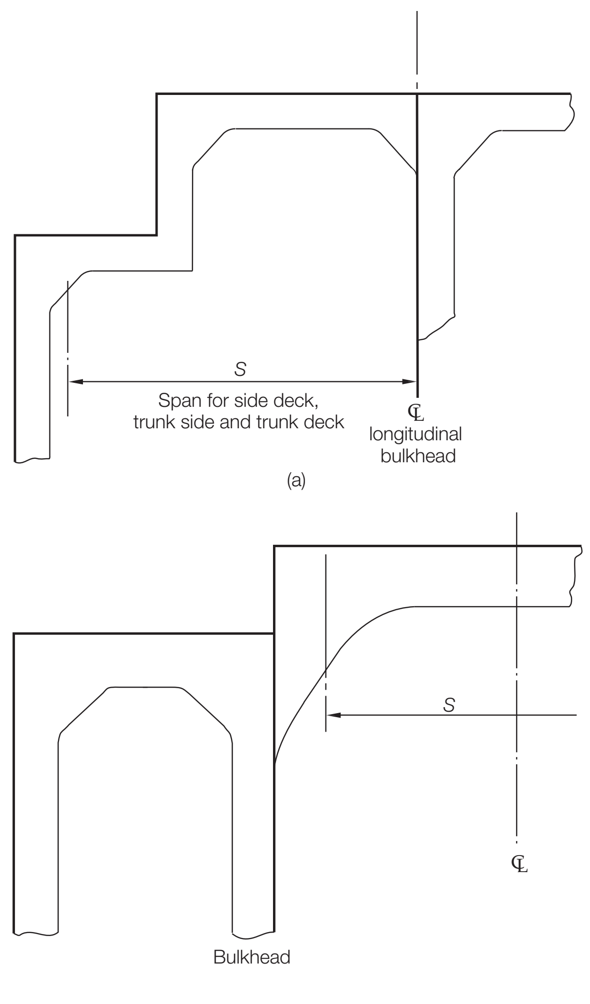
6.3.7 Where the carriage of heated cargoes is contemplated and, in particular, bituminous cargoes, special attention is to be given to the alignment of the scarfing arrangements and softening of the extension bracket toes at the trunk ends to alleviate the effects of thermal stressing.

6.4 Trunk scantlings

6.4.1 The thickness of the trunk top and side plating is to be not less than as required by Ch 9,4 for hull envelope plating, the item numbers for these being as given in Fig. 10.6.3.

6.4.2 The section modulus of trunk longitudinals is to be not less than as required by Ch 9,5 for deck longitudinals.

6.4.3 The section modulus and moment of inertia of the transverses is to be not less than as required by 2.8 for deck transverses.



NOTE:
Spans measured to effective span point

Fig. 10.6.2 Primary structure

6.5 Modification to hull scantlings

6.5.1 The thickness of the deck plating outboard of the trunk side is to be that necessary to obtain the required hull section modulus, but is to be not less than that required by Ch 9,4 multiplied by the factor

$$\frac{2BD}{2BD + b_t h_t}$$

6.5.2 The scantlings of the shell plating, framing, primary structure and bulkheads are to be determined on the basis of the equivalent ship depth D_1, i.e. where the depth, D, enters into the calculation or structural arrangement it is to be replaced by D_1.

6.5.3 The head to the deck at side is to be increased by $(D_1 - D)$.

6.5.4 The head to the highest point of the tank is to be replaced by the actual distance to the highest point of the tank, reduced by the amount $(D + h_t - D_1)$.

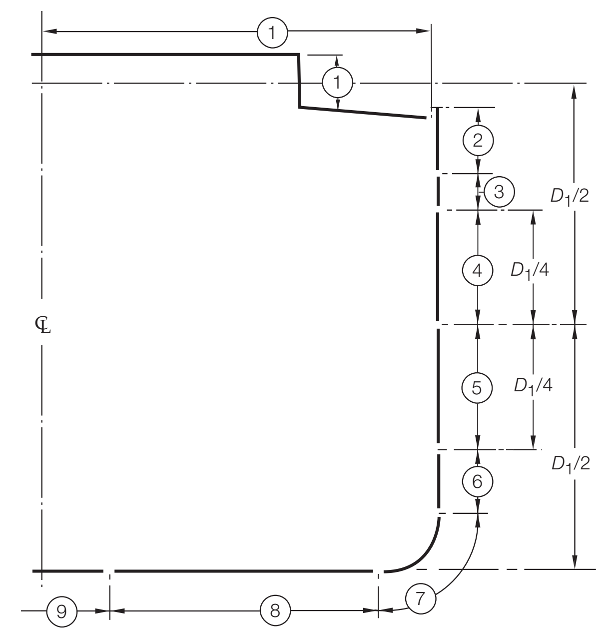


Fig. 10.6.3
Hull envelope plating – Itemisation of parts

Section 7
Construction details and minimum thickness

7.1 Symbols

7.1.1 The symbols used in this Section are defined in Ch 9,10.1.

7.2 Compartment minimum thickness

7.2.1 The requirements of Ch 9,10.2 are also applicable to small conventional single hull tankers.

7.3 Geometric properties and proportions of members

7.3.1 The depth of the web of any primary member is to be not less than 2,5 times the depth of the cut-outs for the passage of secondary members, except where compensation is arranged to provide satisfactory resistance to deflection and shear buckling in the web.

7.3.2 The area of material in the face plate of any primary member is not to exceed:

$0{,}00667 d_w t_w$ cm^2

nor is it to be less than:

$0{,}0167 s_t d_w$ cm^2 for the bottom centreline girder

$0{,}00417 s_t d_w$ cm^2 elsewhere.

7.3.3 The geometric properties of rolled stiffeners and built sections are to be calculated in association with an effective width of attached plating in accordance with Pt 3, Ch 3,3.

7.4 Continuity of primary members

7.4.1 Primary members are to be so arranged as to ensure effective continuity of strength throughout the range of tank structure. Abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead or on other members, arrangements are to be made to ensure that they are in alignment.

7.4.2 The members are to have adequate end fixity, lateral support and web stiffening, and the structure is to be arranged to minimise hard spots or other sources of stress concentration. Openings are to have well rounded corners and smooth edges and are to be located having regard to the stress distribution and buckling strength of the plate panel.

7.5 Primary member web plate stiffening

7.5.1 The webs of primary members are to be supported and stiffened in accordance with the following requirements, which are designated as requirements 'A', 'B', 'C' and 'D'. The application of these requirements is detailed in 7.5, and the corresponding locations indicated in Fig. 10.7.1. Where webs are slotted for the passage of secondary members, the web stiffeners are to be arranged to provide adequate support for the loads transmitted, *see* Pt 3, Ch 10,5.2.

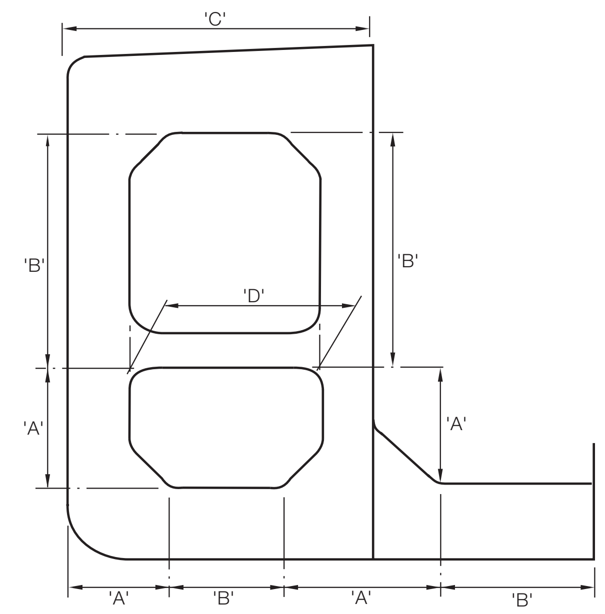


Fig. 10.7.1 Key to application requirements

7.5.2 Where higher tensile steel is used for the primary members, the maximum spacing of stiffeners given in this Section is to be multiplied by $\sqrt{k}$.

7.5.3 In addition to these stiffeners, tripping brackets as required by Ch 9,10.11 are also to be fitted.

7.5.4 For requirement 'A' stiffening:

(a) The thickness, t_w of the web is to be not less than $\dfrac{s}{80}$

(b) Stiffening is generally to be fitted normal to the face plate of the member, but the stiffeners parallel to the face plate will be required when the web depth, d_w, exceeds a value, d_{max} which is to be taken as:

for $s \leq 55t_w$ $\quad d_{max} = 3s$

for $s > 55t_w$ $\quad d_{max} = \dfrac{45s\ t_w}{s - 40t_w}$

(c) Where stiffening parallel to the face plate is required, the distance from the face plate of the member to the nearest stiffener is not to exceed $65t_w$. Further stiffeners are to be fitted at similar spacing so that the distance between the last stiffener and the shell or bulkhead plating does not exceed d_{max}. In way of end brackets to transverse bulkhead primary structure, stiffeners are to be fitted normal to the face plate of the member so that web plate panel dimensions parallel to the face plate do not exceed $80t_w$.

7.5.5 For requirement 'B' stiffening:

(a) The thickness, t_w of the web is to be not less than $\dfrac{s}{85}$

(b) Stiffening is generally to be fitted normal to the face plate of the member, but stiffeners parallel to the face plate will be required when the web depth, d_w, exceeds a value d_{max}, which is to be taken as:

for $s \leq 70t_w$ $\quad d_{max} = 3s$

for $s > 70t_w$ $\quad d_{max} = \dfrac{48s\ t_w}{s - 54t_w}$

(c) Where stiffening parallel to the face plate is required, the distance from the face plate of the member to the nearest stiffener is not to exceed $80t_w$. Further stiffeners are to be fitted at similar spacing so that the distance between the last stiffener and the shell or bulkhead plating does not exceed d_{max}.

7.5.6 For requirement 'C' stiffening:

(a) Stiffening is generally to be fitted normal to the face plate of the member in line with alternate secondary members, but stiffeners parallel to the face plate will be required, when the web depth, d_w exceeds a value, d_{max} which is to be taken as:

for $s \leq 76t_w$ $\quad d_{max} = 3s$

for $s > 76t_w$ $\quad d_{max} = \dfrac{48s\ t_w}{s - 60t_w}$

(b) Where stiffening parallel to the face plate is required, the distance from the face plate of the member to the nearest stiffener is not to exceed $90t_w$. Further stiffeners are to be fitted at similar spacing so that the distance between the last stiffener and the deck plating does not exceed d_{max}.

7.5.7 For requirement 'D' stiffening:

(a) Stiffening parallel to the face plate will be required such that the distance between the stiffener and face plate, or between two stiffeners, does not exceed:

$80t_w$ where $L \leq 90$ m

$55t_w$ where $L \geq 190$ m

with intermediate values by interpolation.

(b) Brackets are to be fitted to support the face plates and stiffeners.

7.6 Inertia and dimensions of stiffeners

7.6.1 The moment of inertia is to be not less than:

(a) For stiffeners normal to the primary member face plate:

$I_s = p\ s\ t_w^3 \times 10^{-4}$ cm^4

Where t_w need not be greater than the values in Table 10.7.1 and p is to be obtained from Table 10.7.2.

(b) For stiffeners parallel to the primary member face plate:

On transverses, webs and stringers

$I_s = 2 l_s^2 A_s$ cm^4

On longitudinal deck and bottom girders

$I_s = 2{,}85 l_s^2 A_s$ cm^4.

Table 10.7.1 Maximum web thickness for stiffener inertia

Requirement	Web thickness t_w, in mm
'A'	$\dfrac{s}{55}$
'B' and 'C'	$\dfrac{s}{70}$
'D'	$\dfrac{s}{80}$ where $L \leq 90$ m $\dfrac{s}{60}$ where $L \geq 190$ m *see* Note
NOTE Intermediate values by interpolation.	

7.6.2 Where stiffeners are fitted in both directions, the inertia of the stiffeners parallel to the face plate of the member is to be not less than that of the stiffeners fitted normally.

7.6.3 The depth of web stiffeners is to be not less than 75 mm.

7.6.4 Where flat bar stiffeners are used, the ratio of depth to thickness is not to exceed 18 $\sqrt{k}$.

Table 10.7.2 Coefficient for stiffener inertia

Aspect ratio of plate panel, $\frac{s}{d}$	1,0 or more	0,9	0,8	0,7	0,6	0,5	0,4	0,3 or less
p	1,5	2,1	2,9	4,2	6,1	9,2	14,6	30,0

NOTES
1. Intermediate values by interpolation.
2. The depth of panel, d, used in calculating aspect ratio may be measured from the face of the secondary member to which the primary member web stiffener is attached.

7.7 Application of stiffening requirements

7.7.1 The requirements as detailed in 7.5 and 7.6 are to be applied in the following locations, *see also* Fig. 10.7.1.

(a) For bottom transverses:
In the centre tank requirement ‘A’ stiffening is to extend for 20 per cent of the breadth of the tank from the longitudinal bulkhead, but at least beyond the toe of the end bracket. In the wing tank, requirement ‘A’ stiffening is to extend at least as far as the toes of the end brackets from the longitudinal bulkhead and the shell. Elsewhere, requirement ‘B’ stiffening is to be fitted.

(b) For transverses at side shell and longitudinal bulkhead:
Requirement ‘A’ stiffening is to extend at least as far as the lower surface of the lower cross-tie. Elsewhere, requirement ‘B’ stiffening is to be fitted.

(c) For deck transverses:
Requirement ‘C’ stiffening is to be fitted.

(d) For stringers and horizontal girders:
Requirement ‘A’ stiffening is to extend for a distance from each end of 20 per cent of the span of the stringer or girder, but at least beyond the toes of the end brackets. Elsewhere, requirement ‘B’ stiffening is to be fitted.

(e) For cross-ties:
Cross-ties are to be suitably stiffened to prevent buckling and twisting. Requirement ‘D’ stiffening is to be fitted.

(f) For shell stringers and vertical webs in fore peak:
Requirement ‘A’ stiffening is to extend the full length of the member.

7.7.2 The application of stiffening requirements to transverse wing structures in wing tanks where no cross-ties are fitted is to be based on the results of direct calculation and will be specially considered.

7.8 Stiffening of continuous longitudinal girders

7.8.1 The webs of continuous longitudinal deck and bottom girders are to be stiffened parallel to the girder face plate.

7.8.2 The stiffeners are to be spaced not more than $55t_w$ mm apart except in way of vertical webs and end brackets, where the spacing is not to exceed $45t_w$ mm. Alternatively, a combination of parallel stiffeners at $55t_w$ mm spacing and normal stiffeners at $45t_w$ mm spacing may be adopted. Particular attention is to be given to the stiffening of the docking girder.

7.8.3 The moment of inertia of stiffeners is to comply with 7.6.

7.9 Stiffening of vertical webs on transverse bulkheads

7.9.1 Vertical webs are to be fitted with stiffeners parallel to the face plate of the web and spaced not more than $60t_w$ mm apart. Stiffeners normal to the face plate are to be fitted when a vertical web supports horizontal stiffeners on transverse bulkheads. The length of stiffener is to be sufficient to distribute the load transmitted, and the connection between web stiffener and bulkhead stiffener is to comply with the relevant requirements of Pt 3, Ch 10,5.2.

7.9.2 The moment of inertia of the stiffeners is to comply with 7.6.

7.10 Docking brackets on bottom centreline girder

7.10.1 Stiffened docking brackets are to be fitted on both sides of the bottom centreline girder, midway between transverses, and are to be connected to a suitable bottom shell longitudinal. The bracket on one side is to be connected to the face plate of the girder but the other may be stopped at a suitable horizontal stiffener.

7.10.2 Additional vertical stiffeners may be required on the bottom panels of the girder to resist docking pressures.

7.11 Lateral stability of primary members

7.11.1 Tripping brackets are generally to be fitted close to the toes of end brackets, in way of cross-ties and elsewhere, so that the spacing between brackets does not exceed the lesser of 4,5 m or 15 times the width of the face plate (20 times in the case of deck transverses). Arrangements in way of the intersections of primary members are to be such as to prevent tripping. A closer spacing of brackets may be required to be adopted with asymmetrical face plates.

7.11.2 To maintain continuity of strength, substantial horizontal and vertical brackets are to be fitted to transverses or stringers at ends of cross-ties. Horizontal brackets are to be aligned with the cross-tie face plates, and vertical end brackets are to be aligned with the cross-tie web.

7.11.3 Tripping brackets are to be connected to the face plate of the bottom transverses. Elsewhere, other than for docking girders, the bracket is to be connected to the face plate whenever the unsupported width of the latter exceeds 150 mm. Where the width of symmetrically placed face plates exceeds 400 mm, a small bracket is to be fitted opposite, and in line with, the tripping bracket. Equivalent support arrangements are to be provided for cross-tie face plates. Particular attention is to be paid to the support of continuous face plates in way of the radius at toes of brackets.

7.11.4 Wide face plates may require additional support between brackets.

7.11.5 In the fore peak tank, if the angle to the normal of the shell plating and the vertical webs exceeds 20°, double tripping brackets are to be fitted to the web at about midspan, but in no case greater than 3,0 m apart.

7.12 Openings in web plating

7.12.1 Where openings are cut in the webs of primary supporting members, the greatest dimension of the opening is not to exceed 20 per cent of the web depth. The opening is to be located so that the edges are not less than 40 per cent of the web depth from the face, and are equidistant from the corners of notches for frames or stiffeners. Openings are to be suitably framed where required.

7.12.2 Lightening holes are not to be cut in horizontal girders on the ship's side and longitudinal bulkheads, in symmetrical webs nor in side transverses and vertical webs in way of cross-ties and their end connections.

7.12.3 Holes cut in primary longitudinal members within 0,1*D* of the deck and bottom are, in general, to be reinforced as required by Ch 9,4.10. Access holes may be cut in deep transverses and girders with suitable compensation to provide satisfactory resistance to deflection and shear buckling in the web.

7.12.4 All holes are to have smooth edges and are to be kept well clear of notches and the toes of brackets.

7.12.5 Small air and drain holes cut in primary members are to be kept clear of the toes of brackets and are to be well rounded with smooth edges. Where holes are cut in primary longitudinal members of higher tensile steel, they are to be elliptical or equivalent to minimise stress concentration.

7.12.6 Where holes are cut for heating coils, the lower edge of the hole is to be not less than 100 mm from the inside of the shell plating. Where large notches are cut in the transverses for the passage of longitudinal framing, adjacent to openings for heating coils, the longitudinal notches are to be collared. Examination of the buckling strength of the web plate panel between notches for longitudinals may be required.

7.13 Brackets connecting primary members

7.13.1 The requirements of Ch 9,10.13 are also applicable to small conventional single hull tankers.

7.14 Arrangements at intersections of continuous secondary and primary members

7.14.1 For details and connections of collars, *see* Pt 3, Ch 10,5.2.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to the arrangements and scantlings within the cargo region of sea-going ore carriers, intended for the carriage of ore in centre holds.

1.1.2 The requirements of Chapter 9 are to be applied to ore carriers, except as required by the provisions of this Chapter.

1.1.3 The scantlings of structural items may be determined by direct calculation. Where the length of the ship exceeds 150 m, the scantlings of the primary supporting structure and the fatigue performance of structural details are to be assessed in accordance with the relevant ShipRight procedures, *see* 1.3.3. In such cases, the calculations are to be submitted for approval.

1.1.4 The additional requirements for ore-carriers for the alternate carriage of oil cargo and dry bulk cargo are given in Pt 4, Ch 9,11.

1.1.5 Ore carriers with a deadweight greater than 200 000 tonnes are to comply with the requirements of Section 12 for single pass loading.

1.2 Structural configuration and ship arrangement

1.2.1 The requirements contained in the Chapter apply to single deck ships with machinery aft, having two longitudinal bulkheads and a double bottom throughout the centre hold. A typical cross- section is indicated in Fig. 11.1.1.

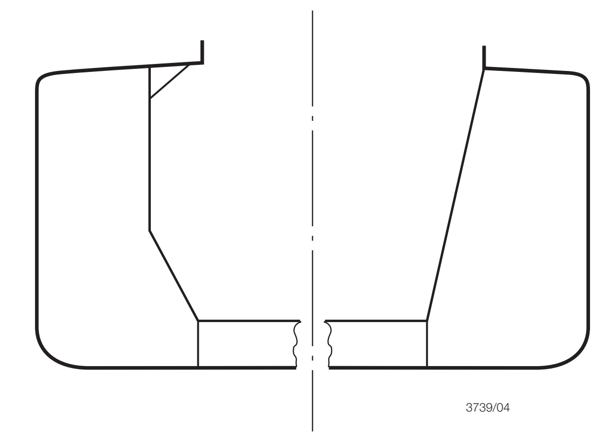


Fig. 11.1.1 Typical cross-section

1.2.2 The bottom, and the deck outside the line of ore hatchways, are to be framed longitudinally within the cargo region. The side shell and longitudinal bulkheads are generally to be framed longitudinally where the length of the ship exceeds 150 m, but alternative proposals will be specially considered. Inside the line of openings, the deck is to be transversely framed.

1.3 Class notation

1.3.1 Sea-going ships complying with the requirements of this Chapter and other relevant Rule requirements for the draught required will be eligible to be classed **100A1 ore carrier, ESP**.

1.3.2 The notation **ESP** serves to identify the ship as being subject to an Enhanced Survey Programme as detailed in Pt 1, Ch 3,3 and Ch 3,6, *see also* Pt 1, Ch 2,2.3.12.

1.3.3 The ShipRight 'Structural Design Assessment' (SDA), 'Fatigue Design Assessment' (FDA) and 'Construction Monitoring' (CM) procedures are mandatory for ships with length, *L*, exceeding 150 m and for ships of abnormal hull-form, or of unusual structural configuration or complexity, *see* Section 10.

1.3.4 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2,2.

1.4 Symbols and definitions

1.4.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, D, T as defined in Pt 3, Ch 1,6.

b = the width of plating supported by the primary member, in metres or mm

h = the load head, in metres, applied to the item under consideration

k = higher tensile steel factor. For the determination of this factor, *see* Pt 3, Ch 2,1. For mild steel k may be taken as 1,0

l_e = effective length of primary or secondary member, in metres, *see* Pt 3, Ch 3,3

s = spacing, in mm, of secondary members

Z = the section modulus, in cm^3, of the primary or secondary member, in association with an effective width of attached plating determined in accordance with Pt 3, Ch 3,3.

1.4.2 The expression 'primary member' as used in this Chapter is defined as a girder, transverse, vertical web, stringer, cross-tie, buttress or double bottom floor. 'Secondary members' are supporting members other than primary members.

■ *Section 2*
Materials and protection

2.1 Materials and grades of steel

2.1.1 Materials and grades of steel are to comply with the requirements of Pt 3, Ch 2.

2.2 Corrosion protection coating for salt-water ballast spaces

2.2.1 The requirements of Pt 3, Ch 2,3.6 are to be complied with.

■ *Section 3*
Longitudinal strength

3.1 General

3.1.1 The longitudinal strength standard is to comply with the relevant requirements of Pt 3, Ch 4.

3.1.2 For ships of length ≥150 m, with holds where any part of the longitudinal bulkhead is located within B/5 or 11,5 m, whichever is less, inboard from the ship's side at right angles to the centreline at the assigned summer load line, the requirements of Ch 7,3 are also to be applied.

■ *Section 4*
Hull envelope plating

4.1 General

4.1.1 The requirements for hull envelope plating as given for oil tankers in Ch 9,4 are to be applied, except as provided for in this Section.

4.2 Deck plating in way of ore hatchways

4.2.1 The arrangement and scantlings of deck plating inside the line of ore hatchways and in way of ore hatchway corners are to be in accordance with the requirements for bulk carriers given in Ch 7,4.

4.3 Hatchways

4.3.1 The scantlings of the cargo hold hatch covers are to comply with Pt 3, Ch 11,2 and Pt 4, Ch 7,12.

4.4 Hatch coamings

4.4.1 The height and construction of hatch coamings are to comply with Pt 4, Ch 7,13.

4.4.2 Wire rope grooving in way of cargo hold openings is to be prevented by fitting suitable protection, such as half-round bars, on the hatch side girders (upper portion of top-side tank plates), hatch end beams, and the upper portion of hatch coamings.

■ *Section 5*
Hull framing

5.1 General

5.1.1 The framing requirements given for oil tankers in Ch 9,5 are to be applied, except as provided for in this Section.

5.1.2 Lateral buckling of longitudinal and transverse ordinary stiffeners is to be assessed in the following areas in association with a factor of safety of not less than 1,15 (allowable utilisation factor to be reduced by at least 1/1,15 = 0,87). Details are to be submitted:

- hatchway coaming;
- inner bottom;
- sloped stiffened panel of topside tanks (if any);
- longitudinal bulkhead;
- top stool and bottom stool of transverse bulkhead (if any) and
- stiffened transverse bulkhead (if any).

5.2 Symbols

5.2.1 The symbols used in this Section are defined as follows:

h = load height, in metres, on the weather deck for primary and secondary members between ore hatchways
= 1,8 for secondary members forward of 0,075L from F.P.
= 4,2 + 2,04E for primary members forward of 0,075L from F.P.
= 1,5 between 0,075L and 0,12L from F.P.
= 1,2 + 2,04E elsewhere

where

$E = \dfrac{0{,}0914 + 0{,}003L}{D - T} - 0{,}15$ but not to be greater than 0,147

K_1 = 1,6 in the forward 0,12L
= 1,06 elsewhere

K_2 = 0,00054 in the forward 0,075L
= 0,00033 elsewhere.

5.2.2 Other symbols are defined in 1.4.

5.3 Bottom longitudinals in double bottom tanks

5.3.1 The section modulus of bottom longitudinals in the double bottom in the centre hold is to satisfy the requirements of Table 1.6.1(b) in Chapter 1.

5.3.2 In general, the span of longitudinals in the double bottom in the centre hold is not to exceed 2,5 m or 0,01L, whichever is the greater, and the span in the wing tanks is not to exceed the greater of 3,6 m or 0,02L.

5.4 Deck structure in way of centre hold

5.4.1 Where the hatch coamings are situated inboard of the longitudinal bulkhead, the deck between the two is to be fitted with suitably supported longitudinals complying with Ch 9,5.

5.5 Primary and secondary members inside line of ore hatchways

5.5.1 The section modulus of secondary members between hatches is to be not less than:

$$Z = k\,(K_1\,T\,D + K_2\,h\,B\,l_e^2\,s)\ \text{cm}^3$$

but need not exceed twice the value given by the second term within the brackets in the formula.

5.5.2 The section modulus of primary members between hatches is to be not less than:

$$Z = 5{,}46k\,b\,h\,l_e^2\quad \text{cm}^3$$

Forward of 0,075L from the forward perpendicular, the depth of the primary member is to be not less than twice that of the secondary member supported.

5.5.3 Particular attention is to be paid to the scarfing of deck beams into the structure outside the line of openings. Substantial brackets or equivalent arrangements are to be provided.

■ *Section 6* Double bottom construction

6.1 General

6.1.1 The double bottom depth and scantlings are to be as required by Ch 7,8 for the double bottom structure of a bulk carrier to which the notation ‘strengthened for heavy cargoes’ is to be assigned. However, where 3.1.2 is not applicable, the requirements of Ch 7,8.8 need not be applied. The required depth of double bottom and scantlings of double bottom structure are to be verified by direct calculation. The calculation is to be submitted.

6.1.2 Where the proposed depth of double bottom exceeds 1,5 times the Rule minimum depth given in Ch 1,8, the scantlings of the floors and girders may be required to be increased to ensure adequate resistance to buckling.

6.1.3 The thickness of inner bottom plating in the cargo hold is to be not less than required by Ch 7,8 for ships having the notation ‘**strengthened for heavy cargoes**’.

6.1.4 For all vessels intended to be unloaded by grabs, the thickness of inner bottom plating is to meet the requirements of Pt 3, Ch 9,9.2.1(a) for a maximum design grab weight specified and recorded in the Loading Manual. For vessels of deadweight >200 000 tonnes, the design grab weight is not to be less than 25 tonnes.

6.1.5 Where the requirements of 6.1.4 are met the descriptive note ‘**holds suitable for unloading by grabs**’ may be employed. Where the design grab weight is 25 tonnes or more the notation ‘**strengthened for regular discharge by heavy grabs**’ may be assigned.

6.2 Arrangement

6.2.1 In way of the cargo hold a centreline girder is to be fitted and side girders spaced not more than 3,8 m apart are generally to be arranged in way of transverse bulkheads. The side girders are to extend at least to the first plate floor adjacent to the bulkhead each side. The outboard side girder is to be continuous, forming the lower part of the longitudinal bulkhead.

6.2.2 Plate floors are to be fitted in line with each transverse in the wing tanks and in way of transverse bulkhead stools. Additional floors are to be so arranged that the spacing of floors does not exceed 2,5 m or 0,01L, whichever is the greater.

6.2.3 Attention is to be given to structural continuity and alignment between double bottom structure and transverses in wing tanks, *see also* 9.2.

6.2.4 Alternative arrangements will be considered on the basis of the results of direct calculations.

Section 7
Longitudinal bulkheads

7.1 General

7.1.1 The requirements for longitudinal oiltight bulkheads given in Ch 9,6 and Ch 9,9 are to be applied, together with the additional requirements of this Section.

7.1.2 Longitudinal bulkhead scantlings are to be additionally assessed against ore loading in accordance with Table 11.7.1.

7.1.3 Longitudinal bulkheads on ore carriers are to be plane with rolled or fabricated longitudinal stiffeners. The bulkhead may be sloped to form a hopper shape in the lower part of the hold or over its full depth.

7.1.4 Where the upper part of the bulkhead is vertical and the lower part sloped to form a hopper shape, the thickness of the bulkhead plating in way of the knuckle may be required to be increased to resist transverse compressive buckling stresses. The knuckle is to be arranged in way of a longitudinal.

7.1.5 The thickness of the lowest strake of sloped bulkhead plating is also to comply with inner bottom requirements as given in 6.1.3. Where this provision results in an increase in thickness, the latter may be gradually tapered above the lowest strake to the required longitudinal bulkhead thickness at the position of the knuckle, or at a point one third of the depth of the bulkhead above the inner bottom, whichever is the lower.

Section 8
Transverse bulkheads

8.1 General

8.1.1 Where the form of construction used for transverse bulkheads in wing tanks is different from that used in centre holds, arrangements are to be made to ensure continuity of transverse strength through the longitudinal bulkhead.

8.2 Transverse watertight bulkheads in wing tanks

8.2.1 The requirements for transverse bulkhead plating, stiffening and primary structure given in Ch 1,9 for deep tank bulkheads are to be applied.

Table 11.7.1 Longitudinal and transverse bulkhead scantlings for ore loading

Item	Longitudinal and transverse bulkhead
Plate thickness including corrugations (mm)	$t = 0{,}004 s\, f \sqrt{\dfrac{K_c H k}{C}} + 3{,}5$ mm
Modulus of rolled and built stiffeners, and symmetrical corrugations (cm^3)	$Z = \dfrac{s\, k\, K_c H\, l_e^2}{22C\, \gamma\, (\omega_1 + \omega_2 + 2)}$ cm^3

Symbols

s, S, k, l as defined in Ch 1,1.5.1

f = 1,1 – s/2500S but not to be taken greater than 1,0

l_e = effective length of stiffening member, in metres, and for bulkhead stiffeners, to be taken as $l - e_1 - e_2$

γ = 1,4 for rolled or built sections and double plate bulkheads
= 1,6 for flat bars
= 1,1 for symmetrical corrugations of deep tank bulkheads
= 1,0 for symmetrical corrugations of watertight bulkheads

ω, e = as defined in Table 1.9.3 in Chapter 1, *see also* Fig. 1.9.1. Where applicable the value of M_2 is to be taken as

$$= \frac{K_c H s\, l^2}{22C}$$

K_c = ore pressure coefficient, to be taken as $\cos^2\alpha + (1 - \sin\psi)\sin^2\alpha$ for inner side (hopper tank, transverse and longitudinal bulkheads, lower stool, vertical upper stool, etc.), and where:

K_c = 0 for top side tank, upper deck and sloped upper stool

α = angle, in degrees, between panel considered and the horizontal plane

ψ = assumed angle of repose, in degrees, of bulk cargo (considered drained and removed); in the absence of more precise evaluation to be taken as ψ = 35° for iron ore

H = height, from position under consideration to deck at side amidships, in metres

C = stowage rate, in m^3/tonne, as defined in Pt 3, Ch 3,5.2. For vessels where 1.1.5 is applicable, C is to include the cargo overshoot specified in 12.4.1(e)

8.3 Transverse watertight bulkheads in centre holds

8.3.1 Scantlings are to comply with Pt 4, Ch 1,9 and assessed against ore loading in accordance with Table 11.7.1. Transverse corrugated bulkhead scantlings may be determined by direct calculations but are not to be less than required by the watertight bulkhead requirements of Pt 4, Ch 1,9.

8.3.2 For ships where the requirements of 3.1.2 are applicable, the requirements for transverse hold bulkheads given for the carriage of dry bulk cargoes in Ch 7,10 are also to be applied.

8.3.3 In general, the bulkheads are to have stiffening or corrugations arranged vertically, supported by top and bottom end stools. Alternative arrangements will, however, be considered.

8.3.4 Where inner bottom plating is increased as required by 6.1.4, the lower part of the transverse bulkhead should also be increased in accordance with Pt 3, Ch 9,9.4.1.

8.4 Non-watertight bulkheads

8.4.1 Non-watertight bulkheads in wing tanks are to comply with the requirements given in Ch 9,8 and Ch 9,9.8.

8.4.2 The bulkhead plating is to be suitably reinforced in way of double bottom scarfing arrangements and the ends of centre hold deck transverses. Openings in wing tank bulkheads are to be kept clear of these areas.

■ *Section 9* Primary structure in wing tanks

9.1 General

9.1.1 The primary structure in the wing tanks is to comply with the requirements given in Ch 9,9.

9.2 Scarfing of double bottom

9.2.1 The inner bottom plating is to be extended into the wing tank in the form of a horizontal diaphragm, arranged to ensure a smooth structural transition in way of transverse primary members and to maintain longitudinal continuity. The diaphragms are to be of sufficient width to provide effective scarfing of the inner bottom into the wing tank structure.

9.2.2 Floors intermediate between transverses are to be backed in the wing tanks by substantial vertical brackets extending transversely over at least three bottom longitudinal spaces and vertically to a sufficient height above the horizontal diaphragms to provide effective support for the double bottom structure.

■ *Section 10* Direct calculations

10.1 Application

10.1.1 Direct calculations are to be employed in the derivation of scantlings where required by the preceding Sections of this Chapter or by related provisions included in Part 3.

10.1.2 Direct calculation methods are also generally to be used where additional calculations are required by the Rules in respect of unusual arrangements.

10.1.3 For complex structural arrangements, e.g., a double plate transverse bulkhead with stool in a centre hold, associated with plane wing tank bulkheads supported by stringers and buttresses, an investigation of bottom primary structure over a full cargo hold length and three-dimensional analysis of the transverse bulkhead structure will generally be required, taking account of applied longitudinal hull bending effects.

10.1.4 The cross-deck structure is to be verified as being capable of supporting transverse compressive stresses resulting from lightship weight, deadweight, hydrostatic and wave loads. For ore carriers that are designed to operate with an asymmetrical loading condition, or large ore carriers with $B \geq 40$ m or $b/w \geq 2,2$, the wave loads should take account of hydrodynamic torque in an oblique sea. The cross-deck structure is to comprise the hatch coamings and beams, the plating and attached stiffeners and the upper stool. Non-corrugated bulkhead plating may also be included.
where

B = moulded breadth, in metres
b = breadth of the deck hatch openings, in metres
w = width of the cross-deck strip between hatchways, in metres.

10.2 Procedures

10.2.1 For details of Lloyd's Register's direct calculation procedures, *see* Pt 3, Ch 1,2. For requirements concerning use of other calculation procedures, *see* Pt 3, Ch 1,3.

10.2.2 Where appropriate to the structural configuration, the direct calculation procedures for tanker primary structure, *see* Ch 9,14, will be adapted for application to ore carriers.

■ *Section 11* Forecastles

11.1 General

11.1.1 A forecastle is to be fitted in accordance with the requirements of Pt 4, Ch 7,14.

Section 12
Single pass loading

12.1 Scope and application

12.1.1 The requirements of this Section are to be applied to all ore carriers with a deadweight greater than 200 000 tonnes. The requirements are for single pass loading where the maximum permissible cargo intake per cargo hold may be loaded in a single loading pour.

12.2 Information required

12.2.1 In addition to the plans required for submission by Pt 3, Ch 1,5.2 and as detailed in the applicable Chapters, the following information is also to be submitted:
(a) Maximum permissible cargo in each cargo hold.
(b) Cargo mass curves for a single and adjacent hold loadings taking into account the cargo overshoot defined in 12.4.1(e).
(c) One or more cargo loading sequences intended for single pass loading, *see* 12.2.2.
(d) Details of ballast and deballast piping arrangements and pumping capacity.
(e) Specification of loading computer.

12.2.2 The cargo loading sequences as required by 12.2.1(c) are to include the following:
(a) Start and end times of each cargo pour and the intended loading rate.
(b) Start and end times of each deballasting operation and the intended discharge rate.
(c) Intermediate points (in time) during pours and between pours. In general, the interval between intermediate points is not to be greater than 1 hour.
(d) The ship's loading condition, including the ship's draughts at the fore and aft perpendiculars, amount of cargo in each hold and amount of ballast in each tank, and the still water bending moments and shear forces, are to be provided for each point (in time) of the loading operation specified in (a), (b) and (c).

12.3 Definitions

12.3.1 **Pour**. A pour is defined by the start and finish of loading of a cargo hold. A pour finishes when the loading equipment changes position to a new cargo hold.

12.3.2 **Overshooting**. Overshooting is to be taken as the consequence of mistiming the loading of cargo, resulting in cargo overloading.

12.4 Cargo loading conditions for design assessment

12.4.1 For the purpose of the design assessment, the following conditions are assumed:
(a) Cargo loading and deballasting operations are co-ordinated, with the deballast capacity and arrangement of the vessel designed to accommodate the specified loading sequences.
(b) The cargo is distributed symmetrically in a hold space.
(c) Deballasting is carried out for each pair of symmetrical port and starboard tanks simultaneously, so that each pair of symmetrical port and starboard ballast tanks contain equal amounts of water ballast throughout deballasting operations.
(d) To improve deballasting and stripping, the trim of the ship is to be, in general, by the stern throughout the cargo loading operation.
(e) A cargo overshoot per cargo hold is taken as 10 per cent of the maximum permissible hold cargo mass or 3000 tonnes, whichever is the lesser, but not less than 5 per cent of the maximum permissible hold cargo weight, in any case. A higher cargo overshoot may be specially considered.
(f) Loading more than one cargo hold simultaneously in a single pass, i.e., simultaneous filling of two or more holds, will be specially considered. The specific loading conditions are to be submitted for appraisal in addition to the condition(s) for standard single-pass loading.

12.5 Design assessment

12.5.1 The following criteria are to be complied with in all cargo loading sequences:
(a) Still water bending moment and shear force are within the allowable limits.
(b) Single hold loading is within the allowable hold mass curve.
(c) Two adjacent holds loading are within the allowable hold mass curve.

12.5.2 Arrangements and scantlings of local stiffeners and plating within the cargo hold region are to comply with Sections 1 to 11 with consideration of the maximum permissible cargo mass per hold in the loading manual and the cargo overshoot specified in 12.4.1(e).

12.5.3 The primary structure and plating within the cargo hold region are to be assessed in accordance with the *ShipRight SDA Procedure for Ore Carriers*.

12.6 Ballast arrangements

12.6.1 The deballasting capacity of the vessel, including arrangement of ballast tanks, pumps and relevant piping system, is to be sufficient for the loading operations as agreed in the approved loading plan.

12.6.2 A smaller diameter stripping system with separate main and branch lines may need to be provided in order to achieve the required deballasting capacity.

12.7 Loading manual

12.7.1 All loading sequences of single pass loading, maximum loading rates and ballast pumping details are to be submitted for approval and included in the Loading Manual. Loading conditions at intermediate points as described in 12.2.2(c) need not be included in the Loading Manual.

12.8 Loading computer

12.8.1 The ship is to be installed with sensors for remote measurement of water ballast, fuel oil and ship's draughts.

12.8.2 In addition, it is recommended that an interface with the onboard loading computer, connecting to the installed sensors detailed in 12.8.1, is to be provided to check the ship's condition during loading and unloading.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies, in general, to manned or unmanned self-propelled or non-self-propelled ships defined as follows:

(a) Dredgers designed to operate wholly or generally for the purpose of raising spoil such as mud, silt, gravel, clay, sand or similar substances, general rubbish or ore, minerals, etc., for the bed of the sea, rivers, lakes, canals or harbours, etc. The dredged material may be placed in suitably designed holds or similar spaces within the ship.

(b) Hopper dredgers, designed to raise spoil, as described in (a), and so arranged that the dredged material may be placed in one or more hoppers within the ship. For the purpose of this definition, a hopper is a hold or other space designed to carry dredged spoil and also arranged to enable such spoil to be discharged through doors or valves in the bottom of the ship. Spaces arranged to be unloaded by means of conveyor belts, suction pipes or similar gear are not to be regarded as hoppers unless adequate bottom doors or valves are also fitted.

(c) Split hopper dredgers, which are designed similarly to that described in (b) but arranged such that the spoil is discharged through the bottom of the ship by means of the split hull being separated using hinges and actuating devices.

(d) Reclamation craft, reclamation ships, etc., which work in a manner similar to dredgers but draw their spoil from dredging craft and discharge it ashore.

(e) Hopper barges designed to carry spoil or dredged material in hoppers within the ship. For the definition of a hopper, *see* 1.1.1(b).

(f) Split hopper barges, which are designed similarly to that described in (e) but arranged such that the spoil is discharged through the bottom of the ship by means of the split hull being separated using hinges and actuating devices.

1.1.2 The scantlings and arrangements are to be as required by Chapter 1, except as otherwise specified in this Chapter.

1.1.3 Where bottom dump doors or valves are fitted, hatch covers are not required. Proposals for the omission of hatch covers where bottom dump doors or valves are not fitted will be specially considered.

1.1.4 Ships which have their machinery placed on a shallow raft, rather than within a hull, will have their scantlings specially considered. Dredgers which resemble drilling rigs, or similar offshore structures, in their design or mode of operation will be considered under the Rules for such structures.

1.1.5 Ships of unusual form or proportions, or intended for unusual dredging methods, will receive individual consideration on the basis of the general standards of the Rules.

1.1.6 The requirements provide for transverse and longitudinal framing of the structure. In general, the midship region scantlings are to extend over the full length of hoppers and holds. The extent is to be not less than 0,4L amidships, and may need to be increased if the design and loading conditions of a particular ship result in its maximum bending moment occurring other than at amidships.

1.2 Stability

1.2.1 Attention is drawn to the thixotropic properties of certain types of dredged material which, as a result of the ship's motions, can cause the spoil to shift within spoil spaces, resulting in undesirable changes in trim or angles of heel. This can be particularly dangerous in ships with closed top spaces.

1.3 Class notations

1.3.1 In general, ships complying with the requirements of this Chapter will be eligible for one of the following classes:

(a) **100A1 dredger**. This class will be assigned to ships as defined in 1.1.1(a).
(b) **100A1 hopper dredger**. This class will be assigned to ships as defined in 1.1.1(b).
(c) **100A1 split hopper dredger**. This class will be assigned to ships as defined in 1.1.1(c)
(d) **100A1 reclamation craft**. This class will be assigned to ships as defined in 1.1.1(d).
(e) **100A1 hopper barge**. This class will be assigned to ships as defined in 1.1.1(e).
(f) **100A1 split hopper barge**. This class will be assigned to ships as defined in 1.1.1(f).

1.3.2 The class notations will be assigned to ships based on the following:

(a) The class notations in 1.3.1 will be assigned to ships which are intended to make unrestricted sea-going voyages, either as part of their work or while transferring from one work area to another as part of their normal operations and have also been designed to perform dredging operations in defined dredging service areas.
(b) Where dredger types listed in 1.3.1(a), 1.3.1(b) and 1.3.1(c) perform dredging operations at reduced freeboards, resulting in a dredging draught (T_m) greater than the summer draught and without a dredging service area restriction, the class notation will be extended as follows: **'dredging draught T_m of … metres in sea states with H_s <... metres'** and will be subject to special requirements of National Authorities, *see* 1.6.1 to 1.6.3.
(c) Where dredger types listed in 1.3.1(a), 1.3.1(b) and 1.3.1(c) perform dredging operations at reduced freeboards, resulting in a dredging draught (T_m) greater than the summer draught but with a dredging service area limited to within 21 nautical miles from shore, the class notation will be extended as follows: **'dredging within 21 miles from shore at a dredging draught T_m of … metres'** and will be subject to special requirements of National Authorities, *see* 1.6.1 and 1.6.2.
(d) Where requested, the assignment of more than one dredging draught may be considered, i.e., **'dredging at draught T_{m1}…'** and **'dredging at draught T_{m2}…'**, etc., provided agreement is obtained from the National Authorities and the applicable requirements of this Chapter are complied with.

1.3.3 Ships intended to be operated only in suitable areas or conditions which have been agreed by the Committee, as defined in Pt 1, Ch 2,2.3.6, 2.3.7, 2.3.8 and 2.3.10, will receive individual consideration on the basis of the Rules with respect to the environmental conditions agreed for the design basis and approval. In particular, dredgers complying with the requirements of this Chapter, and Pt 3, Ch 13,7 for the reduced equipment requirements, will be eligible to be classed:

A1 dredger protected waters service, *see* Pt 1, Ch 2,2.3.6, or

100A1 dredger with service restriction notation,

whichever is applicable. Hopper dredgers, split hopper dredgers, reclamation craft, hopper barges and split hopper barges would be considered similarly.

1.3.4 Where a ship complying with the requirements of this Chapter has the bottom structure additionally strengthened for operating aground in accordance with Section 7, it will be eligible for the special feature notation 'bottom strengthened for operating aground'.

1.3.5 In addition to the above notations, an appropriate descriptive note may be entered in the *Register Book* indicating the type of dredging or reclamation craft (*see* Pt 1, Ch 2,2.6.1), e.g., 'trailing suction dredger', 'cutter suction dredger', 'bucket dredger', 'grab dredger', 'dipper dredger', 'self-discharging sand dredger', etc.

1.3.6 The Regulations for classification and assignment of class notations are given in Pt 1, Ch 2 to which reference should be made.

1.4 Information required

1.4.1 In addition to the information and plans required by Pt 3, Ch 1,5 details of the following are to be submitted:

- Sections through hoppers, wells, pump-rooms and dredging machinery spaces.
- Hopper, hold and well bulkheads and associated weirs.
- Scarfing arrangements at hopper, hold and well ends.
- Hinges, actuating and locking arrangements, together with supporting structure, weld connection details and calculations of design forces for split hull separation devices.
- Deckhouse and deckhouse support structure.
- Outline arrangement and main scantlings of 'A' frames, gantries, positioning spuds, hopper doors and similar items, the strength and integrity of which directly affect the hull structure of the vessel. Support structure in way of 'A' frames, positioning spuds and other dredging structures. Seats of dredging machinery and pumps. If dredging equipment is stored during voyages, plans of any special arrangements for dismantling, storage and reassembly. Sufficient particulars of static and dynamic loading for these items are to accompany the details to enable verification of the strength and effectiveness of the supporting ship structure.
- A full set of stability data which is to be placed on board the ship, *see* Pt 1, Ch 2,3.
- Calculations of hull girder still water bending moment and shear force where applicable, *see* 2.1.1, for the proposed loading conditions, including densities of spoil. When the still water bending moment and block coefficient are being calculated, any water within spoil spaces should be regarded as added weight, whilst that in dredging ladder wells and spud wells should be regarded as lost buoyancy.

1.5 Symbols

1.5.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

B = breadth, in metres, defined as the greatest moulded breadth excluding any localised bulge on the hull associated with the attachment or handling of the dredging gear

C_b = the moulded block coefficient at draught T but is to be taken as not less than 0,6. The block coefficient is to be determined using the length, L. Spoil spaces should be regarded as added weight, whilst dredging ladder wells and spud wells should be regarded as lost buoyancy

C_{bm} = the moulded block coefficient at the dredging draught T_m, but is to be taken as not less than 0,6. The block coefficient is to be determined using length, L. Spoil spaces should be regarded as added weight, whilst dredging ladder wells and spud wells should be regarded as lost buoyancy

D = moulded depth, in metres, to the uppermost continuous deck

L = Rule length, in metres, as defined in Pt 3, Ch 1,6 for ships classed for unrestricted service. For ships classed **A1 protected waters service** where the load waterline is not required to be determined by the International Load Line Convention method, the length is to be measured on the deepest waterline at which the ship is designed to operate. On sea-going vessels with unusual stern arrangement, or with unusual bow arrangement associated with a dredging draught in excess of the summer load line draught, the length, L, will be specially considered

M_s = design still water bending moment, in kNm (tonne-f m), at draught, T, or less

$\bar{M}_s$ = maximum permissible still water bending moment, in kNm (tonne-f m), at draught, T, or less

M_{sm} = design still water bending moment, in kNm (tonne-f m), under dredging conditions at draught, T_m

$\bar{M}_{sm}$ = maximum permissible still water bending moment, in kNm (tonne-f m), under dredging conditions at draught, T_m

M_w = design hull vertical wave bending moment amidships, in kN m (tonne f m), *see* 2.4.1

T = summer draught, in metres, as established by the method described in the International Load Line Convention, measured from top of keel amidships

T_m = maximum dredging draught, in metres, at which the ship is designed to operate. It is to be measured amidships from the top of keel and is to be taken not less than T, *see* 15.1.4

ρ = relative density (specific gravity) which, in general, is to be taken not less than 1,86, or as derived from the stowage rate of spoil. This stowage rate of dredged spoil is to be determined from the maximum spoil weight at dredging draught and volume of spoil space up to the sill of the uppermost overflow weir. The value used in the calculations of scantlings is to be clearly marked on the relevant plans

Hogging bending moments are positive.

1.5.2 For symbols not defined in this Chapter, *see* Chapter 1.

1.6 Requirements for dredgers operating at reduced freeboards

1.6.1 Requirements of IMO DR 68 *Guidelines for the Operation of Dredgers at Reduced Freeboards* are to be complied with.

1.6.2 The dredger is to be of a self discharging type and equipped with bottom valves. When the ship is operating at a reduced freeboard, i.e., 1/2 or 1/3 of its summer freeboard, the capacity of these bottom valves, or a part thereof, is to be sufficient to obtain the summer freeboard by discharging the appropriate amount of cargo within 8 minutes (IMO DR 68 refers).

1.6.3 Where the class notation **'dredging draft T_m of … metres in sea states with H_s <… metres'** is assigned, the Master is to be provided with suitable information on the actual situation of the sea conditions and the forecast in terms of significant wave heights.

■ *Section 2* Longitudinal strength

2.1 General

2.1.1 Longitudinal strength calculations are to be made in accordance with the relevant requirements given in Pt 3, Ch 4, except as indicated in this Section.

2.2 Loading conditions

2.2.1 Details are to be submitted of the following loading conditions for examination of longitudinal strength:

(a) Homogeneous load conditions (including details of densities of spoil) for both departure and arrival at draught, T, and maximum dredging draught, T_m, where this exceeds T, *see also* 15.1.4.
(b) Part loaded conditions (including details of densities of spoil) and ballast conditions for both departure and arrival.
(c) Any specified non-homogeneous load conditions.

2.2.2 If any dredging equipment has to be unshipped, lowered or otherwise specially arranged or stowed before the ship proceeds on a sea-going voyage, this fact is to be indicated on the longitudinal strength information required to be submitted and is also to be clearly stated in the final Loading Manual supplied to the ship.

2.2.3 For loading conditions, and any other preparations required to permit ships with a notation specifying some service limitation to undertake a sea-going voyage, either from port or building to service area or from one service area to another, *see* Pt 1, Ch 2,1.

2.2.4 Where a ship is arranged with two spoil spaces account is to be taken in the calculation of the still water bending moment of either one of these spaces being empty, unless such loading is specifically precluded in the Loading Manual supplied to the ship.

2.2.5 The requirements of Pt 3, Ch 4,8.3 regarding loading instruments are not applicable to dredging and reclamation craft.

2.3 Hull bending strength

2.3.1 Hull bending strength standards are to comply with the relevant requirements of Pt 3, Ch 4, taking account of the contents of 2.4 and 2.5.

2.3.2 For split hopper dredgers or barges, due account is to be taken of the lateral forces and moments on each half hull which are exerted by the pressure of the spoil and dynamic wave loading, *see* 17.2.

2.4 Design vertical wave bending moments

2.4.1 The design vertical wave bending moment at amidships, M_w, is to be determined from Pt 3, Ch 4,5.2 with the ship service factor, f_1, given in Table 12.2.1.

Table 12.2.1 Ship service factors f_1 and f_{wd}

Class Notation	f_1	f_{wd}
+ 100A1…, dredging draught T_m of … metres in sea states with H_s <... metres	1,00	f_{uds}
+100 A1…, dredging within 21 miles from shore at a dredging draught T_m of … metres	0,75	0,60
+A1…, Protected waters service	0,65	0,35
Symbols		
f_{uds} = $2{,}2 H_s L^{-0{,}48}$, not to be taken less than 0,35 nor greater than 1 H_s = significant wave height for the dredging operations at the considered dredging draught T_m		
NOTE The wave reduction factors may only be used for dredgers complying with the applicable requirements of 1.6.1 to 1.6.3.		

2.4.2 The design hull vertical wave bending moment at amidships for dredging conditions, M_{wd}, where draught T_m is greater than T, is given by the following expression:

$$M_{wd} = f_{wd} f_2 M_{wo}$$

where

M_{wo} is determined from Pt 3, Ch 4,5.2, using C_{bm} in place of C_b

f_2 is given in Pt 3, Ch 4,5.2

f_1 and f_{wd} are defined in Table 12.2.1.

2.5 Permissible still water bending moment for dredging conditions

2.5.1 The maximum permissible still water bending moment, $\bar{M}_{sm}$, for dredging conditions where draught T_m exceeds T is not to exceed:

$$\left|\bar{M}_{sm}\right| = \left|\bar{M}_s + f_1 f_2 M_{wo} - M_{wd}\right| \quad \text{kN m (tonne-f m)}$$

where M_{wd} is defined in 2.4.2.

Where applicable, the relevant loading conditions are to be included in the final Loading Manual, *see* 15.1.4 and Pt 3, Ch 4,8.1.

2.6 Calculation of hull section modulus

2.6.1 The hull midship section modulus is to be calculated in accordance with the requirements of Pt 3, Ch 3,3.4 taking account of 2.6.2 and 2.6.3. *See also* 17.1 for split hull arrangements.

2.6.2 Centreline box keels within the hopper spaces may normally be regarded as 100 per cent effective provided that they are effectively scarfed to the vertical keels or equivalent structure at each end of the hopper spaces.

2.6.3 Where a long superstructure or deckhouse is fitted extending within the midship region, the requirements for longitudinal strength in the hull and erection will be specially considered.

2.7 Hull shear strength

2.7.1 Special attention is to be paid to the actual shear forces at the spoil space end bulkheads. The inclusion of the effective thickness of longitudinal bulkheads, centre box keel plating and other longitudinal material at these positions, will be considered in relation to the arrangement of structure proposed.

2.7.2 For ships classed **A1 protected waters service**, *see* 4.6.1.

2.7.3 The vertical wave shear forces, Q_w, are to be calculated in accordance with Pt 3, Ch 4,6. In dredging conditions, where the dredging draught T_m is greater than T, K_2 may be taken as f_{wd}.

Section 3 Deck structure

3.1 Deck plating

3.1.1 Dredgers, hopper dredgers and hopper barges classed for unrestricted service are to have the minimum thicknesses required by Ch 1,4 increased by 2 mm for those areas of the strength deck outside line of openings which are exposed to the weather.

3.1.2 Ships classed **100A1 extended protected waters service** are to have the minimum thicknesses required by Ch 1,4 for all strength deck plating outside line of openings. The minimum value of *s*, used in the formulae, may be taken as 550 mm.

3.1.3 Ships classed **A1 protected waters service** may have the minimum thicknesses as given in Ch 1,4 for all strength deck plating outside line of openings reduced by 1 mm, with an overall minimum of 5 mm. The minimum value of *s*, used in the formulae, may be taken as 550 mm.

3.1.4 Strength deck plating within the line of openings in the midship region, and for 0,075*L* from the ends, is to have a thickness not less than:

$$t = 0{,}01s \text{ mm}$$

3.1.5 The deck plating thickness and supporting structure may be required to be reinforced in those areas of deck which are liable to be subjected to regular, heavy, impact loads such as could occur when maintaining or inspecting large items of dredging gear, etc. It is recommended that consideration be given to increasing the plating thickness in these areas to:

$$t = 0{,}02s \text{ mm}$$

with a minimum

$$t = 10 \text{ mm.}$$

3.2 Deck stiffening

3.2.1 The scantlings of deck beams or longitudinal are to comply with the requirements of Ch 1,4.3.

3.3 Deck supporting structure

3.3.1 The scantlings of the deck supporting structure are to comply with the requirements of Ch 1,4.4.

Section 4 Shell envelope plating

4.1 Keel

4.1.1 On ships over 50 m in length, where there is a centreline well, or where hopper doors are fitted on the ship's centreline, i.e., where no centreline box keel is fitted in a hopper, a keel strake is to be fitted on each side of the well or hopper door opening, dependent upon the proposed docking arrangements for the ship. The width of each keel strake is to be not less than half that required for a centreline keel nor less than 400 mm. The thickness of each keel strake is to be not less than the thickness required for a centreline keel in Ch 1,5.2.

4.2 Bottom shell

4.2.1 The minimum thickness of bottom shell plating amidships on hopper dredgers and hopper barges classed for unrestricted service is to be 15 per cent greater than that required by Ch 1,5.3. The thickness of bottom shell plating on ships classed **A1 protected waters service** is to be not less than:

$$t = \left(5sL\sqrt{D} \times 10^{-5} + 5\right) \text{ mm}$$

or that required for Ch 1,5.3, whichever is the lesser, but with an overall minimum thickness of 6 mm.

4.2.2 Where hoppers extend outside 0,4*L* amidships, the thicknesses required for the bottom shell amidships are to be maintained for at least two frame spaces beyond the ends of the hoppers before being tapered to the end thicknesses.

4.3 Operating aground

4.3.1 For ships intended to operate aground, *see* Section 7.

4.4 Bottom openings

4.4.1 The corners of hopper door openings and of bucket and ladder wells are generally to be parabolic or elliptical on all ships where *L* is greater than 50 m, and should generally be rounded on smaller ships. On ships where *L* is greater than 90 m, the arrangement of hopper and well corners within 0,5*L* amidships should generally be as required for deck hatch corners. The sealing arrangements for hopper doors may lie within the line of the corners, provided that the construction is such as to avoid high stress concentrations in the structure.

4.5 Ships with chines

4.5.1 On ships arranged with two chines each side, the bilge plating should generally be calculated from the bottom plating formulae. On hard chine ships, flanged chines will not generally be approved, but where a chine is formed by knuckling the shell plating, the radius of curvature, measured on the inside of the plate, is to be not less than 10 times the plate thickness. Where a solid round chine bar is fitted, the bar diameter is to be not less than 50 mm or three times the thickness of the thickest abutting plate, whichever is the greater. Where welded chines are used, the welding is to be built up as necessary to ensure that the shell plating thickness is maintained across the weld.

4.6 Side shell

4.6.1 The thickness of the side shell is to be in accordance with Ch 1,5.4. On ships classed **A1 protected waters service** the thickness of the side shell throughout, including at ends, may be reduced by 20 per cent from that required by Ch 1,5.4 and Pt 3, Ch 5 and Pt 3, Ch 6 as appropriate, provided that the combined shear stress does not exceed 110 N/mm^2 (11,2 kgf/mm^2).

4.6.2 Where high compressive loads occur in the sheerstrake, the thickness may be required to be increased to minimise the likelihood of buckling.

4.7 Swim ends

4.7.1 The plating of swim ends is to have a thickness not less than that required for the bottom shell up to the waterline at draught T, *see also* Table 12.7.1. It is to have a thickness not less than that required for side shell in the areas more than 1,0 m above the waterline at draught T_m. In intermediate areas the thickness may be tapered from the bottom to the side shell requirements.

■ *Section 5* Shell envelope framing

5.1 Longitudinal stiffening

5.1.1 The scantlings of bottom and side shell longitudinals are to comply with the requirements given in Table 12.5.1.

5.1.2 For ships intended to operate aground, *see* Section 7.

5.2 Transverse stiffening

5.2.1 For bottom structure with transverse framing, *see* Section 6.

5.2.2 For ships intended to operate aground, *see* Section 7.

Table 12.5.1 Longitudinal stiffening

Position of longitudinals	Modulus
(1) Bottom	$Z = \dfrac{l_e^2\, s\, H\, k\, c}{K_1}$ cm^3 where l_e = effective span of longitudinals, in metres, and is to be taken as not less than 1,85 m except as provided for in 6.3.1 In way of single bottoms H = D In way of double bottoms H = D on ships classed **100A1** or **100A1 extended protected waters service** = T_m for ships classed **A1 protected waters service** c = a factor varying from 1,0 at $\dfrac{D}{2}$ to = $\dfrac{2060}{3620 - 1560F_B}$ at bottom, intermediate values by interpolation. For ships with hogging still water bending moments in loaded conditions and for split hull vessels, c = 1,0 F_B = as defined in Pt 3, Ch 4,5.1 K_1 = 120 on ships classed **100A1** or **100A1 extended protected waters service** = 150 on ships classed **A1 protected waters service** k = higher tensile steel factor, *see* Pt 3, Ch 2,1
(2) Side shell	(a) For ships classed **100A1** or **100A1 extended protected waters service** The minimum modulus of side longitudinals is to be in accordance with Ch 1,6.2 (b) For ships classed **A1 protected waters service** The modulus required by (a) and reduced by 5 per cent
(3) Bilge	The scantlings of bilge longitudinals are to be graduated between those required for the bottom longitudinals and the lowest side longitudinals

5.2.3 The scantlings of side frames amidships are to be in accordance with Ch 1,6 for ships classed for unrestricted service or **100A1 extended protected waters service**. The modulus of side frames may be reduced by eight per cent for ships classed **A1 protected waters service**.

5.3 Primary supporting structure at sides

5.3.1 The spacing of transverses supporting side longitudinals is generally to be in accordance with Ch 1,6.4, but is not to exceed 4,0 m.

5.3.2 Transverses supporting side longitudinals are to comply with the requirements of Ch 1,6.4, except for ships classed with a service restriction notation and all ships classed **A1 protected waters service**, where the requirements are given in Table 12.5.2.

Table 12.5.2 Primary supporting structure at sides

Symbols	Item	Requirement
h = vertical distance from mid-point of span to deck at side, in metres l_e = effective length of supporting member, in metres, *see* Pt 3, Ch 3,3 I = moment of inertia of supporting member, in cm^4, *see* Pt 3, Ch 3,3 S = spacing, or mean spacing, of supporting member, in metres Z = section modulus of supporting member, in cm^3, *see* Pt 3, Ch 3,3	Transverses supporting side longitudinals amidships	All ships classed **100A1 extended protected waters service**: $Z = 9{,}5 S\, h\, l_e^2$ cm^3 All ships classed **A1 protected waters service**: $Z = 9{,}0 S\, h\, l_e^2$ cm^3
	Transverses and web frames supporting side longitudinals abreast of spoil spaces	Inertia of not less than: $I = 2{,}5 l_e\, Z$ cm^4

5.3.3 In way of transverse framing, web frames may be required in way of hopper cross members. Alternative arrangements may be submitted for consideration.

5.3.4 The end connections of side transverses and web frames to deck and bottom transverses abreast of spoil spaces are to be arranged to prevent shear buckling of the members' webs.

5.3.5 For wash bulkheads fitted in lieu of web frames abreast spoil spaces, *see* 8.3.6.

■ *Section 6*
Bottom structure

6.1 General

6.1.1 This Section provides for longitudinal or transverse framing of the bottom structure of ships with single or double bottoms.

6.1.2 For ships intended to operate aground, *see* Section 7.

6.2 Single bottoms transversely framed

6.2.1 The scantlings of single bottom floors, extending for the full width of the ship, are to be in accordance with Ch 1,7 irrespective of the length of the ship. Floors below dredging pumps or similar items which could induce large concentrated loads or large dynamic forces, may be required to be of increased strength. Floors may be recessed locally in way of dredging pumps, etc., provided that suitable compensation is arranged.

6.2.2 The spacing of intercostals and longitudinal side girders is to be such as to ensure continuity of strength at bulkheads, ends of spoil spaces and wells and at ends of machinery seats so far as practicable, *see also* Ch 1,7. An intercostal is to be fitted in the buoyancy space abreast hopper openings when the distance between the hopper opening and the ship's side exceeds 4,0 m.

6.2.3 Abreast of dredging wells and spoil spaces the minimum depth of floor at its inboard end is to be not less than:

$$d_w = 20\,(B + l_e + 2T_m)\ \text{mm}$$

The thickness of the web and area of the face plate are to be as required by Ch 1,7.2.

6.3 Single bottoms longitudinally framed

6.3.1 The spacing of transverses is to be in accordance with 5.3.1, and are to be supplemented by the following arrangements of brackets:

(a) On the ship's centreline, or on each side of dredging wells where there is no structure on the centreline, the brackets are to be spaced not more than 1,25 m apart and are to extend outboard to the first longitudinal, port and starboard. The longitudinals supported by the brackets may be calculated using a nominal transverse spacing of 1,6 m.

(b) On ships where the sides are transversely framed, the brackets are to be fitted at every frame and are to extend inboard to the first longitudinal on the flat of bottom. This longitudinal is to be based on a span equal to the spacing of the transverses.

(c) The thickness of these intermediate brackets is to be not less than:

$$t = \left(0{,}25B + 1{,}85\sqrt{T_m}\right)\ \text{mm.}$$

6.3.2 In areas of high shear loading, the thickness and stiffening of the web plates on transverses, etc., may have to be increased. The depth of transverses is to be not less than 2,5 times the depth of the slot for the bottom longitudinals, and thickness of the web plates is to be not less than 8 mm.

6.3.3 Bottom transverses in spoil space side buoyancy tanks in way of cross-ties are to have a depth, d, of not less than:

$$d = 28B + 205\sqrt{T_m}\ \text{mm}$$

Their arrangement, scantlings and end connections are to be such as to provide proper continuity of strength across the ship. The transverses are to be fitted with stiffeners in way of every shell longitudinal. The stiffeners should, in general, be equivalent to flat bars with a depth one-eighth of the transverse at that point and a thickness not less than the thickness of the transverse.

6.4 Double bottom – General

6.4.1 Self-propelled dredgers and reclamation ships of more than 500 tons gross and intended for International voyages are to be provided with a double bottom extending from the collision bulkhead to the after peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

6.4.2 A double bottom need not be fitted in way of watertight compartments used exclusively for the carriage of liquids provided the safety of the ship, in the event of bottom damage, is not thereby impaired.

6.4.3 The double bottom may, however, be interrupted locally, or fitted with wells in way of dredging pumps and other equipment. Where such openings are large, their scantlings and arrangements will be specially considered.

6.4.4 The scantlings are to be in accordance with Ch 1,8 except for the following:

(a) The Rule thickness of centre girders may be reduced by 2,0 mm on ships classed **A1 protected waters service**.
(b) The Rule thickness of side girders may be reduced by 1,0 mm on ships classed **100A1 extended protected waters service**.
(c) The scantlings of floors, longitudinals and plating supporting the bottom of spaces intended to carry spoil are to be determined in accordance with Section 8.

6.5 Double bottom with transverse framing

6.5.1 Plate floors may be fitted at every frame or may be spaced not more than 3,0 m apart with the shell and inner bottom plating between these floors supported by bracket floors. However, plate floors are to be fitted at every frame in the following areas:

(a) As required for Ch 1,8.5.
(b) Below spaces from which dredged material will be discharged by grabs.
(c) In main propulsion and dredging machinery rooms and in peak tanks.
(d) For three frame spaces at ends of spoil spaces and dredging wells.

6.6 Double bottom with longitudinal framing

6.6.1 In locations other than below spaces intended for dredged spoil the section modulus of inner bottom longitudinals is to be not less than:

$$Z = \frac{l_e^2\, s\, H\, k\, c}{K_1} \text{ cm}^3$$

where

l_e = effective span of longitudinals, in metres, and is to be taken as not less than 1,85 m
s = spacing of longitudinals, in mm
H = height, in metres, from the tank top to the deck at side, (but need not exceed T_m on ships classed **A1 protected waters service**)
c as defined in Table 12.5.1
K_1 = 120 in machinery spaces on ships classed **100A1**
= 150 otherwise
k = higher tensile steel factor, *see* Pt 3, Ch 2,1.

6.6.2 The section modulus of longitudinals below spaces intended for dredged spoil is to comply with the requirements of 8.3.7.

6.6.3 The spacing of transverses is generally to be as for dry cargo ships but is not to exceed 4,0 m. Below main dredging machinery the transverses are generally to be spaced not more than 1,0 m apart.

6.6.4 The ends of longitudinal girders under dredging machinery are to be tapered off or efficiently scarfed into other longitudinal structural items.

■ *Section 7* Bottom strengthening for operating aground

7.1 Application

7.1.1 The scantlings of bottom structure are to comply with the requirements given in Table 12.7.1.

7.1.2 Unless otherwise specified by the Owner, it should be assumed that non-self-propelled dredging and reclamation craft are to operate aground.

Table 12.7.1 Bottom strengthening for operating aground

Item	Requirement	
The following requirements are to be applied to the bottom structure upon which the ship is likely to be supported whilst aground		
(1) Bottom shell, keel and swim end plating	Thickness to be increased by 20% over the minimum requirements of Ch 1,5, with a minimum of 8 mm	
(2) Bottom longitudinals	Scantlings as required by Table 12.5.1(1) taking K_1 = 74 and c = 1,0	
(3) Bilge longitudinals (where fitted)	Scantlings to be the same as bottom longitudinals	
	Transverse framing	Longitudinal framing
(4) Primary stiffening in way of single bottoms, *see* Notes 1 and 2	(a) Floors to be fitted at every frame with vertical stiffeners spaced, in general, not more than 1,25 m apart (b) Side girders to be spaced not more than 2,2 m apart and intermediate 100 mm x 10 mm bulb plate longitudinals, or equivalent, fitted	(a) The spacing of transverses or floors is, in general, not to exceed 2,5 m outboard of wells or 1,85 m elsewhere (b) The panel size nearest the shell plating of web plates of transverses or floors is, in general, not to exceed 80t x 80t where t is the actual web thickness (c) Side girders to be spaced not more than 2,2 m apart
(5) Primary stiffening in way of double bottoms, *see* Notes 1 and 2	(a) Plate floors are to be fitted at every frame with vertical stiffeners spaced, in general, not more than 1,25 m apart (b) Side girders to be spaced not more than 2,5 m apart and intermediate 100 mm x 10 mm bulb plate longitudinals, or equivalent, fitted (c) Where the span of floors between a hopper space and the ship's side exceeds 3,75 m, a longitudinal girder is to be fitted	(a) The spacing of plate floors is, in general, not to exceed 1,85 m (b) Side girders to be spaced not more than 2,5 m apart

NOTES
1. The scantlings of floors, girders and transverses are to be determined in accordance with the requirements of Section 6.
2. The number and size of holes in floors, girder and transverses are to be kept to a minimum, *see* Ch 1,8.

Section 8
Spoil space and well structure

8.1 Symbols and definitions

8.1.1 The symbols used in this Section are defined as follows:

ρ_{ef} = effective specific gravity to be taken, as defined in Table 12.8.1

h = load head, in metres, measured vertically as follows:

(a) For plating, the distance from a point one-third of the height of the plate above its lower edge to the sill of the uppermost overflow weir.

(b) For stiffeners or girders, the distance from the middle of the effective length to the sill of the uppermost overflow weir.

l_e = effective length of stiffening members, in metres, *see* Pt 3, Ch 3,3

s = spacing of stiffeners, in mm

t = plate thickness, in mm

A_1 = cross-sectional area of flange or stiffener, in cm^2, including coaming plating.

Table 12.8.1 Effective specific gravity

Effective specific gravity less than or equal to 1,4	Effective specific gravity greater than 1,4	
$\rho \leq 1,4$	$\rho > 1,4$	
	for vertical boundaries	for boundaries which have an angle, a with the horizontal plane
$\rho_{ef} = \rho$	$\rho_{ef} = 1,4$	$\rho_{ef} = 1,4 + (\rho - 1,4)(\cos\alpha)^2$

8.1.2 Other symbols are defined in 1.5.1.

8.2 General

8.2.1 This Section provides for:

(a) horizontally and vertically stiffened boundary bulkheads to hoppers, and holds intended for dredged spoil, to ladder wells and to spud wells,

(b) protection against flooding in the event of the ladder well or adjacent bottom plating being damaged by objects dredged up by bucket dredgers, and

(c) continuity of transverse strength in spoil spaces and wing tanks abreast of spoil spaces.

8.2.2 As an alternative to the requirements of this Section regarding primary structure, scantlings may be derived on the basis of direct calculation methods, *see* Section 18.

8.2.3 **Continuity of strength.** Arrangements are to be made to ensure continuity of strength at the ends of longitudinal and well side bulkheads. In general, the design should be such that the bulkheads are connected to bottom and deck girders by means of large, suitably shaped brackets arranged to give a good stress flow at their junctions with both the girders and the bulkheads.

8.2.4 **Ladder well cofferdams.** Ladder wells of trailing suction dredgers are to be isolated from the remainder of the dredger's structure by local cofferdams at least 600 mm wide, or are to be otherwise protected to prevent serious flooding due to the well side plating being breached by the ladder structure should this be damaged in service. Ladder wells of bucket dredgers are to be isolated by cofferdams, the extent and widths of which are to be sufficient to contain any damage to the well side bulkheads or bottom shell plating that could result from the impact of large objects brought up in the dredge buckets. In way of the buckets the cofferdam may be extended outboard in the form of a local watertight double bottom.

8.3 Spoil space and well boundaries

8.3.1 The plating thickness of spoil space boundaries is to be not less than the following:

$$t = 0{,}0046 s\, f \sqrt{k\, h\, \rho_{ef}} + 3{,}0 \text{ mm, or}$$

$$t = 8{,}5 \text{ mm, whichever is the greater}$$

In the case of grab dredgers the minimum thickness is to be 10 mm. These thickness requirements also apply to the plating of watertight box keels and inner bottom plating. The value of ρ_{ef} used in the calculations and the height(s) of the overflow weir(s) are to be clearly shown on the midship section plan.

8.3.2 Attention is drawn to the high rate of wear that can occur on spoil space boundaries, and it is recommended that an additional corrosion allowance of 3,0 mm be added on areas subject to particularly onerous conditions. Where such an allowance is added, the fact is to be marked on the relevant plans.

8.3.3 The thickness of plating forming the sides and ends of bucket ladder wells is to be not less than:

$$t = \left(0{,}0055 s \sqrt{T_m} + 3{,}0\right) \text{ mm}$$

In no case, however, is the side plating to have a thickness less than 12 mm nor is the well end plating to have a thickness less than 8,5 mm. Plating forming the boundaries of suction pipe ladder wells is generally to be as required for shell plating. Corrosion allowance on well end plating below bucket ladders may be 2,0 mm.

8.3.4 The thickness of spoil space and ladder well bulkheads may be required to be increased where high shear forces are present.

8.3.5 Bulkheads forming the boundaries of spud wells are to be of increased strength. Each case will be considered on its merits, but in general such bulkheads should have a thickness of not less than 12 mm.

8.3.6 Where non-watertight bulkheads are fitted in the side buoyancy tanks, the thickness of the plating is to be not less than:

(a) t = 6,5 mm, or

(b) t = $(5{,}35 + 0{,}024L)$ mm

whichever is the greater. Where the bulkhead is in the form of a wash bulkhead, the openings should be so arranged that, in general, the distance from lightening holes to any slots cut to accommodate side shell or bulkhead longitudinals is at least equal to 1,5 times the depth of the slot. The edges of large openings are to be stiffened.

8.3.7 The section modulus of framing on spoil space boundaries is to be not less than:

$$Z = \frac{0{,}0113 \rho_{ef}\, s\, h\, l_e^2\, k\, c}{\gamma} \text{ cm}^3$$

where

c = as defined in Table 12.8.2 for longitudinal framing
  = 1,0 for transverse framing

γ = 1,4 for rolled or built sections
  = 1,6 for flat bars.

ρ_{ef} = effective specific gravity, *see* 8.1.1

k = higher tensile steel factor, *see* Pt 3, Ch 2,1

The section modulus of longitudinals below $\frac{D}{2}$ is to be taken not less than the value obtained at $\frac{D}{2}$.

Table 12.8.2 Definition of *c* for longitudinal framing

Symbols	Location	*c, see* Note 2
F_B as defined in Pt 3, Ch 4,5.1	0,8D $\frac{D}{2}$ and above	1,0
	At $\frac{D}{2}$	0,85
	0,2D above base (*see* Note 1)	$\frac{550}{1590 - 1040F_B}$
	Base line (*see* Note 1)	$\frac{2060}{3620 - 1560F_B}$

NOTES
1. For ships with hogging still water bending moments in loaded conditions and for split hull vessels, c = 1,0.
2. Intermediate values are to be calculated by linear interpolation.

8.3.8 The section modulus of stiffeners bounding wells and deep tanks is to satisfy the requirements of Ch 1,9.2.

8.3.9 For non-watertight bulkheads, the modulus of the stiffeners may be 50 per cent of that required for intact bulkheads. The stiffeners are to be bracketed at top and bottom.

8.3.10 Structure supporting spud well plating and bulkheads below, and in way of, 'A' frames and dredging machinery supports, is to be of substantial construction, account being taken of the dynamic loads likely to occur with the dredging machinery in operation.

8.3.11 Horizontal girders supporting stiffeners on spoil space and ladder well boundaries are, in general, to have scantlings as required by Ch 1,9.2 for deep tanks, with ρ and h as defined in 1.5.1 and 8.1.1 respectively and with span, l_e for horizontal girders supporting vertical stiffeners on longitudinal bulkheads, measured between bulkhead bracket and bulkhead bracket, i.e., ignoring any struts which may be fitted between spoil space girder and shell stringer. Alternatively, the section modulus of these horizontal girders may be reduced by 40 per cent from the formula value if struts are fitted on alternate frames between the spoil space girder and a shell stringer. These struts should generally be horizontal and are to have a sectional area as required for pillars by Ch 1,4.4 with ρ as defined in 1.5.1 and h measured from the inboard end of the strut to the height defined in 8.1.1. Web frames and girders are to have scantlings as required by Chapter 1, with ρ and h as defined in 1.5.1 and 8.1.1 respectively.

8.4 Cross-members

8.4.1 Cross-members are to be fitted within the hopper space in line with the bottom and side shell transverses and with the bulkheads in the side buoyancy spaces. Where the spacing between the cross-members exceeds 4 m, the scantlings of all primary members contributing to the continuity of the transverse strength in the spoil space are to be verified by direct calculations, *see also* Pt 3, Ch 1,2.2. Where a box keel is fitted on the centreline, webs are to be fitted within the box keel to ensure proper continuity of strength across the ship in way of the hopper cross-member. The webs required within centreline watertight box keels may have a thickness 3,5 mm less than that required for the hopper cross-members with which they are associated, but their minimum thickness is to be not less than 6,5 mm.

8.4.2 The upper edge of the hopper lower cross-members should, in general, be a height of not less than $\frac{D}{4}$ above the

above the keel in ships with the number 100 in their character of classification. The lower edge should be as low as practicable after allowing for the proper design of hopper doors, suction passages, etc. Lower cross-members may be fabricated from flat plate suitably stiffened or may take the form of a hollow box, generally of triangular cross-section.

8.4.3 The scantlings of box-type cross-members should be determined from the requirements for hopper bulkheads where applicable. When flat plate lower cross-members are fitted, the thickness of the web is to be not less than:

$t = (0{,}7B + 3)$ mm or 8,5 mm

whichever is the greater.

8.4.4 The cross-sectional area of the cross-member web after deducting access openings, lightening holes, etc., is to be not less than:

$A = 6 h_w S_M$ cm^2

where

h_w = height, in metres, of the uppermost hopper overflow weir above the keel

S_M = spacing of the cross-member webs, in metres.

8.4.5 The upper edge of the cross-member is to be stiffened by means of a tube having an outside diameter not less than:

$\delta = 30 l_s$ mm

where

l_s = span, in metres, of the upper edge of the cross-member (to the centreline box girder if fitted),

and a thickness equal to the minimum required cross-tie web thickness, or by an equivalent flange or structure. The lower edge of the cross-member is also to be suitably stiffened.

8.4.6 The cross-member web is to be fitted with stiffeners, spaced not more than 80t mm apart having a modulus of not less than:

$Z = 0{,}04 s\, l_e^2$ cm^3.

8.4.7 The transverse strength of primary structural members, such as upper and lower cross members and wing tank bulkheads, forming transverse ring systems are to be verified by direct calculations, e.g., finite element calculations on the basis of loads arising from hydrostatic, wave, spoil pressure and loadings on closing appliances of bottom openings. The stresses are in general not to exceed the following values:

Bending + axial stress (σ_b)	130/k N/mm^2
Shear stress (T)	70/k N/mm^2
Combined stress	180/k N/mm^2

where

k = higher tensile steel factor, *see* Pt 3, Ch 2,1.

8.5 Pillars within hoppers

8.5.1 Pillars are generally to comply with the requirements of Ch 1,4.4, account being taken of the maximum forces that can be applied by rams or other gear fitted for the purpose of activating hopper doors or valves.

8.6 Continuous coamings

8.6.1 Continuous coamings are to have a plate thickness of not less than 8,5 mm. A minimum thickness of 10 mm is recommended for coamings on grab dredgers. Where the depth of the coaming exceeds 80t, the plating is to be stiffened by one or more horizontal members so spaced that the width of the upper panel of plating does not exceed 65t and the width(s) of the lower panel(s) do(es) not exceed 80t.

8.6.2 Where the coaming is stiffened with flat bar members, the members are to have a breadth not less than $0{,}04S_s$ and a thickness not less than 0,05 times their breadth, or 8,5 mm, whichever is the greater. They are to have a minimum inertia of:

$$I = 2S_s^2 A_1 \text{ cm}^4$$

where

A_1 and I include the coaming plating for mid-panel above to mid-panel below the stiffener, and

S_s = spacing of the brackets required by this sub-Section, in metres.

Where stiffeners other than flat bars are used, they are to have at least the same minimum thickness and inertia as required for flat bars.

8.6.3 The upper edge of the coaming is to be stiffened by a fabricated flange, box girder or equivalent structure having a width not less than $0{,}05S_s$ and an inertia not less than:

$$I = 2{,}86S_s^2 A_1 \text{ cm}^4$$

where

A_1 and I include the coaming plating down to mid-panel below

The thickness and/or attachments of the stiffening member are to be such as to minimise any likelihood of local instability under compression loading.

8.6.4 The coamings are to be supported by substantial brackets spaced generally not more than 3,0 m apart where the coamings have a height of more than 600 mm, nor more than 2,5 m where the coamings have a height of more than 1,0 m but on longitudinally framed ships the brackets are to be arranged in way of each deck transverse. Additional brackets may be required in way of the ends of hopper upper cross-ties, especially those which themselves support hopper door operating rams or similar equipment.

8.6.5 The ends of continuous coamings are to be well scarfed into the ship's structure at the ends of spoil spaces. Unless longitudinal deckhouse bulkheads are fitted in this area, the coamings are to be extended beyond the end of the spoil space opening for a distance of at least one frame space, or 1,5 times the coaming height, whichever is the greater.

■ *Section 9*
Watertight bulkheads

9.1 Arrangements of bulkheads

9.1.1 The number of watertight bulkheads is to be not less than that required for dry cargo ships, *see* Pt 3, Ch 3,4. Their positioning is to be such that one extends the full width of the ship at each end of the spoil spaces, *see also* 8.2. Proposals to dispense with one or more of the watertight bulkheads in that part of the ship in way of spoil spaces may be submitted for consideration. In particular, watertight bulkheads need not be fitted within spoil spaces and an increased spacing of bulkheads in the spaces abreast of spoil spaces will generally be accepted provided that:

(a) Suitable structural compensation is arranged; and
(b) the stability is checked in the damaged condition.

■ *Section 10*
Exposed casings

10.1 Scantlings and access

10.1.1 Exposed casings on ships classed **A1 protected waters service** are to have scantlings as required for deckhouses on dry cargo ships classed **100A1**. On ships classed **100A1**, where T_m equals or exceeds the draught corresponding to a Type 'B-60' ship freeboard, direct access is not permitted to the machinery spaces (including dredging pump-rooms) from the freeboard deck. Doors may be fitted in exposed casing bulkheads, provided that they lead to a space which is of equivalent strength to the casing and is separated from the machinery space by a second watertight door.

■ *Section 11*
Dredging machinery seats and dredging gear

11.1 Dredging machinery seats

11.1.1 The seats supporting the main dredging machinery are to be at least as substantial as those required for the main propulsion machinery for dry cargo ships, *see* Pt 3, Ch 7,6. Continuity between the longitudinal and transverse members of main engine seats and the ship's bottom structure is to be arranged where practicable. Where floors are cut away below dredging pumps, they are to be fitted with face bars, and special care is to be taken to minimise stress-raising details and to ensure good workmanship.

11.2 Dredging gear

11.2.1 Where masts or derrick posts support dredging gear which will be subjected to vibration or other dynamic loads in addition to its true weight, this must be taken into account in the calculations. The dynamic multiplier should be taken between two and three according to the type of machinery and gear used.

Section 12
Ladder wells

12.1 Transverse strength at deck

12.1.1 Where ladder wells are incorporated so that the length of the well exceeds 1,5 times the width of the deck remaining on each side of the well, the portions of the ship on each side of the well are to be adequately cross-connected in the region of their free ends, unless the design of the ship renders this impracticable, in which case alternative arrangements are to be made to avoid high stress concentrations at the inboard end of the well.

Section 13
Fenders

13.1 Fenders and reinforcement in way

13.1.1 Dredgers designed to work in conjunction with hopper barges are to be fitted with permanent rubbing strakes or fenders extending down to their lowest normal operating waterline. On transversely framed vessels it is recommended that the side structure in way of the lower edge of the fender be reinforced by a stringer and/or cross-ties. It is recommended that, where wooden fenders are fitted to dredgers operating in tropical sea-water, the fenders be cut just above the deepest working waterline and a gap be left sufficient to prevent water soaking up into the fenders.

Section 14
Rudders

14.1 Rudders on bucket dredgers

14.1.1 Where bucket dredgers are arranged with bucket ladders at their stern, the ship's rudders are to be kept well clear of the buckets to minimise the likelihood of damage to the rudders by large objects which may be dredged up. For rudder calculations, *see* Pt 3, Ch 13.

Section 15
Spoil space weirs and overflows

15.1 General

15.1.1 All spoil spaces are to be arranged to allow the safe and efficient overboard discharge of excess water in all weather conditions in which the ship is classed to operate. In ships over 90 m in length and in all ships classed for unrestricted service the spoil space overflows are to be arranged via enclosed overflow trunks so designed as to keep the decks of the ship clear of spoil and water.

15.1.2 In general, bulwarks are not to be fitted in way of open top spoil spaces on dredging and reclamation craft.

15.1.3 Where a ship operates at the maximum draught that could be assigned in accordance with the *International Convention on Load Lines, 1966*, the overflow arrangements fitted should ensure that when the spoil space is loaded, this draught is not exceeded.

15.1.4 Where a hopper dredger having releasing arrangements for cargo dumping, e.g., bottom doors, etc., is permitted by an Administration to be assigned a freeboard less than that which could be assigned by the *International Convention on Load Lines, 1966:*

(a) The structural strength and bending moments are to be acceptable for the deeper draught indicated, and
(b) the dredger is to be operated in a zone of operation and in such weather conditions as are considered appropriate.

15.1.5 Adequate arrangements are to be fitted to prevent overloading under any condition of loading having due regard to trim. The size and position of the overflows are to be confirmed by a loading trial, which is to be carried out when the spoil space is loaded with dredgings of the same density as is likely to be loaded in service.

15.1.6 The cutting of overflow discharge trunk openings in the sheerstrake is to be avoided wherever practicable. In ships over 70 m in length, spoil space overflow discharge trunk openings are not to be cut within 800 mm of the upper edge of the sheerstrake. They are to have corner radii of not less than 150 mm, and suitable compensation is to be arranged. In no case is a discharge trunk to pierce the sheerstrake in way of discontinuities such as breaks of superstructure.

Section 16
Scuppers and sanitary discharges and side scuttles

16.1 General

16.1.1 In all areas where mechanical damage might be likely, all side scuttles, scuppers and discharges, including their valves, controls and indicators, are to be well protected. Consideration is to be given to the likelihood of impact damage to scuttles and discharges due to barges coming alongside, and to scuppers becoming blocked by sand or other spoil which may spill onto the decks or other areas being drained.

16.1.2 Consideration will be given to requests for relaxation of requirements relating to scuttles, scuppers and discharges on ships classed **A1 protected waters service**.

Section 17
Split hopper dredgers and barges

17.1 Symbols and definitions

17.1.1 The symbols used in this Section are defined as follows:

H = height of spoil above base line, in metres
H_s = depth of hopper seal, in metres
L_h = length of hopper well, in metres
M_H = design horizontal bending moment in hopper side wall, in kN m (tonne-f m). A moment giving rise to tensile stress in the side shell is to be taken as positive
P = net pressure per metre ship length resulting from the spoil pressure and the hydrostatic load, *see* Fig. 12.17.2
= $4,9\,(p\,(H - H_s)^2 - 1,025\,(T - H_s)^2)$ kN/m
$(0,5\,(p\,(H - H_s)^2 - 1,025\,(T - H_s)^2)$ tonne-f/m)
S_h = span between the centres of hinges, in metres

17.1.2 Other symbols are defined in 1.5.1.

17.2 Hull bending strength

17.2.1 The modulus of the cross-section of the vessel is to be not less than that required by 2.3.1. In addition, the combined stress σ_c, at any point on the cross-section of one half hull, is not to exceed the permissible combined stress σ given in Pt 3, Ch 4,5.5. The combined stress at any point on the cross-section is to be determined from the following expression:

$$\sigma_c = \left(\frac{M_N}{Z_N} + \frac{M_p}{Z_p}\right) \times 10^{-3} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

where

$M_N = \pm M_V \cos\phi \pm M_H \sin\phi$ kN m (tonne-f m)
$M_p = \pm M_H \cos\phi \pm M_V \sin\phi$ kN m (tonne-f m)
$M_V = \pm 0,5\,(M_s + M_w)$ kN m (tonne-f m)

where the still water bending moments hogging and sagging are to be combined with the appropriate wave bending moment to give a total moment, M_V, hogging (positive) and sagging (negative)

M_w is defined in 1.5.1.

f_1 = ship service factor, *see* Table 12.2.1
$M_H = 0,125P\,L_h\,(2S_h - L_h) \pm M_L$ kN m (tonne-f m)
$M_L = 0,286\,f_1\,L^2\,B$ kN m ($0,029\,f_1\,L^2\,B$ tonne-f m)
$P = 4,9\,(\rho\,(H - H_s)^2 - 1,025\,(T - H_s)^2)$ kN m
$(0,5\,(\rho\,(H - H_s)^2 - 1,025\,(T - H_s)^2)$ tonne-f m)

Account is to be taken of the sign of individual bending moment component in the determination of M_N, M_p, M_V and M_H

I_{NN} = second moment of area of the section of one half hull for all longitudinal continuous material about principal axis NN, in m^4
I_{PP} = second moment of area of the section of one half hull for all longitudinal continuous material about principal axis PP, in m^4

$Z_p = \dfrac{I_{PP}}{y_P}$ in m^3, the modulus of section to a point y_P m, from the principal axis PP

$Z_N = \dfrac{I_{NN}}{y_N}$ in m^3, the modulus of section to a point y_N m, from the principal axis NN

ϕ = angle of rotation of the principal axis NN with respect to the global horizontal axis YY, in degrees.

See also Fig. 12.17.1.

17.2.2 The combined stress for dredging conditions, where draught T_m exceeds T, is not to exceed the permissible combined stress σ_c obtained from 17.2.1.

The combined stress is to be obtained from the expression for σ_c given in 17.2.1, substituting the following expression of M_V:

$M_V = \pm 0,5\,(M_{sm} + M_{wd})$ kN m (tonne-f m)

where

$M_{wd} = 0,56f_2\,M_{wo}$ and M_{wo} is determined from Pt 3, Ch 4,5.2, using C_{bm} in place of C_b and f_2 is given in Pt 3, Ch 4,5.2.

17.3 Separation arrangements

17.3.1 Hinges, actuating and locking devices provided to facilitate separation of the split hulls to discharge spoil are to be of efficient design and of adequate strength and scantlings to ensure safe discharge operations. Hydraulic rams or other actuating devices are to have sufficient power to ensure controlled opening operations and to achieve closing of the hulls in all anticipated weather conditions.

17.3.2 Locking devices are to be of a suitable design and strength to ensure that accidental separation of the hulls cannot occur due to ship motions and vibrations.

17.3.3 Hinge pin gudgeons are to be efficiently connected to the hull structure by means of brackets or equivalent and effectively integrated with local structure which is to be suitably reinforced. Suitable reinforcement is to be fitted to local hull structure in way of anchorages for rams and locking devices to ensure efficient transmission of loading from these devices into the hull.

17.3.4 The forces acting on hinges, actuating mechanisms and locking devices are to be determined by direct calculations based on the maximum combination of loading which can be expected in any service condition. In general, this will require the resolution of the static and dynamic systems of force acting on the hulls taking due account of the relative locations of hinges, actuating mechanisms and locking devices. Fig. 12.17.2 illustrates a typical arrangement of hinges and mechanisms together with associated static loads. In general, one half of the load acting on one half hull may be assumed to act on the forward hinge assembly and one half on the after hinge assembly.

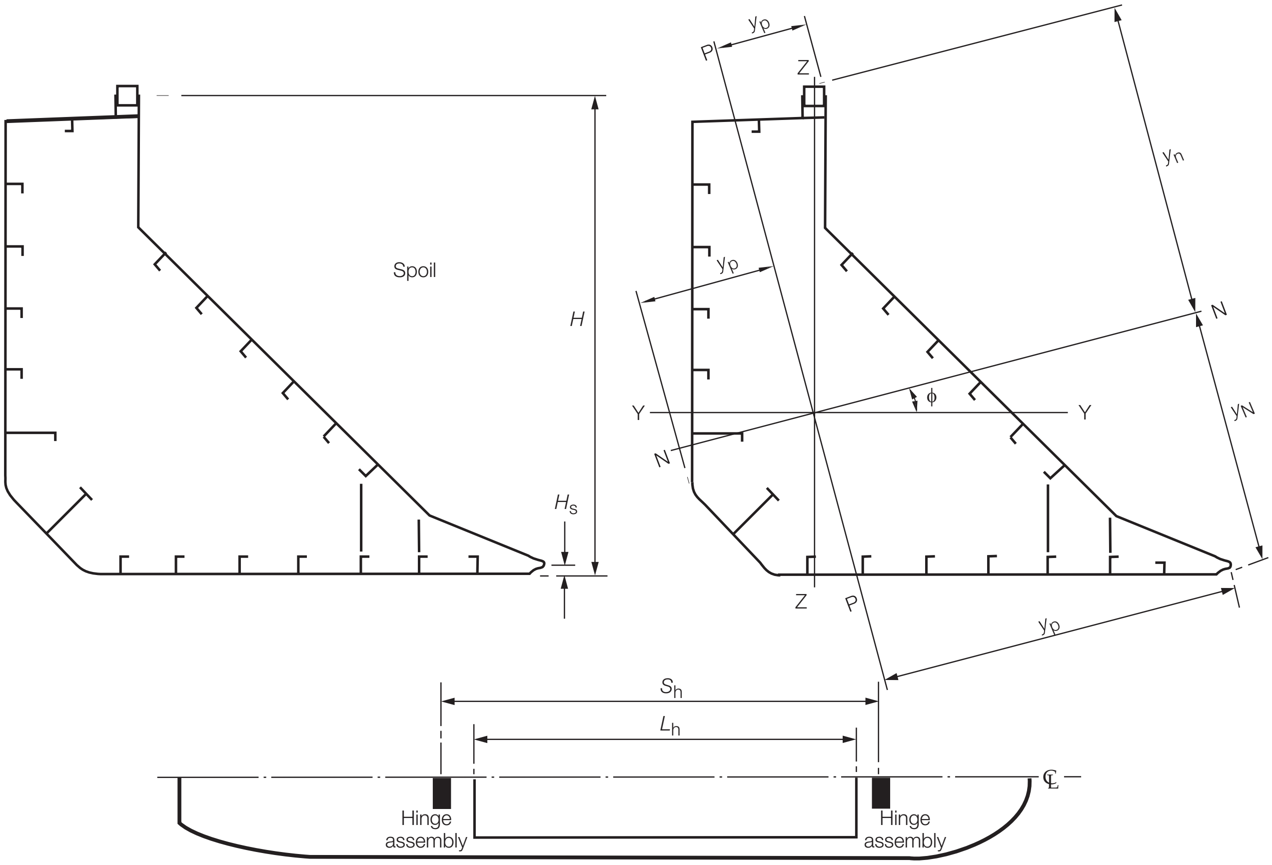


Fig. 12.17.1 Split hulled vessels

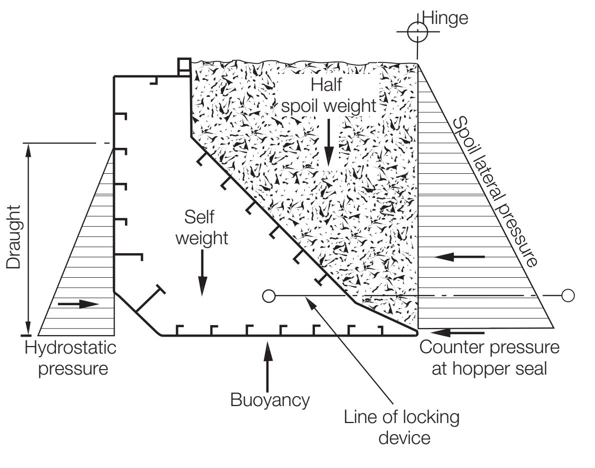


Fig. 12.17.2 Split hopper dredger

17.4 Hinge pins

17.4.1 The diameter of the hinge pins is to be determined using the maximum resultant shear force acting on the pin cross-section in conjunction with an average shear stress not exceeding $\frac{62}{k}$ N/mm² $\left(\frac{6,3}{k}\right.$ kgf/mm²$\left.\right)$

In no case is the diameter of the hinge pin to be less than that calculated from the following expression:

$$D_p = 20 \sqrt{\frac{L^{0,5} B D K}{n}} \text{ mm}$$

where

k = higher tensile steel factor, *see* Pt 3, Ch 2,1

n = the number of pin cross-sections resisting shear forces

and *L*, *B* and *D* are defined in 1.5.1.

17.4.2 Where arrangements are such that hinge pins are subjected to significant bending, the diameter of the pins will be specially considered.

Section 18
Direct calculations

18.1 Application

18.1.1 Direct calculations may be used to assess the scantlings of primary structure in spoil spaces and adjacent structure.

18.1.2 Direct calculations may be required to be submitted in respect of unusual structural arrangements.

18.2 Procedures

18.2.1 Methods applied for direct calculations of scantlings will be given individual consideration dependent on the particular structural configuration, *see also* Pt 3, Ch 1,3.1.

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Section

■ *Scope*

The Chapters in this Part cover the construction and installation of main propulsion and auxiliary machinery systems, together with their associated equipment, boilers, pressure vessels, pumping and piping arrangements and steering gear fitted in classed ships.

■ *Section 1* General

1.1 Machinery to be constructed under survey

1.1.1 In ships built under Special Survey, all important units of equipment are to be surveyed at the manufacturer's works. The workmanship is to be to the Surveyor's satisfaction and the Surveyor is to be satisfied that the components are suitable for the intended purpose and duty. Examples of such units are:

- Main propulsion engines including their associated gearing, flexible couplings, scavenge blowers and superchargers.
- Boilers supplying steam for propulsion or for services essential for the safety or the operation of the ship at sea, including superheaters, economisers, desuper-heaters, steam heated steam generators and steam receivers. All other boilers having working pressures exceeding 3,4 bar (3,5 kgf/cm^2), and having heating surfaces greater than 4,65 m^2.
- Auxiliary engines which are the source of power for services essential for safety or for the operation of the ship at sea.
- Steering machinery.
- Athwartship thrust units, their prime movers and control mechanisms.
- All pumps necessary for the operation of main propulsion and essential machinery, e.g. boiler feed, cooling water circulating, condensate extraction, oil fuel and lubricating oil pumps.
- All heat exchangers necessary for the operation of main propulsion and essential machinery, e.g. air, water and lubricating oil coolers, oil fuel and feed water heaters, de-aerators and condensers, evaporators and distiller units.
- Air compressors, air receivers and other pressure vessels necessary for the operation of main propulsion and essential machinery. Any other unfired pressure vessels for which plans are required to be submitted as detailed in Ch 11,1.6.
- All pumps essential for safety of the ship, e.g., fire, bilge and ballast pumps.
- Valves and other components intended for installation in pressure piping systems having working pressures exceeding 7 bar.
- Alarm and control equipment as detailed in Pt 6, Ch 1.
- Electrical equipment and electrical propelling machinery as detailed in Pt 6, Ch 2.

1.2 Survey for classification

1.2.1 The Surveyors are to examine and test the materials and workmanship from the commencement of work until the final test of the machinery under full power working conditions. Any defects, etc., are to be indicated as early as possible. On completion, the Surveyors will submit a report and if this is found to be satisfactory by the Committee a certificate will be granted and an appropriate notation will be assigned in accordance with Pt 1, Ch 2.

1.3 Alternative system of inspection

1.3.1 Where items of machinery are manufactured as individual or series produced units the Committee will be prepared to give consideration to the adoption of a survey procedure based on quality assurance concepts utilising regular and systematic audits of the approved manufacturing and quality control processes and procedures as an alternative to the direct survey of individual items.

1.3.2 In order to obtain approval, the requirements of Section 6 are to be complied with.

1.4 Departures from the Rules

1.4.1 Where it is proposed to depart from the requirements of the Rules, the Committee will be prepared to give consideration to the circumstances of any special case.

1.4.2 Any novelty in the construction of the machinery, boilers or pressure vessels is to be reported to the Committee.

Section 2
Plans and particulars

2.1 Plans

2.1.1 Before the work is commenced, plans in triplicate of all machinery items, as detailed in the Chapters giving the requirements for individual systems, are to be submitted for consideration. The particulars of the machinery, including power ratings, grade(s) of fuel and design calculations, where applicable, necessary to verify the design, are also to be submitted. Any subsequent modifications are subject to approval before being put into operation. It will not be necessary for plans and particulars to be submitted for each ship, provided the basis plans for the engine size and type have previously been approved as meeting the requirements of these Rules. Any alterations to basis design materials or manufacturing procedure are to be re-submitted for consideration.

2.2 Materials

2.2.1 The materials used in the construction are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). Materials for which provision is not made therein may be accepted, provided that they comply with an approved specification and such tests as may be considered necessary.

2.2.2 Materials used in the construction of machinery and its installation are not to contain asbestos.

2.3 Welding

2.3.1 Welding consumables, plant and equipment are to be in accordance with the requirements specified in Ch 13,1.8 of the Rules for Materials.

2.3.2 Welding procedures and welder qualifications are to be tested and qualified in accordance with the requirements specified in Chapter 12 of the Rules for Materials.

2.3.3 Production weld tests are to be carried out where specified in the subsequent Chapters of these Rules.

2.3.4 All finished welds are to be subjected to non-destructive examination in accordance with the requirements specified in Ch 13,2.12 of the Rules for Materials and or the requirements specified in the subsequent Chapters of these Rules.

Section 3
Operating conditions

3.1 Availability for operation

3.1.1 The design and arrangement are to be such that the machinery can be started and controlled on board ship, without external aid, so that the operating conditions can be maintained under all circumstances.

3.1.2 Machinery is to be capable of operating at defined power ratings with a range of fuel grades specified by the engine, boiler or machinery manufacturer and agreed by the Owner/Operator.

3.1.3 Machinery is to be capable of operating satisfactorily in accordance with the manufacturer's stated operating conditions within an operational profile specified for the ship by the Owner/Operator and agreed by the manufacturer/ system designer.

3.2 Fuel

3.2.1 The flash point (closed cup test) of oil fuel for use in ships classed for unrestricted service is, in general, to be not less than 60°C.

3.2.2 For emergency generator engines, fuel having a flash point of not less than 43°C may be used.

3.2.3 Fuels with flash points lower than 60°C, but not less than 43°C unless specially approved, may be used in ships intended for service restricted to geographical limits where it can be ensured that the temperature of the machinery and boiler spaces will always be 10°C below the flash point of the fuel. In such cases, safety precautions and the arrangements for storage and pumping will be specially considered.

3.2.4 The use of fuel having a lower flash point than specified in 3.2.1 to 3.2.3 as applicable may be permitted provided that such fuel is not stored in any machinery space and the arrangements for the complete installation are specially approved.

3.2.5 For engines operating on 'boil-off' vapours from the cargo, *see* Lloyd's Register's (hereinafter referred to as 'LR') *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk*.

3.3 Power ratings

3.3.1 In the Chapters where the dimensions of any particular component are determined from shaft power, P, in kW (H, in shp), and revolutions per minute, R, the values to be used are to be derived from the following:

- For main propelling machinery, the maximum shaft power and corresponding revolutions per minute giving the maximum torque for which the machinery is to be classed.
- For auxiliary machinery, the maximum continuous shaft power and corresponding revolutions per minute which will be used in service.

3.4 Definitions

3.4.1 Main propulsion engines and turbines are defined as those which drive main propelling machinery directly or indirectly through mechanical shafting and which may also drive electrical generators to provide power for auxiliary services. Auxiliary engines and turbines are defined as those coupled to electrical generators which provide power for auxiliary services, for electrical main propulsion motors or a combination of both.

3.4.2 Units and formulae included in the Rules are shown in SI units followed by metric units in brackets, where appropriate.

3.4.3 Where the metric version of shaft power, i.e. (shp), appears in the Rules, 1 shp is equivalent to 75 kgf m/s or 0,735 kW.

3.4.4 Pressure gauges may be calibrated in bar, where:

1 bar = 0,1 N/mm^2 = 1,02 kgf/cm^2.

3.5 Ambient reference conditions

3.5.1 The rating for classification purposes of main and essential auxiliary machinery intended for installation in sea-going ships to be classed for unrestricted (geographical) service is to be based on a total barometric pressure of 1000 mb, an engine room ambient temperature or suction air temperature of 45°C, a relative humidity of 60 per cent and sea-water temperature or, where applicable, the temperature of the charge air coolant at the inlet of 32°C. The equipment manufacturer is not expected to provide simulated ambient reference conditions at a test bed.

3.5.2 In the case of a ship to be classed for restricted service, the rating is to be suitable for the temperature conditions associated with the geographical limits of the restricted service, *see* Pt 1, Ch 2.

3.6 Ambient operating conditions

3.6.1 Main and essential auxiliary machinery and equipment is to be capable of operating satisfactorily under the conditions shown in Table 1.3.1.

3.6.2 Where it is intended to allow for operation in ambient temperatures outside those shown in Table 1.3.1, the permissible temperatures and associated periods of time are to be specified and details are to be submitted for consideration. Propelling and essential auxiliary machinery, *see* Pt 1, Ch 2,2.8.1, is to retain a continuous level of functional capability under these conditions and any level of degraded performance is to be defined. Operation under these circumstances is not to be the cause of damage to equipment in the system and is additionally to be acceptable to the National Authority of the country in which the ship is to be registered.

Table 1.3.1 Ambient operating conditions

Air		
Installations, Components	Location, arrangement	Temperature range (°C)
Machinery and electrical installations	In enclosed spaces	0 to +45, *see* Note 1
	On machinery component, boilers. In spaces subject to higher and lower temperatures	According to specific local conditions, *see* Note 2
	On the open deck	–25 to +45, *see* Note 1
Water		
Coolant		Temperature (°C)
Sea-water or charge air coolant inlet to charge air cooler		–2 to +32, *see* Notes 1 and 3

NOTES
1. For ships intended to be classed for restricted service, a deviation from the temperatures stated may be considered.
2. Details of local environmental conditions are stated in Annex B of IEC 60092: *Electrical installations in ships – Part 101: Definitions and general requirements.*
3. Charge air cooling arrangements utilising re-circulated cooling to maintain temperatures in a different range are accepted where the machinery and equipment operation is not degraded with a primary supply of cooling in the temperature range stated in this Table.

3.7 Inclination of ship

3.7.1 Main and essential auxiliary machinery is to operate satisfactorily under the conditions as shown in Table 1.3.2.

3.7.2 Any proposal to deviate from the angles given in Table 1.3.2 will be specially considered taking into account the type, size and service conditions of the ship.

3.7.3 The dynamic angles of inclination in Table 1.3.2 may be exceeded in certain circumstances dependent upon ship type and operation. The Shipbuilder is, therefore, to ensure that the machinery is capable of operating under these angles of inclination.

3.8 Power conditions for generator sets

3.8.1 Auxiliary engines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output (kW) and in the case of oil engines and gas turbines, of developing for a short period (15 minutes) an overload power of not less than 10 per cent, *see* Pt 6, Ch 2,8.2. In the case of oil engines, they are to be tested at works trials at an overload power of 10 per cent for a period of 30 minutes, *see* Table 2.11.1 in Pt 5, Ch 2.

Table 1.3.2 Inclination of ship

Installations, components	Angle of inclination, degrees, *see* Note 1			
	Athwartships		Fore-and-aft	
	Static	Dynamic	Static	Dynamic
Main and auxiliary machinery essential to the propulsion and safety of the ship	15	22,5	5 *see* Note 2	7,5
Emergency machinery and equipment fitted in accordance with Statutory Requirements	22,5 *see* Note 3	22,5	10	10

NOTES

1. Athwartships and fore-and-aft inclinations may occur simultaneously.
2. Where the length of the ship exceeds 100 m, the fore-and-aft static angle of inclination may be taken as:

   $$\frac{500}{L} \text{ degrees}$$

   where L = length of ship, in metres.
3. In ships for the carriage of liquefied gas and of liquid chemicals the emergency machinery and equipment fitted in accordance with Statutory Requirements is also to remain operable with the ship flooded to a final athwartships inclination to a maximum angle of 30°.

3.8.2 Engine builders are to satisfy the Surveyors by tests on individual engines that the above requirements, as applicable, can be complied with, due account being taken of the difference between the temperatures under test conditions and those referred to in 3.5. Alternatively, where it is not practicable to test the engine/generator set as a unit, type tests (e.g., against a brake) representing a particular size and range of engines may be accepted. With oil engines and gas turbines any fuel stop fitted is to be set to permit the short period overload power of not less than 10 per cent above full rated output (kW) being developed.

3.9 Astern power

3.9.1 Sufficient astern power is to be provided to maintain control of the ship in all normal circumstances.

3.9.2 Astern turbines are to be capable of maintaining in free route astern 70 per cent of the ahead revolutions, corresponding to the maximum propulsion shaft power for which the machinery is to be classed, for a period of at least 30 minutes without undue heating of the ahead turbines and condensers.

3.10 Machinery interlocks

3.10.1 Interlocks are to be provided to prevent any operation of engines or turbines under conditions that could hazard the machinery and personnel. These are to include 'turning gear engaged', 'low lubricating oil pressure', where oil pressure is essential for the prevention of damage during start up, 'shaft brake engaged' and where machinery is not available due to maintenance or repairs. The interlock system is to be arranged to be 'fail safe'.

3.10.2 Where machinery is provided with manual turning gear, warning devices or notices may be provided as an alternative to interlocks as required by 3.10.1.

■ *Section 4* Machinery room arrangements

4.1 Accessibility

4.1.1 Accessibility, for attendance and maintenance purposes, is to be provided for machinery plants.

4.2 Machinery fastenings

4.2.1 Bedplates, thrust seatings and other fastenings are to be of robust construction, and the machinery is to be securely fixed to the ship's structure to the satisfaction of the Surveyor.

4.3 Resilient mountings

4.3.1 The dynamic angles of inclination in Table 1.3.2 may be exceeded in certain circumstances dependent upon ship type and operation. The Shipbuilder is, therefore, to ensure that the vibration levels of flexible pipe connections, shaft couplings and mounts remain within the limits specified by the component manufacturer for the conditions of maximum dynamic inclinations to be expected during service, start-stop operation and the natural frequencies of the system. Due account is to be taken of any creep that may be inherent in the mount.

4.3.2 Anti-collision chocks are to be fitted together with positive means to ensure that manufacturers' limits are not exceeded. Suitable means are to be provided to accommodate the propeller thrust.

4.3.3 A plan showing the arrangement of the machinery together with documentary evidence of the foregoing is to be submitted.

4.4 Ventilation

4.4.1 All spaces including engine and cargo pump spaces, where flammable or toxic gases or vapours may accumulate, are to be provided with adequate ventilation under all conditions.

4.4.2 Machinery spaces of category A shall be adequately ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather conditions, including heavy weather, a sufficient supply of air is maintained to the spaces for the safety and comfort of personnel and the operation of the machinery. Any other machinery space shall be adequately ventilated, as appropriate for the purpose of that machinery space.

4.5 Fire protection

4.5.1 All surfaces of machinery where the surface temperature may exceed 220°C and where impingement of flammable liquids may occur are to be effectively shielded to prevent ignition. Where insulation covering these surfaces is oil-absorbing or may permit penetration of oil, the insulation is to be encased in steel or equivalent.

4.6 Means of escape

4.6.1 For means of escape from machinery spaces, *see* SOLAS 1974 as amended Regulation II-2/13.4.1 or 13.4.2 or Pt 6, Ch 4,3.4, as applicable.

4.7 Communications

4.7.1 Two independent means of communication are to be provided between the bridge and engine room control station from which the engines are normally controlled, *see also* Pt 6, Ch 1,2.

4.7.2 One of these means is to visually indicate the order and response, both at the engine room control station and on the bridge.

4.7.3 At least one means of communication is to be provided between the bridge and any other control position(s) from which the propulsion machinery may be controlled.

4.8 Category A machinery spaces

4.8.1 'Machinery spaces of Category A' are those spaces and trunks to such spaces which contain:

(a) internal combustion machinery used for main propulsion; or
(b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
(c) any oil-fired boiler or oil fuel unit.

■ *Section 5* **Trials**

5.1 Inspection

5.1.1 Tests of components and trials of machinery, as detailed in the Chapters giving the requirements for individual systems, are to be carried out to the satisfaction of the Surveyors.

5.2 Sea trials

5.2.1 For all types of installation, the sea trials are to be of sufficient duration, and carried out under normal manoeuvring conditions, to prove the machinery under power. The trials are also to demonstrate that any vibration which may occur within the operating speed range is acceptable.

5.2.2 The trials are to include demonstrations of the following:

(a) The adequacy of the starting arrangements to provide the required number of starts of the main engines.
(b) The ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manoeuvring conditions, and so bring the ship to rest from maximum service speed. Results of the trials are to be recorded.
(c) In turbine installations, the ability to permit astern running at 70 per cent of the full power ahead revolutions without adverse effects. This astern trial need only be of 15 minutes' duration, but may be extended to 30 minutes at the Surveyor's discretion.

5.2.3 Where controllable pitch propellers are fitted, the free route astern trial is to be carried out with the propeller blades set in the full pitch astern position. Where emergency manual pitch setting facilities are provided, their operation is to be demonstrated to the satisfaction of the Surveyors.

5.2.4 In geared installations, prior to full power sea trials, the gear teeth are to be suitably coated to demonstrate the contact markings, and on conclusion of the sea trials all gears are to be opened up sufficiently to permit the Surveyors to make an inspection of the teeth. The marking is to indicate freedom from hard bearing, particularly towards the ends of the teeth, including both ends of each helix where applicable. The contact is to be not less than that required by Ch 5,4.2 or Ch 5,5.2, as applicable.

5.2.5 The following information is to be available on board for the use of the master and designated personnel:

- The results of trials to determine stopping times, ship headings and distance;
- For ships having multiple propellers, the results of trials to determine the ability to navigate and manoeuvre with one or more propellers inoperative.
- For ships having a single propulsor driven by multiple engines or electric motors, the results of trials to determine the ability to navigate and manoeuvre with the largest engine or electric motor inoperative.

5.2.6 Where the ship is provided with supplementary means for manoeuvring or stopping, the effectiveness of such means are to be demonstrated and recorded as referred to in 5.2.5.

5.2.7 The stopping distance achieved when ship is initially proceeding ahead with a speed of at least 90 per cent of the ship's speed corresponding to 85 per cent of the maximum rated propulsion power should not exceed 15 ship lengths after the astern order has been given. However, if the displacement of the ship makes this criterion impracticable then in no case should the stopping distance exceed 20 ship lengths.

5.2.8 All trials are to be to the Surveyor's satisfaction.

■ *Section 6* Quality Assurance Scheme for Machinery

6.1 General

6.1.1 This certification scheme is applicable to both individual and series produced items manufactured under closely controlled conditions and will be restricted to works where the employment of quality control procedures is well established. LR will have to be satisfied that the practices employed will ensure that the quality of finished products is to standards which would be demanded when using traditional survey techniques.

6.1.2 The Committee will consider proposed designs for compliance with LR's Rules or other appropriate requirements and the extent to which the manufacturing processes and control procedure ensure conformity of the product to the design. A comprehensive survey will be made by the Surveyors of the actual operation of the quality control programme and of the adequacy and competence of the staff to implement it.

6.1.3 The procedures and practices of manufacturers which have been granted approval will be kept under review.

6.1.4 Approval by another organisation will not be accepted as sufficient evidence that a manufacturer's arrangements comply with LR's requirements.

6.2 Requirements for approval

6.2.1 **Facilities**. The manufacturer is required to have adequate equipment and facilities for those operations appropriate to the level of design, development and manufacture being undertaken.

6.2.2 **Experience**. The manufacturer is to demonstrate that the firm has experience consistent with technology and complexity of the product type for which approval is sought and that the firm's products have been of a consistently high standard.

6.2.3 **Quality policy**. The manufacturer is to define management policies and objectives or quality and ensure that these policies and objectives are implemented and maintained throughout all phases of the work.

6.2.4 **Quality system documentation**. The manufacturer is to establish and maintain a documented quality system capable of ensuring that material or services conform to the specified requirements, including the requirements of this Section.

6.2.5 **Management representative**. The manufacturer is to appoint a management representative preferably independent of other functions, who is to have defined authority and responsibilities for the implementation and maintenance of the quality system.

6.2.6 **Responsibility and authority.** The responsibilities and authorities of senior personnel within the quality system are to be clearly documented.

6.2.7 **Internal audit**. The manufacturer is to conduct internal audits to ensure continued adherence to the system. An audit programme is to be established with audit frequencies scheduled on the basis of the status and importance of the activity and adjusted on the basis of previous results.

6.2.8 **Management review**. The quality system established in accordance with the requirements of this Section is to be systematically reviewed at appropriate intervals by the manufacturer to ensure its continued effectiveness. Records of such management reviews are to be maintained and be made available to the Surveyors.

6.2.9 **Contract review**. The manufacturer is to establish and implement procedures for conducting a contract review prior to and after acceptance to ensure that:

(a) the requirements of the contract are adequately defined and documented;
(b) any requirements differing from those specified in the original enquiry/tender are resolved; and
(c) the manufacturer has the capability to meet and verify compliance to the specified requirements.

6.2.10 **Work instruction**. The manufacturer is to establish and maintain clear and complete written work instructions that prescribe the communication of specified requirements and the performance of work in design, development and manufacture which would be adversely affected by lack of such instructions.

6.2.11 **Documentation and change control**. The manufacturer is to establish and maintain control of all documentation that relates to the requirements of this scheme. This control is to ensure that:

(a) documents are reviewed and approved for adequacy by authorised personnel prior to use, are uniquely identified and include indication of approval and revision status;
(b) all changes to documentation are in writing and are processed in a manner that will ensure their availability at the appropriate location and preclude the use of non-applicable documents;
(c) provision is made for the prompt removal of obsolete documentation from all points of issue or use; and

(d) documents are to be re-issued after a practical number of changes have been issued.

6.2.12 **Records**. The manufacturer is to develop and maintain a system for collection, use and storage of quality records. The period of retention of such records is to be established in writing and is to be subject to agreement by the Committee.

6.2.13 **Design**. The manufacturer is to establish and maintain a design control system appropriate to the level of design being undertaken. Documented design procedures are to be established which:

(a) identify the design practices of the manufacturer's organisation including departmental instructions to ensure the orderly and controlled preparation of design and subsequent verification;
(b) make provision for the identification, documentation and appropriate approval of all design change and modifications;
(c) prescribe methods for resolving incomplete, ambiguous or conflicting requirements; and
(d) identify design inputs such as sources of data, preferred standard parts or materials and design information and provide procedures for their selection and review by the manufacturer for adequacy.

6.2.14 **Purchasing**. The manufacturer is to ensure that purchased material and services conform to specified requirements.

6.2.15 **Selection and approval of sub-contractors and suppliers**. The manufacturer is to establish and maintain records of acceptable suppliers and sub-contractors. The selection of such sources, and the type and extent of control exercised, are to be appropriate to the type of product or service and the suppliers' or sub-contractors' previously demonstrated capability and performance. Documented procedures for approval of new suppliers are to be established and records of vendor assessments (where carried out) are to be maintained and made available to the Surveyors upon request.

6.2.16 **Purchasing data**. Each purchasing document should contain a clear description of the material or service ordered including as applicable, the following:

(a) The type, class, grade, or other precise identification;
(b) The title or other positive identification and applicable issue of specifications, drawings, process requirements, inspection instructions and other relevant data.

6.2.17 **Verification of purchased material and services**. The manufacturer is to ensure that the Surveyors are afforded the right to verify at source or upon receipt that purchased material and services conform to specified requirements. Verification by the Surveyors shall not relieve the manufacturer of his responsibility to provide acceptable material nor is it to preclude subsequent rejection.

6.2.18 **Product identification**. The manufacturer is to establish and maintain a system for identification of the product to relevant drawings, specifications or other documents during all stages of production, delivery and installation.

6.2.19 **Manufacturing control**. The manufacturer is to ensure that those operations which directly affect quality are carried out under controlled conditions. These are to include the following:

(a) Written work instructions wherever the absence of such instructions could adversely affect compliance with specified requirements. These should define the method of monitoring and control of product characteristics.
(b) Established criteria for workmanship through written standards or representative samples.

6.2.20 **Special processes**. Those processes where effectiveness cannot be verified by subsequent inspection and test of the product are to be subjected to continuous monitoring in accordance with documented procedures in addition to the requirements specified in 6.2.19.

6.2.21 **Receiving inspection**. The manufacturer is to ensure that all incoming material is not to be used or processed until it has been inspected or otherwise verified as conforming to specified requirements. In establishing the amount and nature of receiving inspection, consideration is to be given to the control exercised by the supplier and documented evidence of quality conformance supplied.

6.2.22 **In-process inspection**. The manufacturer is to:

(a) perform inspection during manufacture on all characteristics that cannot be inspected at a later stage;
(b) inspect test and identify products in accordance with specified requirements;
(c) establish product conformance to specified requirements by use of process monitoring and control methods where appropriate;
(d) hold products until the required inspections and tests are completed and verified; and
(e) clearly identify non-conforming products to prevent unauthorised use, shipment, or mixing with conforming material.

6.2.23 **Final inspection**. The manufacturer is to perform all inspections and tests on the finished product necessary to complete the evidence of conformance to the specified requirements. The procedures for final inspection and test are to ensure that:

(a) all activities defined in the specification, quality plan or other documented procedure have been completed;
(b) all inspections and tests that should have been conducted at earlier stages have been completed and that the data is acceptable; and
(c) no product is to be dispatched until all the activities defined in the specifications, quality plan or other documented procedure have been completed, unless products have been released with the permission of the Surveyors.

6.2.24 **Inspection equipment**. The manufacturer is to be responsible for providing, controlling, calibrating and maintaining the inspection, measuring and test equipment necessary to demonstrate the conformance of material and services to the specified requirements or used as part of the manufacturing control system required by 6.2.19 and 6.2.20.

6.2.25 **Inspection and test status**. The manufacturer is to establish and maintain a system for the identification of inspection status of all material, components and assemblies by suitable means which distinguish between conforming, non-conforming and uninspected items. The relevant inspection and test procedures and records are to identify the authority responsible for the release of conforming products.

6.2.26 **Control of non-conforming material**.

(a) The manufacturer is to establish and maintain procedures to ensure that material that does not conform to the specified requirements is controlled to prevent inadvertent use, mixing or shipment. Repair, rework or concessions on non-conforming material and reinspection is to be in accordance with documented procedures.

(b) Records clearly identifying the material, the nature and extent of non-conformance and the disposition are to be maintained.

6.2.27 **Sampling procedures**. Where sampling techniques are used by the manufacturer to verify the acceptability of groups of products, the procedures adopted are to be in accordance with the specified requirements or are to be subject to agreement by the Surveyors.

6.2.28 **Corrective action**. The manufacturer is to establish and maintain documented procedures for the review of non-conformances and their disposition. These should provide for:

(a) monitoring of process and work operations and analysis of records to detect and eliminate potential causes of non-conforming material;

(b) continuing analysis of concessions granted and material scrapped or reworked to determine causes and the corrective action required;

(c) an analysis of customer complaints;

(d) the initiation of appropriate action with suppliers or sub-contractors with regard to receipt of non-conforming material; and

(e) an assurance that corrective actions are effective.

6.2.29 **Purchaser supplied material**. The manufacturer is to establish and maintain documented procedures for the control of purchaser supplied material.

6.2.30 **Handling, storage, and delivery**.

(a) The manufacturer is to establish and maintain a system for the identification preservation, segregation and handling of all material from the time of receipt through the entire production process. The system is to include methods of handling that prevent abuse, misuse, damage or deterioration.

(b) Secure storage areas or rooms are to be provided to isolate and protect material pending use. To detect deterioration, at an early stage, the condition of material is to be periodically assessed.

(c) The manufacturer is to arrange for the protection of the quality of his product during transit. The manufacturer is to ensure, in so far as it is practicable, the safe arrival and ready identification of the product at destination.

6.2.31 **Training**. The manufacturer is to follow a policy for recruitment and training which provides an adequate labour force with such skills as are required for each type of work operation. Appropriate records are to be maintained to demonstrate that all personnel performing process control, special processes inspection and test or quality system maintenance activities have appropriate experience or training.

6.3 Arrangements for acceptance and certification of purchased material

6.3.1 The manufacturer is to establish and maintain procedures and controls to ensure compliance with LR's requirements for certification of materials and components at the supplier's plant. The manufacturer's system for control of such purchased material may be based on one of the following alternatives subject to the approval of LR:

(a) Product certification by LR's Surveyors at the supplier's works in accordance with the requirements of the Rules for Materials.

(b) Agreed Inspection Procedures at the manufacturer's plant combined with documentary evidence of vendor assessments, vendor rating records and annual surveillance visits to the suppliers.

(c) Recognition of quality agreements between the manufacturer and his suppliers which are to provide for initial vendor assessments and regular surveillance visits (a minimum of four per year). The quality agreement must identify the individual in the supplier's plant who is charged with the responsibility for release of materials or components and the procedures to be adopted.

6.3.2 The alternatives proposed in 6.3.1(b) and (c) are not acceptable to LR for the following items:

(a) Engine components for which testing is a Rule requirement; and
   (i) the cylinder bore is equal to or exceeds 300 mm; or
   (ii) which are made by open forging techniques.

(b) Cast crankshafts where the journal diameter exceeds 85 mm.

6.3.3 Where the manufacturer's system for control of purchased material is based upon 6.3.1(b) or (c) the Surveyors shall also make surveillance visits to the supplier's works at the minimum specified intervals. The manufacturer is also to make available to the Surveyors documentary evidence of the operation of quality agreements or Agreed Inspection Procedures where applicable.

6.4 Information required for approval

6.4.1 Manufacturers applying for approval under this scheme are to submit the following information:

(a) A description of the products for which certification is required including, where applicable, model or type number.

(b) Applicable plans and details of material used.

(c) An outline description of all important manufacturing plant and equipment.

(d) A summary of equipment used for measuring and testing during manufacture and completion.
(e) The Quality Manual.
(f) A typical production flow chart and quality plan covering all stages from ordering of materials to delivery of the finished product.
(g) The system used for the identification of raw materials, semi-finished and finished products.
(h) The number and qualifications of all staff engaged in testing, inspection and quality control duties.
(j) A list of suppliers of components and manufacturers, proposed procedures to ensure compliance with LR's requirements for certification of materials and components at the supplier's plant.

6.5 Assessment of works

6.5.1 After receipt and appraisal of the information requested in 6.4 an inspection of the works is to be carried out by the Surveyors to examine in detail all aspects of production, and in particular the arrangements for quality control.

6.5.2 The Surveyors will not specify in detail acceptable quality control procedures, but will consider the arrangements proposed by the works in relation to the manufacturing processes and products.

6.5.3 In the event of procedures being considered inadequate, the Surveyors will advise the manufacturer how such procedures are to be revised in order to be acceptable to LR.

6.5.4 Gauging, measuring and testing devices are to be made available to the Surveyors, and where appropriate, personnel for the operation of such devices.

6.6 Approval of works

6.6.1 If the initial assessment of the works confirms that the manufacturing and quality control procedures are satisfactory, the Committee will issue to the manufacturer a Quality Assurance Approval Certificate which will include details of the products for which approval has been given. This Certificate will be valid for three years with renewal subject to satisfactory performance and to a satisfactory triennial re-assessment.

6.6.2 An extension of approval in respect of product type may be given at the discretion of the Committee without any additional survey of the works.

6.6.3 LR will publish a list of manufacturers whose works have been approved.

6.7 Maintenance of approval

6.7.1 The arrangements authorised at each works are to be kept under review by the Surveyors in order to ensure that the approved procedures for manufacture and quality control are being maintained in a satisfactory manner. This is to be carried out by:
(a) regular and systematic surveillance;
(b) intermediate audits at intervals of six months;
(c) triennial re-assessment of the entire quality system.

6.7.2 For the purpose of regular and systematic surveillance the Surveyors are to visit the works at intervals determined by the type of product and the rate of production. The Surveyors are to advise a senior member of the quality control department in regard to any matter with which they are not satisfied.

6.7.3 When minor deficiencies in the approved procedures are disclosed during the systematic surveillance the Surveyors may, at their discretion, apply more intensive supervision, including the direct inspection of products.

6.7.4 Any noteworthy departures from the approved plans of specifications are to be reported to the Surveyors and their written approval obtained prior to despatch of the item.

6.7.5 Minor alterations in the approved procedures may be permitted provided that the Surveyors are advised and their prior concurrence obtained.

6.7.6 In addition to the regular visits by the Surveyors, an intermediate audit is to be carried out every six months. This will normally be carried out by Surveyors other than those regularly in attendance at the works. This audit is to consist of an examination of part of the manufacturer's quality system. An audit plan will be established indicating those areas of the quality system which will be examined during every intermediate audit and the frequency of examination of other areas such that all areas are subject to audit before re-assessment is due.

6.7.7 The manufacturer's entire quality system is to be subject to re-assessment at three-yearly intervals. This is to be conducted by Surveyors nominated by Headquarters.

6.8 Suspension or withdrawal of approval

6.8.1 When the Surveyors have drawn attention to significant faults or deficiencies in the manufacturing or quality control procedures and these have not been rectified, approval of the works will be suspended. In these circumstances the manufacturer will be notified in writing of the Committee's reasons for the suspension of approval.

6.8.2 When approval has been suspended and the manufacturer does not effect corrective measures within a reasonable time, the Committee will withdraw the Quality Assurance Approval Certificate.

6.9 Identification of products

6.9.1 In addition to the normal marking by the manufacturer, all certified products are to be hard stamped on a principal component with a suitable identification, LR's brand and the number of the approved works.

6.9.2 After issue of the Quality Assurance Approval Certificate, products may be dispatched with certificates signed on behalf of the manufacturer by an authorised senior member of the quality control department or by an authorised deputy. These certificates are to be countersigned by the Surveyor to certify that the approved arrangements are being kept under review by regular and systematic auditing of the manufacturer's quality system.

6.9.3 The following declarations are to be included on each certificate:

(a) 'This is to certify that the items described above have been constructed and tested with satisfactory results in accordance with the Rules of Lloyd's Register.
 Signed...
 Manager of QC Department.'

(b) 'This certificate is issued by the manufacturer in accordance with the arrangements authorised by Lloyd's Register in Quality Assurance Approval Certificate No. QA.M.................................. I certify that these arrangements are being kept under review by regular and systematic auditing of the approved manufacturing and quality control procedures.
 Signed...
 Surveyor to Lloyd's Register'.

6.9.4 In the event of noteworthy departures from the approved plan or specification being accepted, a standard 'Concession' form is to be completed and signed by the following authorised persons: the Design Manager, the Quality Control Manager or their deputies. In all cases, where strength or functioning may be affected, the form is to be submitted to the Surveyors for approval and endorsement.

■ *Section 7* Spare gear for machinery installations

7.1 Application

7.1.1 Adequate spare parts for the propelling and essential auxiliary machinery, together with the necessary tools for maintenance and repair, are to be readily available for use.

7.1.2 The spare parts to be supplied and their location is to be the responsibility of the Owner, but they must take into account the design and arrangement of the machinery and the intended service and operation of the ship. Account must also be taken of the recommendations of the manufacturers and any applicable statutory requirement of the country of registration of the ship.

7.2 Guidance for spare parts

7.2.1 For general guidance purposes, spare parts for main and auxiliary machinery installations are shown in the LR's *Spare Gear Guidance* located on Class Direct Live.

Section

■ *Scope*

The requirements of this Chapter are applicable to oil engines (generally known as diesel engines) for main propulsion and to engines intended for essential auxiliary services. Section 3 is not applicable to auxiliary engines having powers of less than 110 kW.

The requirements for type testing of engines at the manufacturer's works are also included.

Arrangements for dual fuel engines will be specially considered.

Primary exhaust gas emissions abatement plant (where fitted) is to meet the requirements of this Chapter; additionally, it is to meet the requirements of Chapter 24. Where secondary exhaust gas emissions abatement systems are fitted to engines, they are to meet the requirements of Chapter 24.

■ *Section 1* Plans and particulars

1.1 Plans

1.1.1 The following plans and particulars as applicable are to be submitted for consideration:

- Crankshaft assembly plan (for each crank-throw).
- Crankshaft details plan (for each crank-throw).
- Thrust shaft or intermediate shaft (if integral with engine).
- Output shaft coupling bolts.
- Main engine securing arrangements where non-metallic chocks are used.
- Type and arrangement of crankcase explosion relief valves.
- Arrangement and welding specifications with details of the procedures for fabricated bedplate, thrust bearing bedplate, crankcases, frames and entablatures. Details of materials welding consumables, fit-up conditions fabrication sequence and heat treatments are to be included.
- Schematic layouts of the following systems:
  - Starting air.
  - Oil fuel.
  - Lubricating oil.
  - Cooling water.
  - Control and safety.
  - Hydraulic oil (for valve lift).
- Shielding of high pressure fuel pipes.
- Combustion pressure-displacement relationship.
- Crankshaft design data as outlined in Section 3.
- High pressure parts for fuel oil injection system with specification of pressures, pipe dimensions and materials.
- For new engine types that have not been approved by LR, the proposed type test programme.
- The type test report on completion of type testing for a new engine type. For mass produced engines a separate report is to be submitted for each engine requiring approval, *see* 17.2.
- Additionally, for mass produced engines:
  - (a) For consideration of an engine type to be approved:
    - (i) Engine specification, *see* 13.1.4.
    - (ii) Manufacturing processes and quality control information, *see* 13.2.3.
    - (iii) List of sub-contractors for main parts.
    - (iv) Procedures for configuring during commissioning.
  - (b) For engines of an approved type to be installed on a ship, a compliance and inspection certificate, *see* 13.4.
- For engine control, alarm monitoring and safety systems, the plans and information required by Pt 6, Ch 1,1.2.
- For electronically controlled engines, the plans and information required by 1.1.6 and 1.1.7.
- Schematic layouts showing details and arrangements of oil mist detection/monitoring and alarm systems.
- Diesel generator test results that state the engine maximum load steps which satisfy the quality of power supply requirements specified in Pt 6, Ch 2,1.7.
- Planned operating profiles for the vessel at sea and during manoeuvring as agreed with the operators.

1.1.2 The following plans are to be submitted for information:

- Longitudinal and transverse cross-section.
- Cast bedplate, thrust bearing bedplate, crankcase and frames.
- Cylinder head assembly.
- Cylinder liner.
- Piston assembly.
- Tie rod.
- Connecting rod, piston rod, and crosshead assemblies.
- Camshaft drive and camshaft general arrangement.
- Shielding and insulation of exhaust pipes.
- Details of turbochargers, *see* Section 14.
- Operation and service manuals.
- Vibration dampers/detuners and moment compensators.
- Thrust bearing assembly (if integral with engine and not integrated in the bedplate).
- Counterweights, where attached to crank-throw, including fastening.
- Main engine holding down arrangement (metal chocks).

1.1.3 Material specifications covering the listed components in 1.1.1 and 1.1.2 are to be forwarded together with details of any surface treatments, non-destructive testing and hydraulic tests.

1.1.4 Plans and details for dead ship condition starting arrangements are to be submitted for appraisal, *see* 9.1.

1.1.5 For engine types built under license it is intended that the above documentation be submitted by the Licensor. Each Licensee is then to submit the following:

- A list, based on the above, of all documents required with the relevant drawing numbers and revision status from both Licensor and Licensee.
- The associated documents where the Licensee proposes design modifications to components. In such cases a statement is to be made confirming the Licensor's acceptance of the proposed changes.

In all cases a complete set of endorsed documents will be required by the Surveyor(s) attending the Licensee's works.

- Diesel generator test results that state the engine maximum load steps which satisfy the quality of power supply requirements specified in Pt 6, Ch 2,1.7.
- Planned operating profiles for the vessel at sea and during manoeuvring as agreed with the operators.

1.1.6 Where engines incorporate electronic control systems the following additional information is to be submitted:

(a) A general overview of the operating principles, supported by schematics explaining the functionality of individual systems and sub-systems. The information is to relate to the engine capability and functionality under defined operating and emergency conditions such as recovery from a failure or malfunction, with particular reference to the functioning of programmable electronic systems and any sub-systems. The information is also to indicate if the engine has different modes of operation, such as to limit exhaust gas emissions and/or to run under an economic fuel consumption mode or any other mode that is electronically controlled.

(b) Operating manuals which describe the particulars of each system and, together with maintenance instructions, include reference to the functioning of sub-systems.

(c) A risk-based analysis of the mechanical, pressure containing, electrical, electronic and programmable electronic systems and arrangements that support the operation of the engine. The analysis is to demonstrate that suitable risk mitigation has been achieved in accordance with 4.2.

(d) Details of hydraulic systems for actuation of subsystems (fuel injection or exhaust), to include details of the design/construction of pipes, pumps, valves, accumulators and the control of valves/pumps. Details of pump drive arrangements are also to be included.

(e) Quality plan for sourcing, design, installation and testing of all components used in the oil fuel and hydraulic oil systems installed with the engine for engine operation.

(f) Fatigue analysis for all high pressure oil fuel and hydraulic oil piping arrangements required for engine operation where failure of the pipe or its connection or a component would be the cause of engine unavailability. The analysis is to concentrate on high pressure components and sub-systems and recognise the pressures and fluctuating stresses that the pipe system may be subject to in normal service.

(g) Evidence of type testing of the engine with the programmable electronic system, or a proposed test plan at the engine builders with the programmable electronic system functioning, to verify the functionality and behaviour under normal operating and fault conditions of the programmable electronic control system.

(h) Schedule of testing at engine builders, pre-sea trial commissioning and sea trials. The test schedules are to identify all modes of engine operation and the sea trials are to include typical port manoeuvres under the intended engine operating modes. The schedule is to include:
  (i) testing and trials to demonstrate that the engine is capable of operating as described in (a);
  (ii) tests to verify that the response of the complete mechanical, hydraulic, electrical and electronic system is as predicted for the intended operational modes; and
  (iii) testing required to verify the conclusions of the risk-based analysis.

  The scope of these tests is to be agreed with LR.

1.1.7 In addition to the applicable plans and particulars required by Pt 6, Ch 1, 1.2.3 to 1.2.6 the following information for control, alarm, monitoring and safety systems relating to the operation of an electronically controlled engine is to be submitted:

(a) Engine configuration details , *see* 4.3.2.
(b) Software quality plans, including configuration management documents.
(c) Software safety evidence.
(d) Software assessment inspection report.

1.1.8 Emergency diesel-generator engine plans, information and test schedules, required for design appraisal, are to be in accordance with Pt 6, Ch 1.

1.1.9 The following plans and particulars are to be submitted for information:

- Cross sectional plans of the assembled turbocharger with main dimensions.
- Fully dimensioned plans of the rotor.
- Material particulars with details of welding and surface treatments.
- Turbo-charger operating and test data.
- A selected turbocharger is to be type tested.
- Manufacturer's burst test assessment.

1.1.10 Where considered necessary Lloyd's Register (hereinafter referred to as 'LR') may require additional documentation to be submitted.

■ *Section 2* **Materials**

2.1 Crankshaft materials

2.1.1 The specified minimum tensile strength of castings and forgings for crankshafts is to be selected within the following general limits:

(a) Carbon and carbon-manganese steel castings – 400 to 550 N/mm^2
(b) Carbon and carbon-manganese steel forgings (normalised and tempered) – 400 to 600 N/mm^2
(c) Carbon and carbon-manganese steel forgings (quenched and tempered) – not exceeding 700 N/mm^2
(d) Alloy steel castings – not exceeding 700 N/mm^2
(e) Alloy steel forgings – not exceeding 1000 N/mm^2
(f) Spheroidal or nodular graphite iron castings – 370 to 800 N/mm^2.

2.1.2 Where it is proposed to use alloy castings, micro alloyed or alloy steel forgings or iron castings, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

2.2 Material test and inspections

2.2.1 Components for engines are to be tested as indicated in Table 2.2.1 and in accordance with the relevant requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.2.2 For components of novel design special consideration will be given to the material test and non-destructive testing requirements.

Table 2.2.1 Test requirements for oil engine components

Component	Material tests	Non-destructive tests: Magnetic particle or Liquid penetrant	Non-destructive tests: Ultrasonic
Crankshaft	all	all	all
Crankshaft coupling flange (non-integral) for main propulsion engines	above 400 mm bore	—	—
Crankshaft coupling bolts	above 400 mm bore	—	—
Steel piston crowns	above 400 mm bore	above 400 mm bore	all
Piston rods	above 400 mm bore	above 400 mm bore	above 400 mm bore
Connecting rods, including bearing caps	all	all	above 400 mm bore
Crosshead	above 400 mm bore	—	—
Cylinder liner	above 300 mm bore	—	—
Cylinder cover	above 300 mm bore	above 400 mm bore	all
Steel castings for welded bedplates	all	all	all
Steel forgings for welded bedplates	all	—	—
Plates for welded bedplates, frames and entablatures	all	—	—
Crankcases, welded or cast	all	—	—
Tie rods	all	above 400 mm bore	—
Turbo-charger, shaft and rotor	above 300 mm bore	—	—
Bolts and studs for cylinder covers, crossheads, main bearings, connecting rod bearings	above 300 mm bore	above 400 mm bore	—
Steel gear wheels for camshaft drives	above 400 mm bore	above 400 mm bore	—

NOTES
1. For closed-die forged crankshafts the ultrasonic examination may be confined to the initial production and to subsequent occasional checks.
2. Magnetic particle or liquid penetrant testing of tie rods may be confined to the threaded portions and the adjacent material over a length equal to that of the thread.
3. Cylinder covers and liners manufactured from spheroidal or nodular graphite iron castings may not be suitable for ultrasonic NDE, depending upon the grain size and geometry. An alternative NDE procedure is to be agreed with LR.
4. Bore dimensions refer to engine cylinder bores.
5. All required material tests are to be witnessed by the Surveyor unless alternative arrangements have been specifically agreed by LR.
6. For mass produced engines, *see* Section 13.

■ *Section 3* Design

3.1 Scope

3.1.1 The formulae given in this Section are applicable to solid, or semi-built crankshafts, having a main support bearing adjacent to each crankpin, and are intended to be applied to a single crankthrow analysed by the static determinate method.

3.1.2 Alternative methods, including a fully documented stress analysis, will be specially considered.

3.1.3 Calculations are to be carried out for the maximum continuous power rating for all intended operating conditions.

3.1.4 Designs of crankshafts not included in this scope will be subject to special consideration.

3.2 Information to be submitted

3.2.1 In addition to detailed dimensioned plans, the following information is required to be submitted:

- Engine type – 4SCSA/2SCSA/in-line/vee.
- Output power at maximum continuous rating (MCR), in kW.
- Output speed at maximum continuous power, in rpm.
- Maximum cylinder pressure, in bar g.
- Mean indicated pressure, in bar g.
- Cylinder air inlet pressure, in bar g.
- Digitised gas pressure/crank angle cycle for MCR.
- Maximum pressure/speed relationship.
- Compression ratio.
- Vee angle and firing interval (if applicable), in degrees.
- Firing order numbered from driving end, *see* Fig. 2.3.1.
- Cylinder diameter, in mm.
- Piston stroke, in mm.
- Mass of connecting rod (including bearings), in kg.
- Centre of gravity of connecting rod from large end centre, in mm.
- Radius of gyration of connecting rod, in mm.

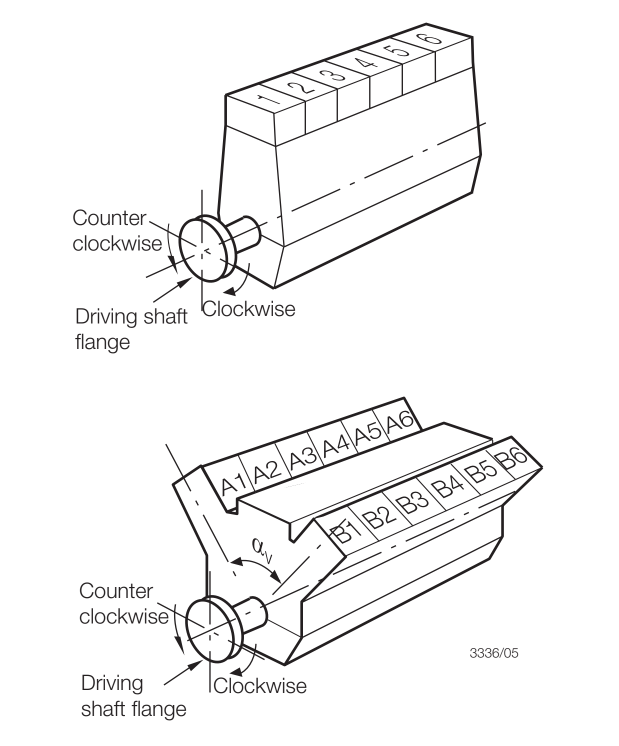


Fig. 2.3.1 Designation of cylinders

- Length of connecting rod between bearing centres, in mm.
- Mass of single crankweb (indicate if webs either side of pin are of different mass values), in kg.
- Centre of gravity of crankweb mass from shaft axis, in mm.
- Mass of counterweights fitted (for complete crankshaft) indicate positions fitted, in kg.
- Centre of gravity of counterweights (for complete crankshaft) measured from shaft axis, in mm.
- Mass of piston (including piston rod and crosshead where applicable), in kg.
- All individual reciprocating masses acting on one crank, in kg.
- Material specification(s).
- Specified minimum UTS, in N/mm^2.
- Specified minimum yield strength, in N/mm^2.
- Method of manufacture.
- Details of fatigue enhancement process (if applicable).
- For semi-built crankshafts – minimum and maximum diametral interference, in mm.

3.3 Symbols

3.3.1 For the purposes of this Chapter the following symbols apply, *see also* Fig. 2.3.2:

h = radial thickness of web, in mm
k_e = bending stress factor
B = transverse breadth of web, in mm
D_p, D_j = outside diameter of pin or main journal, in mm
D_{pi}, D_{ji} = internal diameter of pin or main journal, in mm
D_s = shrink diameter of main journal in web, in mm
d_o = diameter of radial oil bore in crankpin, in mm
F = alternating force at the web centreline, in N
K_1 = fatigue enhancement factor due to manufacturing process
K_2 = fatigue enhancement factor due to surface treatment
M_b = alternating bending moment at web centreline, in N-mm (Note: alternating is taken to be $^1/_2$ range value)
M_{BON} = alternating bending moment calculated at the outlet of crankpin oil bore
M_p, M_j = undercut of fillet radius into web measured from web face, in mm
R_p, R_j = fillet radius at junction of web and pin or journal, in mm
S = stroke, in mm
T = axial thickness of web, in mm
T_a = alternating torsional moment at crankpin or crank journal, in N-mm (Note: alternating is taken to be $^1/_2$ range value)

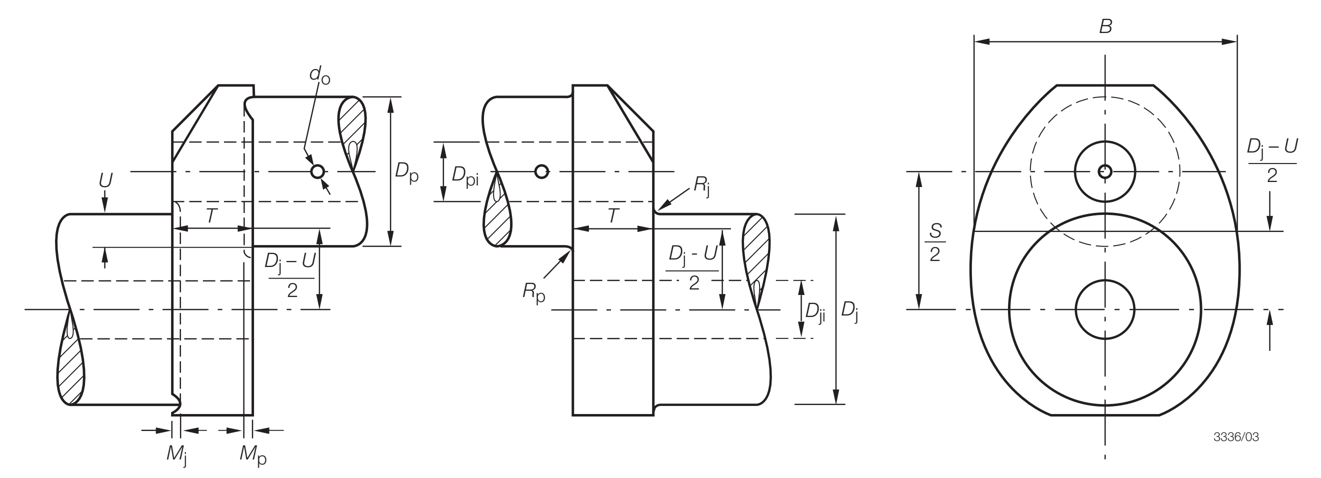
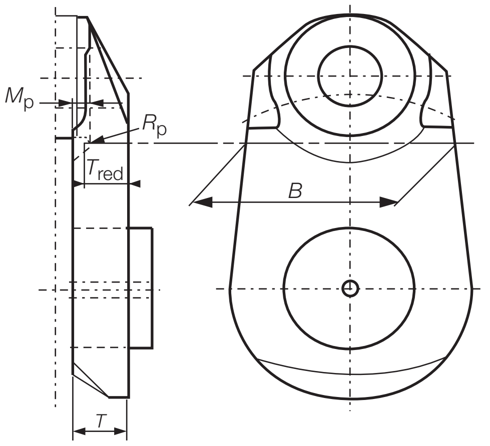


Fig. 2.3.2(a) Crank dimensions necessary for the calculation of stress concentration factors



Crankshaft without overlap

Fig. 2.3.2(b)
Crank dimensions for crankshaft without overlap

U = pin overlap

$= \dfrac{(D_p + D_j - S)}{2}$ mm

α_B = bending stress concentration factor for crankpin
α_T = torsional stress concentration factor for crankpin
β_B = bending stress concentration factor for main journal
β_Q = direct shear stress concentration factor for main journal
β_T = torsional stress concentration factor for main journal
γ_B = bending stress concentration factor for radially drilled oil hole in the crankpin
γ_T = torsional stress concentration factor for radially drilled oil hole in the crankpin
σ_{ax} = alternating axial stress, in N/mm^2
σ_b = alternating bending stress, in N/mm^2
σ_{BON} = alternating bending stress in the outlet of the oil bore, in N/mm^2
σ_p, σ_j = maximum bending stress in pin and main journal taking into account stress raisers, in N/mm^2
σ_{BO} = maximum bending stress in the outlet of the oil bore, in N/mm^2
σ_Q = alternating direct stress, in N/mm^2
σ_U = specified minimum UTS of material, in N/mm^2
σ_y = specified minimum yield stress of material, in N/mm^2
τ_a = alternating torsional stress, in N/mm^2
τ_p, τ_j = maximum torsional stress in pin and main journals taking into account stress raisers, in N/mm^2
τ_{tob} = maximum torsional stress in outlet of crankpin oil bore taking into account stress raisers, in N/mm^2.

3.4 Stress concentration factors

3.4.1 **Geometric factors**. Crankshaft variables to be used in calculating the geometric stress concentrations together with their limits of applicability are shown in Table 2.3.1.

Table 2.3.1 Crankshaft variables

Variable	Range: Lower	Range: Upper
$b = B/D_p$	1,10	2,20
$d_j = D_{ji}/D_p$	0,00	0,80
$d_p = D_{pi}/D_p$	0,00	0,80
$m_j = M_j/D_p$	0,00	r_{jB}
$m_p = M_p/D_p$	0,00	r_p
$r_{jB} = R_j/D_p$	0,03	0,13
$r_{jT} = R_j/D_j$	0,03	0,13
$r_p = R_p/D_p$	0,03	0,13
$t = T/D_p$	0,20	0,80
$t = T_{red}/D_p$ *see* Note 3	0,20	0,80
$d = d_o/D_p$	0,00	0,20
$u = U/D_p$ *see* Note 2		0,50

NOTES
1. Where variables fall outside the range, alternative methods are to be used and full details submitted for consideration.
2. A lower limit of u can be extended down to large negative values provided that:
   (i) If calculated f(rec) < 1 then the factor f(rec) is not to be considered (f(rec) = 1)
   (ii) If u < –0,5 then f(ut) and f(ru) are to be evaluated replacing actual value of u by –0,5.
3. For crankshafts without overlap *see also* 3.4.6.

3.4.2 Crankpin stress concentration factors:

- Bending

α_B = 2,70 f(ut). f(t). f(b). f(r). f(dp). f(dj). f(rec)

where

f(ut) $= 1{,}52 - 4{,}1t + 11{,}2t^2 - 13{,}6\,t^3 + 6{,}07t^4 - u\,(1{,}86 - 8{,}26t + 18{,}2t^2 - 18{,}5t^3 + 6{,}93t^4) - u^2\,(3{,}84 - 25{,}0t + 70{,}6t^2 - 87{,}0t^3 + 39{,}2t^4)$

f(t) $= 2{,}18t^{0{,}717}$

f(b) $= 0{,}684 - 0{,}0077b + 0{,}147b^2$

f(r) $= 0{,}208r_p^{(-0{,}523)}$

f(dp) $= 1 + 0{,}315(d_p) - 1{,}52(d_p)^2 + 2{,}41(d_p)^3$

f(dj) $= 1 + 0{,}27d_j - 1{,}02(d_j)^2 + 0{,}531(d_j)^3$

f(rec) $= 1 + (m_p + m_j)\,(1{,}8 + 3{,}2u)$

valid only between u = –0,5 and 0,5.

- Torsion

α_T = 0,8 f(ru). f(b). f(t)

where

f(ru) $= r_p^{-(0{,}22\,+\,0{,}1u)}$

f(b) $= 7{,}9 - 10{,}65b + 5{,}35b^2 - 0{,}857b^3$

f(t) $= t^{\,(-0{,}145)}$.

3.4.3 Crank journal stress concentration factors (not applicable to semi-built crankshafts):

- Bending

β_B = 2,71f_B(ut). f_B(t). f_B(b). f_B(r). f_B(dj). f_B(dp). f(rec)

where

f_B(ut) $= 1{,}2 - 0{,}5t + 0{,}32t^2 - u\,(0{,}80 - 1{,}15t + 0{,}55t^2) - u^2\,(2{,}16 - 2{,}33t + 1{,}26t^2)$

f_B(t) $= 2{,}24t^{0{,}755}$

f_B(b) $= 0{,}562 + 0{,}12b + 0{,}118b^2$

f_B(r) $= 0{,}191r_{jB}^{(-0{,}557)}$

f_B(dj) $= 1 - 0{,}644d_j + 1{,}23(d_j)^2$

f_B(dp) $= 1 - 0{,}19d_p + 0{,}0073(d_p)^2$

f(rec) $= 1 + (m_p + m_j)\,(1{,}8 + 3{,}2u)$

valid only between u = –0,5 and 0,5.

- Direct shear

$\beta_Q = 3{,}01 f_Q(u).\ f_Q(t).\ f_Q(b).\ f_Q(r).\ f_Q(dp).\ f(rec)$

where

$f_Q(u) = 1{,}08 + 0{,}88u - 1{,}52u^2$

$$f_Q(t) = \frac{t}{0{,}0637 + 0{,}937t}$$

$f_Q(b) = b - 0{,}5$

$f_Q(r) = 0{,}533 r_{JB}^{(-0{,}204)}$

$f_Q(dp) = 1 - 1{,}19 d_p + 1{,}74 (d_p)^2$

$f(rec) = 1 + (m_p + m_j)(1{,}8 + 3{,}2u)$

valid only between $u = -0{,}5$ and $0{,}5$.

- Torsion

where

$\beta_T = 0{,}8 f(ru).\ f(b).\ f(t)$

$f(ru) = r_{jT}^{-(0{,}22 + 0{,}1u)}$

$f(b) = 7{,}9 - 10{,}65b + 5{,}35b^2 - 0{,}857b^3$

$f(t) = t^{(-0{,}145)}$.

3.4.4 Crankpin oil bore stress concentration factors for radially drilled oil holes:

- Bending

$$\gamma_B = 3 - 5{,}88 \bullet \frac{d_o}{D_p} + 34{,}6 \bullet \left(\frac{d_o}{D_p}\right)^2$$

- Torsion

$$\gamma_T = 4 - 6 \bullet \frac{d_o}{D_p} + 30 \bullet \left(\frac{d_o}{D_p}\right)^2$$

3.4.5 Where experimental measurements of the stress concentrations are available these may be used. The full documented analysis of the experimental measurements is to be submitted for consideration.

3.4.6 In the case of semi-built crankshafts when $M_p > R_p$ the web thickness is to be taken as:

$T_{red} = T - (M_p - R_p)$ and the web width B is to be taken in way of the crankpin fillet radius centre *see* Fig. 2.3.2.

3.5 Nominal stresses

3.5.1 The nominal alternating bending stress, σ_b, is to be calculated from the maximum and minimum bending moment at the web centreline taking into account all forces being applied to the crank throw in one working cycle with the crank throw simply supported at the mid length of the main journals.

3.5.2 Nominal bending stresses are referred to the web bending modulus.

3.5.3 Nominal alternating bending stress:

$$\sigma_b = \pm \frac{M_b}{Z_{web}} k_e \quad \text{N/mm}^2$$

$$Z_{web} = \frac{BT^2}{6} \quad \text{mm}^3$$

k_e = 0,8 for crosshead engines
= 1,0 for trunk piston engines.

3.5.4 Nominal alternating bending stress in the outlet of the crankpin oil bore:

$$\sigma_{BON} = \pm \frac{M_{BON}}{Z_{crankpin}}$$

where

M_{BON} is taken as the ½ range value $M_{BON} = \pm \frac{1}{2}(M_{BOmax} - M_{BOmin})$

and

$M_{BO} = (M_{BTO} \cos\psi + M_{BRO} \sin\psi)$, *see* Fig. 2.3.3

The two relevant bending moments are taken in the crankpin cross-section through the oil bore.

M_{BRO} = bending moment of the radial component of the connecting-rod force

M_{BTO} = bending moment of the tangential component of the connecting-rod force

$$Z_{crankpin} = \frac{\pi}{32} \frac{D^4 - d^4}{D}$$

$Z_{crankpin}$ related to the cross-section of axially bored crankpin.

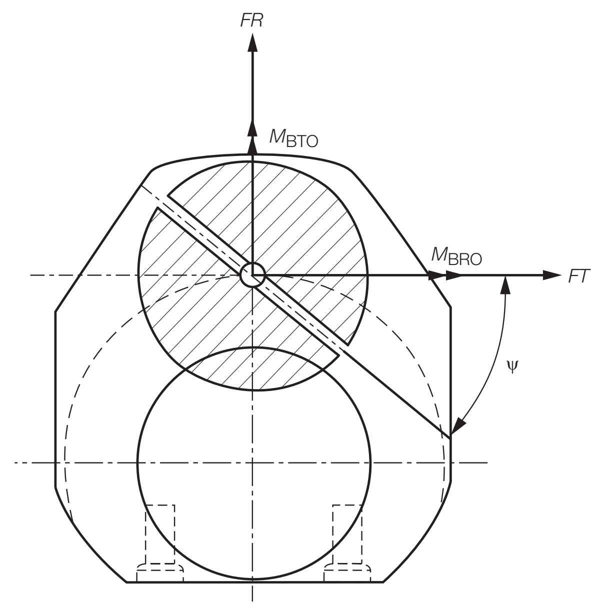


Fig. 2.3.3 Crankpin section through the oil bore

3.5.5 The nominal direct shear stress in the web for the purpose of assessing the main journal is to be added algebraically to the bending stress, using the alternating forces which have been used in deriving M_b in 3.5.3.

3.5.6 Nominal stress is referred to the web cross-section area or the pin cross-section area as applicable.

3.5.7 Nominal alternating direct shear stress:

$$\sigma_Q = \pm \frac{F}{A_{web}} k_e \quad \text{N/mm}^2$$

where

$A_{web} = BT$ mm^2.

3.5.8 The nominal alternating torsional stress, τ_a, is to be taken into consideration. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted.

3.5.9 The results of torsional vibration calculations for the full dynamic system, carried out in accordance with Ch 8,2.2, are to be submitted.

3.5.10 Nominal alternating torsional stress:

$$\tau_a = \pm \frac{T_a}{Z_T} \quad \text{N/mm}^2$$

where

Z_T = torsional modulus of crankpin and main journal

$$= \frac{\pi}{16}\left[\frac{(D^4 - d^4)}{D}\right] \quad \text{mm}^3$$

D = outside diameter of crankpin or main journal, in mm

d = inside diameter of crankpin or main journal, in mm

τ_a is to be ascertained from assessment of the torsional vibration calculations where the maximum and minimum torques are determined for every mass point of the complete dynamic system and for the entire speed range by means of a harmonic synthesis of the forced vibrations from the 1st order up to and including the 15th order for 2-stroke cycle engines and from the 0,5th order up to and including the 12th order for 4-stroke cycle engines. Whilst doing so, allowance must be made for the damping that exists in the system and for unfavourable conditions (misfiring in one of the cylinders when no combustion occurs but only compression cycle). The speed step calculation shall be selected in such a way that any resonance found in the operational speed range of the engine shall be detected.

3.5.11 For the purpose of the crankshaft assessment, the nominal alternating torsional stress considered in calculations is to be the highest calculated value, according to the method described in 3.5.9, occurring at the most torsionally loaded mass point of the crankshaft system.

3.5.12 The approval of the crankshaft will be based on the installation having the largest nominal alternating torsional stress (but not exceeding the maximum figure specified by the engine manufacturer). For each installation it is to be ensured by calculation that the maximum approved nominal alternating torsional stress is not exceeded.

3.5.13 In addition to the bending stress, σ_b, the axial vibratory stress, σ_{ax}, is to be taken into consideration, for crosshead type engines. For trunk type engines, $\sigma_{ax} = 0$. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted. The corresponding crankshaft free-end deflection is also to be stated.

3.6 Maximum stress levels

3.6.1 Crankpin fillet.

- Maximum alternating bending stress:

  $\sigma_p = \alpha_B (\sigma_b + \sigma_{ax})$ N/mm^2

  where

  α_B = bending stress concentration, *see* 3.4.2
- Maximum alternating torsional stress:

  $\tau_p = \alpha_T \tau_a$ N/mm^2

  where

  α_T = torsional stress concentration, *see* 3.4.2

  τ_a = nominal alternating torsional stress in crankpin N/mm^2.

3.6.2 Outlet of crankpin oil bore.

- Maximum alternating bending stress:

  $\sigma_{BO} = \gamma_B (\sigma_{BON} + \sigma_{ax})$ N/mm^2

  where

  γ_B = bending stress concentration factor, *see* 3.4.4
- Maximum alternating torsional stress:

  $\tau_{tob} = \gamma_T \tau_a$ N/mm^2

  where

  γ_T = torsional stress concentration factor, *see* 3.4.4

  τ_a = nominal alternating torsional stress in crankpin N/mm^2.

3.6.3 Crank journal fillet (not applicable to semi-built crankshafts).

- Maximum alternating bending stress:

  $\sigma_j = \beta_B (\sigma_b + \sigma_{ax}) + \beta_Q \sigma_Q$ N/mm^2

  where

  β_B = bending stress concentration, *see* 3.4.3

  β_Q = direct stress concentration, *see* 3.4.3
- Maximum alternating torsional stress:

  $\tau_j = \beta_T \tau_a$ N/mm^2

  where

  β_T = torsional stress concentration, *see* 3.4.3

  τ_a = nominal alternating torsional stress in main journal N/mm^2.

3.7 Equivalent alternating stress

3.7.1 Equivalent alternating stress of the crankpin, σ_{ep}, or crank journal σ_{ej}, is defined as:

$$\sigma_{ep}, \sigma_{ej} = \sqrt{(\sigma + 10)^2 + 3\tau^2} \quad \text{N/mm}^2$$

where

σ = σ_p or σ_j N/mm^2

τ = τ_p or τ_j N/mm^2.

3.7.2 Equivalent alternating stress for the outlet of the crankpin oil bore σ_{eob}, is defined as:

$$\sigma_{eob} = \pm \frac{1}{3} \sigma_{bo} \left[1 + 2\sqrt{1 + \frac{9}{4}\left(\frac{\tau_{to}}{\sigma_{bo}}\right)^2}\right] \quad \text{N/mm}^2$$

3.8 Fatigue strength

3.8.1 The fatigue strength of a crankshaft is based upon the crankpin and crank journal as follows:

$$\sigma_{fp} = K_1 K_2 (0{,}42\sigma_u + 39{,}3)\left(0{,}264 + 1{,}073D_p^{-0{,}2} + \frac{785 - \sigma_u}{4900} + \frac{196}{\sigma_u}\sqrt{\frac{1}{R_p}}\right)$$

To calculate the fatigue strength in the oil bore area, replace R_p with ½d_o and σ_{fp} with σ_{fob}.

$$\sigma_{fj} = K_1 K_2 (0{,}42\sigma_u + 39{,}3)\left(0{,}264 + 1{,}073D_j^{-0{,}2} + \frac{785 - \sigma_u}{4900} + \frac{196}{\sigma_u}\sqrt{\frac{1}{R_j}}\right)$$

where

σ_u = UTS of crankpin or crank journal as appropriate
K_1 = fatigue endurance factor appropriate to the manufacturing process
= 1,05 for continuous grain-flow (CGF) or die-forged
= 1,0 for freeform forged (without CGF)
= 0,93 for cast steel manufactured using a LR approved cold rolling process
K_2 = fatigue enhancement factor for surface treatment.

These treatments are to be applied to the fillet radii
A value for K_2 will be assigned upon application by the engine designers. Full details of the process, together with the results of full scale fatigue tests will be required to be submitted for consideration. Alternatively, the following values may be taken (surface hardened sone to include fillet radii):

K_2 = 1,15 for induction hardened
= 1,25 for nitrided

Where a value of K_1 or K_2 greater than unity is to be applied then details of the manufacturing process are to be submitted.

3.9 Acceptability criteria

3.9.1 The acceptability factor, Q, is to be greater than 1,15:

$Q = \dfrac{\sigma_f}{\sigma_e}$ for crankpin, journal and the outlet of crankpin oil bore

where

σ_f = σ_{fp} or σ_{fj} or σ_{fob}
σ_e = σ_{ep} or σ_{ej} or σ_{eob}.

3.10 Oil hole

3.10.1 The junction of the oil hole with the crankpin or main journal surface is to be formed with an adequate radius and smooth surface finish down to a minimum depth equal to 1,5 times the oil bore diameter.

3.10.2 Fatigue strength calculations or alternatively fatigue test results may be required to demonstrate acceptability.

3.10.3 When journal diameter is equal or larger than the crankpin diameter, the outlets of main journal oil bores are to be formed in a similar way to the crankpin oil bores, otherwise separate fatigue strength calculations or, alternatively, fatigue test results may be required.

3.11 Shrink fit of semi-built crankshafts

3.11.1 The maximum permissible internal diameter in the journal pin is to be calculated in accordance with the following formula:

$$D_{ji} = D_s\sqrt{1 - \frac{4000\text{FoS}\,M_{max}}{\mu\,\pi\,D_s^2\,L_s\,\sigma_{yj}}}$$

where the symbols are as defined in 3.11.7.

3.11.2 When 3.11.1 cannot be complied with, then 3.11.7 is not applicable. In such cases δ_{min} and δ_{max} are to be established from FEM calculations.

3.11.3 The following formulae are applicable to crankshafts assembled by shrinking main journals into the crankwebs.

3.11.4 In general, the radius of transition, R_j, between the main journal diameter, D_j, and the shrink diameter, D_s, is to be not less than 0,015D_j or 0,5($D_s - D_j$).

3.11.5 The distance, *y*, between the underside of the pin and the shrink diameter should be greater than 0,05D_s.

3.11.6 Deviations from these parameters will be specially considered.

3.11.7 The proposed diametral interference is to be within the following limits, *see also* Fig. 2.3.4:

The minimum required diametral interference is to be taken as the greater of:

$$\delta_{min} = \frac{12{,}156 \times 10^6\,(\text{FoS})}{TD_s\,\mu E}\,\frac{P}{R}\,(1 + C)\,\frac{k^2 - l^2}{(k^2 - 1)(1 - l^2)}\ \text{mm}$$

or

$$\delta_{min} = \frac{\sigma_y D_s}{E}\ \text{mm}$$

where

h = minimum radial thickness of the web around the diameter D_s, mm
$k = \dfrac{D_o}{D_s}$
$l = \dfrac{D_{ji}}{D_s}$
C = ratio of torsional vibratory torque to the mean transmitted torque at the P/R rating being considered
D_o = $D_s + 2h$, in mm
D_s = shrink diameter, in mm
E = Young's modulus of elasticity of crankshaft material, in N/mm^2
FoS = Factor of Safety against rotational slippage to be taken as 2,0. A value less than 2,0 may be used where documented by experiments to demonstrate acceptability
P = output power, in kW
R = speed at associated power, in rpm
T = crankweb thickness, in mm
μ = coefficient of static friction to be taken as 0,2 for degreased surfaces. A value greater than 0,2 may be used where documented by experiments to demonstrate acceptability
σ_{yj} = minimum yield strength of material for journal pin

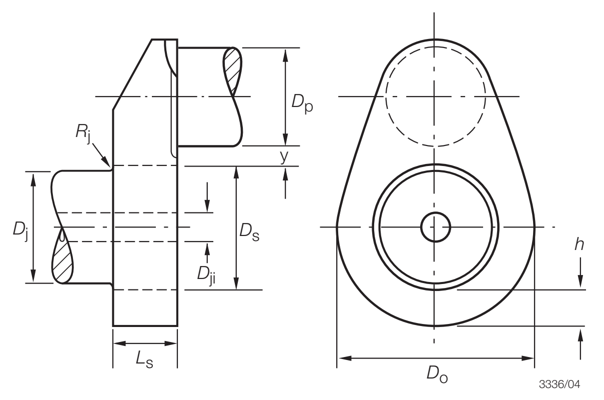


Fig. 2.3.4 Crank throw of semi-built crankshaft

M_{max} = absolute maximum value of the torque taking Ch 8,2 into consideration
L_s = length of shrink fit, in mm.

Maximum diametral interference, δ_{max}, is not to be greater than:

$$\delta_{max} = \frac{\sigma_y D_s}{E} + \frac{0{,}8\, D_s}{1000} \text{ mm.}$$

3.11.8 Reference marks are to be provided on the outer junction of the crankwebs with the journals.

3.12 Alternative method for calculation of stress concentration factors

3.12.1 LR will give consideration to crankshaft design using an alternative method given in LR's *ShipRight procedures for alternative method for calculation of stress concentration factors in the web fillet radii of crankshafts by utilising Finite Element*.

■ *Section 4* Electronically controlled engines

4.1 General

4.1.1 The requirements of this Section are applicable to engines for propulsion, auxiliary or emergency power purposes with programmable electronic systems implemented and used to control fuel injection timing and duration, and which may also control combustion air or exhaust systems. The requirements of this Section also apply to programmable electronic systems used to control other functions (e.g. starting and control air, cylinder lubrication etc.) where essential for the operation of the engine.

4.1.2 These engines may be of the slow, medium or high-speed type. They generally have no direct camshaft driven fuel systems, but have common rail fuel/hydraulic arrangements and may have hydraulic actuating systems for the functioning of the exhaust systems.

4.1.3 The operation of these engines relies on the effective monitoring of a number of parameters such as crank angle, engine speed, temperatures and pressures using programable electronic systems to provide the services essential for the operation of the engine such as fuel injection, air inlet, exhaust and speed control.

4.1.4 Details of proposals to deviate from the requirements of this Section are to be submitted and will be considered on the basis of a technical justification produced by the Enginebuilder.

4.1.5 Each engine is to be configured for the specified performance and is to satisfy the relevant requirements for propulsion, auxiliary or emergency engines.

4.1.6 During the life of the engine details of any proposed changes to control, alarm, monitoring or safety systems which may affect safety and the reliable operation of the engine are to be submitted to LR for approval.

4.2 Risk-based analysis

4.2.1 An analysis is to be carried out in accordance with relevant standards acceptable to LR to demonstrate compliance with the applicable requirements of this sub-Section appropriate to the engine application. The analysis is to be a risk-based consideration of engine operation and ship and personnel safety, and is to demonstrate adequate risk mitigation through fault tolerance and/or reliability in accordance with the specified criteria in 4.2.2 to 4.2.4 relevant to the engine application.

4.2.2 For ships with a single main propulsion engine, a Failure Mode and Effects Analysis (FMEA), or alternative recognised analysis of system reliability, is to be carried out and is to demonstrate that an electronic control system failure:

(a) will not result in the loss of the ability to provide the services essential for the operation of the engine, *see* Pt 6, Ch 1,2.5.7 and 2.13.2;
(b) will not affect the normal operation of the services essential for the operation of the engine other than those services dependent upon the failed part, *see* Pt 6, Ch 1,2.14.4 and 2.14.5; and
(c) will not leave either the engine, or any equipment or machinery associated with the engine, or the ship in an unsafe condition, *see* Pt 6, Ch 1,2.3.13, 2.4.5, 2.5.3, 2.10.3, 2.10.4 and 2.14.5.

4.2.3 A risk-based analysis is to be carried out for:

(a) main engines on ships with multiple main engines or other means of providing propulsion power; and/or
(b) auxiliary engines intended to drive electric generators forming the ship's main source of electrical power or otherwise providing power for essential services.

The analysis is to demonstrate that adequate hazard mitigation has been incorporated in electronically controlled engine systems or the overall ship installation with respect to personnel safety and providing propulsion power and/or power for essential services for the safety of the ship. Arrangements satisfying the criteria of 4.2.2(a) to (c) will also be acceptable.

4.2.4 For engines for emergency power purposes, a risk-based analysis is to be carried out to demonstrate that the design incorporates adequate hazard mitigation such that the likelihood of an electronic control system failure resulting in the loss of the ability to provide emergency power when required has been reduced to a level considered acceptable by LR and that means are provided to detect failures and permit personnel to restore engine availability to operate on demand. Failures which would result in engine failure and/or damage or loss of availability are to be identified and the report is to include documentation of:

(a) component reliability evidence;
(b) failure detection and alarms; and
(c) failure response required to restore engine availability and maintain personnel safety.

4.2.5 The risk-based analysis report is to:

(a) Identify the standards used for analysis and system design.
(b) Identify the engine, its purpose and the associated objectives of the analysis.
(c) Identify any assumptions made in the analysis.
(d) Identify the equipment, system or sub-system, mode of operation and the equipment.
(e) Identify potential failure modes and their causes.
(f) Evaluate the local effects (e.g., fuel injection failure) and the effects on the system as a whole (e.g., loss of propulsion power) of each failure mode.
(g) Identify measures for reducing the risks associated with each failure mode (e.g., system design, failure detection and alarms, redundancy, quality control procedures for sourcing, manufacture and testing, etc.).
(h) Identify trials and testing necessary to prove conclusions.

4.2.6 At sub-system level it is acceptable to consider failure of equipment items and their functions, e.g. failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed, and failure need only be dealt with as a cause of failure of the pump.

4.3 Control engineering systems

4.3.1 Control, alarm, monitoring, safety and programmable electronic systems are to comply with Pt 6, Ch 1 as applicable.

4.3.2 The engine control, alarm monitoring and safety systems are to be configured to comply with the relevant requirements (e.g., operating profile, alarms, shutdowns, etc.) of this Chapter and Pt 6, Ch 1 for an engine for main, auxiliary or emergency power purposes. Details of the engine configuration are to be submitted for consideration identifying:

(a) Local and remote means to carry out system configuration.
(b) Enginebuilder procedures for undertaking configuring.
(c) Roles and responsibilities for configuration (e.g., Enginebuilder, engine packager, system integrator or other nominated party) with accompanying schedule.
(d) Configurable settings and parameters (including those not to be modified from a default value).
(e) Configuration for propulsion, auxiliary or emergency engine application.

Configuration records are to be maintained and are to be made available to the Surveyor at testing and trials and on request in accordance with Pt 6, Ch 1,1.4 and 7.1.3.

4.4 Software

4.4.1 Software lifecycle activities are to be carried out in accordance with an acceptable quality management system, *see* Pt 6, Ch 1,2.13.2 and 2.13.7.

4.4.2 Appropriate safety related processes, methods, techniques and tools are to be applied to software development and maintenance by the Enginebuilder. Selection and application of techniques and measures in accordance with Annex A of IEC 61508-3, *Functional safety of electrical/electronic/programmable electronic systems: Software requirements*, or other relevant standards or codes acceptable to LR, will generally be acceptable.

4.4.3 To demonstrate compliance with 4.4.1 and 4.4.2:

(a) software quality plans and safety evidence are to be submitted for consideration, *see* 4.2.2(b) and (c); and
(b) an assessment inspection of the Enginebuilder's completed development is to be carried out by LR. The inspection is to be tailored to verify application of the standards and codes used in software safety assurance accepted by LR.

■ *Section 5* Construction and welded structures

5.1 Crankcases

5.1.1 Crankcases and their doors are to be of robust construction to withstand anticipated crankcase pressures that may arise during a crankcase explosion, taking into account the installation of explosion relief valves required by Section 6 and the doors are to be securely fastened so that they will not be readily displaced by a crankcase explosion.

5.2 Welded joints

5.2.1 Bedplates and major components of engine structures are to be made with a minimum number of welded joints.

5.2.2 Double welded butt joints are to be adopted wherever possible in view of their superior fatigue strength.

5.2.3 Girder and frame assemblies should, so far as possible, be made from one plate or slab, shaped as necessary, rather than by welding together a number of small pieces.

5.2.4 Steel castings are to be used for parts which would otherwise require complicated weldments.

5.2.5 Care is to be taken to avoid stress concentrations such as sharp corners and abrupt changes in section.

5.2.6 Joints in parts of the engine structure which are stressed by the main gas or inertia loads are to be designed as continuous full strength welds and for complete fusion of the joint. They are to be so arranged that, in general, welds do not intersect, and that welding can be effected without difficulty and adequate inspection can be carried out. Abrupt changes in plate section are to be avoided and where plates of substantially unequal thickness are to be butt welded, the thickness of the heavier plate is to be gradually tapered to that of the thinner plate. Tee joints are to be made with full bevel or equivalent weld preparation to ensure full penetration.

5.2.7 In single plate transverse girders the castings for main bearing housings are to be formed with web extensions which can be butt welded to the flange and vertical web plates of the girder. Stiffeners in the transverse girder are to be attached to the flanges by full penetration welds.

5.3 Materials and construction

5.3.1 Plates, sections, forgings and castings are to be of welding quality in accordance with the requirements of the Rules for Materials, and with a carbon content generally not exceeding 0,23 per cent. Steels with higher carbon contents may be approved subject to satisfactory results from welding procedure tests.

5.3.2 Welding is to be carried out in accordance with the requirements of Chapter 13 of the Rules for Materials, using welding procedures and welders that have been qualified in accordance with Chapter 12 of the Rules for Materials.

5.3.3 Before welding is commenced the component parts of bedplates and framework are to be accurately fitted and aligned.

5.3.4 The welding is to be carried out in positions free from draughts and is to be downhand (flat) wherever practicable. Welding consumables are to be suitable for the materials being joined. Preheating is to be adopted when heavy plates or sections are welded. The finished welds are to have an even surface and are to be free from undercutting.

5.3.5 Welds attaching bearing housings to the transverse girders are to have a smooth contour and, if necessary, are to be made smooth by grinding.

5.4 Post-weld heat treatment

5.4.1 Bedplates are to be given a stress relieving heat treatment except engine types where the bedplate as a whole is not subjected to direct loading from the cylinder pressure. For these types, only the transverse girder assemblies need be stress relieved.

5.4.2 Stress relieving is to be carried out by heating the welded structure uniformly and slowly to a temperature between 580°C and 620°C, holding that temperature for not less than one hour per 25 mm of maximum plate thickness and thereafter allowing the structure to cool slowly in the furnace.

5.4.3 Omission of post-weld heat treatment of bedplates and their sub-assemblies will be considered on application by the Enginebuilder with supporting evidence in accordance with Ch 13,2.10.4 of the Rules for Materials.

5.5 Inspection

5.5.1 Welded engine structures are to be examined during fabrication, special attention being given to the fit of component parts of major joints prior to welding.

5.5.2 Inspection of welds is to be in accordance with the requirements of Ch 13,1.11 of the Rules for Materials.

5.5.3 Welds in transverse girder assemblies are to be crack detected by an approved method to the satisfaction of the Surveyors. Other joints are to be similarly tested if required by the Surveyors.

■ *Section 6* Turning gear

6.1 General requirements

6.1.1 Turning gear is to be provided for all engines to facilitate operating and maintenance regimes as required by the manufacturer.

6.1.2 The turning gear for all main propulsion engines is to be power-driven and, if electric, is to be continuously rated at a value to ensure protection to the weakest part of the machinery.

6.1.3 The turning gear for auxiliary engines may be hand operated (manual) except where this is not practicable, in which case the provision of 6.1.2 is to be complied with.

6.1.4 The turning gear for all engines is to be fitted with safety interlocks which prevent engine operation when engaged, *see* Ch 1,3.10. Indication of engaged/not engaged is to be provided at all start positions.

6.1.5 The remote control device of power-driven turning gear is to be so designed that power is removed from the turning gear when the operating switch is released.

6.1.6 Means are to be provided to secure the turning gear when disengaged.

6.1.7 Overload protection arrangements are to be provided to prevent damage to the electric motor and the turning gear train.

■ *Section 7*
Control and monitoring of main, auxiliary and emergency diesel engines

7.1 General

7.1.1 Control engineering systems are to be in accordance with the requirements of Pt 6, Ch 1.

7.1.2 Oil mist detection, or engine bearing temperature monitors or alternative methods for crankcase protection are to be provided:

(a) When arrangements are fitted to override the automatic shut-down for excessive reduction of the lubricating oil supply pressure.
(b) For engines of 2250 kW and above or having cylinders of more than 300 mm bore.

NOTES

1. For medium and high speed engines, automatic shut-down of the engine is to occur.
2. For slow speed engines, automatic slow-down is to occur.
3. Where arrangements are made to override the automatic slow-down or shut-down due to high oil mist or bearing temperature, the override is to be independent of other overrides.
4. Where the bearing temperature monitoring method is chosen, all bearings in the crankcase are to be monitored where practicable, e.g., main, crankpin, crosshead.
5. Where engine bearing temperature monitors or alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase, details are to be submitted for consideration. The submission is to demonstrate that the arrangements are equivalent to those provided by oil mist detection, *see* 10.8.14.

7.1.3 All main and auxiliary engines intended for essential services are to be provided with means of indicating the lubricating oil pressure supply to them. Where such engines are of more than 37 kW (50 shp), audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. Further, these alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

7.2 Main engine governers

7.2.1 An efficient governor is to be fitted to each main engine so adjusted that the speed does not exceed that for which the engine is to be classed by more than 15 per cent.

7.2.2 Oil engines coupled to electrical generators which are the source of power for main electric propulsion motors are to comply with the requirements for auxiliary engines in respect of governors and overspeed protection devices.

7.3 Auxiliary engine governors

7.3.1 Auxiliary engines intended for driving electric generators are to be fitted with governors which, with fixed setting, are to control the speed within 10 per cent momentary variation and 5 per cent permanent variation when the full load is suddenly taken off or, when after having run on no-load for at least 15 minutes, the load is suddenly applied as follows:

(a) For engines with BMEP less than 8 bar, full load, or
(b) For engines with BMEP greater than 8 bar, $\frac{800}{\text{BMEP}}$ per cent, but not less than one third, of full load, the full load being attained in not more than two additional equal stages as rapidly as possible.

7.3.2 If an engine cannot achieve the requirements of 7.3.1 then the actual load step is to be declared and verified through testing to ensure the requirements specified in Pt 6, Ch 2,1.7 are satisfied.

7.3.3 Emergency engines are to comply with 7.3.1 except that the initial load required by 7.3.1(b) is to be not less than the total connected emergency statutory load, or if their total consumer load is applied in steps, the following requirements are to be met:

(a) the total load is supplied within 45 seconds from power failure on the main switchboard;
(b) the maximum step load is declared and demonstrated; and
(c) the power distribution system is designed such that the declared maximum step loading is not exceeded.

7.3.4 Compliance of time delays and loading sequence with the requirements of 7.3.2 is to be demonstrated at the ship's trials.

7.3.5 For alternating current installations, the permanent speed variation of the machines intended for parallel operation are to be equal within a tolerance of ±0,5 per cent. Momentary speed variations with load changes in accordance with 7.3.1 are to return to and remain within one per cent of the final steady state speed. This should normally be accomplished within five but in no case more than eight seconds. For quality of power supplies, *see* Pt 6, Ch 2,1.7.

7.4 Overspeed protective devices

7.4.1 Each main engine developing 220 kW (300 shp) or over which can be declutched or which drives a controllable pitch propeller, and also each auxiliary engine developing 220 kW (300 shp) and over for driving an electric generator, is to be fitted with an approved overspeed protective device.

7.4.2 The overspeed protective device, including its driving mechanism, is to be independent of the governor required by 7.2 or 7.3 and is to be so adjusted that the speed does not exceed that for which the engine and its driven machinery are to be classed by more than 20 per cent for main engines and 15 per cent for auxiliary engines.

7.5 Unattended machinery

7.5.1 Where main and auxiliary diesel engines are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by 7.5 to 7.7, as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

7.5.2 Where machinery is arranged to start automatically or from a remote control station, interlocks are to be provided to prevent start-up under conditions which could hazard the machinery.

7.5.3 Where machinery specified in this Section is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

7.5.4 Where a first stage alarm together with a second stage alarm and automatic shut-down of machinery are required in the relevant Tables of this Section, the sensors and circuits utilised for the second stage alarm and automatic shut-down are to be independent of those required for the first stage alarm.

7.5.5 Means are to be provided to prevent leaks from high pressure oil fuel injection piping for main and auxiliary engines dripping or spraying onto hot surfaces or into machinery air inlets. Such leakage is to be collected and, where practicable, led to a collector tank(s) fitted in a safe position. An alarm is to be provided to indicate that leakage is taking place. These requirements may also be applicable to high pressure hydraulic oil piping, depending upon the location.

7.6 Oil engines for propulsion purposes

7.6.1 Alarms and safeguards are indicated in 7.6.2 to 7.6.8 and Tables 2.7.1(a) and (b).

7.6.2 Alarms are to operate for the fault conditions shown in Table 2.7.1(a). Where applicable, indication is to be given at the relevant control stations that the speed or power of the main propulsion engine(s) is to be manually reduced or has been reduced automatically.

7.6.3 Alarms are to operate, and automatic shut-down of machinery is to occur for the fault conditions shown in Table 2.7.1(b).

7.6.4 The following engine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the propulsion engine(s).

(a) Lubricating oil supply.
(b) Oil fuel supply, *see also* 7.6.5.
(c) Piston coolant supply, where applicable.
(d) Cylinder coolant supply, where applicable.
(e) Fuel valve coolant supply, where applicable.

7.6.5 The oil fuel supply may be fitted with an automatic control for viscosity instead of the temperature control required by 7.6.4.

7.6.6 Indication of the starting air pressure is to be provided at each control station from which it is possible to start the main propulsion engine(s).

7.6.7 The number of automatic consecutive attempts which fail to produce a start is to be limited to three. For reversible engines which are started and stopped for manoeuvring purposes, means are to be provided to maintain sufficient starting air in the air receivers. For electric starting, *see* 16.4.

7.6.8 Prolonged running in a restricted speed range is to be prevented automatically or, alternatively, an indication of restricted speed ranges is to be provided at each control station.

7.7 Auxiliary engines

7.7.1 Alarms and safeguards are indicated in Table 2.7.2.

7.7.2 For engines operating on heavy oil fuel, automatic temperature or viscosity controls are to be provided.

7.8 Emergency diesel engines

7.8.1 Alarms and safeguards are to be fitted in accordance with Table 2.7.3.

7.8.2 The safety and alarm systems are to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the system and its associated machinery, but also the complete installation, as well as the ship.

7.8.3 Regardless of the engine output power, if shut-downs additional to those specified in Table 2.7.3 are provided except for the overspeed shut-down, they are to be automatically overridden when the engine is in automatic or remote control mode during navigation.

7.8.4 Grouped alarms of at least those items listed in Table 2.7.3 are to be arranged on the bridge.

Table 2.7.1(a) Oil engines for propulsion purposes: Alarms and slow-downs (*see continuation)*

Item	Alarm	Note
Lubricating oil sump level	Low	Engines
Lubricating oil inlet pressure*	1st stage low	Engines. Slow-down
Lubricating oil inlet temperature*	High	Engines
Lubricating oil filters differential pressure	High	—
Oil mist concentration in crankcase or bearing temperature	High	Automatic slow-down of slow speed engines, *see* 7.1.2. One sensor per lubricator unit. Slow-down (automatic on medium and high speed engines)
Cylinder lubricator flow	Low	
Thrust bearing temperature*	High	Slow-down
Common rail servo oil pressure	Low	—
Piston coolant inlet pressure	Low	If a separate system. Slow-down
Piston coolant outlet temperature*	High	Per cylinder (if a separate system). Slow-down
Piston coolant outlet flow*	Low	Per cylinder (if a separate system)
Cylinder coolant inlet pressure or flow*	Low	Slow-down (automatic on medium and high speed engines)
Cylinder coolant outlet temperature*	1st stage high	Per cylinder (if a separate system). Slow-down (automatic on medium and high speed engines)
Engine cooling water system – oil content	High	Where engine cooling water used in oil/water heat exchangers
Sea-water cooling pressure	Low	—
Fuel valve coolant pressure	Low	If a separate system
Fuel valve coolant temperature	High	If a separate system
Oil fuel pressure from booster pump	Low	—
Oil fuel temperature or viscosity*	High and Low	Heavy oil only
Oil fuel high pressure piping*	Leakage	*See* 7.5.5
Common rail fuel oil pressure	Low	—
Charge air cooler outlet temperature	High and Low	4-stoke medium and high speed engines
Scavenge air temperature (fire)	High	Per cylinder (2-stoke engines). Slow-down
Scavenge air receiver water level	High	—

7.8.5 In addition to the fuel oil control from outside the space, a local means of engine shut-down is to be provided.

7.8.6 Local indications of at least those items listed in Table 2.7.3 are to be provided within the same space as the diesel engines and are to remain operational in the event of failure of the alarm and safety systems.

Table 2.7.1(a) Oil engines for propulsion purposes: Alarms and slow-downs (*conclusion*)

Item	Alarm	Note
Exhaust gas temperature*	High	Per cylinder. Slow-down (automatic on medium and high speed engines), *see* Note 5
Exhaust gas temperature deviation from average*	High	Per cylinder, *see* Note 5
Turbo-charger exhaust gas inlet temperature	High	Each turbo-charger *See* Note 6
Turbo-charger exhaust gas outlet temperature*	High	Each turbo-charger
Turbo-charger lubricating oil inlet pressure	Low	If system not integral with turbo-charger
Turbo-charger lubricating oil outlet temperature	High	Each bearing, if system not integral with turbo-charger. *See* Note 7
Starting air pressure*	Low	Before engine manoeuvring valve
Control air pressure	Low	—
Direction of rotation	Wrong way	Reversible engines, *see also* 7.6.7
Automatic start of engine	Failure	*See* 7.6.7
Electrical starting battery charge level	Low	—
Feed water or water/thermal fluid forced circulation flow (if fitted)	Low	*See* Ch 14,6.2.7 and Note 8
Uptake temperature	High	To monitor for soot fires. *See* Notes 8 and 9

NOTES
1. Where ‘per cylinder’ appears in this Table, suitable sensors may be situated on manifold outlets for medium and high speed engines.
2. For engines and gearing of 1500 kW or less, only the items marked* are required.
3. Common sensors are acceptable for alarms and slow-down functions.
4. Except where stated otherwise in the Table, slow-down may be effected by either manual or automatic means, by reduction of speed or power as appropriate.
5. For medium and high speed engine power <500 kW/cylinder, a common sensor for exhaust gas manifold temperature may be fitted.
6. May be combined with exhaust gas outlet temperature high alarm where the turbo-charger is mounted directly on the exhaust manifold.
7. Where the outlet temperature for each bearing cannot be measured due to the design, details of alternative proposals in accordance with the turbo-charger manufacturer’s instructions may be submitted for consideration.
8. Alarm only required when an exhaust gas economiser/boiler/thermal oil heater is fitted.
9. Alternatively, details of an appropriate fire detection system are to be submitted for consideration.

Table 2.7.1(b) Oil engines for propulsion purposes: Alarms and slow-downs

Item	Alarm	Note
Lubricating oil inlet pressure	2nd stage low	Automatic shut-down of engines, *see* 7.5.4
Oil mist concentration in crankcase or bearing temperature	High	Automatic shut-down of medium and high speed engines, *see* 7.1.2
Cylinder coolant outlet temperature	2nd stage high	Automatic shut-down of medium and high speed engines, *see* 7.5.4
Overspeed	High	Automatic shut-down of engine, *see also* 7.4. Details of alternative proposals in accordance with the manufacturerer’s instructions may be submitted for consideration

Table 2.7.2 Auxiliary engines: Alarms and safeguards

Item	Alarm	Note
Lubricating oil inlet temperature	High	—
Lubricating oil inlet pressure	1st stage low	—
	2nd stage low	Automatic shut-down of engine, *see* 7.5.4
Oil mist concentration in crankcase or bearing temperature	High	Automatic shut-down of engine, *see* 7.1.2
Oil fuel high pressure piping	Leakage	*See* 7.5.5
Coolant outlet temperature (for engines >220 kW)	1st stage high	—
	2nd stage high	Automatic shut-down of engine, *see* 7.5.4
Coolant pressure or flow	Low	—
Oil fuel temperature or viscosity	High and Low	Heavy oil only
Overspeed	High	Automatic shut-down of engine, *see also* 7.4. Details of alternative proposals in accordance with the manufacturer's instructions may be submitted for consideration
Common rail servo oil pressure	Low	—
Common rail fuel oil pressure	Low	—
Starting air pressure	Low	—
Electrical starting battery charge level	Low	—
Exhaust gas temperature (for engines >500 kW/cylinder)	High	Per cylinder.
Feed water or water/thermal fluid forced circulation flow (if fitted)	Low	*See* Ch 14,6.2.7 and Note 3
Uptake temperature	High	To monitor for soot fires. *See* Notes 3 and 4

NOTES
1. For emergency diesel engines, including engines used for the emergency source of electrical power required by SOLAS, *see* Ch 2,16.
2. The arrangements are to comply with the requirements of the National Authority concerned.
3. Alarm only required when an exhaust gas economiser/boiler/thermal oil heater is fitted.
4. Alternatively, details of an appropriate fire detection system are to be submitted for consideration.

Table 2.7.3 Emergency diesel engines: Alarms and safeguards

Item	Alarm for engine power <220 kW	Alarm for engine power ≤ 220kW	Note
Fuel oil leakage from pressure pipes	Leakage	Leakage	*See* 7.1.2
Lubricating oil temperature	—	High	—
Lubricating oil pressure	Low	Low	—
Oil mist concentration in crankcase	—	High	*See* Note
Coolant pressure or flow	—	Low	—
Coolant temperature (can be air)	High	High	—
Overspeed	—	High	Automatic shut-down

NOTE
For engines having a power of more than 2250 kW or a cylinder bore of more than 300 mm.

■ *Section 8*
Piping

8.1 Oil fuel, hydraulic and high pressure oil systems

8.1.1 Oil fuel and hydraulic oil piping systems arrangements are to comply with Chapters 12 and 14 as applicable.

8.1.2 Oil fuel pipe systems in general, tanks and their fittings are to comply with the requirements of Chapter 14 and Part 3.

8.1.3 Where pumps are essential for engine operation, not less than two oil fuel and two hydraulic oil pressure pumps are to be provided for their respective service and arranged such that failure of one pump does not render the other inoperative. Each oil fuel pump and hydraulic oil pump is to be capable of supplying the quantity of oil for engine operation at its maximum continuous rating and arranged ready for immediate use.

8.1.4 All external high pressure fuel delivery lines between the high pressure fuel pumps and fuel injectors are to be protected with a jacketed piping system capable of containing fuel from a high pressure line failure. If flexible hoses are used for shielding purposes, these arrangements are to be approved.

8.1.5 The hydraulic oil pressure piping between the high pressure hydraulic pumps and hydraulic actuators is to be protected with a jacketed piping system capable of containing hydraulic oil leakage from a high pressure pipe failure.

8.1.6 Where flammable oils are used in high pressure systems, the oil pipe lines between the high pressure oil pump and actuating oil pistons are to be protected with a jacketed piping system capable of preventing oil spray from a high-pressure line failure.

8.1.7 Accumulators and associated high pressure piping are to be designed, manufactured and tested in accordance with a standard applicable to the maximum pressure and temperature rating of the system.

8.1.8 Diesel engine fuel system components are to be designed to accommodate the maximum peak pressures experienced in service. In particular this applies to the fuel injection pump supply and spill line piping which may be subject to high-pressure pulses from the pump. Connections on such piping systems should be chosen to minimise the risk of pressurised oil fuel leaks.

8.1.9 The protection is to prevent oil fuel or oil fuel mist from reaching a source of ignition on the engine or its surroundings. Suitable drainage arrangements are to be made for draining any oil fuel leakage to collector tank(s) fitted in a safe position. An alarm is to be provided to indicate that leakage is taking place.

8.1.10 Where multi-engined installations are supplied from the same fuel source, means of isolating the fuel supply and spill piping to individual engines are to be provided. These means of isolation are not to affect the operation of the other engines and are to be operable from a position not rendered inaccesible by a fire on any of the engines.

8.1.11 All valves, cocks and screwed connections are to be of a type-tested type applicable to the maximum service conditions anticipated in normal service.

8.1.12 Isolating valves and cocks are to be located as near as practicable to the equipment to be isolated. All valves forming part of the oil fuel and hydraulic oil installation are to be capable of being controlled from readily accessible positions above the working platform.

8.1.13 High pressure oil fuel and high pressure hydraulic oil piping systems are to be provided with high pressure alarms with set points that do not exceed the system design pressures.

8.1.14 High pressure oil fuel and high pressure hydraulic piping systems are to be provided with suitable relief valves on any part of the system that can be isolated and in which pressure can be generated. The settings of the relief valves are not to exceed the design pressures. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressures.

8.1.15 Equipment fitted for monitoring pressures and temperatures in the high pressure oil fuel and high pressure hydraulic oil systems is to comply with a Recognised Standard suitable to the anticipated vibration and temperature conditions.

8.1.16 A fatigue analysis is to be carried out in accordance with a standard applicable to the system under consideration and all anticipated pressure, pulsation and vibration loads are to be addressed. The analysis is to demonstrate that the design and arrangements are such that the likelihood of failure is as low as reasonably practicable. The analysis is to identify all assumptions made and standards to be applied during manufacture and testing of the system. Any potential weak points which may develop due to incorrect construction or assembly are also to be identified.

8.1.17 For high pressure oil containing and mechanical power transmission systems, the quality plan for sourcing, design, installation and testing of components is to address the following issues:
(a) Design and manufacturing standard(s) applied.
(b) Materials used for construction of key components and their sources.
(c) Details of the quality control system applied during manufacture and testing.
(d) Details of type approval, type testing or approved type status assigned to the machinery or equipment.
(e) Details of installation and testing recommendations for the machinery or equipment.

8.2 Exhaust systems

8.2.1 Where the surface temperature of the exhaust pipes and silencer may exceed 220ºC, they are to be water cooled or efficiently lagged to minimise the risk of fire and to prevent damage by heat. Where lagging covering the exhaust piping system including flanges is oil-absorbing or may permit penetration of oil, the lagging is to be encased in sheet metal or equivalent. In locations where the Surveyor is satisfied that oil impingement could not occur, the lagging need not be encased.

8.2.2 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back to the engine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard.

8.2.3 Where the exhausts of two or more engines are led to a common silencer or exhaust gas-heated boiler or economiser, an isolating device is to be provided in each exhaust pipe.

8.2.4 For alternatively fired furnaces of boilers using exhaust gases and oil fuel, the exhaust gas inlet pipe is to be provided with an isolating device and interlocking arrangements whereby oil fuel can only be supplied to the burners when the isolating device is closed to the boiler.

8.2.5 In two-stroke main engines fitted with exhaust gas turbo-blowers which operate on the impulse system, provision is to be made to prevent broken piston rings entering the turbine casing and causing damage to blades and nozzle rings.

8.3 Starting air pipe systems and safety fittings

8.3.1 In designing the compressed air installation, care is to be taken that the compressor air inlets will be located in an atmosphere reasonably free from oil vapour or, alternatively, an air duct from outside the machinery space is to be led to the compressors.

8.3.2 The air discharge pipe from the compressors is to be led direct to the starting air receivers. Provision is to be made for intercepting and draining oil and water in the air discharge for which purpose a separator or filter is to be fitted in the discharge pipe between compressors and receivers.

8.3.3 The starting air pipe system from receivers to main and auxiliary engines is to be entirely separate from the compressor discharge pipe system. Stop valves on the receivers are to permit slow opening to avoid sudden pressure rises in the piping system. Valve chests and fittings in the piping system are to be of ductile material.

8.3.4 Drain valves for removing accumulations of oil and water are to be fitted on compressors, separators, filters and receivers. In the case of any low-level pipelines, drain valves are to be fitted to suitably located drain pots or separators.

8.3.5 The starting air piping system is to be protected against the effects of explosions by providing an isolating non-return valve or equivalent at the starting air supply to each engine.

8.3.6 In direct reversing engines bursting discs or flame arresters are to be fitted at the starting valves on each cylinder; in non-reversing and auxiliary engines at least one such device is to be fitted at the supply inlet to the starting air manifold on each engine. The fitting of bursting discs or flame arresters may be waived in engines where the cylinder bore does not exceed 230 mm.

8.3.7 Alternative safety arrangements may be submitted for consideration.

■ *Section 9* Starting arrangements

9.1 Dead ship condition starting arrangements

9.1.1 Means are to be provided to ensure that machinery can be brought into operation from the dead ship condition without external aid.

9.1.2 Dead ship condition for the purpose of 9.1.1 is to be understood to mean a condition under which the main propulsion plant, boilers and auxiliaries are not in operation. In restoring propulsion, no stored energy for starting and operating the propulsion plant is assumed to be available. Additionally, neither the main source of electrical power nor other essential auxiliaries are assumed to be available for starting and operating the propulsion plant.

9.1.3 Where the emergency source of power is an emergency generator which fully complies with the requirements of Pt 6, Ch 2, this generator may be used for restoring operation of the main propulsion plant, boilers and auxiliaries where any power supplies necessary for engine operation are also protected to a similar level as the starting arrangements.

9.1.4 Where there is no emergency generator installed or an emergency generator does not comply with Pt 6, Ch 2, the arrangements for bringing main and auxiliary machinery into operation are to be such that the initial charge of starting air or initial electrical power and any power supplies for engine operation can be developed on board ship without external aid. If for this purpose an emergency air compressor or an electric generator is required, these units are to be powered by a hand-starting oil engine or a hand-operated compressor. The arrangements for bringing main and auxiliary machinery into operation are to have capacity such that the starting energy and any power supplies for engine operation are available within 30 minutes of a dead ship condition.

9.1.5 For cargo ships of less than 500 gross tons and which are not required to comply with the *International Convention for the Safety of Life at Sea, 1974*, as amended (SOLAS 74), alternative arrangements to those specified in 9.1.3 or 9.1.4 may be proposed for consideration. Details of the alternative arrangements are to be included in the plans and details required by 1.1.5 and are to demonstrate that the arrangements provide for starting from the dead ship condition and are in accordance with any applicable statutory requirements of the National Authority of the country in which the ship is to be registered.

9.2 Air receiver capacity

9.2.1 Where the main engine is arranged for air starting the total air receiver capacity is to be sufficient to provide without replenishment, not less than 12 consecutive starts of the main engine, alternating between ahead and astern if of the reversible type and not less than 6 consecutive starts if of the non-reversible type. At least two air receivers of approximately equal capacity are to be provided. For scantlings and fittings of air receivers, *see* Chapter 11.

9.2.2 For multi-engine installations, the number of starts required for each engine are to be as follows:

(a) Two engines through common reduction gearing:
6 starts per engine for fixed pitch propeller/propellers;
3 starts per engine for controllable pitch propeller/propellers.

(b) Three engines or more through common reduction gearing:
3 starts per engine.

9.2.3 No engine is to have fewer than 3 starts for any arrangement. For electric propulsion arrangements, a minimum of 3 starts per engine with a minimum capacity of 12 starts of the largest start air consumption engine in total are required.

9.3 Electric starting

9.3.1 Where main engines are fitted with electric starters, two batteries are to be fitted. Each battery is to be capable of starting the engines when cold and the combined capacity is to be sufficient without recharging to provide the number of starts of the main engines as required by 9.2. In other respects batteries are to comply with the requirements of Pt 6, Ch 2,11.

9.3.2 Electric starting arrangements for auxiliary engines are to have two separate batteries or be supplied by separate circuits from the main engine batteries when such are provided. Where one of the auxiliary engines only is fitted with an electric starter one battery will be acceptable.

9.3.3 The combined capacity of the batteries for starting the auxiliary engines is to be sufficient for at least three starts for each engine.

9.3.4 Engine starting batteries are to be used only for the purposes of starting the engines and for the engines' own control, alarm, monitoring and safety arrangements. Means are to be provided to ensure that the stored energy in the batteries is maintained at a level required to start the engines, as defined in 9.3.1 and 9.3.3.

9.3.5 Where engines are fitted with electric starting batteries, an alarm is to be provided for low battery charge level.

9.3.6 For cargo ships of less than 500 gross tons which are not required to comply with the *International Convention for the Safety of Life at Sea, 1974*, as amended (SOLAS 74), the emergency source of electrical power may be used as one of the sources of energy required by 9.3.1 or 9.3.2 for electric starting. Where the emergency source of electrical power is an accumulator battery and it is to be used for electric starting, it is to have the additional capacity required to ensure emergency supplies are not compromised and is to be adequately protected and suitably located for use in an emergency.

9.4 Starting of the emergency source of power

9.4.1 Emergency generators are to be capable of being readily started in their cold conditions down to a temperature of 0°C. If this is impracticable, or if lower temperatures are likely to be encountered, consideration is to be given to the provision and maintenance of heating arrangements, so that ready starting will be assured.

9.4.2 Each emergency generator that is arranged to be automatically started is to be equipped with an approved starting system having two independent sources of stored energy, each of which is sufficient for at least three consecutive starts. When hand (manual) starting is demonstrated to be effective, only one source of stored energy need be provided. However, this source of stored energy is to be protected against depletion below the level required for starting.

9.4.3 Provision is to be made to maintain continuously the stored energy at all times, and for this purpose:

(a) Electrical and hydraulic starting systems are to be maintained from the emergency switchboard.

(b) Compressed air starting systems may be maintained by the main or auxiliary compressed air receivers, through a suitable non-return valve, or by an emergency air compressor energised by the emergency switchboard.

(c) All these starting, charging and energy storing devices are to be located in the emergency generator room. These devices are not to be used for any purpose other than the operation of the emergency generator.

9.4.4 When automatic starting is not required by the Rules and where it can be demonstrated as being effective, hand (manual) starting is permissible, such as manual cranking, inertial starters, manual hydraulic accumulators, powder charge cartridges.

9.4.5 When hand (manual) starting is not practicable, the provisions under 9.4.2 and 9.4.3 are to be complied with except that starting may be manually initiated.

9.4.6 Electric starting arrangements are also to satisfy 9.3.2 to 9.3.5.

9.5 Engine control, alarm monitoring and safety system power supplies

9.5.1 Power supplies are to be arranged so that power for electrically powered control, alarm, monitoring and safety systems required for engine starting and operation will remain available in the event of a failure. Power is to remain available to permit starting attempts for the number of starts specified by this Section for each individual source of stored energy.

9.5.2 Where adequate battery and charging capacity exists, an engine starting battery may be used as one source of electrical power required by 9.5.1.

9.5.3 An alarm is to be activated in the event of failure of a power supply and, where applicable, low battery charge level. Manual power supply changeover facilities are permitted.

■ *Section 10* Safety arrangements

10.1 Relief valves

10.1.1 Scavenge spaces in open connection with cylinders are to be provided with explosion relief valves.

10.1.2 Crankcases are to be provided with lightweight spring-loaded valves or other quick-acting and self-closing devices, to relieve the crankcases of pressure in the event of an internal explosion and to prevent any inrush of air thereafter. The valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0,2 bar.

10.1.3 The valve lids are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

10.1.4 Each valve is to be fitted with a flame arrester that permits flow for crankcase pressure relief and prevents the passage of flame following a crankcase explosion. The valves are to be type tested in a configuration that represent the installation arrangements that will be used on an engine and in accordance with Section 18. The valves are to be positioned on engines to minimise the possibility of danger and damage arising from emission of the crankcase atmosphere. Where shielding from the emissions is fitted to a valve, the valve is to be type tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valve.

10.1.5 The valves are to be provided with a copy of the manufacturer's installation and maintenance manual for the size and type of valve being supplied for installation on a particular engine. The manual is to contain the following information:

- Description of valve with details of function and design limits.
- Copy of type test certification.
- Installation instructions.
- Maintenance and in service instructions to include testing and renewal of any sealing arrangements.
- Actions required after a crankcase explosion.

10.1.6 A copy of the installation and maintenance manual required by 10.1.5 is to be provided on board the ship.

10.1.7 Plans showing details and arrangements of the relief valves are to be submitted for approval, *see* 1.1.

10.1.8 The valves are to be provided with suitable markings that include the following information:

- Name and address of manufacturer.
- Designation and size.
- Month/Year of manufacture.
- Approved installation orientation.

10.2 Number of relief valves

10.2.1 In engines having cylinders not exceeding 200 mm bore or having a crankcase gross volume not exceeding 0,6 m^3, relief valves may be omitted.

10.2.2 In engines having cylinders exceeding 200 mm but not exceeding 250 mm bore, at least two relief valves are to be fitted; each valve is to be located at or near the ends of the crankcase. Where the engine has more than eight crankthrows an additional valve is to be fitted near the centre of the engine.

10.2.3 In engines having cylinders exceeding 250 mm but not exceeding 300 mm bore, at least one relief valve is to be fitted in way of each alternate crankthrow with a minimum of two valves. For engines having 3, 5, 7, 9, etc., crankthrows, the number of relief valves is not to be less than 2, 3, 4, 5, etc., respectively.

10.2.4 In engines having cylinders exceeding 300 mm bore at least one valve is to be fitted in way of each main crankthrow.

10.2.5 Additional relief valves are to be fitted for separate spaces on the crankcase, such as gear or chaincases for camshaft or similar drives, when the gross volume of such spaces exceeds 0,6 m^3.

10.3 Size of relief valves

10.3.1 The combined free area of the crankcase relief valves fitted on an engine is to be not less than 115 cm^2/m^3 based on the volume of the crankcase.

10.3.2 The free area of each relief valve is to be not less than 45 cm^2.

10.3.3 The free area of the relief valve is the minimum flow area at any section through the valve when the valve is fully open.

10.3.4 In determining the volume of the crankcase for the purpose of calculating the combined free area of the crankcase relief valves, the volume of the stationary parts within the crankcase may be deducted from the total internal volume of the crankcase.

10.4 Vent pipes

10.4.1 Through ventilation, and any arrangement which could produce a flow of external air within the crankcase, is in principle not permitted except for trunk piston type dual fuel engines where crankcase ventilation is to be provided. Where crankcase vent or breather pipes are fitted, they are to be made as small as practicable and/or as long as possible to minimise the inrush of air after an explosion. Vents or breather pipes from crankcases of main engines are to be led to a safe position on deck or other approved position.

10.4.2 If provision is made for the extraction of gases from within the crankcase, e.g. for oil mist detection purposes, the vacuum within the crankcase is not to exceed 25 mm of water.

10.4.3 Lubricating oil drain pipes from engine sump to drain tank are to be submerged at their outlet ends. Where two or more engines are installed, vent pipes, if fitted, and lubrication oil drain pipes are to be independent to avoid intercommunication between crankcases.

10.5 Warning notice

10.5.1 A warning notice is to be fitted in a prominent position, preferably on a crankcase door on each side of the engine, or alternatively at the engine room control station. This warning notice is to specify that whenever overheating is suspected in the crankcase, the crankcase doors or sight holes are not to be opened until a reasonable time has elapsed after stopping the engine, sufficient to permit adequate cooling within the crankcase.

10.6 Crankcase access and lighting

10.6.1 Where access to crankcase spaces is necessary for inspection purposes, suitably positioned rungs or equivalent arrangements are to be provided as considered appropriate.

10.6.2 When interior lighting is provided it is to be flameproof in relation to the interior and details are to be submitted for approval. No wiring is to be fitted inside the crankcase.

10.7 Fire-extinguishing system for scavenge manifolds

10.7.1 Crosshead type engine scavenge spaces in open connection with cylinders are to be provided with approved fixed or portable fire-extinguishing arrangements which are to be independent of the fire-extinguishing system of the engine room.

10.8 Oil mist detection

10.8.1 Where crankcase oil mist detection arrangements are fitted, they are to be of a type approved by LR, tested in accordance with Section 19 and comply with 10.8.2 to 10.8.15.

10.8.2 The oil mist detection system and arrangements are to be installed in accordance with the engine designer's and oil mist detection equipment manufacturer's instructions/ recommendations. The following particulars are to be included in the instructions:

(a) A schematic layout of the engine oil mist detection and alarm system showing locations of engine crankcase sample points and cabling/piping arrangements together with pipe dimensions to the detector.
(b) Evidence of study to justify the selected locations of sample points and sample extraction rate (if applicable) in consideration of the crankcase arrangements and geometry and the predicted crankcase atmosphere where oil mist can accumulate.
(c) The manufacturer's maintenance and test manual.
(d) Information relating to type or in-service testing of the engine with engine protection system test arrangements having approved types of oil mist detection equipment.

10.8.3 A copy of the oil mist detection equipment maintenance and test manual required by 10.8.2 is to be provided on board ship.

10.8.4 Oil mist detection and alarm information is to be capable of being read from a safe location away from the engine.

10.8.5 In the case of multi engine installations, each engine is to be provided with individual, dedicated oil mist detection arrangements and alarm(s).

10.8.6 Oil mist detection and alarm systems are to be capable of being tested on the test bed and on board when the engine is at a standstill and when the engine is running at normal operating conditions in accordance with test procedures that are acceptable to LR.

10.8.7 Alarms and safeguards for the oil mist detection system are to be in accordance with Pt 6, Ch 1 as applicable.

10.8.8 The oil mist detection arrangements are to provide an alarm indication in the event of a foreseeable functional failure in the equipment and installation arrangements. *See* Pt 6, Ch 1,2.4.5.

10.8.9 The oil mist detection system is to provide an indication that any lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication.

10.8.10 Where oil mist detection equipment includes the use of programmable electronic systems, the arrangements are to be in accordance with Pt 6, Ch 1 as applicable.

10.8.11 Schematic layouts showing details and arrangements of oil mist detection and alarm systems are to be submitted. *See* Pt 5, Ch 1,1.

10.8.12 The equipment together with detectors is to be tested when installed on the test bed and on board ship to demonstrate that the detection and alarm system functions correctly. The testing arrangements are to be to the satisfaction of the Surveyor.

10.8.13 Where sequential oil mist detection arrangements are provided, the sampling frequency and time is to be as short as reasonably practicable.

10.8.14 Where alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase, detailed information is to be submitted for consideration. The information is to include:

(a) Engine particulars – type, power, speed, stroke, bore and crankcase volume.
(b) Details of arrangements designed to prevent the build up of potentially explosive conditions within the crankcase, e.g., bearing temperature monitoring, oil splash temperature monitoring, crankcase pressure monitoring, and recirculation arrangements.
(c) Evidence to demonstrate that the arrangements are effective in preventing the build up of potentially explosive conditions together with details of in-service experience.
(d) Operating instructions and the maintenance and test instructions.

10.8.15 Where it is proposed to use the introduction of inert gas into the crankcase to minimise a potential crankcase explosion, details of the arrangements are to be submitted for consideration.

■ *Section 11* Program for trials of diesel engines to assess operational capability

11.1 Works trials (acceptance test)

11.1.1 Diesel engines which are to be subjected to trials on the test bed at the manufacturer's works and under attendance by the Surveyor(s) are to be tested in accordance with the scope of works trials specified in 11.1.2 to 11.1.10. The scope of the trials is to be agreed between the LR Surveyor and the manufacturer prior to testing. At the discretion of the Surveyor, the scope of the trials may be extended depending on the engine application.

11.1.2 For electronically controlled engines:

(a) works tests in accordance with 1.1.6(h); and
(b) verification of engine configuration, *see* 4.3.2, and that the approved software quality plans, including the software configuration management process, are being applied.

11.1.3 For all stages of the works trials the pertaining operation values are to be measured and recorded by the engine manufacturer. All results are to be compiled in an acceptance protocol to be issued by the engine manufacturer.

11.1.4 In each case given in Table 2.11.1, all measurements conducted at the various load points shall be carried out at steady operating conditions. The readings for 100 per cent power (rated power at rated speed) are to be taken twice at an interval of at least 30 minutes.

11.1.5 The data to be measured and recorded, when testing the engine at various load points, are to include all necessary parameters for the engine operation. The crankshaft deflection is to be checked when this check is required by the manufacturer during the operating life of the engine. Crankshaft deflection measurements are to be taken before (cold condition) and after (hot condition) works acceptance trials.

11.1.6 Checks of components to be presented for inspection after the works trials are left to the discretion of the Surveyor.

11.1.7 The Surveyor may require that after the trials the fuel delivery system is restricted so as to limit the engines to run at not more than 100 per cent power. The setting of the restriction is to be made as applicable to the intended fuel. Any restriction settings, and other changes to the engine's fuel injection equipment required for operation on special fuels, are to be recorded and included by the engine manufacturer.

11.1.8 For the duration of the acceptance test, no interventions or adjustments will be made to the machinery under test.

11.1.9 The testing of exhaust gas emissions is to comply with MARPOL as applicable.

11.1.10 For all stages that the engine is to be tested and where no duration is specified in Table 2.11.1, the load point is to be maintained for a sufficient period to allow pertaining values to be measured and recorded when the engine has achieved a steady operating condition.

11.2 Shipboard trials

11.2.1 After the conclusion of the running-in programme prescribed by the engine manufacturer, engines are to undergo shipboard trials as specified in Table 2.11.2. The scope of the trials is to be agreed between the LR Surveyor and the Shipyard prior to testing.

11.2.2 Engines driving generators or important auxiliaries are to be subjected to an operational test for at least 4 hours. During the test, the set concerned is required to operate at its rated power for an extended period. It is to be demonstrated that the engine is capable of supplying 100 per cent of its rated power, and in the case of shipboard generating sets account shall be taken of the times needed to actuate the generator's overload protection system.

11.2.3 In addition to 11.2.2, for engines driving generators for electric propulsion motors as well as auxiliaries, an operational test is to be carried out of at least 4 hours duration at a load which corresponds to 100 per cent of the electric propulsion motor(s) rated power. The astern/ahead manoeuvring capability of the propulsion system is to be demonstrated.

Table 2.11.1 Scope of works trials for diesel engines

Main engines driving propellers and waterjets		
Trial condition	Duration	Note
100% power (rated power) at rated engine speed, *R*	≥ 60 minutes	After having reached steady conditions
110% power at engine speed corresponding to 1,032**R*	30–45 minutes	After having reached steady conditions (1)
90% (or maximum continuous power), 75%, 50% and 25%	—	Powers in accordance with the nominal propeller curve
Starting and reversing manoeuvres	—	—
Testing of governor and independent overspeed protective device	—	*See* 7.2
Shut down device	—	*See* 7.4
Engines driving generators		
Trial condition	Duration	Note
100% power (rated power) at rated engine speed, *R*	≥ 50 minutes	After having reached steady conditions (2)
110% power	30 minutes	After having reached steady conditions (2) (3)
75%, 50% and 25% power and idle run	—	(2)
Start-up tests	—	—
Testing of governor and independent overspeed protective device	—	*See* 7.3
Shut-down device	—	*See* 7.4

NOTES
1. After running on the test bed, the fuel delivery system of main engines is normally to be so adjusted that overload power cannot be given in service.
2. The test is to be performed at rated speed with a constant governor setting.
3. After running on the test bed, the fuel delivery system of diesel engines driving generators must be adjusted such that overload (110%) power can be given in service after installation on board, so that the governing characteristics including the activation of generator protective devices can be fulfilled at all times.

11.2.4 Trials are to include demonstration of engine control, monitoring, alarm and safety system operation to confirm that they have been provided, installed and configured as intended and in accordance with the relevant requirements for main, auxiliary or emergency engines.

11.2.5 For electronically controlled engines:
(a) shipboard tests in accordance with 1.1.6(h); and
(b) verification of engine configuration, *see* 4.3.2, and that the approved software quality plans, including the software configuration management process, are being *applied.*

11.2.6 The suitability of an engine to burn residual or other special fuels is to be demonstrated, if the machinery installation is arranged to burn such fuels in service. *See also* Pt 6, Ch 1,7.2.1.

11.2.7 At the discretion of the attending Surveyor, the scope of the trials may be expanded in consideration of special operating conditions, such as towing, trawling, etc.

Table 2.11.2 Scope of shipboard trials for diesel engines

Main engines driving fixed-pitch propellers (1) (2)		
Trial condition	Duration	Note
At rated engine speed, *R*	≥ 4 hours	–
At engine speed corresponding to normal continuous power	≥ 2 hours	–
At engine speed corresponding to 1,032**R*	30 minutes	Where the engine adjustment permits, *see* 11.1.7
At minimum on-load speed	–	–
Starting and reversing manoeuvres	–	*See* Sections 9 and 16
In reverse direction of propeller rotation during the dock or sea trials at a minimum engine speed of 0,7**R*	10 minutes	–
Control monitoring, alarms and safety systems	–	Operation to be demonstrated
Where imposed, test to ensure engine can pass safely through barred speed range	–	–
Single engine driving a generator for propulsion only		
Trial condition	Duration	Note
100% power (rated propulsion power), see 11.2.3	≥ 4 hours	(3) (4)
At normal continuous propulsion power	≥ 2 hours	(3) (4)
110% power (rated propulsion power)	30 minutes	–
In reverse direction of propeller rotation at a minimum speed of 70% of the nominal propeller speed	10 minutes	(3) (4)
Starting manoeuvres	–	–
Control monitoring, alarms and safety systems	–	Operation to be demonstrated

NOTES
1. For main propulsion engines driving controllable pitch propellers, waterjets or reversing gears, the tests for main engines driving fixed-pitch propellers apply as appropriate.
2. Controllable pitch propellers are to be tested with various propeller pitches.
3. The tests are to be performed at rated speed with a constant governor setting.
4. Tests are to be based on the rated electrical powers of the electric propulsion motors.

Section 12
Component tests

12.1 Hydraulic tests

12.1.1 In general, items are to be tested by hydraulic pressure as indicated in Table 2.12.1. Where design features are such that modifications to the test requirements shown in Table 2.12.1 are necessary, alternative proposals for hydraulic tests are to be submitted for special consideration.

12.1.2 Where a manufacturer has demonstrated to LR that they have an acceptable quality management system, a manufacturer's hydraulic test certificate may be accepted for engine driven pumps as detailed in Table 2.12.1. Recognition and acceptance of the works quality control processes can be by one of the following routes:

(a) Approval under the LR Quality Scheme for Machinery.
(b) Approval of an alternative quality scheme recognised by LR.
(c) Approval by LR through auditing of the manufacturer's quality system.

12.2 Alignment gauges

12.2.1 All main and auxiliary oil engines exceeding 220 kW (300 shp) are to be provided with an alignment gauge which may be either a bridge weardown gauge, or a micro-meter clock gauge for use between the crankwebs. Only one micrometer clock gauge need be supplied for each ship provided the gauge is suitable for use on all engines.

12.3 Auto frettage

12.3.1 Manufacturers who carry out auto-frettage to enhance the fatigue life of components are to be approved by LR.

12.3.2 LR certificates are to be issued for components subject to autofrettage, provided the attending Surveyors are satisfied that the accepted QA process has been applied.

Table 2.12.1 Test pressures for oil engine components

Item	Test pressure
Fuel injection system: Pump body, pressure side; Valve; Pipe	The lesser of 1,5p or p + 300 bar
Cylinder cover, cooling space Cylinder liner, over the whole length of cooling space Piston crown, cooling space (where piston rod seals cooling space, test after assembly)	7,0 bar
Cylinder jacket, cooling space Exhaust valve, cooling space Turbo-charger, cooling space Exhaust pipe, cooling space Coolers, each side Engine driven pumps (oil, water, fuel, bilge)	The greater of 4,0 bar or 1,5p
Air compressor, including cylinders, covers, intercoolers and aftercoolers	Air side: 1,5p Water side: The greater of 4,0 bar or 1,5p
Scavenge pump cylinder	4,0 bar
Hydraulic systems (piping, pumps, actuators)	1,5p

NOTES
1. p is the maximum working pressure in the item concerned.
2. Pumps used in jerk or timed pump systems need only have the assembled high pressure-containing components hydraulically tested.
3. Turbo-charger air coolers need only be tested on the water side.
4. For forged steel cylinder covers and piston crowns alternative testing methods may be specially considered.
5. For hydraulic systems where design features are such that modifications to the test requirements are necessary, alternative proposals for hydraulic tests are to be submitted for special consideration.
6. Where components are subjected to an autofrettage process approved by LR, the component test pressure may be omitted. The assembled system containing such components is to be shown, where practicable, to be pressure-tight as required for Hydraulic systems.

■ *Section 13* Mass produced engines

13.1 Definition

13.1.1 Mass produced engines, for main and auxiliary purposes, are defined as those which are produced under the following criteria:

(a) In quantity under strict quality control of material and parts, according to a quality assurance scheme acceptable to LR.
(b) By the use of jigs and automatic machine tools designed to machine parts to specified tolerances for interchangeability, and which are verified on a regular inspection basis.
(c) By assembly with parts taken from stock and requiring little or no fitting.
(d) With bench tests carried out on individual assembled engines according to a specified programme.
(e) With appraisal by final examination of engines selected at random after workshop testing.

13.1.2 Castings, forgings and other parts for use in mass produced engines are also to be produced by methods similar to those given in 13.1.1(a), (b) and (c), with appropriate inspection.

13.1.3 Pressure testing of components is to comply with 12.1.1.

13.1.4 The specification of a mass produced engine is to define the limits of manufacture of all component parts. The total production output is to be certified by the manufacturer and verified as may be required, by LR in accordance with the agreed manufacturer's quality assurance scheme, *see* 13.1.1(a).

13.2 Procedure for approval of mass produced engines

13.2.1 The procedure outlined in 13.2.2 to 13.2.5 applies to the inspection and certification of mass produced oil engines having a bore not exceeding 300 mm.

13.2.2 For the approval of a mass produced engine type, the manufacturer is to submit:

(a) The plans and particulars required by 1.1 for assessment.
(b) The information required by 3.2 for assessment.
(c) A list of subcontractors for main parts.
(d) Procedures for the configuring of control, alarm monitoring and safety systems during engine commissioning.

13.2.3 The manufacturer is to supply full information regarding the manufacturing processes and quality control procedures applied in the workshops. The information is to address the following:

(a) Organisation of quality control systems.
(b) Recording of quality control operations.
(c) Qualification and independence of personnel in charge of quality control.

13.2.4 A running type test of at least 100 hours duration is to be carried out on an engine chosen from the production line. The type testing is to comply with 13.5.

13.2.5 LR reserves the right to limit the duration of validity of approval of a mass produced engine. LR is to be informed, without delay, of any change in the design of the engine, including changes to the software and control, alarm monitoring or safety systems, in the manufacturing or quality control processes, in the selection of materials or in the list of subcontractors for main parts.

13.3 Continuous review of production

13.3.1 LR Surveyors are to be provided free access to the manufacturer's workshops and to the quality control files.

13.3.2 The control of production, which is subject to survey, is to include the following:

(a) Inspection and testing records are to be maintained to the satisfaction of the Surveyor.
(b) The system for identification of parts is to be in accordance with recognised practice, and acceptable to LR.
(c) The manufacturer is to provide full information about the quality control of the parts supplied by subcontractors for which certification may be required. LR reserves the right to apply direct and individual inspection procedures for parts supplied by subcontractors when deemed necessary.
(d) At the request of an attending LR Surveyor, a workshop test may be required for an individual engine.

13.4 Compliance and inspection certificate

13.4.1 Each engine which is to be installed on a ship classed by LR is to be supplied with a statement certifying that the engine is identical to the one which underwent the tests specified in 13.2.4, and state the test and inspection results. The statement is to be made on a form agreed with LR. Each statement is to include the identification number which appears on the engine. A copy of this statement is to be submitted to LR.

13.4.2 The certificate is to include reference to the manufacturer's procedures to be followed during commissioning for configuring control, alarm monitoring and safety systems for multi-purpose engines or other engine types that require parameters and settings to be adjusted for the intended application.

Section 14 Turbo-chargers

14.1 Dynamic balancing

14.1.1 All rotors are to be dynamically balanced on final assembly to the Surveyor's satisfaction.

14.2 Overspeed test

14.2.1 All fully bladed rotor sections and impeller/inducer wheels are to be overspeed tested for three minutes at either 20 per cent above the maximum permissible speed at room temperature or 10 per cent above the maximum permissible speed at the normal working temperature.

14.3 Mechanical running test

14.3.1 Turbo-chargers are to be given a mechanical running test of 20 minutes duration at the maximum permissible speed.

14.3.2 Upon application, with details of an historical audit covering previous testing of turbo-chargers manufactured under an approved quality assurance scheme, consideration will be given to confining the test outlined in 14.3.1 to a representative sample of turbochargers.

Section 15 Mass produced turbo-chargers

15.1 Application

15.1.1 The following procedure applies to the inspection of exhaust driven turbo-chargers which are manufactured on the basis of mass production methods similar to 13.1 as applicable and for which the maker has requested the approval.

15.2 Procedure for approval of mass produced turbo-chargers

15.2.1 The procedure outlined in 15.2.2 to 15.2.5 applies to the inspection and certification of mass produced turbo-chargers when a simplified method of inspection has been requested by the manufacturers.

15.2.2 For the approval of a mass produced turbo-charger, the manufacturer is to submit, in addition to the plans and particulars required by 1.1.10, a list of main current suppliers and subcontractors for rotating parts and an operation and maintenance manual.

15.2.3 The manufacturer will supply full information regarding the material and quality control system used in the organisation as well as the inspection methods, the way of recording and proposed frequency, and the method of material testing of important parts.

15.2.4 A Type test, *see* 14.2, is to be carried out on a standard unit taken from the assembly line and is to be witnessed by the Surveyor. The performance data which may have to be verified are to be made available at the time of the type test. For manufacturers who have facilities for testing the turbo-charger unit on an engine for which the turbo-charger is intended, substitution of the hot running test by a test run of one hour's duration at overload (110 per cent of the rated output) may be considered.

15.2.5 LR reserves the right to limit the duration of validity of approval of a mass produced turbo-charger. LR is to be informed, without delay, of any change in the design of the turbo-charger, in the manufacturing or control processes, in the selection of materials or in the list of subcontractors for main parts.

15.3 Continuous inspection of individual units

15.3.1 LR Surveyors are to be provided with free access to the manufacturer's workshop to inspect at random the quality control measures and to witness the tests required by 15.3.3 to 15.3.7 as deemed necessary, and to have free access to all control records and subcontractor's certificates.

15.3.2 Each individual unit is to be tested in accordance with 15.3.4 to 15.3.7 by the maker who is to issue a final certificate.

15.3.3 Rotating parts of the turbo-charger blower are to be marked for easy identification with the appropriate certificate.

15.3.4 Material tests of the rotating parts are to be carried out by the maker or his subcontractor in accordance with the requirements of the Rules for Materials as applicable. The relevant certificate is to be produced and filed to the satisfaction of the Surveyor.

15.3.5 Pressure tests are to be carried out in accordance with Table 2.12.1. Special consideration will be given where design or testing features may require modification of the test requirements.

15.3.6 Dynamic balancing and overspeed tests are to be carried out, *see* 14.1 and 14.2, in accordance with the approved procedure for quality control. If each forged wheel is individually controlled by an approved non-destructive examination method, then no overspeed test may be required except for wheels of the type test unit.

15.3.7 A mechanical running test, *see* 14.3, is to be carried out. The duration of the running test may be reduced to 10 minutes provided that the manufacturer is able to verify the distribution of defects established during the running tests on the basis of a sufficient number of tested turbo-chargers. For manufacturers who have facilities in their works for testing the turbo-chargers on an engine for which the turbo-chargers are intended, the bench test may be replaced by a test run of 20 minutes at overload (110 per cent of the rated output) on this engine.

15.4 Compliance and certificate

15.4.1 For every turbo-charger unit liable to be installed on an engine intended for a ship classed by LR, the manufacturer is to supply a statement certifying that the turbo-charger is identical with one that underwent the tests specified in 15.2.4 and that prescribed tests were carried out. Results of these tests are to be also stated. This statement is to be made on a form agreed with LR and a copy is to be sent to LR. Each statement must have a number which is to appear on the turbo-charger.

■ *Section 16* Air compressors

16.1 General requirements

16.1.1 The requirements of this Section are applicable to reciprocating air compressors intended for starting main engines and auxiliary engines providing essential services.

16.1.2 Two or more air compressors are to be fitted having a total capacity, together with a topping-up compressor where fitted, capable of charging the air receivers within 1 hour from atmospheric pressure, to the pressure sufficient for the number of starts required by 16.12. At least one of the air compressors is to be independent of the main propulsion unit and the capacity of the main air compressors is to be approximately equally divided between them. The capacity of an emergency compressor which may be installed to satisfy the requirements of 9.1 is to be ignored.

16.1.3 The compressors are to be so designed that the temperature of the air discharged to the starting air receivers will not substantially exceed 93°C in service. A small fusible plug or an alarm device operating at 121°C is to be provided on each compressor to give warning of excessive air temperature. The emergency air compressor is excepted from these requirements.

16.1.4 Each compressor is to be fitted with a safety valve so proportioned and adjusted that the accumulation with the outlet valve closed will not exceed 10 per cent of the maximum working pressure. The casings of the cooling water spaces are to be fitted with a safety valve or bursting disc so that ample relief will be provided in the event of the bursting of an air cooler tube. It is recommended that compressors be cooled by fresh water.

16.2 Plans and particulars

16.2.1 Detailed plans, particulars, dimensional drawings and material specifications for compressor crankshafts are to be submitted in triplicate. Plans and particulars for other parts and calculations where applicable are to be submitted to LR upon request.

16.2.2 Where compressors of a special type or design are proposed, the requirements of Pt 7, Ch 15 are to be applied.

16.3 Materials

16.3.1 The specified minimum tensile strength of castings and forgings for compressor crankshafts are to be within the limits given in 2.1.1 and for grey cast iron to be not less than 300 N/mm^2.

16.3.2 Where it is proposed to use materials outside the ranges specified in 16.3.1, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

16.3.3 Materials for components are to be tested as indicated in 2.2.

16.3.4 For crankshafts with a calculated crank pin diameter equal to or greater than 50 mm, they are to be manufactured and tested in accordance with the requirements of the LR Rules for Materials. For calculated crank pin diameters less than 50 mm, a manufacturers' certificate may be accepted, *see* Ch 1,3.1.3(c) of the LR Rules for Materials.

16.4 Design and construction

16.4.1 A fully documented fatigue strength analysis is to be submitted indicating a factor of safety of 1,5 at the design loads based on a suitable fatigue strength criterion. Alternatively, the requirements of 16.4.2 to 16.4.6 may be used.

16.4.2 The diameter, d_p, of a compressor crankshaft is to be not less than d, determined by the following formula, when all cranks on the shaft are located between two main bearings only:

$$d = V_c \left(\frac{D^2 p Z}{78,5}\left(\frac{S}{16} + \frac{a\,b}{a+b}\right)\right)^{1/3} \text{ mm}$$

where

a = distance between inner edge of one main bearing and the centreline of the crankpin nearest the centre of the span, in mm

b = distance from the centreline of the same crankpin to the inner edge of the adjacent main bearing, in mm

$a+b$ = span between inner edges of main bearings, in mm

d_p = proposed minimum diameter of crankshaft, in mm

p = design pressure, in bar g, as defined in Ch 12,1.3.1

D = diameter of cylinder, in mm

S = length of stroke, in mm

V_c = 1,0 for shafts having one cylinder per crank, or

Table 2.16.1 Angle between cylinders

Number of crankpins	Number of cylinders per crank	Angle between cylinders, in degrees		
1 or 2	2	45	60	90
3	2	45	60	—
4	2	45	60	—
1	3	45	60	90
2	3	45	60	—
3	3	45	—	—
1	4	45	60	—
2	4	45	—	—

= 1,05 for 90°
= 1,18 for 60°
= 1,25 for 45°
between adjacent cylinders on the same crankpin

for the shaft and cylinder arrangements as detailed in Table 2.16.1

$Z = \dfrac{560}{\sigma_u + 160}$ for steel

$Z = \dfrac{700}{\sigma_u + 260 - 0{,}059 d_p}$ for spheroidal or nodular graphite cast iron

$Z = \dfrac{700}{\sigma_u + 260 - 0{,}069 d_p}$ for grey cast iron

σ_u = specified minimum tensile strength of crankshaft material, in N/mm^2.

16.4.3 Where the shaft is supported additionally by a centre bearing, the diameter is to be evaluated from the half shaft between the inner edges of the centre and outer main bearings. The diameter so found for the half shaft is to be increased by six per cent for the full length shaft diameter.

16.4.4 The dimensions of crankwebs are to be such that Bt^2 is to be not less than given by the following formulae:

$0{,}4d^3$ for the web adjacent to the bearing
$0{,}75d^3$ for intermediate webs

where

B = breadth of web, in mm
d = minimum diameter of crankshaft as required by 16.4.2, in mm
t = axial thickness of web which is to be not less than $0{,}45d$ for the web adjacent to the bearing, or $0{,}60d$ for intermediate webs, in mm.

16.4.5 Fillets at the junction of crankwebs with crankpins or journals are to be machined to a radius not less than $0{,}05d$. Smaller fillets, but of a radius not less than $0{,}025d$, may be used provided the diameter of the crankpin or journal is not less than cd,

where

$c = 1{,}1 - 2\dfrac{r}{d}$ but to be taken as not less than 1,0

d = minimum diameter of crankshaft as required by 16.4.2, in mm
r = fillet radius, in mm.

16.4.6 Fillets and oil holes are to be rounded to an even contour and smooth finish.

16.4.7 An oil level sight glass or oil level indicator is to be fitted to the crankcase.

16.4.8 The crankcases of compressors are to be designed to withstand a pressure equal to the maximum working pressure of the system.

16.4.9 Compressors with shaft power exceeding 500 kW are to have torsional vibration analysis determined in accordance with Ch 8,2 as applicable.

16.4.10 The cooler dimensions for sea-water cooled stage air coolers are to be based on an inlet temperature of not less than 32°C. Where fresh water cooling is used, the cooling water inlet temperature is not to be greater than 40°C.

16.4.11 The cooler dimensions for air cooled stage air coolers are to be based on an air temperature of not less than 45°C.

16.4.12 The piping to and from the air compressor is to be arranged to prevent condensation from entering the cylinders.

16.5 Testing

16.5.1 Cylinders and liners of air compressors are to be subjected to hydraulic pressure tests at 1,5 times the final pressure of the stage concerned.

16.5.2 The compressed air chambers of the intercoolers and after coolers of air compressors are to be subjected to hydraulic pressure tests at 1,5 times the final pressure of the stage concerned.

16.6 Safety arrangements and monitoring

16.6.1 Air compressors are to be arranged and located so as to minimise the intake of air contaminated by oil or water.

16.6.2 Where one compressor stage comprises several cylinders which can be shut off individually, each cylinder shall be equipped with a safety valve and a pressure gauge.

16.6.3 After the final stage, all air compressors are to be equipped with a water trap and after cooler. The water traps, after coolers and the compressed air spaces between the stages are to be provided with discharge devices at their lowest points.

16.6.4 Each compressor stage shall be fitted with a suitable pressure gauge, the scale of which must indicate the relevant maximum permissible working pressure.

16.7 Crankcase relief valves

16.7.1 In compressors having cylinders not exceeding 200 mm bore or having a crankcase gross volume not exceeding 0,6 m^3, crankcase relief valves may be omitted.

16.7.2 Crankcases are to be provided with lightweight spring-loaded valves or other quick-acting and self-closing devices to relieve the crankcases of pressure in the event of an internal explosion and to prevent any inrush of air thereafter. The valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0,2 bar.

16.7.3 The valve lids are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

16.7.4 Each valve is to be fitted with a flame arrester that permits flow for crankcase pressure relief and prevents the passage of flame following a crankcase explosion.

16.7.5 The valves are to be provided with a copy of the manufacturer's installation and maintenance manual for the size and type of valve being supplied. The manual is to contain the following information:

(a) Description of valve with details of function and design limits.
(b) Copy of type test certification.
(c) Installation instructions.
(d) Maintenance and in-service instructions to include testing and renewal of any sealing arrangements.
(e) Actions required after a crankcase explosion.

16.7.6 A copy of the installation and maintenance manual required by 16.7.3 is to be provided on board the ship.

16.7.7 Plans showing details and arrangements of the crankcase relief valves are to be submitted for approval, *see* 1.1.

16.7.8 The valves are to be provided with suitable markings that include the following information:

(a) Name and address of manufacturer.
(b) Designation and size.
(c) Month/Year of manufacture.
(d) Approved installation orientation.

16.8 Number of crankcase relief valves

16.8.1 In compressors having cylinders exceeding 200 mm but not exceeding 250 mm bore, at least two relief valves are to be fitted; where more than one relief valve is required, the valves are to be located at or near the ends of the crankcase.

16.8.2 In compressors having cylinders exceeding 250 mm but not exceeding 300 mm bore, at least one relief valve is to be fitted in way of each alternate crankthrow with a minimum of two valves. For compressors having 3, 5, 7, 9, etc., crankthrows, the number of relief valves is not to be less than 2, 3, 4, 5, etc., respectively.

16.8.3 In compressors having cylinders exceeding 300 mm bore, at least one valve is to be fitted in way of each main crankthrow.

16.8.4 Additional relief valves are to be fitted for separate spaces on the crankcase, such as gear or chain cases, when the gross volume of such spaces exceeds 0,6 m^3.

16.9 Size of crankcase relief valves

16.9.1 The combined free area of the crankcase relief valves fitted on a compressor is to be not less than 115 cm^2/m^3 based on the volume of the crankcase.

16.9.2 The free area of each relief valve is to be not less than 45 cm^2.

16.9.3 The free area of the relief valve is the minimum flow area at any section through the valve when the valve is fully open.

16.9.4 In determining the volume of the crankcase for the purpose of calculating the combined free area of the crankcase relief valves, the volume of the stationary parts within the crankcase may be deducted from the total internal volume of the crankcase.

16.10 Vent pipes

16.10.1 Where crankcase vent or breather pipes are fitted, they are to be made as small as practicable and/or as long as possible to minimise the inrush of air after an explosion.

■ *Section 17* Type testing – General

17.1 Engines

17.1.1 New engine types or developments of existing types are to be subjected to an agreed programme of type testing to complement the design appraisal and review of documentation.

17.1.2 Guidelines for type testing of engines will be supplied on application.

17.1.3 Wherever practical, type tests are to be conducted with the engine control systems operational in the approved configuration, *see* 1.1 and 4.3.2. Configuration management documents are to be reviewed at testing for validity and referenced in the type test report.

17.1.4 An engine type is defined in terms of:

- basic engine data: e.g. bore, stroke
- working cycle: 2 stroke, 4 stroke
- cylinder arrangement: in-line, vee
- cylinder rating
- fuel supply: e.g. direct, or indirect injection, dual fuel
- gas exchange: natural aspiration, pressure charging arrangement.

17.1.5 Where an engine type has subsequently proved satisfactory in service with a number of applications a maximum uprating of 10 per cent may be considered without a further complete type test.

17.1.6 A type test will be considered to cover engines of a given design for a range of cylinder numbers in a given cylinder arrangement.

17.2 Mass produced engines

17.2.1 The requirements in this section are applicable to the type testing of mass produced internal combustion engines where the manufacturer has requested approval. Omission or simplification of the type test requirements will be considered by LR for engines of an established type on application by the manufacturer.

17.2.2 The engine to be tested is to be selected from the production line and agreed by LR.

17.2.3 The type tests are to be conducted with the engine control systems operational in the approved configuration, *see* 1.1 and 4.3.2. Configuration management documents are to be reviewed at testing for validity and referenced in the type test report.

17.2.4 The duration and programme of type tests is to include the following:
(a) 80 h at rated output.
(b) 8 h at 110 per cent overload.
(c) 10 h at varying partial loads (25 per cent, 50 per cent, 75 per cent and 90 per cent of rated output).
(d) 2 h at maximum intermittent loads.
(e) Starting tests.
(f) Reverse running of direct reversing engines.
(g) Testing of speed governor.
(h) Testing of overspeed device.
(j) Testing of lubricating oil system failure alarm device.
(k) Testing of the engine with turbo-charger out of action when applicable.
(l) Testing of minimum speed for main propulsion engines and the idling speed for auxiliary engines.

17.2.5 The type tests in 17.2.4 at the required outputs are to be combined together in working cycles for the whole duration within the limits indicated. *See also* 17.2.11 and 17.2.12.

17.2.6 The overload testing required by 17.2.4 is to be carried out with the following conditions:
(a) 110 per cent of rated power at 103 per cent revolutions per minute for engines directly driving propellers.
(b) 110 per cent of rated power at 100 per cent revolutions per minute for engines driving electrical generators or for other auxiliary purposes.

17.2.7 For prototype engines, the duration and programme of tests are to be specially agreed between the manufacturer and LR.

17.2.8 As far as practicable during type testing the following particulars are to be continuously recorded:
(a) Ambient air temperature.
(b) Ambient air pressure.
(c) Atmospheric humidity.
(d) External cooling water temperature.
(e) Fuel and lubrication oil characteristics.

17.2.9 In addition to the particulars stated in 17.2.8 and as far as practicable, the following are also to be continuously measured and recorded:
(a) Engine revolutions per minute.
(b) Brake power.
(c) Torque.
(d) Maximum combustion pressure.
(e) Indicator pressure diagrams where practicable.
(f) Exhaust smoke (with an approved smoke meter).
(g) Lubricating oil pressure and temperature.
(h) Exhaust gas temperature in exhaust manifold, and, where facilities are available, from each cylinder.
(j) For turbocharged engines:
- Turbocharger revolutions per minute.
- Air temperature and pressures before and after turbo-blower and charge cooler.
- Exhaust gas temperature and pressures before and after the turbine.
- The cooling water inlet temperature to the charge air cooler.

17.2.10 After the type test, the main parts and especially those subject to wear are to be dismantled for examination by LR Surveyors.

17.2.11 For engines that are required to be approved for different purposes (multi-purpose engines), and that have different performances profiles and control, alarm monitoring and safety systems configurations for each purpose, the programme and duration of test is to be modified to cover the whole range of the engine performance, taking into account the most severe conditions and intended purpose(s).

17.2.12 The rated output for which the engine is to be tested is the output corresponding to that declared by the manufacturer and agreed by LR, i.e. actual maximum power which the engine is capable of delivering continuously between the normal maintenance intervals stated by the manufacturer at the rated speed and under the stated ambient conditions.

17.3 Turbo-chargers

17.3.1 A type test is to consist of a hot gas running test of at least one hour duration at the maximum permissible speed and maximum permissible temperature. Following the test the turbo-charger is to be completely dismantled for examination of all parts.

17.3.2 Alternative arrangements will be specially considered.

Section 18
Type testing procedure for crankcase explosion relief valves

18.1 Scope

18.1.1 To specify type tests and identify standard test conditions using methane gas and air mixture to demonstrate that LR requirements are satisfied for crankcase explosion relief valves intended to be fitted to engines and gear cases.

18.1.2 The test procedure is only applicable to explosion relief valves fitted with flame arresters. Where internal oil wetting of a flame arrester is a design feature of an explosion relief valve, alternative testing arrangements that demonstrate compliance with these requirements may be proposed by the manufacturer. The alternative testing arrangements are to be submitted to LR for approval.

18.2 Purpose

18.2.1 The purpose of type testing crankcase explosion relief valves is fourfold:

(a) To verify the effectiveness of the flame arrester.
(b) To verify that the valve closes after an explosion.
(c) To verify that the valve is gas/air tight after an explosion.
(d) To establish the level of overpressure protection provided by the valve.

18.3 Test facilities

18.3.1 Test houses carrying out type testing of crankcase explosion relief valves are to meet the following requirements:

(a) The test houses where testing is carried out are to be accredited to a National or International Standard for the testing of explosion protection devices such as ISO/IEC 17025.
(b) The test facilities are to be acceptable to LR.
(c) The test facilities are to be equipped so that they can perform and record explosion testing in accordance with this procedure.
(d) The test facilities are to have equipment for controlling and measuring a methane gas in air concentration within a test vessel to an accuracy of ±0,1 per cent.
(e) The test facilities are to be capable of effective point-located ignition of a methane gas in air mixture.
(f) The pressure measuring equipment is to be capable of measuring the pressure in the test vessel in at least two positions, one at the valve and the other at the test vessel centre. The measuring arrangements are to be capable of measuring and recording the pressure changes throughout an explosion test at a frequency recognising the speed of events during an explosion. The result of each test is to be documented by video recording and by recording with a heat sensitive camera.
(g) The test vessel for explosion testing is to have documented dimensions. The dimensions are to be such that the vessel is not pipe-like with the distance between dished ends being not more than 2,5 times the diameter. The internal volume of the test vessel is to include any standpipe arrangements.
(h) The test vessel is to be provided with a flange, located centrally at one end at 90 degrees to the vessel longitudinal axis for mounting the explosion relief valve. The test vessel is to be arranged in an orientation consistent with how the valve will be installed in service, i.e., in the vertical plane or the horizontal plane.
(j) A circular flat plate is to be provided for fitting between the pressure vessel flange and valve to be tested with the following dimensions:
    (i) Outside diameter of 2 times the outer diameter of the valve top cover.
    (ii) Internal bore having the same internal diameter as the valve to be tested.
(k) The test vessel is to have connections for measuring the methane in air mixture at the top and bottom.
(l) The test vessel is to be provided with a means of fitting an ignition source at a position as specified in 18.4.3.
(m) The test vessel volume is to be as far as practicable, related to the size and capability of the relief valve to be tested. In general, the volume is to correspond to the requirement in 10.3.1 for the free area of explosion relief valve to be not less than 115 cm^2/m^3 of crankcase gross volume, e.g., the testing of a valve having 1150 cm^2 of free area, would require a test vessel with a volume of 10 m^3. The following is to apply:
    (i) Where the free area of relief valves is greater than 115 cm^2/m^3 of the crankcase gross volume, the volume of the test vessel is to be consistent with the design ratio.
    (ii) In no case is the volume of the test vessel to vary by more than ±15 per cent from the design cm^2/m^3 volume ratio.

18.4 Explosion test process

18.4.1 All explosion tests to verify the functionality of crankcase explosion relief valves are to be carried out using an air and methane mixture with a volumetric methane concentration of 9,5 per cent ±0,5 per cent. The pressure in the test vessel is to be not less than atmospheric and is not to exceed the opening pressure of the relief valve.

18.4.2 The concentration of methane in the test vessel is to be measured at the top and bottom of the vessel and these concentrations are not to differ by more than 0,5 per cent.

18.4.3 The ignition of the methane and air mixture is to be made at the centreline of the test vessel at a position approximately one third of the height or length of the test vessel opposite to where the valve is mounted.

18.4.4 The ignition is to be made using a maximum 100 joule explosive charge.

18.5 Valves to be tested

18.5.1 The valves used for type testing (including testing specified in 18.5.3) are to be selected from the manufacturer's normal production line for such valves by the LR Surveyor witnessing the tests.

18.5.2 For approval of a specific valve size, three valves are to be tested in accordance with 18.5.3 and 18.6. For a series of valves, *see* 18.8.

18.5.3 The valves selected for type testing are to have been previously tested at the manufacturer's works to demonstrate that the opening pressure is in accordance with the specification within a tolerance of ±20 per cent and that the valve is air tight at a pressure below the opening pressure for at least 30 seconds. This test is to verify that the valve is air tight following assembly at the manufacturer's works and that the valve begins to open at the required pressure demonstrating that the correct spring has been fitted.

18.5.4 The type testing of valves is to recognise the orientation in which they are intended to be installed on the engine or gear case. Three valves of each size are to be tested for each intended installation orientation, i.e. in the vertical and/or horizontal positions.

18.6 Method

18.6.1 The following requirements are to be satisfied at explosion testing:
(a) The explosion testing is to be witnessed by a LR Surveyor.
(b) Where valves are to be installed on an engine or gear case with shielding arrangements to deflect the emission of explosion combustion products, the valves are to be tested with the shielding arrangements fitted.
(c) Successive explosion testing to establish a valve's functionality is to be carried out as quickly as possible during stable weather conditions.
(d) The pressure rise and decay during all explosion testing is to be recorded.
(e) The external condition of the valves is to be monitored during each test for indication of any flame release by video and heat sensitive camera.

18.6.2 The explosion testing is to be in three stages for each valve that is required to be approved as being type tested.

18.6.3 **Stage 1.** Two explosion tests are to be carried out in the test vessel with the circular plate as specified in 18.3.1(j) fitted and the opening in the plate covered by a 0,05 mm thick polythene film. These tests establish a reference pressure level for determination of the capability of a relief valve in terms of pressure rise in the test vessel, *see* 18.7.1(f).

18.6.4 **Stage 2**:
(a) Two explosion tests are to be carried out on three different valves of the same size. Each valve is to be mounted in the orientation for which approval is sought i.e., in the vertical or horizontal position with the circular plate described in 18.3.1(j) located between the valve and pressure vessel mounting flange.
(b) The first of the two tests on each valve is to be carried out with a 0,05mm thick polythene bag, having a minimum diameter of three times the diameter of the circular plate and volume not less than 30 per cent of the test vessel, enclosing the valve and circular plate. Before carrying out the explosion test the polythene bag is to be empty of air. The polythene bag is required to provide a readily visible means of assessing whether there is flame transmission through the relief valve following an explosion. During the test, the explosion pressure will open the valve and some unburned methane/air mixture will be collected in the polythene bag. When the flame reaches the flame arrester and if there is flame transmission through the flame arrester, the methane/air mixture in the bag will be ignited and this will be visible.
(c) Provided that the first explosion test successfully demonstrated that there was no indication of combustion outside the flame arrester and there are no signs of damage to the flame arrester or valve, a second explosion test without the polythene bag arrangement is to be carried out as quickly as possible after the first test. During the second explosion test, the valve is to be visually monitored for any indication of combustion outside the flame arrester and video records are to be kept for subsequent analysis. The second test is required to demonstrate that the valve can still function in the event of a secondary crankcase explosion.
(d) After each explosion, the test vessel is to be maintained in the closed condition for at least 10 seconds to enable the tightness of the valve to be ascertained. The tightness of the valve can be verified during the test from the pressure/time records or by a separate test after completing the second explosion test.

18.6.5 **Stage 3**. Carry out two further explosion tests as described in Stage 1. These further tests are required to provide an average baseline value for assessment of pressure rise, recognising that the test vessel ambient conditions may have changed during the testing of the explosion relief valves in Stage 2.

18.7 Assessment and records

18.7.1 For the purposes of verifying compliance with the requirements of this Section, the assessment and records of the valves used for explosion testing is to address the following:
(a) The valves to be tested are to have evidence of appraisal/approval by LR, *see also* 18.5.1.
(b) The designation, dimensions and characteristics of the valves to be tested are to be recorded. This is to include the free area of the valve and of the flame arrester and the amount of valve lift at 0,2 bar.
(c) The test vessel volume is to be determined and recorded.
(d) For acceptance of the functioning of the flame arrester there is not to be any indication of flame or combustion outside the valve during an explosion test.
(e) The pressure rise and decay during an explosion is to be recorded, with indication of the pressure variation showing the maximum overpressure and steady underpressure in the test vessel during testing. The pressure variation is to be recorded at two points in the pressure vessel.

(f) The effect of an explosion relief valve in terms of pressure rise following an explosion is ascertained from maximum pressures recorded at the centre of the test vessel during the three stages. The pressure rise within the test vessel due to the installation of a relief valve is the difference between average pressure of the four explosions from Stages 1 and 3 and the average of the first tests on the three valves in Stage 2. The pressure rise is not to exceed the limit specified by the manufacturer.

(g) The valve tightness is to be ascertained by verifying from the records at the time of testing that an under-pressure of at least 0,3 bar is held by the test vessel for at least 10 seconds following an explosion. This test is to verify that the valve has effectively closed and is reasonably gas-tight following dynamic operation during an explosion.

(h) After each explosion test in Stage 2, the external condition of the flame arrester is to be examined for signs of serious damage and/or deformation that may affect the operation of the valve.

(j) After completing the explosion tests, the valves are to be dismantled and the condition of all components ascertained and documented. In particular, any indication of valve sticking or uneven opening that may affect the operation of the valve is to be noted. Photographic records of the valve condition are to be taken and included in the report.

18.8 Design series qualification

18.8.1 The qualification of quenching devices to prevent the passage of flame can be evaluated for other similar devices of identical type where one device has been tested and found satisfactory.

18.8.2 The quenching ability of a flame arrester depends on the total mass of quenching lamellas/mesh. Provided the materials, thickness of materials, length of lamellas/thickness of mesh layer and the quenching gaps are the same, then the same quenching ability can be qualified for different size of flame arresters subject to (a) and (b) being satisfied.

(a) $\dfrac{n_1}{n_2} = \sqrt{\dfrac{S_1}{S_2}}$

(b) $\dfrac{A_1}{A_2} = \dfrac{S_1}{S_2}$

where

n_1 = total depth of flame arrester corresponding to the number of lamellas of size 1 quenching device for a valve with a relief area equal to S_1

n_2 = total depth of flame arrester corresponding to the number of lamellas of size 2 quenching device for a valve with a relief area equal to S_2

A_1 = free area of quenching device for a valve with a relief area equal to S_1

A_2 = free area of quenching device for a valve with a relief area equal to S_2.

18.8.3 The qualification of explosion relief valves of larger sizes than that which has been previously satisfactorily tested in accordance with 18.6 and 18.7 can be evaluated where valves are of identical type and have identical features of construction subject to the following:

(a) The free area of a larger valve does not exceed three times +5 per cent that of the valve that has been satisfactorily tested.

(b) One valve of the largest size, subject to (a), requiring qualification is subject to satisfactory testing required by 18.5.3 and 18.6.4 except that a single valve will be accepted in 18.6.4(a) and the volume of the test vessel is not to be less than one-third of the volume required by 18.3.1(m).

(c) The assessment and records are to be in accordance with 18.7, noting that 18.7.1(f) will only be applicable to Stage 2 for a single valve.

18.8.4 The qualification of explosion relief valves of smaller sizes than that which has been previously satisfactorily tested in accordance with 18.6 and 18.7 can be evaluated where valves are of identical type and have identical features of construction subject to the following:

(a) The free area of a smaller valve is not less than one third of that of the valve that has been satisfactorily tested.

(b) One valve of the smallest size, subject to (a), requiring qualification is subject to satisfactory testing required by 18.5.3 and 18.6.4 except that a single valve will be accepted in 18.6.4(a) and the volume of the test vessel is not to be more than the volume required by 18.3.1(m).

(c) The assessment and records are to be in accordance with 18.7, noting that 18.7.1(f) will only be applicable to Stage 2 for a single valve.

18.9 The report

18.9.1 The test house is to deliver a full report that includes the following information and documents:

(a) Test specification.
(b) Details of test pressure vessel and valves tested.
(c) The orientation in which the valve was tested, (vertical or horizontal position).
(d) Methane in air concentration for each test.
(e) Ignition source.
(f) Pressure curves for each test.
(g) Video recordings of each valve test.
(h) The assessment and records stated in 18.7.

18.10 Approval

18.10.1 The approval of an explosion relief valve is at the discretion of LR based on the appraisal of plans and particulars and the test facility's report of the results of type testing.

■ *Section 19* Type testing procedure for crankcase oil mist detection and alarm equipment

19.1 Scope

19.1.1 To specify the tests required to demonstrate that crankcase oil mist detection and alarm equipment intended to be fitted to diesel engines satisfy LR requirements.

19.1.2 This test procedure is also applicable to oil mist detection and alarm arrangements intended for gear cases.

19.2 Purpose

19.2.1 The purpose of type testing crankcase oil mist detection and alarm equipment is seven fold:
(a) To verify the functionality of the system.
(b) To verify the effectiveness of the oil mist detectors.
(c) To verify the accuracy of oil mist detectors.
(d) To verify the alarm set points.
(e) To verify time delays between oil mist leaving the source and alarm activation.
(f) To verify functional failure detection.
(g) To verify the influence of optical obscuration on detection.

19.3 Test facilities

19.3.1 Test houses carrying out type testing of crankcase detection and alarm equipment are to satisfy the following criteria:
(a) A full range of facilities for carrying out the environmental and functionality tests required by this procedure shall be available and be acceptable to LR.
(b) The test house that verifies the functionality of the equipment is to be equipped so that it can control, measure and record oil mist concentration levels in terms of mg/l to an accuracy of ±10 per cent in accordance with this procedure.

19.4 Equipment testing

19.4.1 The range of tests is to include the following for the alarm/monitoring panel:
(a) Functional tests described in 19.5.
(b) Electrical power supply failure test.
(c) Power supply variation test.
(d) Dry heat test.
(e) Damp heat test.
(f) Vibration test.
(g) EMC test.
(h) Insulation resistance test.
(j) High voltage test.
(k) Static and dynamic inclinations, if moving parts are contained.

19.4.2 The range of tests is to include the following for the detectors:
(a) Functional tests described in 19.5.
(b) Electrical power supply failure test.
(c) Power supply variation test.
(d) Dry heat test.
(e) Damp heat test.
(f) Vibration test.
(g) EMC test.
(h) Insulation resistance test.
(j) High voltage test.
(k) Static and dynamic inclinations.

19.5 Functional tests

19.5.1 All tests to verify the functionality of crankcase oil mist detection and alarm equipment are to be carried out in accordance with 19.5.2 to 19.5.6 with an oil mist concentration in air, known in terms of mg/l to an accuracy of ±10 per cent.

19.5.2 The concentration of oil mist in the test chamber is to be measured in the top and bottom of the chamber and these concentrations are not to differ by more than 10 per cent. *See* 19.7.2(a).

19.5.3 The oil mist monitoring arrangements are to be capable of detecting oil mist in air concentrations of between 0 and 10 per cent of the lower explosive limit (LEL), which corresponds to an oil mist concentration of approximately 50 mg/l (13 per cent oil-air mixture) or between 0 and a percentage corresponding to a level not less than twice the maximum oil mist concentration alarm set point.

19.5.4 The alarm set point for oil mist concentration in air is to provide an alarm at a maximum setting corresponding to not more than 5 per cent of the LEL or approximately 2,5 mg/l.

19.5.5 Where alarm set points can be altered, the means of adjustment and indication of set points are to be verified against the equipment manufacturer's instructions.

19.5.6 Where oil mist is drawn into a detector via piping arrangements, the time delay between the sample leaving the crankcase and operation of the alarm is to be determined for the longest and shortest lengths of pipes recommended by the manufacturer. The pipe arrangements are to be in accordance with the manufacturer's instructions/recommendations.

19.5.7 Detector equipment that is in contact with the crankcase atmosphere and may be exposed to oil splash and spray from engine lubricating oil is to be tested to demonstrate that openings do not occlude or become blocked under continuous oil splash or spray conditions. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by LR.

19.5.8 Detector equipment may be exposed to water vapour from the crankcase atmosphere which may affect the sensitivity of the equipment, it is to be demonstrated that exposure to such conditions will not affect the functional operation of the detector equipment. Where exposure to water vapour and/or water condensation has been identified as a possible source of equipment malfunctioning, testing is to demonstrate that any mitigating arrangements such as heating are effective. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by LR. This testing is in addition to that required by 19.4.2(e) and is concerned with the effects of condensation caused by the detection equipment being at a lower temperature than the crankcase atmosphere.

19.6 Detectors and alarm equipment to be tested

19.6.1 The detectors and alarm equipment selected for the type testing are to be selected from the manufacturer's normal production line by the LR Surveyor witnessing the tests.

19.6.2 Two detectors are to be tested. One is to be tested in the clean condition and the other in a condition representing the maximum level of lens obscuration specified by the manufacturer.

19.7 Method

19.7.1 The requirements of 19.7 are to be satisfied at type testing.

19.7.2 Oil mist generation is to satisfy the following:

(a) Oil mist is to be generated with suitable equipment using an SAE 80 monograde mineral oil or equivalent and supplied to a test chamber having a volume of not less than 1 m^3. The oil mist produced is to have a maximum droplet size of 5 μm. The oil droplet size is to be checked using the sedimentation method.

(b) The oil mist concentrations used are to be ascertained by the gravimetric deterministic method or equivalent. For this test, the gravimetric deterministic method is a process where the difference in weight of a 0,8 μm pore size membrane filter is ascertained from weighing the filter before and after drawing 1 litre of oil mist through the filter from the oil mist test chamber. The oil mist chamber is to be fitted with a recirculating fan.

(c) Samples of oil mist are to be taken at regular intervals and the results plotted against the oil mist detector output. The oil mist detector is to be located adjacent to where the oil mist samples are drawn off.

(d) The results of a gravimetric analysis are considered invalid and are to be rejected if the resultant calibration curve has an increasing gradient with respect to the oil mist detection reading. This situation occurs when insufficient time has been allowed for the oil mist to become homogeneous. Single results that are more than 10 per cent below the calibration curve are to be rejected. This situation occurs when the integrity of the filter unit has been compromised and not all of the oil is collected on the filter paper.

(e) The filters require to be weighed to a precision of 0,1 mg and the volume of air/oil mist sampled to 10 ml.

19.7.3 The testing is to be witnessed by an LR Surveyor where type testing approval is required by LR.

19.7.4 Oil mist detection equipment is to be tested in the orientation (vertical, horizontal or inclined) in which it is intended to be installed on an engine or gear case as specified by the equipment manufacturer.

19.7.5 Type testing is to be carried out for each type of oil mist detection and alarm equipment for which a manufacturer seeks LR approval. Where sensitivity levels can be adjusted, testing is to be carried out at the extreme and mid-point level settings.

19.8 Assessment

19.8.1 Assessment of oil mist detection equipment devices after testing is to address the following:

(a) The equipment to be tested is to have evidence of design appraisal/approval by LR, *See also* 19.6.1.

(b) Details of the detection equipment to be tested are to be recorded, such as name of manufacturer, type designation, oil mist concentration assessment capability and alarm settings.

(c) After completing the tests, the detection equipment is to be examined and the condition of all components ascertained and documented. Photographic records of the monitoring equipment condition are to be taken and included in the report.

19.9 Design series qualification

19.9.1 The approval of one type of detection equipment may be used to qualify other devices having identical construction details. Proposals are to be submitted for consideration.

19.10 The report

19.10.1 The test house is to provide a full report which includes the following information and documents:

(a) Test specification.

(b) Details of equipment tested.

(c) Results of tests.

19.11 Acceptance

19.11.1 Acceptance of crankcase oil mist detection equipment is at the discretion of LR based on the appraisal of plans and particulars and the test house report of the results of type testing.

19.11.2 The following information is to be submitted to LR for acceptance of oil mist detection equipment and alarm arrangements:

(a) Description of oil mist detection equipment and system including alarms.
(b) Copy of the test house report identified in 19.10.
(c) Schematic layout of engine oil mist detection arrangements showing location of detectors/sensors and piping arrangements and dimensions.
(d) Maintenance and test manual which is to include the following information:
- Intended use of equipment and its operation.
- Functionality tests to demonstrate that the equipment is operational and that any faults can be identified and corrective actions notified.
- Maintenance routines and spare parts recommendations.
- Limit setting and instructions for safe limit levels.
- Where necessary, details of configurations in which the equipment is and is not to be used.

■ *Cross-references*

The pumping arrangements, including cooling water and lubricating oil systems, are to comply with the requirements of Chapter 14.

For spare gear, *see* Chapter 1,7.

Section

■ *Scope*

The requirements of this Chapter are applicable to steam turbines for main propulsion and also, where powers exceed 110 kW (150 shp), to those for essential auxiliary services.

■ *Section 1* Plans and particulars

1.1 Plans

1.1.1 The following plans are to be submitted for consideration, together with particulars of materials, maximum shaft powers and revolutions per minute, *see* Ch 1,3.3. The pressures and temperatures applicable at maximum shaft power and under the emergency conditions of 5.2 are to be stated or indicated on the plans.

- General arrangement.
- Sectional assembly.
- Rotors and couplings.
- Casings.

1.1.2 For the emergency conditions of 5.3, full particulars of the means proposed for emergency propulsion are to be submitted.

1.1.3 Where rotors and castings are of welded construction, details of the welded joints are also to be submitted for consideration.

1.1.4 In general, plans for auxiliary turbines need not be submitted.

■ *Section 2* Materials

2.1 General

2.1.1 In the selection of materials, consideration is to be given to their creep strength, corrosion resistance and scaling properties at working temperatures to ensure satisfactory performance and long life under service conditions.

2.1.2 Grey cast iron is not to be used for temperatures exceeding 260°C.

2.2 Materials for forgings

2.2.1 Turbine rotors and discs are to be of forged steel. For carbon and carbon-manganese steel forgings, the specified minimum tensile strength is to be selected within the limits of 400 and 600 N/mm^2 (41 and 61 kgf/mm^2). For alloy steel rotor forgings, the specified minimum tensile strength is to be selected within the limits of 500 and 800 N/mm^2 (51 and 82 kgf/mm^2). For discs and other alloy steel forgings, the specified minimum tensile strength is to be selected within the limits of 500 and 1000 N/mm^2 (51 and 102 kgf/mm^2).

2.2.2 For alloy steels, details of the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval.

2.2.3 When it is proposed to use material of higher tensile strength, full details are to be submitted for approval.

■ *Section 3* Design and construction

3.1 General

3.1.1 In the design and arrangement of turbine machinery, adequate provision is to be made for the relative thermal expansion of the various turbine parts, and special attention is to be given to minimising casing and rotor distortion under all operating conditions.

3.1.2 Turbine bearings are to be so disposed and supported that lubrication is not adversely affected by heat flow from adjacent hot parts of the turbine. Effective means are to be provided for intercepting oil leakage and preventing oil from reaching high temperature glands and casings and steam pipes. Drainage openings and drain pipes from oil baffle pockets are to be sufficiently large to prevent excessive accumulation and leakage of oil.

3.2 Welded components

3.2.1 Turbine rotors, cylinders and associated components fabricated by means of welding will be considered for acceptance if constructed by firms whose works are properly equipped to undertake welding to equivalent standards, for rotors and cylinders respectively, to those required by the Rules for Class 1 and Class 2/1 welded pressure vessels, *see* Ch 17, Sections 1 to 7.

3.2.2 Welding is to be carried out in accordance with the requirements of Ch 13,4 of the *Rules for Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) using welding procedures and welders that have been qualified in accordance with Chapter 12 of the Rules for Materials.

3.2.3 Before work is commenced, manufacturers are to submit for consideration details of proposed welding procedures and their proposals for routine examination of joints by non-destructive means.

3.2.4 Materials used in the construction of turbine rotors, cylinders, diaphragms, condensers, etc., are to be of welding quality.

3.2.5 Where it is proposed to construct rotors from two or more forged components joined by welding, full details of the chemical composition, mechanical properties and heat treatment of the materials, together with particulars of the welding consumables, an outline of the welding procedure, method of fabrication and heat treatment, are to be submitted for consideration.

3.2.6 Joints in rotors and major joints in cylinders are to be designed as full-strength welds and for complete fusion of the joint.

3.2.7 Adequate preheating is to be employed for mild steel cylinders and components and where the metal thickness exceeds 44 mm, and for all low alloy steel cylinders and components and for any part where necessitated by joint restraint.

3.2.8 Stress relief heat treatment is to be applied to all cylinders and associated components on completion of the welding of all joints and attached structures. For details of stress relief procedure, temperature and duration, *see* Ch 13,4.11 of the Rules for Materials.

3.2.9 For all welded components, weld procedure tests are to be in accordance with Ch 12,2.7 of the Rules for Materials.

3.2.10 Production weld tests are to be performed according to the requirements of Ch 13,4.5 of the Rules for Materials.

3.3 Stress raisers

3.3.1 Smooth fillets are to be provided at abrupt changes of section of rotors, spindles, discs, blade roots and tenons. The rivet holes in blade shrouds are to be rounded and radiused on top and bottom surfaces, and tenons are to be radiused at their junction with blade tips. Balancing holes in discs are to be well rounded and polished.

3.3.2 Surveyors are to be satisfied as to the workmanship and riveting of blades to shroud bands, and that the blade tenons are free from cracks, particularly with high tensile blade material. Test samples are to be sectioned and examined, and pull-off tests made if considered necessary by the Surveyors.

3.4 Shrunk-on rotor discs

3.4.1 Main turbine rotor discs fitted by shrinking are to be secured with keys, dowels or other approved means.

3.5 Vibration

3.5.1 Care is to be taken in the design and manufacture of turbine rotors, rotor discs and blades to ensure freedom from undue vibration within the operating speed range. Consideration of blade vibration should include the effect of centrifugal force, blade root fixing, metal temperature and disc flexibility where appropriate.

3.5.2 For the vibration and alignment of main propulsion systems formed by the turbines geared to the line shafting, *see* Chapter 8.

3.6 External influences

3.6.1 Pipes and ducts connected to turbine casings are to be so designed that no excessive thrust loads or moments are applied by them to the turbines. Gratings and any fittings in way of sliding feet or flexible-plate supports are to be so arranged that casing expansion is not restricted. Where main turbine seatings incorporate a tank structure, consideration is to be given to the temperature variation of the tank in service to ensure that turbine alignment will not be adversely affected.

3.7 Steam supply and water system

3.7.1 In the arrangement of the gland sealing system, the pipes are to be made self-draining and every precaution is to be taken against the possibility of condensed steam entering the glands and turbines. The steam supply to the gland sealing system is to be fitted with an effective drain trap. In the air ejector re-circulating water system, the connection to the condenser is to be so located that water cannot impinge on the L.P. rotor or casing.

3.8 Turning gear

3.8.1 Turning gear is to be provided for all turbines to facilitate operating and maintenance regimes as required by the manufacturer.

3.8.2 The turning gear for all propulsion turbines is to be power-driven and, if electric, is to be continuously rated.

3.8.3 The turning gear for auxiliary turbines may be hand operated (manual) except where this is not practicable, in which case the provision of 3.8.2 is to be complied with.

3.8.4 The turning gear for all turbines is to be fitted with safety interlocks which prevent steam valve actuation for turbine operation when engaged *see* Ch 1,3.9. Indication of engaged/ not engaged is to be provided at all start positions.

3.8.5 The remote control device of power-driven turning gear is to be so designed that power is removed from the turning gear when the operating switch is released.

3.8.6 Means are to be provided to secure the turning gear when disengaged.

■ *Section 4*
Safety arrangements

4.1 Low vacuum and overpressure protective devices

4.1.1 In order to provide a warning, due to excessive pressure, to personnel in the vicinity of the exhaust ends of main turbines, sentinel relief valves are to be provided at the exhaust ends or other approved positions. The relief valve discharge outlets are to be visible and suitably guarded if necessary. Where a low vacuum cut-out device is provided, the sentinel relief valve at the L.P. exhaust may be omitted.

4.1.2 In order to provide a warning, due to excessive pressure, to personnel in the vicinity of the exhaust ends of auxiliary turbines, sentinel relief valves are to be provided at the exhaust ends. The relief valve discharge outlets are to be visible and suitably guarded if necessary. Low vacuum or overpressure cut-out devices, as appropriate, are also to be provided for auxiliary turbines not installed with their own condensers.

4.2 Bled steam connections

4.2.1 Non-return or other means, which will prevent steam and water returning to the turbines, are to be fitted in bled steam connections.

4.3 Steam strainers

4.3.1 Efficient steam strainers are to be provided close to the inlets to ahead and astern high pressure turbines, or alternatively at the inlets to the manoeuvring valves.

■ *Section 5*
Emergency arrangements

5.1 Lubricating oil failure

5.1.1 Arrangements are to be made for the steam to the ahead propulsion turbines to be automatically shut-off in the event of failure of the lubricating oil pressure; however, steam is to be made available at the astern turbine for braking purposes in such an emergency, *see* Chapter 14 for emergency oil supply.

5.1.2 Auxiliary turbine arrangements are to be such that steam supply is automatically shut-off in the event of failure of the lubricating oil pressure.

5.2 Single screw ships

5.2.1 In single screw ships fitted with cross compound steam turbine installations in which two or more turbines are separately coupled to the same main gear wheel, the arrangements are to be such as to enable safe navigation when the steam supply is led direct to the L.P. turbine and either the H.P or L.P. turbine can exhaust direct to the condenser. Adequate arrangements and controls are to be provided for these emergency operating conditions so that the pressure and temperature of the steam will not exceed those which the turbines and condenser can safely withstand.

5.2.2 The necessary pipes and valves or fittings for these arrangements are to be readily available and properly marked. A fit up test of all combinations of pipes and valves is to be performed prior to the first sea trials.

5.2.3 The permissible power/speeds of the operating turbines(s) when operating without one of the turbines (all combinations) is to be specified and information provided on board.

5.2.4 The operation of the turbines under emergency conditions is to be assessed for the potential influence on shaft alignment and gear teeth loading conditions.

5.3 Single main boiler

5.3.1 Ships intended for unrestricted service, fitted with steam turbines and having a single main boiler, are to be provided with means to ensure emergency propulsion in the event of failure of the main boiler.

Section 6
Control and monitoring of main and auxiliary steam turbines

6.1 General

6.1.1 Control engineering systems are to be in accordance with the requirements of Pt 6, Ch 1.

6.1.2 All main and auxiliary steam turbines intended for essential services are to be provided with means of indicating the lubricating oil pressure supply to them. Where such turbines are of more than 37 kW (50 shp), audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. Further, these alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

6.2 Overspeed protective devices

6.2.1 An overspeed protective device is to be provided for main and auxiliary turbines to shut off the steam automatically and prevent the maximum designed speed being exceeded by more than 15 per cent.

6.2.2 Where two or more turbines of a compound main turbine installation are separately coupled to the same main gear wheel, and one overspeed protective device is provided, this is to be fitted to the L.P. ahead turbine. Hand trip gear for shutting off the steam in an emergency is to be provided at the manoeuvring platform.

6.3 Speed governors

6.3.1 Where a turbine installation incorporates a reverse gear, electric transmission or reversible propeller, a speed governor in addition to, or in combination with, the overspeed protective device is to be fitted, and is to be capable of controlling the speed of the unloaded turbine without bringing the overspeed protective device into action.

6.3.2 Auxiliary turbines intended for driving electric generators are to be fitted with speed governors which, with fixed settings, are to control the speed within 10 per cent momentary variation and 5 per cent permanent variation when full load is suddenly taken off or put on. The permanent speed variations of alternating current machines intended for parallel operations are to equalise within a tolerance of ±0,5 per cent.

6.4 Unattended machinery

6.4.1 Where machinery steam turbines are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by 6.4 to 6.6, as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

6.4.2 Where machinery is arranged to start automatically or from a remote control station, interlocks are to be provided to prevent start-up under conditions which could hazard the machinery.

6.4.3 Where machinery specified in this Section is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

6.4.4 Where a first stage alarm together with a second stage alarm and automatic shut-down of machinery are required in the relevant Tables of this Section, the sensors and circuits utilised for the second stage alarm and automatic shut-down are to be independent of those required for the first stage alarm.

6.5 Steam turbine machinery for propulsion purposes

6.5.1 Alarms and safeguards are indicated in 6.5.2 to 6.5.6 and Table 3.6.1.

6.5.2 Audible and visual alarms are to operate, and indication is to be given at the relevant control stations to stop or reduce the speed of the turbine(s) for the following fault conditions:
(a) Excessive turbine vibration.
(b) Excessive axial movement of turbine rotor.
(c) Low vacuum in main condenser.
(d) High condensate level in main condenser.

6.5.3 Reduction of speed may be effected by either manual or automatic control.

6.5.4 Means are to be provided to prevent the risk of thermal distortion of the turbines, by automatic steam spinning, when the shaft is stopped in the manoeuvring mode. An audible and visual alarm is to be provided at the relevant control stations when the shaft has been stopped for a predetermined time.

6.5.5 The following turbine services are to be fitted with automatic controls so as to maintain steady state conditions throughout the normal operating range of the propulsion turbine(s):
(a) Lubricating oil supply temperature.
(b) Condenser condensate level.
(c) Gland steam pressure.

6.5.6 Prolonged running in a restricted speed range is to be prevented automatically, or alternatively, indication of restricted speed ranges is to be provided at each control station.

6.6 Auxiliary steam turbines

6.6.1 Alarms and safeguards are indicated in Table 3.6.2.

Table 3.6.1 Steam turbine machinery: Alarms and safeguards

Item	Alarm	Note
Lubricating oil pressure	1st stage low 2nd stage low	— Automatic shut-down, *see* 6.4.4
Lubricating oil temperature	High	—
Lubricating oil sump level	Low	—
Lubricating oil filters differential pressure	High	—
Bearing temperatures or bearing oil outlet temperature	High	—
Astern turbine temperature	High	—
Gland steam pressure	High and Low	—
Thrust bearing temperature	High	—
Sea-water pressure or flow	Low	—
Turbine vibration	High	
Axial movement of turbine rotor	High	Shut-down or speed reduction or turbine(s)
Main condenser vacuum	Low	
Main condenser condensate level	High	
Overspeed	High	*See* 6.2

Table 3.6.2 Auxiliary engines and auxiliary steam turbines: Alarms and safeguards

Item	Alarm	Note
Lubricating oil inlet temperature	High	—
Lubricating oil inlet pressurre	1st stage low 2nd stage low	— Automatic shut-down of turbine, *see* 6.4.4
Condenser vacuum	Low	Automatic shut-down of turbine, *see* 6.4.4
Axial displacement of rotor	High	
Overspeed	High	*See* Ch 4,4

■ *Section 7* Tests and equipment

7.1 Stability testing of turbine rotors

7.1.1 All solid forged H.P. turbine rotors intended for main propulsion service where the inlet steam temperature exceeds 400°C are to be subjected to at least one thermal stability test. This requirement is also applicable to rotors constructed from two or more forged components joined by welding. The test may be carried out at the forge or turbine builders' works:

(a) after heat treatment and rough machining of the forging; or
(b) after final machining; or
(c) after final machining and blading of the rotor.

The stabilising test temperature is to be not less than 28°C above the maximum steam temperature to which the rotor will be exposed, and not more than the tempering temperature of the rotor material. For details of a recommended test procedure and limits of acceptance, *see* the Rules for Materials. Other test procedures may be adopted if approved.

7.1.2 Where main turbine rotors are subjected to thermal stability tests at both forge and turbine builders' works, the foregoing requirements are applicable to both tests. It is not required that auxiliary turbine rotors be tested for thermal stability, but, if such tests are carried out, the requirement for main turbine rotors will be generally applicable.

7.2 Balancing

7.2.1 All rotors as finished-bladed and complete with half-coupling are to be dynamically balanced to the Surveyor's satisfaction, in a machine of sensitivity appropriate to the size of rotor.

7.3 Hydraulic tests

7.3.1 Manoeuvring valves are to be tested to twice the working pressure. The nozzle boxes of impulse turbines are to be tested to 1,5 times the working pressure.

7.3.2 The cylinders of all turbines are to be tested to 1,5 times the working pressure in the casing, or to 2,0 bar (2,0 kgf/cm^2), whichever is the greater.

7.3.3 For test purposes, the cylinders may be sub-divided with temporary diaphragms for distribution of test pressures.

7.3.4 Condensers are to be tested in the steam space to 1,0 bar (1,0 kgf/cm^2). The water space is to be tested to the maximum pressure which the pump can develop at ship's full draught with the discharge valve closed plus 0,7 bar (0,7 kgf/cm^2), with a minimum test pressure of 2,0 bar (2,0 kgf/cm^2). Where the operating conditions are not known, the test pressure is to be not less than 3,4 bar (3,5 kgf/cm^2), *see* Chapter 14.

7.4 Indicators for movement

7.4.1 Indicators for determining the axial position of rotors relative to their casings, and for showing the longitudinal expansion of casings at the sliding feet, if fitted, are to be provided for main turbines. The latter indicators should be fitted at both sides and be readily visible.

7.5 Weardown gauges

7.5.1 Main and auxiliary turbines are to be provided with bridge weardown gauges for testing the alignment of the rotors.

■ *Cross-references*

The pumping arrangements, including cooling water and lubricating oil systems, are to comply with the requirements of Chapters 13 and 14.

For lists of spare gear to be carried, *see* Chapter 1,7.

■ *Scope*

The requirements of this Chapter are applicable to gas turbines for main propulsion and also, where powers exceed 110 kW (150 shp), to those for essential auxiliary services. The requirements do not apply to exhaust gas turbo-blowers.

Approval will be in respect of the mechanical integrity of the gas turbine (including gas generator and power turbine), intake and exhaust ducting configuration, acoustic enclosure configuration (where appropriate), fuel, lubricating oil and starter systems, control alarm and monitoring systems and other critical support systems.

Type approval of the gas turbine bare engine will be required as part of the approval process for first of type.

Primary exhaust gas emissions abatement plant (where fitted) is to meet the requirements of this Chapter; additionally, it shall meet those of Chapter 24. Where secondary exhaust gas emissions abatement systems are fitted to gas turbines, they are to meet the requirements of Chapter 24.

■ *Section 1*
General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with Chapter 1 *General Requirements for the Design and Construction of Machinery*, Pt 6, Ch 1 *Control Engineering Systems*, and Pt 6, Ch 2 *Electrical Engineering*.

1.2 Standard reference conditions

1.2.1 Where power, efficiency, heat rate or specific consumption refer to standard conditions (ISO 2314), such conditions are to be:

(a) for the intake air at the compressor flange (compressor intake flare):
- a total pressure of 101,3 kPa;
- an ambient temperature of 15°C;
- a relative humidity of 60 per cent; and

(b) for the exhaust at the turbine exhaust flange (or recuperator outlet):
- a static pressure of 101,3 kPa.

1.3 Power ratings

1.3.1 Where the dimensions of any particular component are determined from shaft power, P, in kW, and revolutions per minute, R, the values are those defined in Chapter 1.

1.4 Gas turbine type approval

1.4.1 New gas turbine types or developments of existing types are to be type approved in accordance with Lloyd's Register's (hereinafter referred to as 'LR') *Type Approval System Procedure – Test Specification GT04*.

1.4.2 Where a gas turbine type has subsequently proved satisfactory in service with a number of applications, a maximum power uprating of 10 per cent may be considered without a further complete design re-assessment and type test.

1.5 Inclination of vessel

1.5.1 Gas turbines are to operate satisfactorily under the conditions of inclinations as shown in Table 1.3.2 in Chapter 1.

■ *Section 2*
Particulars to be submitted

2.1 Plans and information

2.1.1 The following plans are to be submitted for consideration:
- Casings.
- Combustion chambers, intercoolers and heat exchangers.
- Compressor and gas generator rotating components.
- Control engineering systems, *see* Pt 6, Ch 1.
- Cooling and sealing air arrangements for compressor and gas generator components: Schematic only.
- Cooling water system: Schematic only, where applicable.
- Fuel systems: Schematic only.
- Gas turbine unit acoustic enclosure, if applicable, including ventilation and drainage systems: Schematic only.
- Inlet and exhaust ducting arrangement.
- Lubricating oil systems: Schematic only.
- Nozzles, blades and blade attachments.
- Oil fuel systems: Schematic only.
- Power turbine components.
- Rotors, bearings and couplings.
- Sectional assembly.
- Securing arrangement, including details of resilient mounts, where applicable.
- Starting system: Schematic only.

2.1.2 The following information and calculations, where applicable, are to be submitted:

(a) Operational requirements:
- Proposed field of application and operational limitations.
- Power/speed operational envelope.
- Calculations and information for short-term high power operation.
- Operation and maintenance manuals including the declared lives of critical components and overhaul schedules recommended by the manufacturer.

(b) Calculations of the critical speeds of blade and rotor vibration, giving full details of the basic assumptions, *see also* 4.3.1.

(c) Analysis of the effect of rotor blade release together with details of operating experience, *see also* 4.3.2.

(d) High temperature characteristics of the materials, including (at working temperatures) the associated creep rate and rupture strength for the designed service life, fatigue strength, corrosion resistance and scaling properties.

(e) Material requirements:
- Particulars of heat treatment, including stress relief.
- Material specifications covering the listed components together with details of any surface treatments, non-destructive testing and hydraulic tests.

(f) The most onerous pressures and temperatures to which each component may be subjected are to be indicated on plans or provided as part of the design specification.

(g) Calculations of the steady state stresses, including the effect of stress raisers, etc., in the compressor and turbine rotors and blading at the maximum speed and temperature in service. Such calculations are to indicate the designed service life and be accompanied, where possible, by test results substantiating the limiting criteria.

(h) Details of calculations and tests to establish the service life of other stressed or safety critical components, including bearings, seals, couplings and gearing. Calculations and tests are to take account of all relevant environmental factors including the particular type of service and fuel intended to be used.

(j) Mounting requirements:
- Securing arrangements, including details of resilient mounts.
- Calculations concerning the amplitude and frequency of vibration associated with resilient type mountings.

(k) A Failure Mode and Effects Analysis (FMEA).

(l) Miscellaneous:
- Design standard of intake filtration for water particulate and corrosive marine salts.
- Details of compressor washing system.
- Fuel specification.

2.1.3 Components fabricated by means of welding will be considered for acceptance if constructed by firms whose works are properly equipped to undertake welding of the standards appropriate to the components. Details are to be submitted for consideration.

2.1.4 Before work is commenced, manufacturers are to submit for consideration details of proposed welding procedures and their proposals for routine examination of joints by non-destructive means.

2.1.5 The manufacturer's proposals for testing the gas turbine are to be submitted for consideration and are to include rotor balancing techniques, methods of determining the soundness of pressure casings and heat exchanger tests, *see* Section 1.

■ *Section 3* Materials

3.1 Materials for forgings

3.1.1 Details of materials for rotors and discs are to be submitted for approval.

3.2 Material tests and inspection

3.2.1 Components are to be tested in accordance with the relevant requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials.

3.2.2 For components of novel design, special consideration will be given to the material test and non-destructive testing requirements.

■ *Section 4* Design and construction

4.1 General

4.1.1 All parts of compressors, turbines, etc., are to have clearances and fits consistent with adequate provision for the relative thermal expansion of the various components. Provision is to be made to limit the distortion of the casing and rotor under all normal operating conditions.

4.1.2 Gas generator and power turbine bearings are to be so disposed and supported that lubrication is not adversely affected by heat flow from adjacent hot parts. Effective means are to be provided for intercepting oil leakage and preventing oil from reaching high temperature glands and casings.

4.2 Vibration

4.2.1 The design and manufacture of compressor and turbine rotors, rotor discs and rotor blades are to ensure freedom from undue vibration within the full operating speed range. Where critical speeds are found by calculation to occur within the operating speed range, vibration tests may be required in order to verify the calculations, *see also* Chapter 8.

4.2.2 Vibration monitoring is to form an integral part of the gas turbine safety and control system. The vibration monitoring system is to be capable of detecting the out-of-balance of major parts with means being provided to shutdown the gas turbine, before an over-critical situation occurs, i.e. multiple rotor blade or disc release.

4.3 Containment

4.3.1 Gas turbines and power turbines are to be designed and installed, so far as is practicable, to contain debris in the event of rotor blade release.

4.3.2 In the event of a major component failure, when the turbine casing may not contain the debris; oil fuel, lubricating oil and other potentially hazardous systems or equipment are, where practicable, to be located outside of the plane of high speed rotating parts. This requirement also applies to fire detection and extinction equipment, *see also* Section 5.

4.3.3 Gas turbine ancillaries containing flammable products are to be segregated or protected from high temperature areas.

4.4 Intake and exhaust ducts

4.4.1 Air intakes are to be designed and located to minimise the possibility of ingestion of harmful objects. Means are also to be provided for detecting and preventing icing up of air intakes.

4.4.2 Suitable intake filtration is to be provided to control the ingestion of water, particulate and corrosive marine salts within the gas turbine manufacturer's specified limits.

4.4.3 Where an air intake enclosure forms the connection between the ship's downtake and the gas turbine installation, a suitable alarm function is to be provided to give warning when an unacceptable air intake pressure loss is reached at the air inlet (bellmouth) of the gas turbine.

4.4.4 Intakes are to be designed such that material cannot become detached due to air flow or corrosion. Fixing bolts and fastenings are to be positively locked so that they cannot work loose.

4.4.5 Multi-engine installations are to have separate intakes and exhausts so arranged as to prevent induced circulation through a stopped gas turbine unit.

4.4.6 The arrangement of the exhaust duct is to be such as to prevent, under normal conditions of ship motion and atmospheric conditions, exhaust gases being drawn into machinery spaces, air conditioning systems and intakes.

4.4.7 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back into the gas turbine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard. Erosion/corrosion-resistant shut-off flaps or other devices are to be fitted on the hull side shell or pipe end with suitable arrangements made to prevent water flooding the machinery space.

4.5 External influences

4.5.1 Pipes and ducting connected to casings are to be so designed that they apply no excessive loads or moments to the compressors and turbines.

4.5.2 Platform gratings and fittings in way of the supports are to be so arranged that casing expansion is not restricted.

4.5.3 Where the gas turbine seating incorporates a tank structure, any temperature variation of the tank in service is not to adversely affect the gas generator and power turbine alignment.

4.5.4 For machinery fastening arrangements, including resilient mounting, *see* Chapter 1.

4.6 Corrosive deposits

4.6.1 Means are to be provided for periodic removal of salt deposits and atmospheric contaminants from blading and internal surfaces.

4.7 Acoustic enclosures

4.7.1 Acoustic enclosures, where fitted, are to be provided with an access door, adequate internal lighting and one or more observation windows to allow the viewing of critical parts of the gas turbine.

4.7.2 A suitable ventilation system, designed to maintain all components within their safe working temperature under all operating conditions is to be provided.

4.7.3 The ventilation system is to be fitted with shut-off flaps arranged to close automatically upon activation of the enclosure's fire detection and extinguishing system.

4.7.4 Acoustic enclosure fire safety arrangements are to comply with the requirements of Pt 6, Ch 1 and the *International Convention for the Safety of Life at Sea, 1974*, as amended (SOLAS 74), *see also* 8.7.1.

4.8 Thermal insulation

4.8.1 Where surfaces of the gas generator, power turbine and exhaust volute exceed a temperature of 220°C during operation, these are to be suitably insulated and clad to minimise the risk of fire and prevent damage by heat to adjacent components, *see* 5.1.5.

4.9 Welded construction

4.9.1 Welding is to be carried out in accordance with the requirements of Chapter 13 of the Rules for Materials, using welding procedures and welders that have been qualified in accordance with Chapter 12 of the Rules for Materials.

4.9.2 Stress relief heat treatment is to be applied to all cylinders, rotors and associated components on completion of all welding, *see* Chapter 17.

4.10 Turning gear

4.10.1 Gas generator turning gear is to be provided to facilitate operating and maintenance regimes as required by the manufacturer.

4.10.2 The turning gear may be hand operated (manual) except where this is not practicable. If electrically driven, the motor is to be continuously rated.

4.10.3 The turning gear is to be fitted with safety interlocks which prevent engine operation when engaged, *see* Ch 1,3.9. Indication of engaged/not engaged is to be provided at all start positions.

4.10.4 The remote control device of power-driven turning gear is to be so designed that power is removed from the turning gear when the operating switch is released.

4.10.5 If permanently attached, means are to be provided to secure the turning gear when disengaged.

■ *Section 5* Piping systems

5.1 General

5.1.1 Gas turbine piping systems are, in general, to comply with the requirements given in Chapter 12 and Chapter 14, due regard being paid to the particular type of installation. For the burning of compressed natural gas, *see* the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases*.

5.1.2 The materials and/or their surface treatment used for the storage and distribution of oil fuel are to be selected such that they do not introduce contamination or modify the properties of the fuel.

5.1.3 Corrosion resistant materials are to be used in all fuel pipes between the treatment and combustion systems.

5.1.4 Suitable fuel treatment systems, including filtration and centrifuging, are to be provided to control the level of water and particulate contamination within the engine manufacturer's specified limits.

5.1.5 The gas turbine design and construction are to minimise the possibility of a fire fed by fuel or lubricating oil leaks.

5.1.6 In dual-fuel applications, provision is to be made for automatic isolation of both primary and standby fuel supplies to the engine in the event of a fire.

5.2 Oil fuel systems

5.2.1 Oil fuel arrangements are to comply with the requirements of Chapter 14.

5.2.2 All external high pressure oil fuel delivery lines between the pressure fuel pumps and fuel metering valves are to be protected with a jacketed piping system capable of containing fuel from a high pressure line failure to prevent oil fuel or oil fuel mist from reaching a source of ignition on the engine or its surroundings.

5.2.3 Suitable arrangements are to be made for draining any oil fuel leakage from the protection required by 5.2.2 and to prevent contamination of the lubricating oil by oil fuel. An alarm is to be provided to indicate that leakage is taking place.

5.2.4 At least two filters are to be fitted in the oil fuel supply lines to the gas turbine and be so arranged that any filter may be cleaned without interrupting the supply of filtered oil fuel to the gas turbine.

5.3 Lubricating oil systems

5.3.1 Lubricating oil arrangements are to comply with the requirements of Chapter 14.

5.3.2 Where the lubricating oil for gas turbines is circulated under pressure, provision is to be made for the efficient filtration of the oil. At least two filters are to be fitted in the lubricating oil supply lines to the gas turbine and be so arranged that any filter may be cleaned without interrupting the supply of filtered lubricating oil to the gas turbine.

5.4 Cooling systems

5.4.1 Cooling water arrangements are to comply with the requirements of Chapter 14, where appropriate.

Section 6
Starting arrangements

6.1 General

6.1.1 Equipment for initial starting of gas turbines is to be provided and arranged such that the necessary initial charge of starting air, hydraulic or electrical power can be developed on board the ship without external aid. If, for this purpose, an emergency air compressor or electric generator is required, these units are to be power-driven by manually-started oil engines, except in the case of small installations where a hand-operated compressor of approved capacity may be accepted.

6.1.2 Alternatively, other devices of approved type may be accepted as a means of providing the initial start.

6.1.3 Where the integrity of the starting system is susceptible to overspeed conditions, appropriate alarm and/or trip functions are to be provided, *see also* Pt 6, Ch 1.

6.2 Purging before ignition

6.2.1 Means are to be provided to clear all parts of the gas turbine of the accumulation of oil fuel or for purging gaseous fuel before ignition commences on starting, or recommences after failure to start. The purge is to be of sufficient duration to displace at least three times the volume of the exhaust system.

6.3 Air starting

6.3.1 Where the gas turbine is arranged for air starting, the total air receiver capacity is to be sufficient to provide, without replenishment, not less than six consecutive starts. At least two air receivers of approximately equal capacity are to be provided to satisfy the plant air start requirements. For scantlings and fittings of air receivers, *see* Chapter 11.

6.3.2 For multi-engine installations, three consecutive starts per engine are required.

6.4 Electric starting

6.4.1 Where the gas turbine is fitted with electric starters powered from batteries, two batteries are to be fitted. Each battery is to be capable of starting the gas turbine and the combined capacity is to be sufficient without recharging to provide the number of starts required by 6.3.1 or 6.3.2.

6.4.2 The requirements for battery installations are given in Pt 6, Ch 2.

6.5 Hydraulic starting

6.5.1 Where the gas turbine is arranged for hydraulic starting, the capacity of the power pack is to be sufficient to provide the number of starts of the gas turbine as required by 6.3.1 or 6.3.2.

Section 7
Tests

7.1 Dynamic balancing

7.1.1 All compressor and turbine rotors as finished-bladed and complete with all relevant parts such as half-couplings, are to be dynamically balanced in accordance with the manufacturer's specification in a machine of sensitivity appropriate to the size of rotor.

7.2 Hydraulic testing

7.2.1 Where design permits, casings are to be tested to a hydraulic pressure equal to 1,5 times the highest pressure in the casing during normal operation, or 1,5 times the pressure during starting, whichever is the higher. For test purposes, if necessary, the casings may be subdivided with temporary diaphragms for distribution of test pressure. Where the operating temperature exceeds 300°C the test pressure is to be suitably corrected.

7.2.2 Where hydraulic testing is impracticable, 100 per cent non-destructive tests by ultrasonic or radiographic methods are to be carried out on all casing parts with satisfactory results. Where ultrasonic tests have been carried out, the manufacturer is to provide documentary evidence that ultrasonic examination has been carried out by an approved operator and that there were no indications of defects which could be expected to have a prejudicial effect on the operational performance of the gas turbine.

7.2.3 The shell and tube arrangement of intercoolers and heat exchangers are to be tested to 1,5 times their maximum working pressure.

7.3 Overspeed tests

7.3.1 Before installation, it is to be satisfactorily demonstrated that the gas turbine is capable of safe operation for five minutes at 5 per cent above the nominal setting of the overspeed protective device, or 15 per cent above the maximum design speed, whichever is the higher.

7.3.2 Where it is impracticable to overspeed the complete installation, each compressor and turbine rotor completely bladed and with all relevant parts such as half-couplings, are to be overspeed-tested individually at the appropriate speed.

Section 8
Control, alarm and safety systems

8.1 General

8.1.1 Control alarm and safety systems are to comply with the requirements of Pt 6, Ch 1.

8.1.2 All gas turbines intended for essential services are to be provided with means of indicating the lubricating oil pressure supply to them. Where such turbines are of more than 37 kW (50 shp), audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. Further, these alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

8.2 Overspeed protection and shutdown system

8.2.1 The gas turbine is to be protected against overspeed by the provision of a suitable device(s) capable of shutting-down the gas turbine safely before a dangerous overspeed condition occurs.

8.3 Power turbine inlet over-temperature control

8.3.1 The power turbine is to be protected against over-temperature by the provision of a suitable device(s) capable of controlling the temperature within acceptable limits or shutting-down the gas turbine safely to prevent damage.

8.4 Flameout

8.4.1 Indication is to be provided for identifying poor combustion from each combustion chamber, flame-out and failure to ignite conditions, *see also* 6.2.1.

8.5 Lubricating oil system

8.5.1 Means are to be provided to accurately determine the pressure and temperature of the lubricating oil supply to the various parts of the gas generator and power turbine, and scavenge oil and return systems to ensure safe operation.

8.5.2 Means are to be provided to ensure that the temperature of the lubrication oil supply is automatically controlled to maintain steady-state conditions throughout the normal operating range of the gas turbine.

8.5.3 Where the oil supply to the power turbine is fed from a separate supply system, similar arrangements to those detailed above are to be provided.

8.6 Hand trip arrangement

8.6.1 Means are to be provided, at both the local and remote control/operating positions, to manually initiate the shut-down of the gas turbine in an emergency.

8.7 Fire detection, alarm and extinguishing systems

8.7.1 The gas turbine installation is to be provided with a fire detection, alarm and extinguishing system. The requirements of Pt 6, Ch 1 and the *International Convention for the Safety of Life at Sea, 1974* as amended (SOLAS 74) are to be complied with.

8.8 Unattended machinery

8.8.1 Where gas turbines are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by 8.8 to 8.9 as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

8.8.2 Where machinery is arranged to start automatically or from a remote control station, interlocks are to be provided to prevent start-up under conditions which could hazard the machinery.

8.8.3 Where machinery specified in this Section is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

8.8.4 Where a first stage alarm together with a second stage alarm and automatic shut-down of machinery are required in the relevant Tables of this Section, the sensors and circuits utilised for the second stage alarm and automatic shut-down are to be independent of those required for the first stage alarm. LR will consider alternative arrangements which provide an equivalent level of safety.

8.9 Gas turbine machinery

8.9.1 Alarms and safeguards are indicated in 8.9.2 to 8.9.4 and Table 4.8.1.

8.9.2 The following turbine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the turbine:

(a) Lubricating oil supply.
(b) Oil fuel supply, *see also* 8.9.3.
(c) Exhaust gas.

8.9.3 The oil fuel supply may be fitted with an automatic control for viscosity instead of the temperature control required by 8.9.2.

8.9.4 A means of manually shutting off the fuel in an emergency is to be provided at the manoeuvring station.

Table 4.8.1 Gas turbine machinery: Alarms and safeguards

Item	Alarm	Note
Overspeed	High	Automatic shut-down *see also* 8.2
Power turbine inlet temperature	1st stage high	Automatic power reduction
	2nd stage high	Automatic shut-down *see also* 8.3
Flame failure	Failure	Automatic shut-down, *see also* 8.4
Failure to ignite	Failure	Automatic shut-down, *see also* 8.4
Lubricating oil pressure	1st stage low	—
	2nd stage low	Automatic shut-down, *see also* 8.5
Lubricating oil temperature	High	*See also* 8.5
Lubricating oil filter differential pressure	High	—
Scavenge oil temperature	High	—
Scavenge oil pressure	Low	Automatic shut-down
Bearing temperature	High	—
Turbine vibration	1st stage high	—
	2nd stage high	Automatic shut-down, *see also* 4.2
Oil fuel supply pressure	Low	—
Oil fuel supply temperature	High	—
Oil fuel leakage	High	*See also* 5.2
Automatic starting	Failure	Automatic shut-down
Control system	Failure	Automatic shut-down
Air intake pressure	Low	*See also* 4.4.4
Feed water or water/thermal fluid forced circulation flow (if fitted)	Low	*See* Ch 14,6.2.7 and Note 4
Uptake temperature	High	To monitor for soot fires. *See* Notes 4 and 5

NOTES
1. For two-stage alarms, *see also* 8.8.4.
2. For requirements on purging before ignition, *see* Ch 4,6.2.1.
3. Where a requirement for disabling the automatic protection and safety system devices for machinery and engineering systems has been defined by the Owner, the consequences of using the disabling arrangements are to be established and included in the operations procedures and orders provided on board ship. Details of any disabling arrangements are to be submitted to LR for consideration in each instance.
4. Alarm is required only when suitable for operation on residual fuel grades and an exhaust gas economiser/boiler/thermal oil heater is fitted.
5. Alternatively, details of an appropriate fire detection system are to be submitted for consideration.

Section

■ *Scope*

The requirements of this Chapter, except where otherwise stated are applicable to oil engine gearing for main propulsion purposes and for oil engine gearing for driving auxiliary machinery which is essential for the safety of the ship or for safety of persons on board where the transmitted powers exceed 220 kW (300 shp) for propulsion drives, and 110 kW (150 shp) for auxiliary drives. Alternatively calculations using the methods defined in ISO 6336 – *Calculation of load capacity of spur and helical gears*, will be considered. In any mesh, the terms pinion and wheel refer to the smaller and larger gear respectively. For turbine gearing the loading factors K_A, $K_{F\alpha}$, $K_{F\beta}$, $K_{H\alpha}$, $K_{H\beta}$ and K_γ will be considered. Bevel gears will be specially considered on the basis of a conversion to equivalent helical gears. For torsional vibration requirements, *see* Ch 8,2.3.

■ *Section 1*
Plans and particulars

1.1 Gearing plans

1.1.1 Particulars of the gearing are to be submitted with the plans for all propulsion gears and for auxiliary gears where the transmitted power exceeds 110 kW (150 shp), as follows:

(a) Plans and information demonstrating conformance with the applicable Rules and Standards as stated in scope.
(b) Shaft power and revolution for each pinion.
(c) Number of teeth in each gear.
(d) Reference diameters.
(e) Helix angles at reference diameters.
(f) Normal pitches of teeth at reference diameters.
(g) Tip diameters.
(h) Root diameters.
(j) Face widths and gaps, where applicable.
(k) Pressure angles of teeth (normal or transverse) at reference diameters.
(l) Accuracy grade Q in accordance with ISO 1328 or an equivalent Standard.
(m) Surface texture of tooth flanks and roots.
(n) Minimum backlash.
(o) Centre distance.
(p) Basic rack tooth form.
(q) Protuberance and final machining allowance.
(r) Details of post hobbing processes, if any.
(s) Details of tooth flank corrections, if adopted.
(t) Case depth for surface-hardened teeth.
(u) Shrinkage allowance for shrunk-on rims and hubs.
(v) Type of coupling proposed for oil engine applications.

1.2 Material specifications

1.2.1 Specifications for materials of pinions, pinion sleeves, wheel rims, gear wheels, and quill shafts, giving chemical composition, heat treatment and mechanical properties, are to be submitted for approval with the plans of gearing.

1.2.2 Where the teeth of a pinion or gear wheel are to be surface hardened, i.e., carburised, nitrided, tufftrided or induction-hardened, the proposed specification and details of the procedure are to be submitted for approval.

■ *Section 2*
Materials

2.1 Material properties

2.1.1 In the selection of materials for pinions and wheels, consideration is to be given to their compatibility in operation. Except in the case of low reduction ratios, for gears of through-hardened steels, provision is also to be made for a hardness differential between pinion teeth and wheel teeth. For this purpose, the specified minimum tensile strength of the wheel rim material is not to be more than 85 per cent of that of the pinion.

2.1.2 Subject to 2.1.1, the specified minimum tensile strength is to be selected within the following limits:

Pinion and pinion sleeves	550 to 1050 N/mm^2 (56 to 107 kgf/mm^2)
Gear wheels and rims	400 to 850 N/mm^2 (41 to 87 kgf/mm^2)

A tensile strength range is also to be specified and is not to exceed 120 N/mm^2 (12 kgf/mm^2) when the specified minimum tensile strength is 600 N/mm^2 (61 kgf/mm^2) or less. For higher strength steels, the range is not to exceed 150 N/mm^2 (15 kgf/mm^2).

2.1.3 Unless otherwise agreed, the full specified minimum tensile strength of the core is to be 800 N/mm^2 (82 kgf/mm^2) for induction-hardened or nitrided gearing and 750 N/mm^2 (76 kgf/mm^2) for carburised gearing.

2.1.4 For nitrided gearing, the full depth of the hardened zone is to be not less than 0,5 mm and the hardness is to be not less than 500 HV for a depth of 0,25 mm.

2.2 Non-destructive tests

2.2.1 An ultrasonic examination is to be carried out on all gear blanks where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm.

2.2.2 Magnetic particle or liquid penetrant examination is to be carried out on all surface-hardened teeth. This examination may also be requested on the finished machined teeth of through-hardened gears.

■ *Section 3*
Design

3.1 Symbols

3.1.1 For the purposes of this Chapter the following symbols apply:

a = centre distance, in mm
b = face width, in mm
d = reference diameter, in mm
d_a = tip diameter, in mm
d_{an} = virtual tip diameter, in mm
d_b = base diameter, in mm
d_{bn} = virtual base diameter, in mm
d_{en} = virtual diameter to the highest point of single tooth pair contact, in mm
d_f = root diameter, in mm
d_{fn} = virtual root diameter, in mm
d_n = virtual reference diameter, in mm
d_s = shrink diameter, in mm
d_w = pitch circle diameter, in mm
f_{ma} = tooth flank misalignment due to manufacturing errors, in μm
f_{pb} = maximum base pitch deviation of wheel, in μm
f_{Sh} = tooth flank misalignment due to wheel and pinion deflections, in μm
f_{Sho} = intermediary factor for the determination of f_{Sh}
g_α = length of line of action for external gears, in mm:
$= 0{,}5\sqrt{(d_{a1}^2 - d_{b1}^2)} + 0{,}5\sqrt{(d_{a2}^2 - d_{b2}^2)} - a \sin\alpha_{tw}$
for internal gears:
$= 0{,}5\sqrt{(d_{a1}^2 - d_{b1}^2)} - 0{,}5\sqrt{(d_{a2}^2 - d_{b2}^2)} + a \sin\alpha_{tw}$
h = total depth of tooth, in mm
h_{ao} = basic rack addendum of tool, in mm
h_F = bending moment arm for root stress, in mm
h_W = sum of actual tooth addenda of pinion and wheel, in mm
m_n = normal module, in mm
n = rev/min of pinion
q = machining allowances, in mm
q_s = notch parameter
q' = intermediary factor for the determination of C_γ
u = gear ratio = $\dfrac{\text{Number of teeth in wheel}}{\text{Number of teeth in pinion}} \geq 1$
v = linear speed at pitch circle, in m/s
x = addendum modification coefficient
y_α = running in allowance, in μm
y_β = running in allowance, in μm
z = number of teeth
z_n = virtual number of teeth
$= \dfrac{z}{\cos^2 \beta_b \cos \beta}$
C_γ = tooth mesh stiffness (mean total mesh stiffness per unit face width), in N/mm μm
F_t = nominal tangential tooth load, in N
$= \dfrac{P}{nd}\ 19{,}098 \times 10^6$
F_β = total tooth alignment deviation (maximum value specified), in μm
$F_{\beta x}$ = actual longitudinal tooth flank deviation before running in, in μm
$F_{\beta y}$ = actual longitudinal tooth flank deviation after running in, in μm
HV = Vickers hardness number
K_A = application factor
$K_{F\alpha}$ = transverse load distribution factor
$K_{F\beta}$ = longitudinal load distribution factor
$K_{H\alpha}$ = transverse load distribution factor
$K_{H\beta}$ = longitudinal load distribution factor
K_v = dynamic factor
$K_{v\alpha}$ = dynamic factor for spur gears
$K_{v\beta}$ = dynamic factor for helical gears
K_γ = load sharing factor
P = transmitted power, in kW
P_r = radial pressure at shrinkage surface, in N/mm²
P_{ro} = protuberance of tool, in mm
Q = accuracy grade derived from ISO 1328 – *Cylindrical gears – ISO system of accuracy*
R_a = surface roughness – arithmetical mean deviation (C.L.A.) as determined by an instrument having a minimum wavelength cut-off of 0,8 mm and for a sampling length of 2,5 mm, in μm
S_{pr} = residual undercut left by protuberance in mm
$S_{F\,min}$ = minimum factor of safety for bending stress
S_{Fn} = tooth root chord in the critical section, in mm
$S_{H\,min}$ = minimum factor of safety for Hertzian contact stress
Y_D = design factor
Y_F = tooth form factor
$Y_{R\,rel\,T}$ = relative surface finish factor
Y_S = stress concentration factor
Y_{ST} = stress correction factor
Y_x = size factor
Y_β = helix angle factor
$Y_{\delta\,rel\,T}$ = relative notch sensitivity factor
Z_E = material elasticity factor
Z_H = zone factor
Z_R = surface finish factor
Z_V = velocity factor
Z_X = size factor
Z_β = helix angle factor
Z_ε = contact ratio factor
α_{en} = pressure angle at the highest point of single tooth contact, in degrees
α_n = normal pressure angle at reference diameter, in degrees
α_t = transverse pressure angle at reference diameter, in degrees
α_{tw} = transverse pressure angle at pitch circle diameter, in degrees
α_{Fen} = angle for application of load at the highest point of single tooth contact, in degrees
β = helix angle at reference diameter, in degrees
β_b = helix angle at base diameter, in degrees
γ = intermediary factor for the determination of f_{Sh}
ε_α = transverse contact ratio
$= \dfrac{g_\alpha \cos \beta}{\pi\, m_n \cos \alpha_t}$

$\varepsilon_{\alpha n}$ = virtual transverse contact ratio
ε_β = overlap ratio
$= \dfrac{b \sin \beta}{\pi\, m_n}$
ε_γ = total contact ratio
ρ_{ao} = tip radius of tool, in mm
ρ_c = relative radius of curvature at pitch point, in mm
$= \dfrac{a \sin \alpha_{tw}\, u}{\cos \beta_b\,(1 + u)^2}$
ρ_F = tooth root fillet radius at the contact of the 30° tangent, in mm
σ_y = yield or 0,2 per cent proof stress, in N/mm^2
σ_B = ultimate tensile strength, in N/mm^2
σ_F = bending stress at tooth root, in N/mm^2
$\sigma_{F\,lim}$ = endurance limit for bending stress in N/mm^2
σ_{FP} = allowable bending stress at the tooth root, in N/mm^2
σ_H = Hertzian contact stress at the pitch circle, in N/mm^2
$\sigma_{H\,lim}$ = endurance limit for Hertzian contact stress, in N/mm^2
σ_{HP} = allowable Hertzian contact stress, in N/mm^2

Subscript:
$_1$ = pinion
$_2$ = wheel
$_0$ = tool.

3.2 Tooth form

3.2.1 The tooth profile in the transverse section is to be of involute shape, and the roots of the teeth are to be formed with smooth fillets of radii not less than $0{,}25m_n$.

3.2.2 All sharp edges left on the tips and ends of pinion and wheel teeth after hobbing and finishing are to be removed.

3.3 Tooth loading factors

3.3.1 For values of application factor, K_A *see* Table 5.3.1.

Table 5.3.1 Values of K_A

Main and auxiliary gears	K_A
Main propulsion oil engine reduction gears:	
Hydraulic coupling or equivalent on input	1,10
High elastic coupling on input	1,30
Other coupling	1,50
Auxiliary gears:	
Electric and diesel engine drives with hydraulic coupling or equivalent on input	1,00
Diesel engine drives with high elastic coupling on input	1,20
Diesel engine drives with other couplings	1,40

3.3.2 Load sharing factor, K_γ. The value for K_γ is to be taken as 1,15 for multi-engine drives or split torque arrangements. Otherwise K_γ is to be taken as 1,0. Alternatively, where measured data exists, a derived value will be considered.

3.3.3 Dynamic factor, K_v:

For helical gears with $\varepsilon_\beta \geq 1$:
$K_v = 1 + Q^2 v z_1\, 10^{-5} = K_{v\beta}$
For helical gears with $\varepsilon_\beta < 1$:
$K_v = K_{v\alpha} - \varepsilon_\beta\,(K_{v\alpha} - K_{v\beta})$
For spur gears:
$K_v = 1 + 1{,}8Q^2 v z_1\, 10^{-5} = K_{v\alpha}$

where $\dfrac{v z_1}{100} > 14$ for helic gears, and

where $\dfrac{v z_1}{100} > 10$ for spur gears the value of K_v will be specially considered.

3.3.4 Longitudinal load distribution factors, $K_{H\beta}$ and $K_{F\beta}$:

$$K_{H\beta} = 1 + \frac{b\, F_{\beta y}\, C_\gamma}{2\, F_t\, K_A\, K_\gamma\, K_v}$$

Calculated values of $K_{H\beta} > 2$ are to be reduced by improved accuracy and helix correction as necessary:

where
$F_{\beta y} = F_{\beta x} - y_\beta$ and
$F_{\beta x} = 1{,}33\, f_{Sh} + f_{ma}$
$f_{ma} = {}^2/_3\, F_\beta$ at the design stage, or
$f_{ma} = {}^1/_3\, F_\beta$ where helix correction has been applied

$f_{Sh} = f_{Sho}\, \dfrac{F_t\, K_A\, K_\gamma\, K_v}{b}$ where

f_{Sho} = $23\gamma 10^{-3}$ µm mm/N for gears without helix correction and without end relief, or
= $16\gamma 10^{-3}$ µm mm/N for gears without helix correction but with end relief, where

$\gamma = \left(\dfrac{b}{d_1}\right)^2$ for single helical and spur gears

$= 3\left(\dfrac{b}{2d_1}\right)^2$ for double helical gears

The following minimum values are applicable, these also being the values where helix correction has been applied:
f_{Sho} = 10×10^{-3} µm mm/N for helical gears, or
= 5×10^{-3} µm mm/N for spur gears

For through-hardened steels and surface hardened steels running on through-hardened steels:

$y_\beta = \dfrac{320}{\sigma_{H\,lim}}\, F_{\beta x}$ when

$y_\beta \leq \dfrac{12800}{\sigma_{H\,lim}}$ µm, and

For surface hardened steels, when
$y_\beta = 0{,}15F_{\beta x}$
$y_\beta \leq 6$ µm
$K_{F\beta} = K_{H\beta}^{\ n}$

where

$$n = \frac{\left(\frac{b}{h}\right)^2}{1 + \frac{b}{h} + \left(\frac{b}{h}\right)^2}$$

NOTES

1. $\dfrac{b}{h}$ is to be taken as the smaller of $\dfrac{b_1}{h_1}$ or $\dfrac{b_2}{h_2}$

2. For double helical gears $\frac{b}{2}$ is to be substituted for b in the equation for n.

3.3.5 Transverse load distribution factors, $K_{H\alpha}$ and $K_{F\alpha}$

$K_{H\alpha} = K_{F\alpha} \geq 1{,}00$

where

$\varepsilon_\gamma \leq 2$

$$K_{H\alpha} = \frac{\varepsilon_\gamma}{2} \left\{0{,}9 + \frac{0{,}4 C_\gamma (f_{pb} - y_\alpha)\, b}{F_t K_A K_\gamma K_v K_{H\beta}}\right\}$$

where

$\varepsilon_\gamma > 2$

$$K_{H\alpha} = 0{,}9 + 0{,}4 \sqrt{\frac{2(\varepsilon_\gamma - 1)}{\varepsilon_\gamma}} \left\{\frac{C_\gamma (f_{pb} - y_\alpha)\, b}{F_t K_A K_\gamma K_v K_{H\beta}}\right\}, \text{ but}$$

$$K_{H\alpha} \leq \frac{\varepsilon_\gamma}{\varepsilon_\alpha Z_\varepsilon^2} \text{ and}$$

$$K_{F\alpha} \leq \frac{\varepsilon_\gamma}{0{,}25\varepsilon_\gamma + 0{,}75}$$

When tip relief is applied f_{pb} is to be half of the maximum specified value:

$$y_\alpha = \frac{160}{\sigma_{H\,lim}} f_{pb} \text{ for through-hardened steels, when}$$

$$y_\alpha \leq \frac{6400}{\sigma_{H\,lim}} \;\mu\text{m and}$$

$y_\alpha = 0{,}075 f_{pb}$ for surface hardened steels, when

$y_\alpha \leq 3\,\mu$m

When pinion and wheel are manufactured from different materials:

$$y_\alpha = \frac{y_{\alpha 1} + y_{\alpha 2}}{2}$$

3.3.6 Tooth mesh stiffness, C_γ:

$$C_\gamma = \frac{0{,}8}{q'} \cos\beta\,(0{,}75\varepsilon_a + 0{,}25) \text{ N/mm }\mu\text{m}$$

where

$$q' = 0{,}04723 + \frac{0{,}1551}{z_{n1}} + \frac{0{,}25791}{z_{n2}} - 0{,}00635 x_1 - \frac{0{,}11654 x_1}{z_{n1}} - 0{,}00193 x_2 - \frac{0{,}24188 x_2}{z_{n2}} + 0{,}00529 x_1^2 + 0{,}00182 x_2^2$$

For internal gears $z_{n2} = \infty$

Other calculation methods for C_γ will be specially considered.

3.4 Tooth loading for surface stress

3.4.1 The Hertzian contact stress, σ_H, at the pitch circle is not to exceed the allowable Hertzian contact stress, σ_{HP}.

$$\sigma_H = Z_H Z_E Z_\varepsilon Z_\beta \sqrt{\frac{F_t (u+1)}{d_1\, b\, u}}\; K_A K_\gamma K_v K_{H\beta} K_{H\alpha} \text{ and}$$

$$\sigma_{HP} = \frac{\sigma_{H\,lim} Z_R Z_V Z_X}{S_{H\,min}} \text{ for the pinion/wheel combination}$$

where

$$Z_H = \sqrt{\frac{2\cos\beta_b \cos\alpha_{tw}}{\cos^2\alpha_t \sin\alpha_{tw}}}$$

$Z_E = 189{,}8$ for steel

$$Z_\varepsilon = \sqrt{\frac{4 - \varepsilon_\alpha}{3}(1 - \varepsilon_\beta) + \frac{\varepsilon_\beta}{\varepsilon_\alpha}} \text{ for } \varepsilon_\beta < 1 \text{ and}$$

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}} \text{ for } \varepsilon_\beta \geq 1$$

$$Z_\beta = \sqrt{\cos\beta}$$

$$Z_R = \left(\frac{1}{R_a}\right)^{0{,}11} \text{ but } Z_R \leq 1{,}14$$

Where R_a is the surface roughness value of the tooth flanks. When pinion and wheel tooth flanks differ then the larger value of R_a is to be taken.

$$Z_v = 0{,}88 + 0{,}23\left(0{,}8 + \frac{32}{v}\right)^{-0{,}5}$$

For values of Z_x, *see* Table 5.3.2
$\sigma_{H\,lim}$, *see* Table 5.3.3
$S_{H\,lim}$, *see* Table 5.3.4.

Table 5.3.2 Values of Z_x

Pinion heat treatment		Z_x
Carburised and induction-hardened	$m_n \leq 10$ $10 < m_n < 30$ $30 \leq m_n$	1,00 $1{,}05 - 0{,}005 m_n$ 0,9
Nitrided	$m_n < 7{,}5$ $7{,}5 < m_n < 30$ $30 \leq m_n$	1,00 $1{,}08 - 0{,}011 m_n$ 0,75
Through-hardened	All modules	1,00

Table 5.3.3 Values of endurance limit for Hertzian contact stress, $\sigma_{H\,lim}$

Heat treatment Pinion	Wheel	$\sigma_{H\,lim}$ N/mm^2
Through-hardened	Through-hardened	$0{,}46\sigma_{B2} + 255$
Surface-hardened	Through-hardened	$0{,}42\sigma_{B2} + 415$
Carburised, nitrided or induction hardened	Soft bath nitrided (Tufftrided)	1000
Carburised, nitrided or induction-hardened	Induction-hardened	$0{,}88\,HV_2 + 675$
Carburised or nitrided	Nitrided	1300
Carburised	Carburised	1500

Table 5.3.4 Factors of safety

	$S_{H\,min}$	$S_{F\,min}$
Main propulsion gears	1,4	1,8
Auxiliary gears	1,15	1,40

3.5 Tooth loading for bending stress

3.5.1 The bending stress at the tooth root, σ_F is not to exceed the allowable tooth root bending stress σ_{FP}

$$\sigma_F = \frac{F_t}{b\,m_n} Y_F\,Y_S\,Y_\beta\,K_A\,K_\gamma\,K_v\,K_{F\beta}\,K_{F\alpha} \quad \text{N/mm}^2$$

$$\sigma_{FP} = \frac{\sigma_{F\,lim}\,Y_{ST}\,Y_{\delta\,rel\,T}\,Y_{R\,rel\,T}\,Y_x}{S_{F\,min}\,Y_D} \quad \text{N/mm}^2$$

For values of $S_{F\,min}$, *see* Table 5.3.4
$\sigma_{F\,lim}$, *see* Table 5.3.5
Stress correction factor Y_{ST} = 2.

Table 5.3.5 Values of endurance limit for bending stress, $\sigma_{F\,lim}$

Heat treatment	$\sigma_{F\,lim}$ N/mm^2
Through-hardened carbon steel	$0{,}09\sigma_B + 150$
Through-hardened alloy steel	$0{,}1\sigma_B + 185$
Soft bath nitrided (Tufftrided)	330
Induction-hardened	0,35 HV + 125
Gas nitrided	390
Carburised A	450
Carburised B	410

NOTES
1. A is applicable for Cr Ni Mo carburising steels.
2. B is applicable for other carburising steels.

3.5.2 Tooth form factor, Y_F:

$$Y_F = \frac{6\,\dfrac{h_F}{m_n}\cos\alpha_{F\,en}}{\left(\dfrac{S_{Fn}}{m_n}\right)^2\cos\alpha_n}$$

where
h_F, $\alpha_{F\,en}$ and S_{Fn} are shown in Fig. 5.3.1.

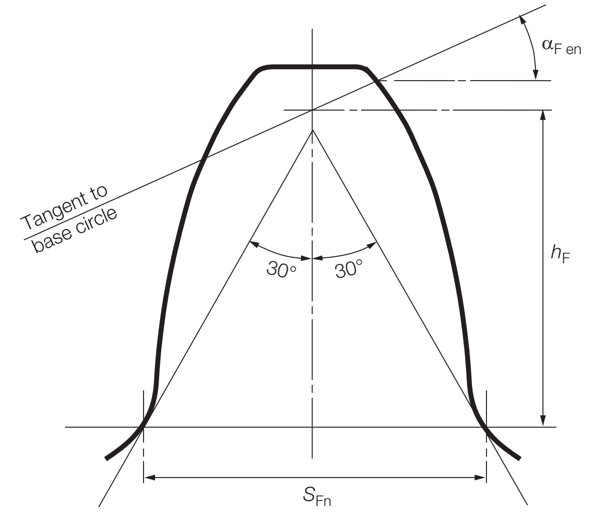
$$\frac{S_{Fn}}{m_n} = z_n \sin\left(\frac{\pi}{3} - \nu\right) + \sqrt{3}\left(\frac{G}{\cos\nu} - \frac{\rho_{ao}}{m_n}\right)$$

where

$$\nu = \frac{2G}{z_n}\tan\nu - H$$

$$G = \frac{\rho_{ao}}{m_n} - \frac{h_{ao}}{m_n} + x$$

$$H = \frac{2}{z_n}\left(\frac{\pi}{2} - \frac{E}{m_n}\right) - \frac{\pi}{3}$$



NOTE
For helical gears the normal section is taken with the virtual number of teeth

Fig. 5.3.1 Normal tooth section

$$E = \frac{\pi}{4}m_n - h_{ao}\tan\alpha_n + \frac{S_{pr}}{\cos\alpha_n} - (1 - \sin\alpha_n)\frac{\rho_{ao}}{\cos\alpha_n}$$

E, h_{ao}, α_n, S_{pr} and ρ_{ao} are shown in Fig. 5.3.2

$$\frac{\rho_F}{m_n} = \frac{\rho_{ao}}{m_n} + \frac{2G^2}{\cos\nu\,(z_n\cos^2\nu - 2G)}$$

$$d_{en} = \frac{2z}{|z|}\left\{\left[\sqrt{\left(\frac{d_{an}}{2}\right)^2 - \left(\frac{d_{bn}}{2}\right)^2} - \frac{\pi d\cos\beta\cos\alpha_n}{|z|}(\varepsilon_{an} - 1)\right]^2 + \left(\frac{d_{bn}}{2}\right)^2\right\}^{1/2}$$

where

$$d_{an} = d_n + d_a - d$$

$$d_n = \frac{d}{\cos^2\beta_b}$$

$$d_{bn} = d_n\cos\alpha_n$$

$$\varepsilon_{an} = \frac{\varepsilon_a}{\cos^2\beta_b}$$

$$\gamma_e = \frac{\dfrac{\pi}{2} + 2x\tan\alpha_n}{z_n} + \text{inv.}\,\alpha_n - \text{inv.}\,\alpha_{en}$$

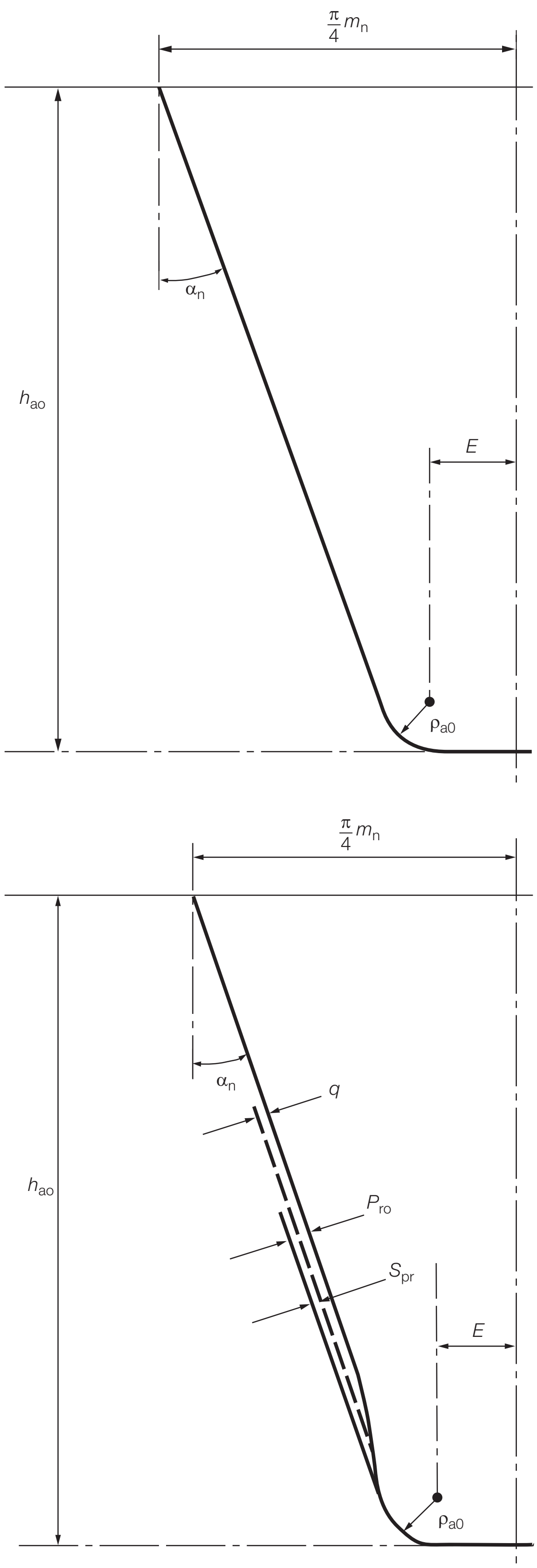
where

$$\alpha_{en} = \text{arc}\cos\frac{d_{bn}}{d_{en}}$$

$$\frac{h_F}{m_n} = \frac{1}{2}\left[(\cos\gamma_e - \sin\gamma_e\tan\alpha_{F\,en})\frac{d_{en}}{m_n} - z_n\cos\left(\frac{\pi}{3} - \nu\right) - \frac{G}{\cos\nu} + \frac{\rho_{ao}}{m_n}\right]$$

where

$$\alpha_{F\,en} = \alpha_{en} - \gamma_e.$$



NOTES
1. Dimensions shown on rack profile of tooth
2. $S_{pr} = P_{ro} - q$

Fig. 5.3.2 External tooth forms

3.5.3 For internal tooth forms the form factor is calculated, as an approximation, for a substitute gear rack with the form of the basic rack in the normal section, but having the same tooth depth as the internal gear:

$$\frac{S_{Fn2}}{m_n} = 2\left[\frac{\pi}{4} + \tan\alpha\left(\frac{h_{ao2} - \rho_{ao2}}{m_n}\right) + \left(\frac{\rho_{ao2} - S_{pr}}{m_n \cos\alpha_n}\right) - \frac{\rho_{ao2}}{m_n}\cos\frac{\pi}{6}\right], \text{ and}$$

$$\frac{h_{F2}}{m_n} = \frac{d_{en2} - d_{fn2}}{2m_n} - \left[\frac{\pi}{4} + \left(\frac{h_{ao2}}{m_n} - \frac{d_{en2} - d_{fn2}}{2m_n}\right)\tan\alpha_n\right]\tan\alpha_n - \frac{\rho_{ao2}}{m_n}\left(1 - \sin\frac{\pi}{6}\right)$$

where

$\alpha_{F\,en}$ is taken as being equal to α_n

$$\rho_{F2} = \frac{\rho_{ao2}}{2}$$

d_{en2} is calculated as d_{en} for external gears, and

$d_{fn} = d - d_f - d_n$.

3.5.4 Stress concentration factor, Y_s

$$Y_s = (1{,}2 + 0{,}13L)\, q_s^{\left(\frac{1}{1{,}21 + 2{,}3/L}\right)}$$

where

$$L = \frac{S_{Fn}}{h_F}$$

$$q_s = \frac{S_{Fn}}{2\rho_F}$$

when $q_s < 1$ the value of Y_s is to be specially considered. The formula for Y_s is applicable to external gears with $\alpha_n = 20°$ but may be used as an approximation for other pressure angles and internal gears.

3.5.5 Helix angle factor Y_β

$$Y_\beta = 1 - \left(\varepsilon_\beta \frac{\beta}{120}\right), \text{ if } \varepsilon_\beta > 1 \text{ let } \varepsilon_\beta = 1$$

but $Y_b \geq 1 - 0{,}25\varepsilon_b \geq 0{,}75$.

3.5.6 Relative notch sensitivity factor, $Y_{\delta\,rel\,T}$

$Y_{\delta\,rel\,T} = 1 + 0{,}036\,(q_s - 2{,}5)\left(1 - \frac{\sigma_y}{1200}\right)$ for through-hardened steels

$Y_{\delta\,rel\,T} = 1 + 0{,}008\,(q_s - 2{,}5)$ for carburised and induction-hardened steels, and

$Y_{\delta\,rel\,T} = 1 + 0{,}04\,(q_s - 2{,}5)$ for nitrided steels.

3.5.7 Relative surface finish factor, $Y_{R\,rel\,T}$

$Y_{R\,rel\,T} = 1{,}674 - 0{,}529\,(6R_a + 1)^{0{,}1}$ for through-hardened, carburised and induction hardened steels, and

$Y_{R\,rel\,T} = 4{,}299 - 3{,}259\,(6R_a + 1)^{0{,}005}$ for nitrided steels.

3.5.8 Size factor, Y_x

Y_x = 1,00, when $m_n \le 5$
Y_x = $1,03 - 0,006 m_n$ for through hardened steels
Y_x = 0,85, when $m_n \ge 30$
Y_x = $1,05 - 0,01 m_n$ for surface-hardened steels
Y_x = 0,80, when $m_n \ge 25$.

3.5.9 Design factor, Y_D

Y_D = 0,83 for gears treated with a controlled shot peening process
Y_D = 1,5 for idler gears
Y_D = 1,25 for shrunk on gears, or

$$Y_D = 1 + \frac{0{,}2 d_s^2\, d\, P_r\, b}{F_t\, \sigma_{F\,lim}\, (d_f^2 - d_s^2)}, \text{ otherwise}$$

Y_D = 1,00.

3.6 Factors of safety

3.6.1 Factors of safety are shown in Table 5.3.4.

3.7 Design of enclosed gear shafting

3.7.1 This sub-Section is applicable to solid shafting enclosed within the gearcase of single input/single output gearing. Alternative configurations and hollow shaft designs, final gear wheel shafts and thrust shafts are to be in accordance with Ch 6,3.3 and Ch 6,3.4 respectively.

3.7.2 The diameter of the enclosed gear shafting adjacent to the pinion or wheel is to be not less than the greater of d_b or d_t, where:

$$d_b = 365 \left(\frac{P\,L}{R\, d_w\, S_b}\right)^{1/3} \left(1 + \left(\frac{\tan\alpha_n}{\cos\beta} + \frac{\tan\beta\, d_w}{L}\right)^2\right)^{1/6}$$

$$d_t = 365 \left(\frac{P}{R\, S_s}\right)^{1/3}$$

where

S_b = $45 + 0{,}24\, (\sigma_u - 400)$ and
S_s = $42 + 0{,}09\, (\sigma_u - 400)$
L = span between shaft bearing centres, in mm
α_n = normal pressure angle at the gear reference diameter, in degrees
β = helix angle at the gear reference diameter, in degrees
d_w = pitch circle diameter of the gear teeth, in mm
σ_u = specified minimum tensile strength of the shaft material, in N/mm^2.

NOTE
P in kW and R in rpm are as defined in Ch 1,3.3.
Numerical value used for σ_u is not to exceed 800 N/mm^2 for gear and thrust shafts.

3.7.3 For the purposes of the above it is assumed that the pinion or wheel is mounted symmetrically spaced between bearings.

3.7.4 Outside a length equal to the required diameter at the pinion or wheel, the diameter may be reduced, if applicable, to that required for d_t.

3.7.5 For bevel gear shafts, where a bearing is located adjacent to the gear section, the diameter of the shaft is be not less than d_t. Where a bearing is not located adjacent to the gear the diameter of the shaft will be specially considered.

■ *Section 4* Construction

4.1 Gear wheels and pinions

4.1.1 Where castings are used for wheel centres, any radial slots in the periphery are to be fitted with permanent chocks before shrinking-on the rim.

4.1.2 Where bolts are used to secure side plates to rim and hub, the bolts are to be a tight fit in the holes and the nuts are to be suitably locked by means other than welding.

4.1.3 Where welding is employed in the construction of wheels, the welding procedure is to be approved by the Surveyors before work is commenced. For this purpose, welding procedure approval tests are to be carried out with satisfactory results. Such tests are to be representative of the joint configuration and materials. Wheels are to be stress relieved after welding. All welds are to have a satisfactory surface finish and contour. Magnetic particle or liquid penetrant examination of all important welded joints is to be carried out to the satisfaction of the Surveyors.

4.1.4 In general, arrangements are to be made so that the interior structure of the wheel may be examined. Alternative proposals will be specially considered.

4.2 Accuracy of gear cutting and alignment

4.2.1 The machining accuracy (Q grade) of pinions and wheels is to be demonstrated to the satisfaction of the Surveyors. For this purpose records of measurements should be available for review by Surveyors on request.

4.2.2 Where allowance has been given for end relief or helix correction the normal shop meshing tests are to be supplemented by tooth alignment traces or other approved means to demonstrate the effectiveness of such modifications.

4.3 Gearcases

4.3.1 Gearcases and their supports are to be designed sufficiently stiff such that misalignment at the mesh due to movements of the external foundations and the thermal effects under all conditions of service do not disturb the overall tooth contact.

4.3.2 For gearcases fabricated by fusion welding the carbon content of steels should generally not exceed 0,23 per cent. Steels with higher carbon content may be approved subject to satisfactory results from weld procedure tests.

4.3.3 Gearcases are to be stress relief heat treated on completion of all welding.

4.3.4 Inspection openings are to be provided at the peripheries of gearcases to enable the teeth of pinions and wheels to be readily examined. Where the construction of gearcases is such that sections of the structure cannot readily be moved for inspection purposes, access openings of adequate size are also to be provided at the ends of the gearcases to permit examination of the structure of the wheels. Their attachment to the shafts is to be capable of being examined by removal of bearing caps or by equivalent means.

■ *Section 5* Tests

5.1 Balance of gear pinions and wheels

5.1.1 All rotating elements, (e.g. pinion and wheel shaft assemblies and coupling parts), are to be appropriately balanced.

5.1.2 The permissible residual unbalance, *U*, is defined as follows:

$$U = \frac{60m}{N} \times 10^3 \text{ g mm for } N \leq 3000$$

$$U = \frac{24m}{N} \times 10^3 \text{ g mm for } N > 3000$$

where

m = mass of rotating element, kg

N = maximum service rev/min of the rotating element.

5.1.3 Where the size or geometry of a rotating element precludes measurement of the residual unbalance, a full speed running test of the assembled gear unit at the manufacturer's works will normally be required to demonstrate satisfactory operation.

5.2 Meshing tests

5.2.1 Initially, meshing gears are to be carefully matched on the basis of the accuracy measurements taken. The alignment is to be demonstrated in the workshop by meshing in the gearbox without oil clearance in the bearings. Meshing is to be carried out with the gears locating in their light load positions and a load sufficient to overcome pinion weight and axial movement is to be imposed.

5.2.2 The gears are to be suitably coated to demonstrate the contact marking. The marking is to reflect the accuracy grade specified and end relief of helix correction, where these have been applied.

5.2.3 For gears without helix correction the marking is to be not less than shown in Table 5.5.1.

Table 5.5.1 No load tooth contact marking

ISO accuracy grade	Contact marking area
Q ≤ 5	40% h_w for 50% *b* and 20% h_w for a further 40% *b*
Q ≥ 6	40% h_w for 35% *b* and 20% h_w for a further 35% *b*

NOTES
1. Where *b* is face width and h_w is working tooth depth.
2. For spur gears the values of h_w should be increased by a further 10%.

5.2.4 For gears with end relief of helix correction the marking is to correspond to the designed no load contact pattern.

5.2.5 A permanent record is to be made of the meshing contact for purpose of checking the alignment when installed on board ship.

5.2.6 The full load tooth contact marking is to be not less than shown in Table 5.5.2.

Table 5.5.2 Full load tooth contact marking

ISO accuracy grade	Contact marking area
Q ≤ 5	70% h_w for 60% *b* and 50% h_w for a further 30% *b*
Q ≥ 6	60% h_w for 45% *b* and 40% h_w for a further 35% *b*

NOTES
1. Where *b* is face width and h_w is working tooth depth.
2. For spur gears the values of h_w should be increased by a further 10%.

5.3 Backlash

5.3.1 The normal backlash between any pair of gears should not be less than:

$$\frac{a\alpha_n}{90\,000} = + 0{,}1 \text{ mm}$$

5.3.2 The normal backlash is not to exceed three times the value calculated in 5.3.1.

5.4 Alignment

5.4.1 Reduction gears with sleeve bearings, for main and auxiliary purposes are to be provided with means for checking the internal alignment of the various elements in the gearcases.

5.4.2 In the case of separately mounted reduction gearing for main propulsion, means are to be provided by the gear manufacturer to enable the Surveyors to verify that no distortion of the gearcase has taken place, when chocked and secured to its seating on board ship.

5.4.3 Further requirements are given in Ch 8,5.

Section 6
Control and monitoring

6.1 General

6.1.1 Control engineering systems are to be in accordance with Pt 6, Ch 1.

6.1.2 All main and auxiliary gear units intended for essential services are to be provided with means of indicating the lubricating oil pressure supply to them. Audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. Further, these alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

6.2 Unattended machinery

6.2.1 Where machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, it is to be provided with the alarms and safety arrangements required by 6.2, as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

6.2.2 Where machinery specified in this Section is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

6.2.3 Where a first stage alarm together with a second stage alarm and automatic shut-down of machinery are required in the relevant Tables of this Section, the sensors and circuits utilised for the second stage alarm and automatic shut-down are to be independent of those required for the first stage alarm.

6.2.4 Alarms and safeguards are indicated in Table 5.6.1.

Cross-reference

For lubricating oil systems, *see* Chapter 14.

Table 5.6.1 Main and auxiliary gear units: Alarms and safeguards

Item	Alarm	Note
Lubricating oil sump level	Low	—
Lubricating oil inlet pressure*	1st stage low	Slow-down
Lubricating oil inlet pressure*	2nd stage low	Automatic shut-down
Lubricating oil inlet temperature*	High	—
Thrust bearing temperature*	High	Slow-down

NOTE
For transmitted powers of 1500 kW or less, only the items marked * are required.

Section

Scope

The requirements of this Chapter relate, in particular, to formulae for determining the diameters of shafting for main propulsion installations, but requirements for couplings, coupling bolts, keys, keyways, sternbushes and other associated components are also included. The diameters may require to be modified as a result of alignment considerations and vibration characteristics, *see* Chapter 8, or the inclusion of stress raisers, other than those contained in this Chapter.

Alternative calculation methods for determining the diameters of shafting for main propulsion and their permissible torsional stresses will be considered by LR. Any alternative calculation method is to include all relevant loads on the complete dynamic shafting system under all permissible operating conditions. Consideration is to be given to the dimensions and arrangements of all shaft connections. Moreover, an alternative calculation method is to take into account design criteria for continuous and transient operating loads (dimensioning for fatigue strength) and for peak operating loads (dimensioning for yield strength). The fatigue strength analysis may be carried out separately for different load assumptions, for example as given below.

Shafts complying with the applicable Rules in Chapter 6 and Chapter 8 satisfy the following:

(a) Low cycle fatigue criterion (typically $<10^4$), i.e. the primary cycles represented by zero to full load and back to zero, including reversing torque if applicable. This is addressed by the formulas in Ch 6,3.1, 3.5 and 3.6.

(b) High cycle fatigue criterion (typically $>>10^7$), i.e. torsional vibration stresses permitted for continuous operation as well as reverse bending stresses and the accumulated fatigue due to torsional vibration when passing through a barred speed range or any other transient condition with associated stresses beyond those permitted for continuous operation. This is addressed by the formulas in Ch 8,2.5. The influence of reverse bending stresses is addressed by the safety margins inherent in the formulas from Ch 6,3.1, 3.5 and 3.6.

Section 1
Plans and particulars

1.1 Shafting plans

1.1.1 The following plans, together with the necessary particulars of the machinery, including the maximum power and revolutions per minute, are to be submitted for consideration before the work is commenced:

- Final gear shaft.
- Thrust shaft.
- Intermediate shafting.
- Tube shaft, where applicable.
- Screwshaft.
- Screwshaft oil gland.
- Sternbush.

1.1.2 The specified minimum tensile strength of each shaft is to be stated.

1.1.3 In addition, a shafting arrangement plan indicating the relative positions of the main engines, flywheel, flexible coupling, gearing, thrust block, line shafting and bearings, sterntube, 'A' bracket and propeller, as applicable, is to be submitted for information.

Section 2
Materials

2.1 Materials for shafts

2.1.1 The specified minimum tensile strength of forgings for shafts is to be selected within the following general limits:

(a) Carbon and carbon-manganese steel –
400 to 760 N/mm^2 (41 to 77,5 kgf/mm^2). *See also* 3.5.1.

(b) Alloy steel – not exceeding 800 N/mm^2 (82 kgf/mm^2).

2.1.2 Where it is proposed to use alloy steel, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

2.1.3 Where shafts may experience vibratory stresses close to the permissible stresses for transient operation, the materials are to have a specified minimum tensile strength of 500 N/mm^2 (51 kgf/mm^2).

2.1.4 Where materials with greater specified or actual tensile strengths than the limitations given above are used, reduced shaft dimensions or higher permissible vibration stresses are not acceptable when derived from the formulae used in Section 3.1, 3.5, 3.6 and Ch 8,2.5.

2.2 Ultrasonic tests

2.2.1 Ultrasonic tests are required on shaft forgings where the diameter is 250 mm or greater.

Section 3
Design

3.1 Intermediate shafts

3.1.1 The diameter, d, of the intermediate shaft is to be not less than determined by the following formula:

$$d = Fk \sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_u + 160}\right)} \quad \text{mm}$$

$$\left(d = Fk \sqrt[3]{\frac{H}{R}\left(\frac{57}{\sigma_u + 16}\right)} \quad \text{mm}\right)$$

where

k = 1,0 for shafts with integral coupling flanges complying with 3.7 or with shrink fit couplings, *see* 3.1.4

= 1,10 for shafts with keyways in tapered or cylindrical connections, where the fillet radii in the transverse section of the bottom of the keyway are to be not less than 0,0125d

= 1,10 for shafts with transverse or radial holes where the diameter of the hole (d_h) is not greater than 0,3d

= 1,20 for shafts with longitudinal slots, *see* 3.1.6

F = 95(86) for turbine installations, electric propulsion installations and oil engine installations with slip type couplings

= 100 (90,5) for other oil engine installations

P (H) and R are defined in Ch 1,3.3 (losses in gearboxes and bearings are to be disregarded)

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2 (kgf/mm^2), *see* 2.1.3

After a length of 0,2d from the end of a keyway, transverse hole or radial hole and 0,3d from the end of a longitudinal slot, the diameter of the shaft may be gradually reduced to that determined with k = 1,0.

3.1.2 For shafts with design features other than stated in 3.1.1, the value of k will be specially considered.

3.1.3 The Rule diameter of the intermediate shaft for oil engines, turbines and electric propelling motors may be reduced by 3,5 per cent for ships classed exclusively for smooth water service, and by 1,75 per cent for ships classed exclusively for service on the Great Lakes.

3.1.4 For shrink fit couplings k refers to the plain shaft section only. Where shafts may experience vibratory stresses close to the permissible stresses for continuous operation, an increase in diameter to the shrink fit diameter is to be provided, e.g. a diameter increase of 1 to 2 per cent and a blending radius as described in 3.8.

3.1.5 Keyways are in general not to be used in installations with a barred speed range.

3.1.6 The application of k = 1,20 is limited to shafts with longitudinal slots having a length of not more than 0,8d and a width of not more than 0,1d and a diameter of central hole d_i of not more than 0,8d, *see* 3.7. The end rounding of the slot is not to be less than half the width. An edge rounding should preferably be avoided as this increases the stress concentration slightly. The values of c_K, *see* Table 8.2.1 in Pt 5, Ch 8, are valid for 1, 2 and 3 slots, i.e. with slots at 360, 180 and 120 degrees apart respectively.

3.2 Gear quill shafts

3.2.1 The diameter of the quill shaft is to be not less than given by the following formula:

$$\text{Diameter of quill shaft} = 101 \sqrt[3]{\frac{P\,400}{R\,\sigma_u}} \quad \text{mm}$$

$$\left(91 \sqrt[3]{\frac{H\,41}{R\,\sigma_u}} \quad \text{mm}\right)$$

where

P (H) and R are as defined in Ch 1,3.3

σ_u = specified minimum tensile strength of the material, in N/mm^2 (kgf/mm^2) but is not to exceed 1100 N/mm^2 (112 kgf/mm^2).

3.3 Final gear wheel shafts

3.3.1 Where there is only one pinion geared into the final wheel, or where there are two pinions which are set to subtend an angle at the centre of the shaft of less than 120 degrees, the diameter of the shaft at the final wheel and the adjacent journals is to be not less than 1,15 times that required for the intermediate shaft.

3.3.2 Where there are two pinions geared into the final wheel opposite, or nearly opposite, to each other, the diameter of the shaft at the final wheel and the adjacent journals is to be not less than 1,1 times that required for the intermediate shaft.

3.3.3 In both 3.3.1 and 3.3.2, abaft the journals, the shaft may be gradually tapered down to the diameter required for an intermediate shaft determined according to 3.1, where σ_u is to be taken as the specified minimum tensile strength of the final wheel shaft material, in N/mm^2 (kgf/mm^2).

3.4 Thrust shafts

3.4.1 The diameter at the collars of the thrust shaft transmitting torque, or in way of the axial bearing where a roller bearing is used as a thrust bearing, is to be not less than that required for the intermediate shaft in accordance with 3.1 with a k value of 1,10. Outside a length equal to the thrust shaft diameter from the collars, the diameter may be tapered down to that required for the intermediate shaft with a k value of 1,0. For the purpose of the foregoing calculations, σ_u is to be taken as the minimum tensile strength of the thrust shaft material, in N/mm^2 (kgf/mm^2).

3.5 Screwshafts and tube shafts

3.5.1 The diameter, d_p of the screwshaft immediately forward of the forward face of the propeller boss or, if applicable, the forward face of the screwshaft flange, is to be not less than determined by the following formula:

$$d_p = 100k \sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_u + 160}\right)} \text{ mm}$$

$$\left(d_p = 90{,}5k \sqrt[3]{\frac{P}{R}\left(\frac{57}{\sigma_u + 16}\right)} \text{ mm}\right)$$

where

k = 1,22 for a shaft carrying a keyless propeller fitted on a taper, or where the propeller is attached to an integral flange, and where the shaft is fitted with a continuous liner or is oil lubricated and provided with an approved type of oil sealing gland

= 1,26 for a shaft carrying a keyed propeller and where the shaft is fitted with a continuous liner or is oil lubricated and provided with an approved type of oil sealing gland

P (H) and R are defined in Ch 1,3.3, (losses in gearboxes and bearings are to be disregarded)

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2 (kgf/mm^2) but is not to be taken as greater than 600 N/mm^2 (61 kgf/mm^2). *See* 2.1.3.

3.5.2 The diameter, d_p of the screwshaft determined in accordance with the formula in 3.5.1 is to extend over a length not less than that to the forward edge of the bearing immediately forward of the propeller or $2{,}5d_p$ whichever is the greater.

3.5.3 The diameter of the portion of the screwshaft and tube shaft, forward of the length required by 3.5.2 to the forward end of the forward stern tube seal, is to be determined in accordance with the formula in 3.5.1 with a k value of 1,15. The change of diameter from that determined with k = 1,22 or 1,26 to that determined with k = 1,15 should be gradual, *see* 3.7.

3.5.4 Screwshafts which run in sterntubes and tube shafts may have the diameter forward of the forward stern tube seal gradually reduced to the diameter of the intermediate shaft. Abrupt changes in shaft section at the screwshaft/ tube shaft to intermediate shaft couplings are to be avoided, *see* 3.7.

3.5.5 Unprotected screwshafts and tube shafts of corrosion-resistant material will be specially considered.

3.5.6 For shafts of non-corrosion-resistant materials which are exposed to sea-water, the diameter of the shaft is to be determined in accordance with the formula in 3.5.1 with a k value of 1,26 and σ_u taken as 400 N/mm^2 (41 kgf/mm^2).

3.6 Hollow shafts

3.6.1 Where the thrust, intermediate and tube shafts and screwshafts have central holes, the outside diameters of the shafts are to be not less than given by the following formula:

$$d_o = d \sqrt[3]{\frac{1}{\left[1 - \left(\frac{d_i}{d_o}\right)^4\right]}}$$

where

d_o = outside diameter, in mm

d = Rule size diameter of solid shaft, in mm

d_i = diameter of central hole, in mm.

However, where the diameter of the central hole does not exceed 0,4 times the outside diameter, no increase over Rule size need be provided.

3.7 Couplings and transitions of diameters

3.7.1 The minimum thicknesses of the coupling flanges are to be equal to the diameters of the coupling bolts at the face of the couplings as required by 3.8 and, for this purpose, the minimum tensile strength of the bolts is to be taken as equivalent to that of the shafts. For intermediate shafts, thrust shafts and the inboard end of the screwshaft, the thickness of the coupling flange is in no case to be less than 0,20 of the diameter of the intermediate shaft as required by 3.1.

3.7.2 The fillet radius at the base of the coupling flange is to be not less than 0,08 of the diameter of the shaft at the coupling but, in the case of crankshafts, the fillet radius at the centre coupling flanges may be 0,05 of the diameter of the shaft at the coupling. The fillets are to have a smooth finish and are not to be recessed in way of nut and bolt heads.

3.7.3 Where the propeller is attached by means of a flange, the thickness of the flange is to be not less than 0,25 of the actual diameter of the adjacent part of the screwshaft. The fillet radius at the base of the coupling flange is to be not less than 0,125 of the diameter of the shaft at the coupling.

3.7.4 All couplings which are attached to shafts are to be of approved dimensions.

3.7.5 Where couplings are separate from the shafts, provision is to be made to resist the astern pull.

3.7.6 Where a coupling is shrunk on to the parallel portion of a shaft or is mounted on a slight taper, e.g. by means of the oil pressure injection method, full particulars of the coupling including the interference fit are to be submitted for special consideration.

3.7.7 Transitions of diameters are to be designed with either a smooth taper or a blending radius. In general, a blending radius equal to the change in diameter is recommended.

3.8 Coupling bolts

3.8.1 Close tolerance fitted bolts transmitting shear are to have a diameter, at the joining faces of the couplings not less than given by the following formula:

$$\text{Diameter of coupling bolts} = \sqrt{\frac{240}{nD}\,\frac{10^6}{\sigma_u}\,\frac{P}{R}} \text{ mm}$$

where

n = number of bolts in the coupling

D = pitch circle diameter of bolts, in mm

σ_u = specified minimum tensile strength of bolts, in N/mm^2

P (H) and R are as defined in Ch 1,3.3.

3.8.2 At the joining faces of couplings, other than within the crankshaft and at the thrust shaft/crankshaft coupling, the Rule diameter of the coupling bolts defined in 3.8.1 may be reduced by 5,2 per cent for ships classed exclusively for smooth water service, and 2,6 per cent for ships classed exclusively for service on the Great Lakes.

3.8.3 Where dowels or expansion bolts are fitted to transmit torque in shear they are to comply with the requirements of 3.8.1. The expansion bolts are to be installed, and the bolt holes in the flanges are to be correctly aligned, in accordance with manufacturer's instructions.

3.8.4 The minimum diameter of tap bolts or of bolts in clearance holes at the joining faces of coupling flanges, pretensioned to 70 per cent of the bolt material yield strength value, is not to be less than:

$$d_R = 1{,}348\sqrt{\left(\frac{120\;10^6 F\,P\,(1+C)}{R\,D} + Q\right)\frac{1}{n\,\sigma_y}}$$

where

d_R is taken as the lesser of:

(a) Mean of effective (pitch) and minor diameters of the threads.

(b) Bolt shank diameter away from threads. (Not for waisted bolts which will be specially considered.)

P (H) and R are as defined in Ch 1,3.3.

F = 2,5 where the flange connection is not accessible from within the ship

= 2,0 where the flange connection is accessible from within the ship

C = ratio of vibratory/mean torque values at the rotational speed being considered

D = pitch circle diameter of bolt holes, in mm

Q = external load on bolt in N (+ve tensile load tending to separate flange, –ve)

n = number of tap or clearance bolts

σ_y = bolt material yield stress in N/mm^2.

3.8.5 Consideration will be given to those arrangements where the bolts are pretensioned to loads other than 70 per cent of the material yield strength.

3.8.6 Where clamp bolts are fitted they are to comply with the requirements of 3.8.4 and are to be installed, and the bolt holes in the flanges correctly aligned, in accordance with manufacturer's instructions.

3.9 Bronze or gunmetal liners on shafts

3.9.1 The thickness, t, of liners fitted on screwshafts or on tube shafts, in way of the bushes, is to be not less, when new, than given by the following formula:

$$t = \frac{D + 230}{32} \text{ mm}$$

where

t = thickness of the liner, in mm

D = diameter of the screwshaft or tube shaft under the liner, in mm.

3.9.2 The thickness of a continuous liner between the bushes is to be not less than 0,75t.

3.9.3 Continuous liners should preferably be cast in one piece.

3.9.4 Where liners consist of two or more lengths, these are to be butt welded together. In general, the lead content of the gunmetal of each length forming a butt welded liner is not to exceed 0,5 per cent. The composition of the electrodes or filler rods is to be substantially lead-free.

3.9.5 The circumferential butt welds are to be of multi-run, full penetration type. Provision is to be made for contraction of the weld by arranging for a suitable length of the liner containing the weld, if possible about three times the shaft diameter, to be free of the shaft. To prevent damage to the surface of the shaft during welding, a strip of heat resisting material covered by a copper strip should be inserted between the shaft and the liner in way of the joint. Other methods for welding this joint may be accepted if approved. The welding is to be carried out by an approved method and to the Surveyor's satisfaction.

3.9.6 Each continuous liner or length of liner is to be tested by hydraulic pressure to 2,0 bar (2,0 kgf/cm^2) after rough machining.

3.9.7 Liners are to be carefully shrunk on, or forced on, to the shafts by hydraulic pressure. Pins are not to be used to secure the liners.

3.9.8 Effective means are to be provided for preventing water from reaching the shaft at the part between the after end of the liner and the propeller boss.

3.10 Keys and keyways

3.10.1 Round ended or sled-runner ended keys are to be used, and the keyways in the propeller boss and cone of the screwshaft are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the screwshaft at the top of the cone. The sharp edges at the top of the keyways are to be removed.

3.10.2 Two screwed pins are to be provided for securing the key in the keyway, and the forward pin is to be placed at least one-third of the length of the key from the end. The depth of the tapped holes for the screwed pins is not to exceed the pin diameter, and the edges of the holes are to be slightly bevelled.

3.10.3 The distance between the top of the cone and the forward end of the keyway is to be not less than 0,2 of the diameter of the screwshaft at the top of the cone.

3.10.4 The effective sectional area of the key in shear, is to be not less than $\dfrac{d^3}{2{,}6d_1}$ mm^2

where
d = diameter, in mm, required for the intermediate shaft determined in accordance with 3.1, based on material having a specified minimum tensile strength of 400 N/mm^2 (41 kgf/mm^2) and k = 1
d_1 = diameter of shaft at mid-length of the key, in mm.

3.11 Propellers

3.11.1 For keyed and keyless propellers, *see* Chapter 7.

3.12 Sternbushes

3.12.1 The length of the bearing in the sternbush next to and supporting the propeller is to be as follows:

(a) For water lubricated bearings which are lined with lignum vitae, rubber composition or staves of approved plastics material, the length is to be not less than four times the diameter required for the screwshaft under the liner.
(b) For water lubricated bearings lined with two or more circumferentially spaced sectors of an approved plastics material, in which it can be shown that the sectors operate on hydrodynamic principles, the length of the bearing is to be such that the nominal bearing pressure will not exceed 5,5 bar (5,6 kgf/cm^2). The length of the bearing is to be not less than twice its diameter.
(c) For oil lubricated bearings of synthetic material the flow of lubricant is to be such that overheating, under normal operating conditions, cannot occur. The acceptable nominal bearing pressure will be considered upon application and is to be supported by the results of an agreed test programme. In general, the length of the bearing is not to be less than 2,0 times the rule diameter of the shaft in way of the bearing.
(d) For bearings which are white-metal lined, oil lubricated and provided with an approved type of oil sealing gland, the length of the bearing is to be approximately twice the diameter required for the screwshaft and is to be such that the nominal bearing pressure will not exceed 8,0 bar (8,1 kgf/cm^2). The length of the bearing is to be not less than 1,5 times its diameter.
(e) For bearings of cast iron and bronze which are oil lubricated and fitted with an approved oil sealing gland, the length of the bearing is, in general, to be not less than four times the diameter required for the screwshaft.
(f) For bearings which are grease lubricated, the length of the bearing is to be not less than four times the diameter required for the screwshaft.

3.12.2 Forced water lubrication is to be provided for all bearings lined with rubber or plastics and for those bearings lined with lignum vitae where the shaft diameter is 380 mm or over. The supply of water may come from a circulating pump or other pressure source. Flow indicators are to be provided for the water service to plastics and rubber bearings. The water grooves in the bearings are to be of ample section and of a shape which will be little affected by weardown, particularly for bearings of the plastics type.

3.12.3 Bearings of synthetic material are to be supplied finished machined to design dimensions within a rigid bush. Means are to be provided to prevent rotation of the lining within the bush during operation.

3.12.4 All sternbushes are to be adequately secured in the sterntube/housings.

3.12.5 The shut-off valve or cock controlling the supply of water is to be fitted direct to the after peak bulkhead, or to the sterntube where the water supply enters the sterntube forward of the bulkhead.

3.12.6 Oil sealing glands fitted in ships classed for unrestricted service must be capable of accommodating the effects of differential expansion between hull and line of shafting in sea temperatures ranging from arctic to tropical. This requirement applies particularly to those glands which span the gap and maintain oiltightness between the sterntube and the propeller boss.

3.12.7 Where a tank supplying lubricating oil to the sternbush is fitted, it is to be located above the load water-line and is to be provided with a low level alarm device in the engine room.

3.12.8 Where sternbush bearings are oil lubricated, provision is to be made for cooling the oil by maintaining water in the after peak tank above the level of the sterntube or by other approved means.

3.12.9 Two temperature sensors or other approved arrangements that can, where practicable, be replaced without dry-docking or divers are to be provided to ascertain the sterntube aft end bearing temperature.

3.12.10 Where there is compliance with the terms of 3.12.1(c) and (d) to the Surveyor's satisfaction, a screwshaft will be assigned the notation **OG** in the *Supplement to the Register Book* for Periodical Survey purposes, *see* Pt 1, Ch 3.

3.12.11 Screwshafts which are grease lubricated are not eligible for the **OG** notation.

3.12.12 Where an ***IWS** (In-water Survey) notation is to be assigned, *see* Pt 1, Ch 2,2.3.11, means are to be provided for ascertaining the clearance in the sternbush with the vessel afloat.

3.13 Vibration and alignment

3.13.1 For the requirements for torsional, axial and lateral vibration, and for alignment of the shafting, *see* Chapter 8.

Section

■ *Section 1* Plans and particulars

1.1 Details to be submitted

1.1.1 A plan, in triplicate, of the propeller is to be submitted for approval, together with the following particulars using the symbols shown:

(a) Maximum blade thickness of the expanded cylindrical section considered, *T*, in mm.
(b) Maximum shaft power, *see* Ch 1,3.3, *P*, in kW (*H*, in shp).
(c) Estimated ship speed at design loaded draught in the free running condition at maximum shaft power and corresponding revolutions per minute, *see* (b) and (d).
(d) Revolutions per minute of the propeller at maximum power, *R*.
(e) Propeller diameter, *D*, in metres.
(f) Pitch at 25 per cent radius (for solid propellers only), $P_{0,25}$, in metres.
(g) Pitch at 35 per cent radius (for controllable pitch propellers only), $P_{0,35}$, in metres.
(h) Pitch at 60 per cent radius $P_{0,6}$, in metres.
(j) Pitch at 70 per cent radius $P_{0,7}$, in metres.
(k) Length of blade section of the expanded cylindrical section at 25 per cent radius (for solid propellers only), $L_{0,25}$, in mm.
(l) Length of blade section of the expanded cylindrical section at 35 per cent radius (for controllable pitch propellers only) $L_{0,35}$, in mm.
(m) Length of blade section of the expanded cylindrical section at 60 per cent radius, $L_{0,6}$, in mm.
(n) Rake at blade tip measured at shaft axis (backward rake positive, forward rake negative), *A*, in mm.
(o) Number of blades, *N*.
(p) Developed area ratio, *B*.
(q) Material: type and specified minimum tensile strength.
(r) θ_s, skew angle, in degrees, *see* Fig. 7.1.1.
(s) Connection of propeller to shaft – details of fit, push-up, securing, etc.

1.1.2 For propellers having a skew angle equal to or greater than 50°, in addition to the particulars detailed in 1.1.1, details are to be submitted of:

(a) Full blade section details at each radial station defined for manufacture.
(b) A detailed blade stress computation supported by the following hydrodynamic data for the ahead mean wake condition and when absorbing full power:
  (i) Radial distribution of lift and drag coefficients, section inflow velocities and hydrodynamic pitch angles.
  (ii) Section pressure distributions calculated by either an advised inviscid or viscous procedure.

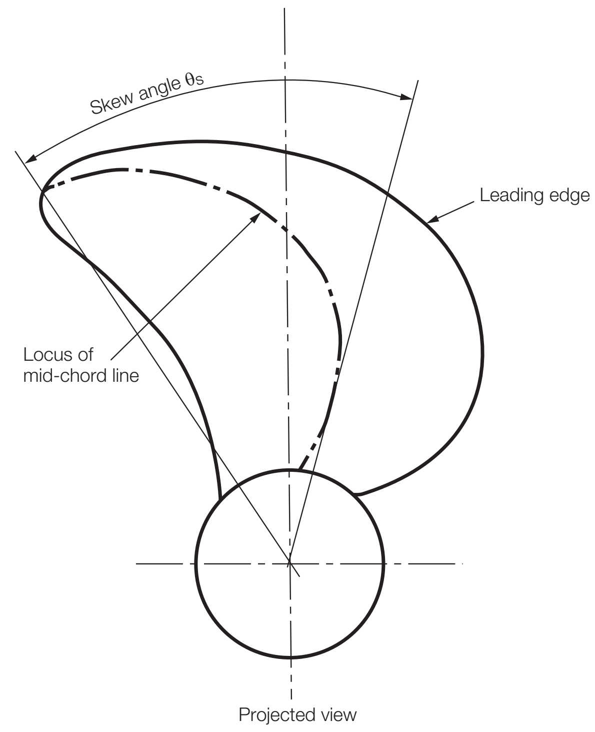


Fig. 7.1.1 Definition of skew angle

1.1.3 For blades of fixed pitch propellers with skew angle of 30º or greater, the stresses in the propeller blade during astern operation are not to exceed 80 per cent of the propeller blade material proof stress. Consideration is to be given to failure conditions and a factor of safety of 1,5 is to be attained using an acceptable fatigue failure criteria. Documentary evidence confirming that these criteria are satisfied is to be submitted.

1.1.4 The maximum skew angle of a propeller blade is defined as the angle, in projected view of the blade, between a line drawn through the blade tip and the shaft centreline and a second line through the shaft centreline which acts as a tangent to the locus of the mid-points of the helical blade sections, *see* Fig. 7.1.1.

1.1.5 Where propellers and similar devices of unusual design are intended for more than one operating regime, such as towing or trawling, then a detailed blade stress calculation for each operating condition, indicating the rotational and ship speed, is to be submitted for consideration.

1.1.6 Where it is proposed to fit the propeller to the screwshaft without the use of a key, plans of the boss, tapered end of screwshaft, propeller nut and, where applicable, the sleeve, are to be submitted.

1.1.7 Where a sleeve is fitted, details of the proposed type of material and mechanical properties are also to be submitted.

1.1.8 In cases where the ship has been the subject of model wake field tests, a copy of the results is to be submitted.

■ *Section 2* **Materials**

2.1 Castings

2.1.1 Castings for propellers and propeller blades are to comply with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). The specified minimum tensile strength is to be not less than stated in Table 7.2.1.

2.1.2 Where it is proposed to use materials which are not included in Table 7.2.1, details of the chemical composition, mechanical properties and density are to be submitted for approval.

2.1.3 Spheroidal cast iron load transmitting components of contro lable pitch mechanisms, are to be manufactured, tested and certified in accordance with Chapter 7 of the Rules for Materials, and have an elongation of not less than 12 per cent.

■ *Section 3* **Design**

3.1 Minimum blade thickness

3.1.1 For propellers having a skew angle of 25° or less, as defined in 1.1.4, the minimum blade thickness, *T*, of the propeller blades at 25 per cent radius for solid propellers, 35 per cent radius for controllable pitch propellers, neglecting any increase due to fillets, and at 60 per cent radius, is to be not less than:

$$T = \frac{KCA}{EFULN} + 100\sqrt{\frac{3150MP}{EFRULN}} \text{ mm}$$

$$\left(T = \frac{KCA}{9{,}81EFULN} + 27{,}4\sqrt{\frac{3150MH}{EFRULN}} \text{ mm}\right)$$

where

L = $L_{0,25}$, $L_{0,35}$, or $L_{0,6}$, as appropriate

$K = \dfrac{GBD^3R^2}{675}$

G = density, in g/cm^3, *see* Table 7.2.1

U = allowable stress, in N/mm^2 (kgf/mm^2) *see* 3.1.2, 3.1.3, 3.1.4, and Table 7.2.1

$E = \dfrac{\text{actual face modulus}}{0{,}09T^2 L}$

For aerofoil sections with and without trailing edge washback, *E* may be taken as 1,0 and 1,25 respectively

Table 7.2.1 Materials for propellers

Material	SI units			Metric units		
	Specified minimum tensile strength N/mm^2	*G* Density g/cm^3	*U* Allowable stress N/mm^2	Specified minimum tensile strength kgf/mm^2	*G* Density g/cm^3	*U* Allowable stress kgf/mm^2
Grey cast iron	250	7,2	17,2	25	7,2	1,75
Spheroidal or nodular graphite cast iron	400	7,3	20,6	41	7,3	2,1
Carbon steels	400	7,9	20,6	41	7,9	2,1
Low alloy steels	440	7,9	20,6	45	7,9	2,1
13% chromium stainless steels	540	7,7	41	55	7,7	4,2
Chromium-nickel austenitic stainless steel	450	7,9	41	46	7,9	4,2
Duplex stainless steels	590	7,8	41	60	7,8	4,2
Grade Cu 1 Manganese bronze (high tensile brass)	440	8,3	39	45	8,3	4,0
Grade Cu 2 Ni-Manganese bronze (high tensile brass)	440	8,3	39	45	8,3	4,0
Grade Cu 3 Ni-Aluminium bronze	590	7,6	56	60	7,6	5,7
Grade Cu 4 Mn-Aluminium bronze	630	7,5	46	64	7,5	4,7

$$\left.\begin{aligned} C &= 1{,}0 \\ F &= \frac{P_{0,25}}{D} + 0{,}8 \\ M &= 1{,}0 + \frac{3{,}75D}{P_{0,7}} + 2{,}8\,\frac{P_{0,25}}{D} \end{aligned}\right\}\ \text{for solid propellers at 25 per cent radius}$$

$$\left.\begin{aligned} C &= 1{,}4 \\ F &= \frac{P_{0,35}}{D} + 1{,}6 \\ M &= 1{,}35 + \frac{5D}{P_{0,7}} + 2{,}6\,\frac{P_{0,35}}{D} \end{aligned}\right\}\ \text{for controllable pitch propellers at 35 per cent radius}$$

$$\left.\begin{aligned} C &= 1{,}6 \\ F &= \frac{P_{0,6}}{D} + 4{,}5 \\ M &= 1{,}35 + \frac{5D}{P_{0,7}} + 1{,}35\,\frac{P_{0,6}}{D} \end{aligned}\right\}\ \text{for all propellers at 60 per cent radius}$$

3.1.2 The fillet radius between the root of a blade and the boss of a propeller is to be not less than the Rule thickness of the blade or equivalent at this location. Composite radiused fillets or elliptical fillets which provide a greater effective radius to the blade are acceptable and are to be preferred. Where fillet radii of the required size cannot be provided, the value of U is to be multiplied by $\left(\frac{r}{T}\right)^{0,2}$

where
r = proposed fillet radius at the root, in mm
T = Rule thickness of the blade at the root, in mm

Where a propeller has bolted-on blades, consideration is also to be given to the distribution of stress in the palms of the blades. In particular, the fillets of recessed bolt holes and the lands between bolt holes are not to induce stresses which exceed those permitted at the outer end of the fillet radius between the blade and the palm.

3.1.3 For propellers having skew angles of greater than 25°, but less than 50°, the mid-chord thickness, $T_{sk0,6}$, at the 60 per cent radius is to be not less than:

$$T_{sk0,6} = 0{,}54T_{0,6}\sqrt{1 + 0{,}1\theta_s} \quad \text{mm}$$

The mid-chord thickness, $T_{sk\ root}$, at 25 or 35 per cent radius, neglecting any increase due to fillets, is to be not less than:

$$T_{sk\ root} = 0{,}75T_{root}\sqrt[4]{1 + 0{,}1\theta_s} \quad \text{mm}$$

where
θ_s = proposed skew angle as defined in 1.1.4
$T_{0,6}$ = thickness at 60 per cent radius, calculated by 3.1.1, in mm
T_{root} = thickness at 25 per cent radius or 35 per cent radius, calculated by 3.1.1, in mm

The thicknesses at the remaining radii are to be joined by a fair curve and the sections are to be of suitable aerofoil section.

3.1.4 Results of detailed calculations where carried out, are to be submitted.

3.1.5 For cases where the composition of the propeller material is not specified in Table 7.2.1, or where propellers of the cast irons and carbon and low alloy steels shown in this Table are provided with an approved method of cathodic protection, special consideration will be given to the value of U.

3.1.6 The value U may be increased by 10 per cent for twin screw and outboard propellers of triple screw ships.

3.1.7 Where the design of a propeller has been based on analysis of reliable wake survey data in conjunction with a detailed fatigue analysis and is deemed to permit scantlings less than required by 3.1.1 or 3.1.3, a detailed stress computation for the blades is to be submitted for consideration.

3.2 Keyless propellers

3.2.1 The symbols used in 3.2.2 (oil injection method of fitting) and 3.2.3 to 3.2.7 (dry fitting cast iron sleeve) are defined as follows:

d_1 = diameter of the screwshaft cone at the mid-length of the boss or sleeve, in mm
d_2 = outside diameter of the sleeve at its mid- length, in mm
d_3 = outside diameter of the boss at its mid-length, in mm
d_i = bore diameter of screwshaft, in mm

$$h = \frac{2}{E_2}\left(\frac{1}{k_1^2 - 1}\right)$$

$$k_1 = \frac{d_2}{d_1}$$

$$k_2 = \frac{d_3}{d_2}$$

$$k_3 = \frac{d_3}{d_1}$$

$$l = \frac{d_i}{d_1}$$

$$p_1 = \frac{2M}{A_1\theta_1 V_1}\left(-1 + \sqrt{1 + V_1\left(\frac{F_1^2}{M^2} + 1\right)}\right)$$

$$p_2 = \frac{2M}{A_2\theta_2 V_2}\left(-1 + \sqrt{1 + V_2\left(\frac{F_2^2}{M^2} + 1\right)}\right)$$

$$p_{10} = \frac{2M}{A_1\theta_1 V_1}\left(-1 + \sqrt{1 + V_1\left(\frac{F_{10}^2}{M^2} + 1\right)}\right)$$

$$p_{20} = \frac{2M}{A_2\theta_2 V_2}\left(-1 + \sqrt{1 + V_2\left(\frac{F_{20}^2}{M^2} + 1\right)}\right)$$

A_1 = contact area of fitting at screwshaft, in mm^2
A_2 = contact area of fitting at outside of sleeve, in mm^2

$$B_1 = \frac{1}{E_2}\left(\frac{k_1^2 + 1}{k_1^2 - 1} + \nu_2\right) + \frac{1}{E_1}\left(\frac{1 + l^2}{1 - l^2} - \nu_1\right)$$

$$B_2 = \frac{1}{E_3}\left(\frac{k_2^2+1}{k_2^2-1}+\nu_3\right)+\frac{1}{E_2}\left(\frac{k_1^2+1}{k_1^2-1}-\nu_2\right)$$

$$B_3 = \frac{1}{E_3}\left(\frac{k_3^2+1}{k_3^2-1}+\nu_3\right)+\frac{1}{E_1}\left(\frac{1+l^2}{1-l^2}-\nu_1\right)$$

C = 0 for turbine installations

$= \dfrac{\text{vibratory torque at the maximum service speed}}{\text{mean torque at the maximum service speed}}$

for oil engine installations

E_1 = modulus of elasticity of screwshaft material, in N/mm^2 (kgf/mm^2)

E_2 = modulus of elasticity of sleeve material, in N/mm^2 (kgf/mm^2)

E_3 = modulus of elasticity of propeller material, in N/mm^2 (kgf/mm^2)

$$F_1 = \frac{2Q}{d_1}(1+C)$$

$$F_2 = \frac{2Q}{d_2}(1+C)$$

$$F_{10} = \frac{2Q}{d_1}\left(1+C+\frac{I_f}{100}\right)$$

$$F_{20} = \frac{2Q}{d_2}\left(1+C+\frac{I_f}{100}\right)$$

I_f = percentage increase for Ice Class 1D and 1E, obtained from Table 2.5.1 in Pt 8, Ch 2,5

M = propeller thrust, in N (kgf)

Q = mean torque corresponding to P (H) and R as defined in Ch 1,3.3, in N mm (kgf mm)

T_1 = temperature at time of fitting propeller on shaft, in °C

T_2 = temperature at time of fitting sleeve into boss, in °C

$$V_1 = 0{,}51\left(\frac{\mu_1}{\theta_1}\right)^2 - 1$$

$$V_2 = 0{,}51\left(\frac{\mu_2}{\theta_2}\right)^2 - 1$$

$Y = B_1 B_2 - h^2 k_1^2$

α_1 = coefficient of linear expansion of screwshaft material, in mm/mm/°C

α_2 = coefficient of linear expansion of sleeve material, in mm/mm/°C

α_3 = coefficient of linear expansion of propeller material, in mm/mm/°C

θ_1 = taper of the screwshaft cone, but is not to exceed $\dfrac{1}{15}$ on the diameter, i.e. $\theta_1 \le \dfrac{1}{15}$

θ_2 = taper of the outside of the sleeve

μ_1 = coefficient of friction for fitting of boss assembly on shaft

= 0,13 for oil injection method of fitting

μ_2 = coefficient of friction for fitting sleeve into the boss

ν_1 = Poisson's ratio for screwshaft material

ν_2 = Poisson's ratio for sleeve material

ν_3 = Poisson's ratio for propeller material

Consistent sets of units are to be used in all formulae.

3.2.2 Where it is proposed to fit a keyless propeller by the oil shrink method, the pull-up, δ on the screwshaft is to be not less than:

$$\delta_T = \frac{d_1}{\theta_1}\left(p_1 B_3 + (\alpha_3-\alpha_1)(35-T_1)\right) \text{ mm}$$

or, where Ice Class notation is required, the greater of δ_T or δ_O, where

$$\delta_O = \frac{d_1}{\theta_1}\left(p_{10} B_3 - (\alpha_3-\alpha_1)\, T_1\right) \text{ mm}$$

The yield stress or 0,2 per cent proof stress, σ_o of the propeller material is to be not less than:

$$\sigma_O = \frac{1{,}4}{B_3}\left(\frac{\theta_1\,\delta_p}{d_1} + T_1(\alpha_3-\alpha_1)\right)\frac{\sqrt{3k_3^4+1}}{k_3^2-1} \quad \text{N/mm}^2\ (\text{kgf/mm}^2)$$

where

δ_p = proposed pull-up at the fitting temperature

The start point load, W, to determine the actual pull-up is to be not less than:

$$W = A_1\left(0{,}002+\frac{\theta_1}{20}\right)\left(p_1+\frac{18}{B_3}(\alpha_3-\alpha_1)\right) \text{ N (kgf)}$$

3.2.3 Where a cast iron sleeve is first fitted to the bore of the propeller boss by an interference fit, the push-up load of the sleeve into the boss, W_2, is to be not less than:

$$W_{2T} = \frac{A_2}{B_2}\left(\mu_2+\frac{\theta_2}{2}\right)\left(B_2 p_2 - hp_1 + (\alpha_3-\alpha_2)(35-T_2)\right) \text{ N (kgf)}$$

or, where Ice Class notation is required, the greater of W_{2T} or W_{20}

where

$$W_{20} = \frac{A_2}{B_2}\left(\mu_2+\frac{\theta_2}{2}\right)\left(B_2 p_{20} - hp_{10} - (\alpha_3-\alpha_2)\, T_2\right) \text{ N (kgf)}$$

The pull-up of the sleeve in the boss at the fitting temperature is to be in accordance with the following formula:

$$\delta_2 = \frac{W_2 B_2 d_2}{A_2\left(\mu_2+\frac{\theta_2}{2}\right)\theta_2} \text{ mm}$$

The push-up load, W_1, of the combined boss and sleeve on a steel screwshaft is to be not less than:

$$W_{1T} = A_1\left(\mu_1+\frac{\theta_1}{2}\right)\left(p_1+\frac{hk_1^2}{Y}(\alpha_3-\alpha_2)(35-T_1)\right) \text{ N (kgf)}$$

or where Ice Class notation is required, the greater of W_{1T} or W_{10} where

$$W_{10} = A_1\left(\mu_1+\frac{\theta_1}{2}\right)\left(p_{10}-\frac{hk_1^2}{Y}(\alpha_3-\alpha_2)T_1\right) \text{ N (kgf)}$$

The push-up distance of the combined boss and sleeve on a steel screwshaft is to be in accordance with the following formula:

$$\delta_1 = \frac{W_1 d_1 Y}{A_1 B_2 \theta_1\left(\mu_1+\frac{\theta_1}{2}\right)} \text{ mm}$$

3.2.4 Where a cast iron sleeve is fitted into the boss by means of Araldite, the conditions are to satisfy those of 3.2.3 except that the value of W_2 is to be taken as equivalent to:

$$W_2 = A_2 \left(0,25 + \frac{\theta_2}{2}\right)\left(p_A + \frac{(\alpha_3 - \alpha_2)(18 - T_2)}{B_2}\right) \text{ N (kgf)}$$

where

p_A = 3,5 N/mm²
(p_A = 0,35 kgf/mm²)

3.2.5 For the triple element keyless propeller, the yield stress or 0,2 per cent proof stress of the propeller material, σ_o is to be not less than:

$$\sigma_o = 1,4 p_3 \sqrt{\frac{3k_2^4 + 1}{k_2^2 - 1}} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

where

$$p_3 = \frac{W_1\, h}{A_1\, B_2 \left(\mu_1 + \frac{\theta_1}{2}\right)} + \frac{W_2}{A_2 \left(\mu_2 + \frac{\theta_2}{2}\right)} + \frac{\alpha_3 - \alpha_2}{B_2}\left(T_2 + \frac{h^2\, k_1^2}{Y}\, T_1\right)$$

3.2.6 Where the sleeve is manufactured of material having an elongation in excess of five per cent, the yield point or 0,2 per cent proof stress of the sleeve material, σ_o is to be not less than:

$$\sigma_o = \frac{1,6}{k_1^2 - 1} \sqrt{3k_1^4 (p_3 - p_5)^2 + (p_3\, k_1^2 - p_5)^2} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

or

$$\sigma_o = \frac{1,6}{k_1^2 - 1} \sqrt{3k_1^4 (p_4 - p_6)^2 + (p_4\, k_1^2 - p_6)^2} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

where

$$p_4 = p_3 - \frac{35 B_1}{Y} (\alpha_3 - \alpha_2)$$

$$p_5 = \frac{W_1}{A_1 \left(\mu_1 + \frac{\theta_1}{2}\right)} + \frac{h\, k_1^2}{Y} (\alpha_3 - \alpha_2)\, T_1$$

$$p_6 = p_5 - \frac{35 h\, k_1^2}{Y} (\alpha_3 - \alpha_2)$$

3.2.7 Where the sleeve is manufactured of material having an elongation not more than five per cent, the minimum specified ultimate tensile strength σ_u, based on the ruling section, is to be not less than:

$$\sigma_u = \frac{2,4}{k_1^2 - 1} \left(p_5 \left(\frac{5k_1^2 + 3}{4}\right) - 2 p_3\, k_1^2\right) \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

or

$$\sigma_u = \frac{2,4}{k_1^2 - 1} \left(p_6 \left(\frac{5k_1^2 + 3}{4}\right) - 2 p_4\, k_1^2\right) \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

3.2.8 Where it is proposed to use a sleeve manufactured from a material other than cast iron, full details are to be submitted for consideration.

■ *Section 4* **Fitting of propellers**

4.1 Propeller boss

4.1.1 The propeller boss is to be a good fit on the screwshaft cone. The forward edge of the bore of the propeller boss is to be rounded to about a 6 mm radius. In the case of keyed propellers, the length of the forward fitting surface is to be about one diameter and where the fitting is by means of a hydraulic nut, the requirements of 4.2 and 4.3, where appropriate, are applicable.

4.2 Shop tests of keyless propellers

4.2.1 The bedding of the propeller, or the sleeve where applicable with the shaft, is to be demonstrated in the shop to the satisfaction of the Surveyors. Sufficient time is to be allowed for the temperature of the components to equalise before bedding. Alternative means for demonstrating the bedding of the propeller will be considered.

4.2.2 Means are to be provided to indicate the relative axial position of the propeller boss on the shaft taper.

4.3 Final fitting of keyless propellers

4.3.1 After verifying that the propeller and shaft are at the same temperature and the mating surfaces are clean and free from oil or grease, the propeller is to be fitted on the shaft to the satisfaction of the Surveyors. The propeller nut is to be securely locked to the shaft.

4.3.2 Permanent reference marks are to be made on the propeller boss, nut and shaft to indicate angular and axial positioning of the propeller. Care is to be taken in marking the inboard end of the shaft taper to minimise stress raising effects.

4.3.3 The outside of the propeller boss is to be hard stamped with the following details:

(a) For the oil injection method of fitting, the start point load and the axial pull-up at 0°C and 35°C.
(b) For the dry fitting method, the push-up load at 0°C and 35°C.

4.3.4 A copy of the fitting curve relative to temperature and means for determining any subsequent movement are to be placed on board.

Section 5
Control and monitoring

5.1 General

5.1.1 Control engineering systems are to be in accordance with the requirements of Pt 6, Ch 1.

5.2 Unattended machinery

5.2.1 Where controllable pitch propellers are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by 5.2 to 5.3, as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

5.2.2 Where machinery specified in this Section is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

5.3 Controllable pitch propellers and transverse thrust units

5.3.1 Alarms and safeguards are indicated in 5.3.2 to 5.3.5 and Table 7.5.1. For azimuth thrusters, *see also* Chapter 20.

5.3.2 For controllable pitch propellers for main propulsion, a standby or alternative power source of actuating medium for controlling the pitch of the propelling blades is to be provided. Automatic start of the standby pump supplying hydraulic power for pitch control is to be provided.

5.3.3 Controllable pitch propellers for main propulsion are to be provided with indications of shaft speed, direction and magnitude of thrust and propeller pitch as a measure of the propeller blade or actuator movement at each station from which it is possible to control shaft speed or propeller pitch.

5.3.4 Where transverse thrust units are remotely controlled, means are to be provided at the remote control station to stop the propulsion unit.

5.3.5 Transverse thrust units are to be provided with indications of direction and magnitude of thrust and propeller pitch at each station from which it is possible to control the propeller pitch.

Table 7.5.1 Controllable pitch propellers and transverse thrust units: Alarms and safeguards

Item	Alarm	Note
Hydraulic system pressure	Low	—
Hydraulic oil supply tank level	Low	—
Hydraulic oil temperature	High	Where an oil cooler is fitted
Power supply to the control system between the remote control station and hydraulic actuator	Failure	*See* Pt 6, Ch 1,2.5.2

Section

■ *Scope*

The requirements of this Chapter are applicable to the following systems:

(a) Main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

(b) Machinery driven at constant speed by oil engines, developing 110 kW and over, for essential auxiliary services including generator sets which are the source of power for main electric propulsion motors.

Unless otherwise advised, it is the responsibility of the Shipbuilder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

■ *Section 1* General

1.1 Basic requirements

1.1.1 The systems are to be free from excessive torsional, axial, lateral and linear vibration, and are to be aligned in accordance with accepted tolerances and taking into account the requirements of 5.5.

1.1.2 System designs are to take account of the potential effects of engine and component malfunction and variability in characteristic values such as stiffness and damping of flexible couplings and dampers or engine misfire conditions.

1.1.3 Where torques, stresses or amplitudes are found to exceed the limits for continuous operation, restrictions in speed and/or power will be imposed.

1.1.4 Where significant changes are subsequently made to a dynamic system which has been approved, (e.g. by changing the original design parameters of the prime movers and/or propulsion shafting system or by fitting a propeller or flexible coupling of different design from the previous), revised calculations may require to be submitted for consideration. Details of all such changes are to be submitted.

1.2 Resilient mountings

1.2.1 For resilient mountings, *see* Ch 1,4.3.

1.3 Flexible couplings

1.3.1 Where the shafting system incorporates flexible couplings, the effects of such couplings on the various modes of vibration are to be considered, *see* Sections 2, 3 and 4.

■ *Section 2* Torsional vibration

2.1 General

2.1.1 In addition to the shafting complying with the requirements of Chapters 1 to 7 and 20 (where applicable), approval is also dependent on the torsional vibration characteristics of the complete shafting system(s) being found satisfactory.

2.1.2 Further to the Scope of this Chapter, the requirements of this Section are applicable:

(a) to ships that are required to comply with the *International Convention for the Safety of Life at Sea,1974*, as amended, (SOLAS); and

(b) for all other ships where any one main engine has a power output exceeding 500 kW.

2.2 Particulars to be submitted

2.2.1 Torsional vibration calculations, showing the mass elastic values, associated natural frequencies and an analysis of the vibratory torques and stresses for the full dynamic system.

2.2.2 Particulars of the division of power and utilisation, throughout the speed range, for turbines, multi-engine or other combined power installations, and those with power take-off systems. For multi-engined installations, special considerations associated with the possible variations in the mode of operation and phasing of engines.

2.2.3 Enginebuilder's harmonic torque data used in the torsional vibration calculations, *see* 2.3.3.

2.2.4 Details of operating conditions encountered in service for prolonged periods, e.g. idling speed, range of trawling revolutions per minute, combinator characteristics for installations equipped with controllable pitch propellers.

2.2.5 Details, obtained from the manufacturers, of the principal characteristics of machinery components such as dampers and couplings, confirming their capability to withstand the effects of vibratory loading including, where appropriate, heat dissipation. Evidence that the data which is used to represent the characteristics of components, which has been quoted from other sources, is supported by a programme of physical measurement and control.

2.2.6 Where installations include electric motors, generators or non-integral pumps, drawings showing the principal dimensions of the shaft, together with manufacturer's estimates of mass moment of inertia for the rotating parts.

2.2.7 Details of vibration or performance monitoring proposals where required.

2.3 Scope of calculations

2.3.1 Calculations are to be carried out, by recognised techniques, for the full dynamic system formed by the oil engines, turbines, motors, generators, flexible couplings, gearing, shafting and propeller, where applicable, including all branches.

2.3.2 Calculations are to give due consideration to the potential deviation in values used to represent component characteristics due to manufacturing/service variability.

2.3.3 The calculations carried out on oil engine systems are to be based on the Enginebuilders' harmonic torque data. The calculations are to take account of the effects of engine malfunctions commonly experienced in service, such as a cylinder not firing (i.e. no injection but with compression) giving rise to the highest torsional vibration stresses in the shafting. Calculations are also to take account of a degree of imbalance between cylinders, which is characteristic of the normal operation of an engine under service conditions.

2.3.4 Whilst limits for torsional vibration stress in crankshafts are no longer stated explicitly, calculations are to include estimates of crankshaft stress at all designated operating/service speeds, as well as at any major critical speed.

2.3.5 Calculations are to take into account the possible effects of excitation from propeller rotation. Where the system shows some sensitivity to this phenomenon, propeller excitation data for the installation should be used as a basis for calculation, and submitted.

2.3.6 Where the torsional stiffness of flexible couplings varies with torque, frequency or speed, calculations should be representative of the appropriate range of effective dynamic stiffness.

2.4 Symbols and definitions

2.4.1 The symbols used in this Section are defined as follows:

d = minimum diameter of shaft considered, in mm
d_i = diameter of internal bore, in mm
k = the factor used in determining minimum shaft diameter, defined in Ch 6,3.1.1 and 3.5.1
r = ratio N/N_s or N_c/N_s whichever is applicable
C_d = a size factor defined as $0{,}35 + 0{,}93d^{-0{,}2}$
C_k = a factor for different shaft design features, *see* Table 8.2.1
N = engine speed, in rev/min
N_c = critical speed, in rev/min

Table 8.2.1 C_k factors

Intermediate shafts with	
Integral coupling flange and straight sections	1,0
Shrink fit coupling	1,0
Keyway, tapered connection	0,60
Keyway, cylindrical connection	0,45
Radial hole	0,50
Longitudinal slot	0,30 (*see* 2.4.4)
Thrust shafts external to engines	
On both sides of thrust collar	0,85
In way of axial bearing where a roller bearing is used as a thrust bearing	0,85
Propeller shafts	
Flange mounted or keyless taper fitted propellers	0,55
Key fitted propellers	0,55
Between forward end of aft most bearing and forward stern tube seal	0,80
NOTE The determination of C_k – factors for shafts other than shown in this Table will be specially considered by LR.	

N_s = maximum continuous engine speed, in rev/min, or, in the case of constant speed generating sets, the full load speed, in rev/min
Q_s = rated full load mean torque
σ_u = specified minimum tensile strength of the shaft material, in N/mm^2
τ_c = permissible stress due to torsional vibrations for continuous operation, in N/mm^2
τ_t = permissible stress due to torsional vibrations for transient operation, in N/mm^2
e = slot width, in mm
l = slot length, in mm.

2.4.2 Alternating torsional vibration stresses are to be based on half-range amplitudes of stress resulting from the alternating torque (which is superimposed on the mean torque) representing the synthesis of all harmonic orders present.

2.4.3 All vibration stress limits relate to the synthesis or measurement of total nominal torsional stress and are to be based on the plain section of the shafting neglecting stress raisers.

2.4.4 For a longitudinal slot C_k = 0,3 is applicable within the dimension limitations given in Pt 5 Ch 6,3.1.6. If the slot dimensions are outside these limitations, or if the use of another C_k is desired, the actual stress concentration factor (*scf*) is to be documented or determined from 2.4.5, in which case:

$$C_k = \frac{1{,}45}{scf}$$

Note that the *scf* is defined as the ratio between the maximum local principal stress and $\sqrt{3}$ times the nominal torsional stress (determined for the bored shaft without slots).

2.4.5 **Stress concentration factor of slots**. The stress concentration factor (*scf*) at the ends of slots can be determined by means of the following empirical formulae:

$$scf = \alpha_{t(hole)} + 0{,}8\,\frac{\frac{(l - e)}{d}}{\sqrt{\left(1 - \frac{d_i}{d}\right)\frac{e}{d}}}$$

This formula applies to:

- Slots at 120 or 180 or 360 degrees apart.
- Slots with semicircular ends. A multi-radii slot end can reduce the local stresses, but this is not included in this empirical formula.
- Slots with no edge rounding (except chamfering), as any edge rounding increases the *scf* slightly.

$\alpha_{t(hole)}$ represents the stress concentration of radial holes and can be determined as :

$$\alpha_{t(hole)} = 2{,}3 - 3\,\frac{e}{d} + 15\left(\frac{e}{d}\right)^2 + 10\left(\frac{e}{d}\right)^2\left(\frac{d_i}{d}\right)^2$$

where

e = hole diameter, in mm

or simplified to $\alpha_{t(hole)} = 2{,}3$.

2.5 Limiting stress in propulsion shafting

2.5.1 The following stress limits apply to intermediate shafts, thrust shafts and to screwshafts fully protected from seawater. For screwshafts, the limits apply to the minimum sections of the portions of the screwshaft as defined in Ch 6,3.5.

2.5.2 In the case of unprotected screwshafts, special consideration will be given.

2.5.3 In no part of the propulsion shafting system may the alternating torsional vibration stresses exceed the values of τ_c for continuous operation, and τ_t for transient running, given by the following formulae:

$$\tau_c = \frac{\sigma_u + 160}{18}\,C_k\,C_d\left(3 - 2r^2\right) \text{ for } r < 0{,}9 \quad \text{N/mm}^2$$

$$\tau_c = \frac{\sigma_u + 160}{18}\,C_k\,C_d\,1{,}38 \text{ for } 0{,}9 \le r \le 1{,}05 \quad \text{N/mm}^2$$

$$\tau_t = \pm\,1{,}7\tau_c\,\frac{1}{\sqrt{C_k}} \text{ for } r \le 0{,}8 \quad \text{N/mm}^2$$

2.5.4 In general, the tensile strength of the steel used is to comply with the requirements of Ch 6,2. For the calculation of the permissible limits of stresses due to torsional vibration, σ_u is not to be taken as more than 800 N/mm^2 in the case of alloy steel intermediate shafts, or 600 N/mm^2 in the case of carbon and carbon-manganese steel intermediate thrust and propeller shafts.

2.5.5 Where the scantlings of coupling bolts and straight shafting differ from the minimum required by the Rules, special consideration will be given.

2.6 Generator sets

2.6.1 Natural frequencies of the complete set are to be sufficiently removed from the firing impulse frequency at the full load speed, particularly where flexible couplings are interposed between the engine and generator.

2.6.2 Within the speed limits of $0{,}95N_s$ and $1{,}05N_s$ the vibration stresses in the transmission shafting are not to exceed the values given by the following formula:

$$\tau_c = \pm\,(21 - 0{,}014d) \quad \text{N/mm}^2.$$

2.6.3 Vibration stresses in the transmission shafting due to critical speeds which have to be passed through in starting and stopping, are not to exceed the values given by the following formula:

$$\tau_t = 5{,}5\tau_c.$$

2.6.4 The amplitudes of the total vibratory inertia torques imposed on the generator rotors are to be limited to $\pm 2{,}0Q_s$ in general, or to $\pm 2{,}5Q_s$ for close-coupled revolving field alternating current generators, over the speed range from $0{,}95N_s$ to $1{,}05N_s$. Below $0{,}95N_s$ the amplitudes are to be limited to $\pm 6{,}0Q_s$. Where two or more generators are driven from one engine, each generator is to be considered separately in relation to its own rated torque.

2.6.5 The rotor shaft and structure are to be designed to withstand these magnitudes of vibratory torque. Where it can be shown that they are capable of withstanding a higher vibratory torque, special consideration will be given.

2.6.6 In addition to withstanding the vibratory conditions over the speed range from $0{,}95N_s$ to $1{,}05N_s$, flexible couplings, if fitted, are to be capable of withstanding the vibratory torques and twists arising from transient criticals and short-circuit currents.

2.6.7 In the case of alternating current generators, resultant vibratory amplitudes at the rotor are not to exceed ±3,5 electrical degrees under both full load working conditions and the malfunction condition mentioned in 2.3.3.

2.7 Other auxiliary machinery systems

2.7.1 The relevant requirements of 2.6.1, 2.6.2 and 2.6.3 are also applicable to other machinery installations such as pumps or compressors with the speed limits being taken as $0{,}95N_s$ to $1{,}10N_s$.

2.8 Other machinery components

2.8.1 **Torsional vibration dampers**. The use of dampers or detuners to limit vibratory stress due to resonances which occur within the range between $0{,}85N_s$ and $1{,}05N_s$ are to be considered. If fitted, these should be of a type which makes adequate provision for dissipation of heat. Where necessary, performance monitoring may be required.

2.8.2 **Flexible couplings**:

(a) Flexible couplings included in an installation are to be capable of transmitting the mean and vibratory loads without exceeding the makers' recommended limits for angular amplitude or heat dissipation.

(b) Where calculations indicate that the limits recommended by the manufacturer may be exceeded under misfiring conditions, a suitable means is to be provided for detecting and indicating misfiring. Under these circumstances power and/or speed restrictions may be required. Where machinery is non-essential, disconnection of the branch containing the coupling would be an acceptable action in the event of misfiring.

2.8.3 **Gearing**:

(a) The torsional vibration characteristics are to comply with the requirements of 2.3. The sum of the mean and of the vibratory torque should not exceed four-thirds of the full transmission torque, at MCR, throughout the speed range. In cases where the proposed transmission torque loading on the gear teeth is less than the maximum allowable, special consideration will be given to the acceptance of additional vibratory loading on the gears.

(b) Where calculations indicate the possibility of torque reversal, the operating speed range is to be determined on the basis of observations during sea trials.

2.9 Measurements

2.9.1 Where calculations indicate that the limits for torsional vibration within the range of working speeds are exceeded, measurements, using an appropriate technique, may be taken from the machinery installation for the purpose of approval of torsional vibration characteristics, or determining the need for restricted speed ranges, and the confirmation of their limits.

2.9.2 Where differences between calculated and measured levels of stress, torque or angular amplitude arise, the stress limits are to be applied to the stresses measured on the completed installation.

2.9.3 The method of measurement is to be appropriate to the machinery components and the parameters which are of concern. Where shaft stresses have been estimated from angular amplitude measurements, and are found to be close to limiting stresses as defined in 2.5, strain gauge techniques may be required. When measurements are required, detailed proposals are to be submitted.

2.10 Vibration monitoring

2.10.1 Where calculations and/or measurements have indicated the possibility of excessive vibratory stresses, torques or angular amplitudes in the event of a malfunction, vibration or performance monitoring, directly or indirectly, may be required.

2.11 Restricted speed and/or power ranges

2.11.1 Restricted speed and/or power ranges will be imposed to cover all speeds where the stresses exceed the limiting values, τ_C, for continuous running, including one-cylinder misfiring conditions if intended to be continuously operated under such conditions. For controllable pitch propellers with the possibility of individual pitch and speed control, both full and zero pitch conditions are to be considered. Similar restrictions will be imposed, or other protective measures required to be taken, where vibratory torques or amplitudes are considered to be excessive for particular machinery items. At each end of the restricted speed range the engine is to be stable in operation.

2.11.2 The restricted speed range is to take account of the tachometer speed tolerances at the barred speeds.

2.11.3 Critical responses which give rise to speed restrictions are to be arranged sufficiently removed from the maximum revolutions per minute to ensure that, in general, at r = 0,8 the stress due to the upper flank does not exceed τ_C.

2.11.4 Provided that the stress amplitudes due to a torsional critical response at the borders of the barred speed range are less than τ_C under normal and stable operating conditions the speed restriction derived from the following formula may be applied:

$$\frac{16}{18 - r} N_C \text{ to } \frac{18 - r}{16} N_C \text{ inclusive.}$$

2.11.5 Where calculated vibration stresses due to criticals below $0{,}8N_S$ marginally exceed τ_C or where the critical speeds are sharply tuned, the range of revolutions restricted for continuous operation may be reduced.

2.11.6 In cases where the resonance curve of a critical speed has been derived from measurements, the range of revolutions to be avoided for continuous running may be taken as that over which the measured vibration stresses are in excess of τ_C, having regard to the tachometer accuracy.

2.11.7 Where restricted speed ranges under normal operating conditions are imposed, notice boards are to be fitted at the control stations stating that the engine is not to be run continuously between the speed limits obtained as above, and the engine tachometers are to be marked accordingly.

2.11.8 Where vibration stresses approach the limiting value, τ_t, the range of revolutions restricted for continuous operation may be extended. The notice boards are to indicate that this range must be passed through rapidly.

2.11.9 For excessive vibratory torque, stress or amplitude in other components, based on 2.8.1 to 2.8.3, the limits of any speed/power restriction are to be such as to maintain acceptable levels during continuous operation.

2.11.10 Where the restrictions are imposed for the contingency of an engine malfunction or component failure, the limits are to be entered in the machinery Operating Manual.

2.11.11 Restricted speed ranges in one-cylinder misfiring conditions on ships with single engine propulsion are to enable safe navigation whereby sufficient propulsion power is available to maintain control of the ship.

2.11.12 There are to be no restricted speed ranges imposed above a speed ratio of r = 0,8 under normal operating conditions.

2.12 Tachometer accuracy

2.12.1 Where restricted speed ranges are imposed as a condition of approval, the tachometer accuracy is to be checked against the counter readings, or by equivalent means, in the presence of the Surveyors to verify that it reads correctly within ± 2 per cent in way of the restricted range of revolutions.

2.13 Governor control

2.13.1 Where there is a significant critical response above and close to the maximum service speed, consideration is to be given to the effect of temporary overspeed.

■ *Section 3* Axial vibration

3.1 General

3.1.1 For all main propulsion shafting systems, the Shipbuilders are to ensure that axial vibration amplitudes are satisfactory throughout the speed range. Where natural frequency calculations indicate significant axial vibration responses, sufficiently wide restricted speed ranges will be imposed. Alternatively, measurements may be used to determine the speed ranges at which amplitudes are excessive for continuous running.

3.2 Particulars to be submitted

3.2.1 The results of calculations, together with recommendations for any speed restrictions found necessary.

3.2.2 Enginebuilder's recommendation for axial vibration amplitude limits at the non-driving end of the crankshaft or at the thrust collar.

3.2.3 Estimate of flexibility of the thrust bearing and its supporting structure.

3.2.4 The requirement for calculations to be submitted may be waived upon request provided evidence of satisfactory service experience of similar dynamic installations is submitted.

3.3 Calculations

3.3.1 Calculations of axial vibration natural frequency are to be carried out using appropriate techniques, taking into account the effects of flexibility of the thrust bearing, for shaft systems where the propeller is:

(a) Driven directly by a reciprocating internal combustion engine.
(b) Driven via gears, or directly by an electric motor, and where the total length of shaft between propeller and thrust bearing is in excess of 60 times the intermediate shaft diameter.

3.3.2 Where an axial vibration damper is fitted, the calculations are to consider the effect of a malfunction of the damper.

3.3.3 For those systems as defined in 3.3.1(b) the propeller speed at which the critical frequency occurs may be estimated using the following formula:

$$\frac{0{,}98}{N}\left(\frac{ab}{a+b}\right)^{1/2} \quad \text{rev/min}$$

where

$a = \dfrac{E}{G\,l^2}(66{,}2 + 97{,}5A - 8{,}88A^2)^2 \quad (\text{c/min})^2$

$b = 91{,}2\,\dfrac{k}{M_e} \quad (\text{c/min})^2$

d = internal diameter of shaft, in mm
k = estimated stiffness at thrust block bearing, in N/m
l = length of shaft line between propeller and thrust bearing, in mm
m = mass of shaft line considered, in kg
= $0{,}785\,(D^2 - d^2)\,G\,l$
$A = \dfrac{m}{M}$
D = outside diameter of shaft, taken as an average over length l, in mm
E = modulus of elasticity of shaft material, in N/mm^2
G = density of shaft material, in kg/mm^3
M = dry mass of propeller, in kg
M_e = $M\,(A + 2)$
N = number of propeller blades

Where the results of this method indicate the possibility of an axial vibration resonance in the vicinity of the maximum service speed, calculations using a more accurate method will be required.

3.4 Measurements

3.4.1 Where calculations indicate the possibility of excessive axial vibration amplitudes within the range of working speeds under normal or malfunction conditions, measurements are required to be taken from the shafting system for the purpose of determining the need for restricted speed ranges.

3.5 Restricted speed ranges

3.5.1 The limits of any speed restriction are to be such as to maintain axial amplitudes within recommended levels during continuous operation.

3.5.2 Limits of a speed restriction, where required, may be determined by calculation or on the basis of measurement.

3.5.3 Where a speed restriction is imposed for the contingency of a damper malfunction, the speed limits are to be entered in the machinery Operating Manual and regular monitoring of the axial vibration amplitude is required. Details of proposals for monitoring are to be submitted.

3.6 Vibration monitoring

3.6.1 Where a vibration monitoring system is to be specified, details of proposals are to be submitted.

■ *Section 4* Lateral vibration

4.1 General

4.1.1 For all main propulsion shafting systems, the Shipbuilders are to ensure that lateral vibration characteristics are satisfactory throughout the speed range.

4.2 Particulars to be submitted

4.2.1 Calculations of the lateral vibration characteristics of shafting systems having supports outboard of the hull or incorporating cardan shafts are to be submitted.

4.3 Calculations

4.3.1 The calculations in 4.2.1, taking account of bearing, oil-film (where applicable) and structural dynamic stiffnesses, are to investigate the excitation frequencies giving rise to all critical speeds which may result in significant amplitudes within the speed range, and are to indicate relative deflections and bending moments throughout the shafting system.

4.3.2 The calculated natural frequencies of the system are to be compared to both the shaft rotational orders and propeller blade passing frequencies. Where cardan shafts are fitted, the shaft second rotational orders are also to be considered.

4.3.3 Requirements for calculations may be waived upon request provided evidence of satisfactory service experience of similar dynamic installations is submitted.

4.4 Measurements

4.4.1 Where calculations indicate the possibility of significant lateral vibration responses within the range of ±20 per cent of the M.C.R. speed, measurements using an appropriate recognised technique may be required to be taken from the shafting system for the purpose of determining the need for restricted speed ranges.

4.4.2 The method of measurement is to be appropriate to the machinery arrangement and the modes of vibration which are of concern. When measurements are required, detailed proposals are to be submitted in advance.

■ *Section 5* Shaft alignment

5.1 General

5.1.1 Shaft alignment calculations are to be carried out for main propulsion shafting rotating at propeller speed, including the crankshaft of direct drive systems or the final reduction gear wheel on geared installations. The Builder is to make available shaft alignment procedures detailing the proposed alignment method and checks for these arrangements.

5.2 Particulars to be submitted for approval – Shaft alignment calculations

5.2.1 Shaft alignment calculations are to be submitted to LR for approval for the following shafting systems:

(a) All geared installations, where the screwshaft has a diameter of 300 mm or greater in way of the aftmost bearing, except for multiple input/single output geared installations, in which case all such installations will be submitted for approval.
(b) All direct drive installations which incorporate 3 or fewer bearings supporting the intermediate and screwshaft aft of the prime mover.
(c) Where prime movers in a direct drive installation or shaftline bearings are installed on resilient mountings.
(d) All systems where the screwshaft has a diameter of 800 mm or greater in way of the aftmost bearing.

5.2.2 The shaft alignment calculations are to take into account the:

(a) thermal displacements of the bearings between cold static and hot dynamic machinery conditions;
(b) buoyancy effect of the propeller immersion due to the ship's operating draughts;
(c) effect of predicted hull deformations over the range of the ship's operating draughts, where known;
(d) effect of filling the aft peak ballast tank upon the bearing loads, where known;
(e) gear forces, where appropriate, due to prime-mover engagement on multiple input/single output installations. For multiple input systems, consideration is to be given to each possible combination of inputs;
(f) propeller offset thrust effects;

(g) maximum allowed bearing weardown, for water or grease-lubricated sterntube bearings, and its effect on the bearing loads.

5.2.3 The shaft alignment calculations are to state the:

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the ship's operating profile, for the machinery in cold and hot, static and dynamic conditions;
(b) bearing influence coefficients and the deflection, slope, bending moment and shear force along the shaftline;
(c) details of propeller offset thrust;
(d) details of proposed slope-bore of the aftermost sterntube bearing, where applicable;
(e) manufacturer's specified limits for bending moment and shear force at the shaft couplings of the gearbox/prime movers;
(f) estimated bearing weardown rates for water or grease-lubricated sterntube bearings;
(g) expected hull deformation effects and their origin, *viz*. whether finite element calculations or measured results from sister or similar ships have been used;
(h) anticipated thermal rise of prime movers and gearing units between cold static and hot running conditions; and
(j) manufacturer's allowable bearing loads.

5.3 Shaft alignment procedures

5.3.1 A shaft alignment procedure is to be made available for review and for the information of the attending surveyors for all main propulsion installations detailing, as a minimum,

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the ship's operating profile, for the machinery in cold and hot, static and dynamic conditions;
(b) maximum permissible loads for the proposed bearing designs;
(c) design bearing offsets from the straight line;
(d) design gaps and sags;
(e) location and loads for the temporary shaft supports;
(f) expected relative slope of the shaft and the bearing in the aftermost sterntube bearing;
(g) details of slope-bore of the aftermost sterntube bearing, where applied;
(h) proposed bearing load measurement technique and its estimated accuracy;
(j) jack correction factors for each bearing where the bearing load is measured using a specified jacking technique;
(k) proposed shaft alignment acceptance criteria, including the tolerances; and
(l) flexible coupling alignment criteria.

5.4 Design and installation criteria

5.4.1 For main propulsion installations, the shafting is to be aligned to give, in all conditions of ship loading and machinery operation, bearing load distribution satisfying the requirements of 5.4.2.

5.4.2 Design and installation of the shafting is to satisfy the following criteria:

(a) The Builder is to position the bearings and construct the bearing seatings to minimise the effects of hull deflections under any of the ship's operating conditions with the aim of optimising the bearing load distribution.
(b) Relative slope between the propeller shaft and the aftermost sterntube bearing is, in general, not to exceed 3×10^{-4} rad in the static condition.
(c) Sterntube bearing loads are to satisfy the requirements of Ch 6,3.12.
(d) Evidence is to be provided to LR demonstrating that bearings of synthetic material have been verified as being within the tolerance stated by the bearing manufacturer for diameter, ovality, and straightness after installation.
(e) Bearings of synthetic material are to be verified as being within tolerance for ovalilty and straightness, circumferentially and longitudinally, after installation.
(f) The sterntube forward bearing static load is to be sufficient to prevent unloading in all static and dynamic operating conditions, including the transient conditions experienced during manoeuvring turns and during operation in heavy weather.
(g) Intermediate shaft bearings' loads are not to exceed 80 per cent of the bearing manufacturer's allowable maximum load, for plain journal bearings, based on the bearing projected area.
(h) Equipment manufacturer's bearing loads are to be within the manufacturer's specified limits, i.e. prime movers, gearing.
(j) Resulting shear forces and bending moments are to meet the equipment manufacturer's specified coupling conditions.
(k) The manufacturer's radial, axial and angular alignment limits for the flexible couplings are to be maintained.

5.5 Measurements

5.5.1 The system bearing load measurements are to be carried out to verify that the design loads have been achieved. In general the measurements will be carried out by the jack-up measurement technique using calibrated equipment.

5.5.2 For the first vessel of a new design an agreed programme of static shaft alignment measurements is to be carried out in order to verify that the shafting has been installed in accordance with the design assumptions and to verify the design assumptions in respect of the hull deflections and the effects of machinery temperature changes. The programme is to include static bearing load measurements in a number of selected conditions. Depending on the ship type and the operational loading conditions that are achievable prior to and during sea trials these should include, where practicable, combinations of light ballast cold, full ballast cold, full ballast hot and full draught hot with aft peak tank empty and full.

5.5.3 For vessels of an existing design or similar to an existing design where evidence of satisfactory service experience is submitted for consideration and for subsequent ships in a series a reduced set of measurements may be accepted. In such cases the minimum set of measurements is to be sufficient to verify that the shafting has been installed in accordance with the design assumptions and are to include at least one cold and one hot representative condition.

5.5.4 Where calculations indicate that the system is sensitive to changes in alignment under different service conditions, the shaft alignment is to be verified by measurements during sea trials using an approved strain gauge technique.

5.6 Flexible couplings

5.6.1 Where the shafting system incorporates flexible couplings, the effects of such couplings on the various modes of vibration are to be considered, *see* Sections 2, 3 and 4.

Section

■ *Section 1* Scope

1.1 General

1.1.1 This Chapter applies to podded propulsion units where used for propulsion, dynamic positioning duty or as the sole means of steering.

1.1.2 For the purposes of these Rules, a podded propulsion unit is any propulsion or manoeuvring device that is external to the normal form of the ship's hull and houses a propeller powering device.

1.1.3 The requirements of this Chapter relate to podded propulsion units powered by electric propulsion motors, (and are in addition to the requirements for Electric Propulsion in Pt 6, Ch 2,16 and other relevant Sections). Podded propulsion units with other drive arrangements will be subject to individual consideration.

1.1.4 The structural requirements stated in 5.1, 5.2 and 5.3 relate to podded propulsion units having a pod body with single supporting strut with or without an integral slewing ring arrangement, *see* Fig. 9.1.1. Novel and unconventional arrangements will be subject to individual consideration. In such cases, the designers are advised to contact LR in the early stages of the design for advice on the manner and content of design information required for formal classification appraisal.

1.1.5 The aft end structures associated with podded installations are to be examined with respect to potential slamming, *see* Pt 4, Ch 2.

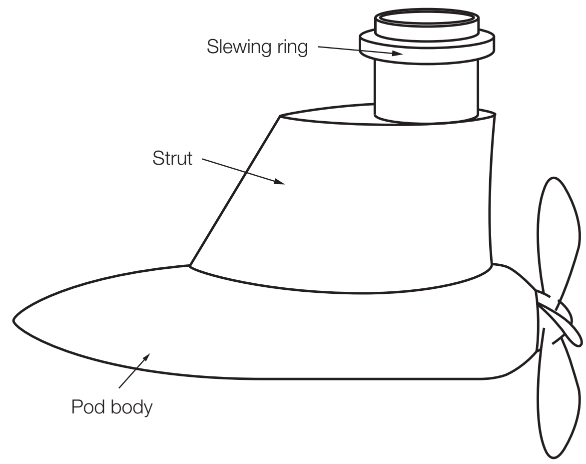


Fig. 9.1.1 Podded propulsion unit

1.1.6 It is the shipbuilder's responsibility to ensure that all installed equipment is suitable for operation in the location and under all anticipated environmental conditions associated with the design of the ship which is to include temperature, humidity, vibration and impulsive accelerations.

1.1.7 The design of a podded propulsor system is to take into account a range of operating conditions which are to include the following:

- All ahead seagoing conditions up to and including the maximum rated output of the podded propulsor while maintaining a steady course under foreseeable sea and wind conditions.
- The ability of the ship to change direction rapidly at the declared steering angles with the ship running at maximum ahead service speed.
- Executing a steady turning manoeuvre with a tactical diameter not greater than 5*L* and advance not greater than 4,5*L* whilst maintaining a power corresponding to the test speed, where *L* is the length measured between the aft and forward perpendiculars. Test speed is defined as a speed of at least 90 per cent of the ship's speed corresponding to 85 per cent of the maximum rated power of the podded propulsor.
- Changing heading, manoeuvring in and out of harbour both ahead and astern, at slow speeds, stationary and starting from rest in foreseeable current and wind conditions.
- Berthing manoeuvres in the case of azimuthing podded propulsion units.
- Rapid acceleration and deceleration manoeuvres where the ship's operating profile demands this capability.
- Holding stationary positions over-ground under different conditions.
- Stopping manoeuvre as required by Ch 1,5.2.
- Manoeuvring in ice where ice class is required.

Section 2
General requirements

2.1 Pod arrangement

2.1.1 In general, for a ship to be assigned an unrestricted service notation, a minimum of two podded propulsion units are to be provided where these form the sole means of propulsion. For vessels where a single podded propulsion unit is the sole means of propulsion, an evaluation of a detailed engineering and safety justification will be conducted by LR, *see* 2.2.2. This evaluation process will include the appraisal of a Failure Modes and Effects Analysis (FMEA) to verify that sufficient levels of redundancy and monitoring are incorporated in the podded propulsion unit's essential support systems and operating equipment.

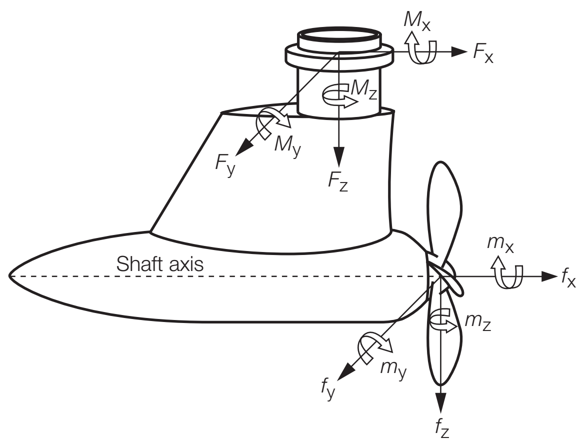


Fig. 9.2.1 Pod co-ordinate system

2.2 Plans and information to be submitted

2.2.1 In addition to the plans required by Chapters 5, 6, 7, 8, 14 and 19, and Pt 6, Ch 1 and Ch 2, the following plans and information are required to be submitted for appraisal:

(a) Description of the ship's purpose/capabilities together with the pod's intended operational modes in support of these capabilities.
(b) Power transmitted at MCR condition (shaft power and rpm) and other maximum torque conditions, e.g. bollard pull.
(c) Maximum transient thrust, torque and other forces and moments experienced during all envisaged operating modes as permitted by the steering and propulsor drive control systems.
(d) Details of the electric propulsion motor short-circuit torque and motor air gap tolerance.
(e) Sectional assembly in the Z-X plane, *see* Fig. 9.2.1.
(f) Specifications of materials and NDE procedures for components essential for propulsion and steering operation to include propulsion shaft and slewing ring bearings, gearing and couplings, *see* 4.1.
(g) Details of intended manoeuvring capability of the ship in each operating condition. (To be declared by the shipyard, *see also* 3.1.1).
(h) Design loads for both the pod structure and propeller together with podded propulsion unit design operating modes, *see* 2.4.1, 6.3.7, 6.6.6 and 6.6.7.
(j) Supporting data and direct calculation reports. This is to include, where applicable, an assessment of anticipated global accelerations acting on the ship's machinery and equipment which may potentially affect the reliable operation of the propulsion system for all foreseeable seagoing and operating conditions. Typically, this may include response to slamming, extreme ship motions and pod interaction. *See also* 1.1.5.
(k) Structural component details including: strut, pod body, bearing supports, bearing end caps, ship's structure in way of podded propulsion unit integration and a welding Table showing a key to weld symbols used on the plans specifying weld size, type, preparation and heat treatment. The information should include the following:
    - Detailed drawings showing the structural arrangement, dimensions and scantlings.
    - Welding and structural details.
    - Connections between structural components (bolting).
    - Casting's chemical and mechanical properties.
    - Forging's chemical and mechanical properties.
    - Material grades for plate and sections.
(l) Nozzle structure, its support arrangements, together with related calculations for all permitted operating conditions where the propeller operates in a nozzle (duct), *see* Pt 3, Ch 13,3.
(m) Propeller shaft bearing mounting and housing arrangement details, *see also* 6.3.6.
(n) Details of propeller shaft and steering bearings, where roller bearings are used supporting calculations are to be submitted, *see* 6.3.7 and 6.6.7.
(o) Propeller shaft seal details.
(p) Details of propeller shaft and pod steering securing/locking and means of aligning the securing/locking arrangements.
(q) Cooling systems piping system schematic.
(r) Details of any lubricating oil conditioning systems (filtering/cooling/heating) and control arrangements necessary to ensure the continuous availability of the required lubricating oil quality to the propeller shaft bearings.
(s) Details of installed condition monitoring equipment.
(t) Details of the derivation of any duty factor used in the design of the steering gears.
(u) Identification of any potentially hazardous atmospheric conditions together with details of how the hazard will be countered, this should include a statement of the maximum anticipated air temperature within the pod during full power steady state operation, *see* 2.3.
(v) Where provided, access and closing arrangements for pod unit inspection and maintenance.
(w) Heat balance calculations for pods having an electric propulsion motor but no active cooling system, *see* 6.7.4.
(x) Details of proposed testing and trials required by Section 9.
(y) Details of emergency steering and pod securing arrangements. *See* 6.3.11.
(z) Quality plan for electronic control systems and electrical actuating systems.

2.2.2 Where an engineering and safety justification report is required, the following supporting information is to be submitted:

- A Failure Mode and Effects Analysis (FMEA), *see* 2.5.
- Design standards and assumptions.
- Limiting operating parameters.
- A statement and evidence in respect of the anticipated reliability of any non-duplicated components.

2.2.3 Recommended installation, inspection, maintenance and component replacement procedures (*see also* 5.1.2). This is to include any in-water/underwater engineering procedures where recommended by the pod manufacturer. *See also* 6.5.7 and Section 10.

2.3 Pod internal atmospheric conditions

2.3.1 Machinery and electrical equipment installed within the pod unit are to be suitable for operation, without degraded performance, at the maximum anticipated air temperature and humidity conditions within the pod unit with the pod operating at its maximum continuous rating in sea water of not less than 32°C after steady state operating conditions have been achieved.

2.3.2 Precautions are to be taken to prevent as far as reasonably practicable the possibility of danger to personnel and damage to equipment arising from the development of hazardous atmospheric conditions within the pod unit. Circumstances that may give rise to these conditions are to be identified and the counter measures taken are to be defined.

2.4 Global loads

2.4.1 The overall strength of the podded propulsion unit structure is to be based upon the maximum anticipated in-service loads, including the effects of ship manoeuvring and of ship motion (*see* Table 14.8.1 in Pt 3, Ch 14). This is to include the effects of any pod to pod and/or pod to ship hydrodynamic interference effects. The designer is to supply the following maximum load and moment values to which the unit may be subjected with a description of the operating condition at which they occur.

- F_x, Force in the longitudinal direction;
- F_y, Force in the transverse direction;
- F_z, self weight, in water, augmented by the ship's pitch and heave motion and flooded volume where applicable, *see* Pt 3, Ch 14;
- M_x, moment at the slewing ring about the pod unit's global longitudinal axis;
- M_y, moment at the slewing ring about the pod unit's global transverse axis;
- M_z, moment at the slewing ring about the pod unit's vertical axis (maximum dynamic duty steering torque on steerable pods).

The directions of the X, Y and Z axes, with the origin at the centre of the slewing ring, are shown in Fig. 9.2.1.

2.4.2 Where the maximum forces and moments defined in 2.4.1 cannot be accurately calculated, then, an estimate of these loadings is to be stated together with an assessment of the associated error tolerances for the sequences of permitted design manoeuvres, *see* 1.1.7. Typically this will include emergency astern manoeuvres, zig zag manoeuvres and pod interaction. Such estimates are to be defined on a load versus pod angle basis. In the case of pod to pod and/or pod to ship hydrodynamic interaction effects these, must be defined for the most severely affected propulsor.

2.4.3 Where control systems are installed to limit the operation of the podded drive to defined angles at defined ship speeds, this information may be taken into consideration when determining the pod unit loading.

2.4.4 Where pod units are fixed about their Z axis, then maximum global loads, to be used as the basis of the structural appraisal, are to be determined for inflows in 5 degree increments between the extremes of anticipated inflow angle during manoeuvring with ship at full speed and maximum propeller thrust.

2.4.5 The podded propulsor is to be capable of withstanding a blade root failure due to fatigue occurring at the maximum rated output of the podded propulsor without initiating a failure in other parts of the propulsor system.

2.5 Failure Modes and Effects Analysis (FMEA)

2.5.1 An FMEA is to be carried out where a single podded propulsion unit is the vessel's sole means of propulsion, *see* 2.1.1. The FMEA is to identify components where a single failure could cause loss of all propulsion and/or steering capability and the proposed arrangements for preventing and mitigating the effects of such a failure. The assessment required by Pt 6, Ch 2,16.2.2 may be considered for demonstrating the acceptability of the proposed design for propulsion power purposes.

2.5.2 The FMEA is to be carried out using the format presented in Table 22.2.1 in Chapter 22 or an equivalent format that addresses the same reliability issues. Analyses in accordance with IEC 60812, *Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)*, or IMO MSC Resolution 36(63) Annex 4 – *Procedures for Failure Mode and Effects Analysis*, would be acceptable.

2.5.3 The FMEA is to be organised in terms of equipment and function. The effects of item failures at a stated level and at higher levels are to be analysed to determine the effects on the system as a whole. Actions for mitigation of the effects of failure are to be determined, *see* 2.5.1.

2.5.4 The FMEA is to:

(a) identify the equipment or sub-system and mode of operation;
(b) identify potential failure modes and their causes;
(c) evaluate the effects on the system of each failure mode;
(d) identify measures for reducing the risks associated with each failure mode;
(e) identify measures for preventing failure; and
(f) identify trials and testing necessary to prove conclusions.

2.5.5 At sub-system level it is acceptable, for the purpose of these Rules, to consider failure of equipment items and their functions, e.g. failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed. In addition, their failure need only be dealt with as a cause of failure of the pump.

2.5.6 Where FMEA is used for consideration of systems that depend on software-based functions for control or co-ordination, the analysis is to investigate failure of the functions rather than a specific analysis of the software code itself.

2.6 Ice Class requirements

2.6.1 Where an ice class notation is included in the class of a ship, additional requirements as detailed in Part 8 are to be complied with as applicable.

■ *Section 3* Functional capability

3.1 General

3.1.1 The arrangement of podded propulsion units is to be such that the ship can be satisfactorily manoeuvred to a declared performance capability. The operating conditions covered are to include the following:

(a) Maximum continuous shaft power/speed to the propeller in the ahead condition at the declared steering angles and sea conditions.
(b) Manoeuvring speeds of the propeller shaft in the ahead and astern direction at the declared steering angles and sea conditions.
(c) The stopping manoeuvre described in Ch 1,5.2.2(b).
(d) All astern running conditions for the ship.
(e) Manoeuvring in ice where ice class is required.

3.1.2 The main steering arrangements are to be capable of changing the direction of the ship's directional control system from one side to the other at declared steering angle limits at an average rotational speed of not less than 0,4 rev/min with the ship initially operating at its maximum ahead service speed.

3.1.3 The steering mechanism for podded units used for Dynamic Positioning applications with an associated class notation, is to be capable of a rotational speed of not less than 1,5 rev/min.

3.1.4 The auxiliary steering arrangements are to be:

(a) Capable of changing the direction of the ship's directional control system from one side to the other at declared steering angle limits at an average rotational speed of not less than 0,083 rev/min, with the ship running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater.
(b) For all ships, operated by power where necessary to meet the requirements of (a) and in any ship having power more than 2,500 kW propulsion power per thruster unit.

■ *Section 4* Materials

4.1 General

4.1.1 The materials used for major structural and machinery components are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). These components include hull support structure, pod body, pod strut, shafting and propellers.

4.1.2 Components of novel design or components manufactured from materials not covered by the Rules for Materials are to be subject to evaluation and approval by Lloyd's Register (hereinafter referred to as 'LR') prior to manufacture.

4.1.3 Material specifications, *see* 2.2.1(f), for propulsion shaft and slewing ring bearings, gearing and couplings are to be approved by LR prior to manufacture. The specification is to include details of the grade of material, including the target range of chemical composition that is to be reported on the certificate, the required mechanical properties, heat treatment details including temperatures and hold times, details of necessary non-destructive examinations including acceptance levels. Additionally, any steel cleanness or microstructure requirements are to be included. These components are to be manufactured under survey.

4.1.4 For propulsion shaft rolling element bearings, the amount of retained austenite is to be determined and is not to exceed 4 per cent for nominally bainitic structures.

4.1.5 Where load carrying threaded fasteners screw directly into structural castings, the integrity of the casting is to be such that there is no porosity or shrinkage in the area of the connection.

Section 5
Structure design and construction requirements

5.1 Pod structure

5.1.1 Podded unit struts and pod bodies may be of cast, forged or fabricated construction or a combination of these construction methods.

5.1.2 Means are to be provided to enable the shaft, bearings and seal arrangements to be examined in accordance with LR's requirements and the manufacturer's recommendations.

5.1.3 When high tensile steel fasteners are used as part of the structural arrangement and there is a risk that these fasteners may come into contact with sea-water, carbon-manganese and low alloy steels with a specified tensile strength of greater than 950 N/mm^2 are not to be used due to the risk of hydrogen embrittlement.

5.1.4 For steerable pod units, an integral slewing ring is to be arranged at the upper extremity of the strut to provide support for the slewing bearing.

5.1.5 The strut is to have a smooth transition from the upper mounting to the lower hydrodynamic sections.

5.1.6 For fabricated structures, vertical and horizontal plate diaphragms are to be arranged within the strut and, where necessary, secondary stiffening members are to be arranged.

5.1.7 Pod unit structure scantling requirements are shown in Table 9.5.1. Where the scantling requirements in Table 9.5.1 cannot be satisfied, direct calculations carried out in accordance with 5.3 may be considered.

5.1.8 The connection between the strut and the pod body should generally be effected through large radiused fillets in cast pod units or curved plates in fabricated pod units.

5.1.9 The structural response under the most onerous combination of loads is not to exceed the normal operational requirements of the propulsion or steering system components.

5.1.10 For cast pod structures, the elongation of the material on a gauge length of 5,65 $\sqrt{S_o}$ is to be not less than 12 per cent where S_o is the actual cross sectional area of the test piece.

5.1.11 In castings, sudden changes of section or possible constriction to the flow of metal during casting are to be avoided. All fillets are to have adequate radii, which should, in general, be not less than 75 mm.

Table 9.5.1 Podded propulsion unit – Fabricated structure requirements

Location	Requirement	Notes
Strut external shell plating	Thickness, in mm, is to be not less than: $t = 0{,}0063 s\, f\, (h_7\, k)^{0,5}$	The minimum thickness of plating diaphragms and primary webs within the strut is to be not to less than the Rule requirement for the strut external plating. For internal diaphragms, panel stiffening is to be provided where the ratio of spacing to plate thickness (s/t) exceeds 100. Where there are no secondary members, s is to be replaced by S.
Strut primary framing	The section modulus in cm^3 is to be not less than: $z = 7{,}75 h_7\, l_e^2\, S\, k$	This does not apply to full breadth plate diaphragms.
Strut secondary stiffening	The section in cm^3 is to be not less than: $z = 0{,}0056 h_7\, l_e^2\, s\, k$	This does not apply to full breadth plate diaphragms.
Cylindrical pod body external shell plating	Thickness, in mm, is to be not less than: $t = 3{,}0 R_g\, (h_7\, k)^{0,5}$	Not to be less than the Rule basic shell end thickness from Table 3.2.1 in Pt 3, Ch 3,2
Symbols		
f = panel aspect ratio correction factor = $[1{,}1 - s/(2500S)]$ h_7 = $(T + C_w + 0{,}014V^2)$ k = local higher tensile steel factor, as in Pt 3, Ch 2 l_e = effective span of the member under consideration, in metres s = the frame spacing of secondary members, in mm C_w = design wave amplitude, in metres, as in Pt 4, Ch 1,1.5 R_g = mean radius of pod body tube, in metres S = the spacing of primary members, in metres T = the vessel scantling draft, in metres, as in Pt 3, Ch 1,6.1 V = ship service speed, in knots, as in Pt 3, Ch 1,6.1.		

5.1.12 Castings are to comply with the requirements of Chapters 4 or 7 of the Rules for Materials.

5.2 Hull support structure

5.2.1 For supporting the main slewing bearing outer races, a system of primary structural members is to be provided in order to transfer the maximum design loads and moments from the podded propulsion unit into the ship's hull without undue deflection. Due account is also to be taken of the loads induced by the maximum ship's motions in the vertical direction resulting from combined heave and pitch motion of the ship. Account is also to be taken of any manoeuvring conditions that are likely to give rise to high mean or vibratory loadings induced by the podded propulsion unit. *See* 2.2.1(c).

5.2.2 The hull support structure in way of the slewing bearing should be sufficiently stiff that the bearing manufacturer's limits on seating flatness are not exceeded due to hull flexure as a consequence of the loads defined under 5.2.1.

5.2.3 Generally, the system of primary members is to comprise a pedestal girder directly supporting the slewing ring and bearing. The pedestal girder is to be integrated with the ship's structure by means of radial girders and transverses aligned at their outer ends with the ship's bottom girders and transverses, *see* Fig. 9.5.1. Proposals to use alternative arrangements that provide an equivalent degree of strength and rigidity may be submitted for appraisal.

5.2.4 The ship's support structure in way of the podded unit may be of double or single bottom construction. Generally, podded drives should be supported where practical within a double bottom structure; however final acceptance of the supporting arrangements will be dependent upon satisfying the stress criteria set out in Table 9.5.2, *see also* 5.3.5.

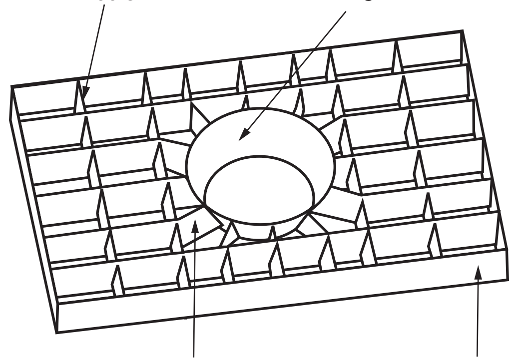


Fig. 9.5.1 Hull support structure

5.2.5 The shell envelope plating and tank top plating in way of the aperture for the podded drive (i.e. over the extent of the radial girders shown in Fig. 9.5.1) are to be increased by 50 per cent over the Rule minimum thickness to provide additional local stiffness and robustness. However the thickness of this plating is not to be less than the actual fitted thickness of the surrounding shell or tank top plating.

5.2.6 The scantlings of the primary support structure in way of the podded drive are to be based upon the limiting design stress criteria specified in Table 9.5.2, *see also* 5.3.5. Primary member scantlings are, however, not to be less than those required by Pt 3, Ch 6,5.

5.2.7 The pedestal girder is to have a thickness not less than the required shell envelope minimum Rule thickness in way. Where abutting plates are of dissimilar thickness then the taper requirements of Pt 3, Ch 10,2 are to be complied with.

Table 9.5.2 Direct calculation maximum permissible stresses for steel fabricated structures

Permissible stress values		
Location	Podded drive structure	Podded drive/hull interface
X-Y shear stress	$0{,}26\sigma_o$	$0{,}35\sigma_o$
Direct stress due to bending	$0{,}33\sigma_o$	$0{,}63\sigma_o$
Von Mises stress	$0{,}40\sigma_o$	$0{,}75\sigma_o$
Localised Von Mises peak stresses	σ_o	σ_o
Symbols		
σ_o = minimum yield strength of the material		

NOTES
1. The values stated above are intended to give an indication of the levels of stress in the pod and ship structure for the maximum loads which could be experienced during normal service.
2. If design is based on extreme or statistically low probability loads, then proposals to use alternative acceptance stress criteria may be considered.

5.2.8 In general, full penetration welds are to be applied at the pedestal girder boundaries and in way of the end connections between the radial girders and the pedestal girder. Elsewhere, for primary members, double continuous fillet welding is to be applied using a minimum weld factor of 0,34.

5.3 Direct calculations

5.3.1 Finite element or other direct calculation techniques may be employed in the verification of the structural design. The mesh density used is to be sufficient to accurately demonstrate the response characteristics of the structure and to provide adequate stress and deflection information. A refined mesh density is to be applied to geometry transition areas and those locations where high localised stress or stress gradients are anticipated.

5.3.2 Model boundary constraints are generally to be applied in way of the slewing ring/ship attachment only.

5.3.3 The loads applied to the mathematical model, *see* 2.4.1, are to include the self weight, dynamic acceleration due to ship motion, hydrodynamic loads, hydrostatic pressure, propeller forces and shaft bearing support forces. In situations where a pod can operate in the flooded conditions or where flooding of a pod adds significant mass to the pod, details are to be included.

5.3.4 Based on the most onerous combination of normal service loading conditions, the stress criteria shown in Table 9.5.2 are not to be exceeded. *See also* 2.2.1(c).

5.3.5 Where the structural design is based on a fatigue assessment and the stress criteria shown in Table 9.5.2 are not applicable, details of cumulative load history and stress range together with the proposed acceptance criteria are to be submitted for consideration.

5.3.6 For cast structures, the localised von Mises stress should not exceed 0,6 times the nominal 0,2 per cent proof or yield stress of the material for the most onerous design condition.

■ *Section 6* Machinery design and construction requirements

6.1 General

6.1.1 The requirements detailed in Chapter 1 are applicable.

6.1.2 Means are to be provided whereby normal operation of the podded propulsion system can be sustained or readily restored if one of the supporting auxiliaries becomes inoperative, *see also* 2.1.1. Consideration shall be given to the malfunctioning of:

- sources of lubricating oil pressure,
- sources of cooling,
- hydraulic, pneumatic or electrical means for control of the podded propulsor.

6.2 Gearing

6.2.1 If gearing is used in the propulsion system then the requirements of Chapter 5 are applicable.

6.3 Propulsion shafting

6.3.1 In addition to meeting the requirements of Chapters 6 and 8, the pod propulsion shafting supporting an electric motor is to be sufficiently stiff that both static and dynamic shaft flexure are within the motor manufacturer's limits for all envisaged operating conditions.

6.3.2 There is to be no significant lateral vibration response that may cause damage to the shaft seals within ±20 per cent of the running speed range. For vibration analysis computations the influence of the slewing ring and shaft bearing stiffnesses together with the contribution from the seating stiffnesses are to be included in the calculation procedures.

6.3.3 As an alternative to the requirements of Chapter 6, a fatigue strength analysis of shafting components indicating a factor of safety of 1,5 at the design loads based on a suitable fatigue failure criterion may be submitted for consideration. The effects of stress concentrations, material properties and operating environment are to be taken into account.

6.3.4 With the exception of the propeller connection (requirements stated in Chapter 7) couplings relying on friction are to have a factor of safety of 2,5 against slippage at the maximum rated torque. In order to reduce the possibility of fretting, a grip stress of not less than 20 N/mm^2 is to be attained.

6.3.5 The effects of motor short-circuit torque on the shafting system should not prevent continued operation once the fault has been rectified.

6.3.6 The arrangement of shaft bearings is to take account of shaft thermal expansion, misalignment of bearings, shaft slope through the bearings and manufacturing tolerances. Additionally, the influence of the pod deflection on the shaft bearing alignment is to be considered under the most onerous mechanical and hydrodynamic loading conditions.

6.3.7 Propeller shaft roller bearing life calculations are to take account of the following loadings:

- Shaft, motor, propeller and other shaft appendages' weights;
- Forces due to ship's motion;
- The propeller-generated forces and moments about the three Cartesian axes related to the shaft; f_x, f_y, f_z, m_x, m_y, m_z, *see* Fig. 9.2.1;
- Variance of propeller-generated forces and moments with pod azimuth angle. This load variance should take account of the motor control characteristics;
- Forces due to pod rotation, including gyroscopic forces;
- A predicted azimuth service profile for the pod indicating the proportion of time spent at various azimuth angles;
- Loads due to hydrodynamic interaction between pods;
- Any additional loads experienced during operation in ice conditions (for Ice Class notations);
- Where validation of the above loadings is available, detailed calculations must demonstrate that the bearing life when operating at the normal duty profile will comfortably exceed the time between 5-yearly surveys. Parameters used to justify the bearing life, i.e. those related to oil cleanliness, viscosity limits and material quality are to be quoted.

6.3.8 Where detailed validation of the loadings identified in 6.3.7. is not available, the calculations for roller bearings are to indicate a bearing life greater than 65,000 hours at the maximum continuous rating of the podded drive taking into account the azimuth angle duty cycle. Any parameters used to justify this life, i.e. those related to oil cleanliness, water contamination and viscosity limits are to be quoted. Proposals for the use of a shaft bearing of life less than 65,000 hours will be considered on application with details of alleviating factors and supporting documentation; however, this bearing life must exceed the time between surveys.

6.3.9 The design of the shaft line bearings is to take account of the maximum and minimum operating temperatures likely to be encountered during both a voyage cycle and, more widely, during the ship's operational life. Furthermore, any anticipated temperature distributions through the bearing components and structures are to be included in the design calculations.

6.3.10 Means are to be provided for detecting shaft bearing deterioration. Where rolling element shaft bearings are used in single pod applications or in pods where the motor power exceeds 6 MW, vibration monitoring of the shaft bearings is to be provided. The bearing monitoring system is to be suitable for the local bearing conditions and is to be able to differentiate from other vibration sources such as propeller cavitation or ship motions.

6.3.11 In multi-podded propulsor systems or ships having at least one pod in association with other propulsion devices and where the individual pod installed power is greater than 5 MW, means are to be provided to hold the propeller for an inoperable unit stationary whilst the other pod(s) propel the vessel at a manoeuvring speed of not less than 7 knots. Operating instructions displayed at the holding mechanism's operating position are to include a direction to inform the bridge of any limitation in ship's speed required as a result of the holding mechanism being activated.

6.3.12 Shaft seals for maintaining the watertight integrity of the pod are to be Type Approved to a standard acceptable to LR. The seals are to be designed to withstand the extremes of operation for which they are intended and this is to include extremes of temperature, vibration, pressure and shaft movement.

6.3.13 In single pod installations, the integrity of shaft seals is to be evaluated on the basis of a double failure. In such installations, seal duplication is to be used with indication of failure of one seal being provided.

6.4 Propeller

6.4.1 The requirements of Chapter 7 are to be complied with.

6.4.2 Where propeller scantlings have been determined by a detailed fatigue analysis, based on reliable wake survey data as described in Ch 7,3.1.7, a factor of safety of 1,5 against suitable fatigue failure criteria is to be demonstrated. The effects of fillet stress concentrations, residual stress, fluctuating loads and material properties are to be taken into account.

6.5 Bearing lubrication system

6.5.1 The bearing lubrication system is to be arranged to provide a sufficient quantity of lubricant of a quality, viscosity and temperature acceptable to the bearing manufacturer under all ship operating conditions.

6.5.2 In addition to the requirements detailed in this Section, the requirements of Chapter 14, sub-Sections 8.1, 8.5, 8.7 and 8.9 are to be complied with.

6.5.3 For systems employing forced lubrication, the sampling points required by Ch 14,8.13.6 are to be located such that the sample taken is representative of the oil present at the bearing.

6.5.4 For lubricating oil systems employing gravity feed, the arrangements are to be such as to permit oil sampling and oil changes in accordance with the manufacturer's instructions for the safe and reliable operation of the propulsion system.

6.5.5 Where continuous operation of the lubricating oil system is essential for the pod to operate at its maximum continuous rating, a standby pump in accordance with Ch 14,8.2.2 is to be provided. In such systems, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the pod.

6.5.6 Where bearings are grease lubricated, means are to be provided for collecting waste grease to enable analysis for particulates and water. The arrangements for collecting waste grease are to be in accordance with the pod manufacturer's recommendations. Alternative arrangements which demonstrate that bearings are satisfactorily lubricated will be considered.

6.5.7 Pipework conveying lubricating oil is to be sited such that any possible leakage from joi#ts will not impinge on electrical equipment, hot surfaces or other sources of ignition, *see also* Ch 13,2.9.3.

6.5.8 The procedures for flushing the lubrication system are to be defined. This procedure is to embrace the following conditions:
(a) Initial installation.
(b) Post maintenance situations.
(c) Major dry-docking refits.
See Section 10.

6.6 Steering system

6.6.1 The requirements of Chapter 19, Sections 1, 2, 3, 6, 7 and 8 are to be complied with where applicable. *See also* 3.1.

6.6.2 For vessels where a single podded propulsion unit is the sole means of propulsion, the requirement for auxiliary steering arrangements in Ch 19,2 is to be achieved by means of two or more identical power units.

6.6.3 For vessels with more than one steerable podded propulsion unit, the requirement for auxiliary steering arrangements in Ch 19,2 is to be achieved by equipping each of the pod units with its own dedicated and independent steering gear control system and power actuating system. Consideration will be given to alternative arrangements providing equivalence can be demonstrated.

6.6.4 Steering arrangements, other than of the hydraulic type, may be accepted provided that there are means of limiting the maximum torque to which the steering arrangement may be subjected.

6.6.5 The steering mechanism is to be provided with power that is sufficient for the maximum steering torques present during the declared functional capability identified in 3.1 and is to be demonstrated for the most onerous specified manoeuvring trial, *see* Section 9.

6.6.6 Geared arrangements employed for steering are to consider the following conditions:
- A design maximum dynamic duty steering torque, M_z, *see* 2.4.1;
- A static duty ($\leq 10^3$ load cycles) steering torque. The static duty steering torque should not be less than M_W, the maximum torque which can be generated by the steering gear mechanism.

The minimum factors of safety, as derived using ISO 6336 Calculation of load capacity of spur and helical gears, or a recognised National Standard, are to be 1.5 on bending stress and 1,0 on Hertzian contact stress. The use of a duty factor in the dynamic duty strength calculations is acceptable but the derivation of such a factor, based on percentage of time spent at a percentage of the maximum working torque, should be submitted to LR for consideration and acceptance.

6.6.7 Slewing ring bearing capacity calculations are to take account of:
- Pod weight in water;
- Gyroscopic forces from the propeller and motor;
- Hydrodynamic loads on pod; and
- Forces due to ship's motions.

The calculations are to demonstrate that the factor of safety against the maximum combination of the above forces is not less than 2. The calculations are to be carried out in accordance with a suitable declared standard.

6.6.8 Means of allowing the condition of the slewing gears and bearings to be assessed are to be provided.

6.6.9 On multi podded ships, means are to be provided to secure each pod unit's slewing mechanism in its mid position in the event of a steering system failure. These arrangements are to be of sufficient strength to hold the pod in position at the ship's manoeuvring speed to be taken as not less than 7 knots, *see also* 6.3.9. Operating instructions displayed at the securing mechanism's operating position are to include a direction to inform the bridge of any limitation in ship's speed required as a result of the securing mechanism being activated.

6.7 Ventilation and cooling systems

6.7.1 Means are to be provided to ensure that air used for motor cooling purposes is of a suitable temperature and humidity as well as being free from harmful particles.

6.7.2 Cooling water supplies are to comply with Ch 14,7. *See also* Pt 6, Ch 2,9.6.

6.7.3 On single podded installations, a standby cooling arrangement of the same capacity as the main cooling system, is to be provided and available for immediate use.

6.7.4 For pods having an electric propulsion motor but no active cooling system, heat balance calculations as required by 2.2.1(w) are to demonstrate that the pod unit and associated systems are able to function satisfactorily over all operating conditions, *see* Ch 1,3.5.

6.8 Pod drainage requirements

6.8.1 Unless the electrical installation is suitable for operation in a flooded space, means are to be provided to ensure that leakage from shaft bearings or the propeller seal do not reach the motor windings, or other electrical components. Account is to be taken of cooling air flow circulating within the pod unit.

6.8.2 Where the design of a pod space has a requirement to be maintained in a dry condition, two independent means of drainage are to be provided so that liquid leakage may be removed from the pod unit at all design angles of heel and trim, *see* Ch 1,3.6.

6.8.3 Pipework conveying leakage from the pod is to be sited such that any leakage from joints will not impinge on electrical equipment, *see also* Ch 13,2.9.3.

6.9 Hydraulic actuating systems

6.9.1 Hydraulic actuating systems are to comply with Ch 14,9 and Ch 19,3 as applicable.

■ *Section 7* Electrical equipment

7.1 General

7.1.1 The electrical installation is to be designed, constructed and installed in accordance with the requirements of Pt 6, Ch 2.

7.1.2 Means are to be provided to prevent electrical currents flowing across shaft bearings, which may cause their premature failure.

7.1.3 Steering gear electrical systems are to comply with Ch 19,5.

7.1.4 Details are to be submitted to demonstrate the suitability of cables and busbars intended to operate at temperatures exceeding 95°C, *see* Pt 6, Ch 2,7.2.2 and 11.4.3.

7.2 Slip rings

7.2.1 Where slip rings are incorporated in the design, the details of the following are to be submitted for consideration:

(a) temperature rise test reports;
(b) maximum permitted temperature ratings and design operating temperatures for materials;
(c) where applicable, arrangements for forced air or liquid cooling;
(d) for data communication link slip rings, evidence to demonstrate compliance with Pt 6, Ch 1,2.11.3;
(e) suitability for use under the conditions of vibration expected to arise in normal operation;
(f) evidence of satisfactory operation under the normal angles of inclination given in Pt 6, Ch 2,1.10;
(g) cable securing arrangements; and
(h) evidence of electromagnetic compatibility of control, alarm and safety systems with power circuits.

7.2.2 Where forced cooling is used on slip rings, an alarm is to be initiated to indicate the failure of the forced cooling and it is to be possible to operate the slip ring at a reduced power level defined by the Manufacturer in the event of failure of the forced cooling.

■ *Section 8* Control engineering systems

8.1 General

8.1.1 Control engineering arrangements are to be in accordance with Pt 6, Ch 1.

8.1.2 Steering gear control, monitoring and alarm systems are to comply with Ch 19,4 and Ch 19,5.

8.1.3 Steering control is to be provided for podded drives from the navigating bridge and locally.

8.1.4 An indication of the angular position of the podded propulsion unit(s) and the magnitude of the thrust is to be provided at each station from which it is possible to control the direction of thrust. This indication is to be independent of the steering control system.

8.1.5 Emergency Stop Functions are to be provided at the remote control station(s), independent of the podded drive control system, to stop each podded drive in an emergency. *See also* Pt 6, Ch 2,16.4.7.

8.1.6 Where programmable electronic equipment is used to prevent loads exceeding those for which the system has been designed (*see* 2.4.3), then either:

(a) A fully independent hard wired backup is to be provided; or
(b) The software is to be certified in accordance with LR's Software Conformity Assessment System – Assessment Module GEN1 (1994) and have an independent solution showing redundancy with design diversity, etc., *see* Pt 6, Ch 1,2.13 of the Rules.

8.1.7 Where a propulsion system which includes a podded propulsor unit is controlled by a series of interactive and integrated programmable electronic systems, then these are to comply with the requirements of Pt 6, Ch 1,2.13 of the Rules.

8.1.8 For electronic control systems and electrical actuating systems, an overall quality plan for sourcing, design, installation and testing is to address the following issues:

(a) Standard(s) applied.
(b) Details of the quality control system applied during manufacture and testing.
(c) Details of type approval, type testing or approved type status assigned to the equipment.
(d) Details of installation and testing recommendations for the equipment.
(e) Details of any local and/or remote diagnostic arrangements where assessment and alteration of control parameters can be made which can affect the operation of the podded propulsor unit.
(f) Software lifecycle activities, including configuration management and arrangements for software upgrades.

8.1.9 The quality plan referred to in 8.1.8 to identify the process for verification of the functional outputs from the electronic control systems with particular reference to system integrity, consistency, security against unauthorised changes to software and maintaining the outputs within acceptable tolerances of stated performance for safe and reliable operation of the podded propulsor unit.

8.1.10 For the permitted range of operating conditions, the control system is to be capable of protecting the podded propulsor from experiencing mechanical loads that may initiate damage while permitting the desired manoeuvres to take place.

8.2 Monitoring and alarms

8.2.1 The requirements for alarms and monitoring arrangements are to be in accordance with Ch 19,5.3 and Table 9.8.1. These alarms are in addition to the requirements of Pt 6, Ch 2,16.

8.2.2 Alarms specified in Table 9.8.1 are to be in accordance with the alarm system specified by Pt 6, Ch 1,2,3.

8.2.3 Sensors for control, monitoring and alarm systems required by the Rules and located within the pod are to be duplicated in order that a single sensor failure does not inhibit system functionality.

8.2.4 Pod unit dry space pumping arrangements are to function automatically in the event of a high liquid level being detected in the pod unit.

8.2.5 Spaces intended to be dry are to be provided with arrangements to indicate water ingress in accordance with 8.2.6 and Table 9.8.1.

8.2.6 The number and location of dry space level detectors are to be such that accumulation of liquids will be detected at all design angles of heel and trim.

8.2.7 Condition monitoring arrangements are not to interface with the operation of safety systems which may cause slow-down or shut-down of the propulsion system. *See also* Pt 6, Ch 1,2.6.8.

Table 9.8.1 Additional alarms and safeguards for podded propulsion units

Item	Alarm	Note
Podded drive azimuth angle	—	Indicator, *see* 8.1.4
Propulsion motors	Power supply failure	To be indicated on the navigating bridge
Propulsion motor power limitation or automatic reduction	Activated	*See also* Pt 6, Ch 2,16.4.9
Hydraulic oil system pressure	Low	To be indicated on the navigating bridge
Bearing temperature	High	For grease lubricated bearings
Motor temperature	High	*See* Pt 6, Ch 2,16.1.3
Lubricating oil supply pressure	Low	If separate forced lubrication for shaft bearings; to be indicated on the navigating bridge
Lubricating oil temperature	High	*See also* Pt 6, Ch 2,15.5.9
Lubricating oil tank level for motor bearings	Low	
Water in lubricating oil for motor bearings	High	Required for single podded propulsion units only
Motor cooling air inlet temperature	High	
Motor cooling air outlet temperature	High	
Motor cooling air flow	Low	
Shaft bearing vibration monitoring	High	*See* 6.3.10. Monitoring is to allow bearing condition to be gauged using trend analysis
Shaft sealing	Failure	*See* 6.3.13
Dry space water pump operation	Abnormal	Alarm set to indicate a frequency or duration exceeding that which would normally be expected
Dry space water level	1st stage high 2nd stage high	— Propulsion motor is to shut down automatically, *See* Note
Slip ring forced cooling	Failure	*See* 7.2.2

NOTE
The second stage dry space water level high alarm is not needed where the electrical equipment installed within the pod is suitable for operation in flooded spaces, *see* 6.8.1.

Section 9
Testing and trials

9.1 General

9.1.1 The following requirements are to be complied with:

- Ch 1,5.2 for sea trials.
- Ch 19,7.2 for steering trials.

In addition, the functional capability specified in 3.1.1 is to be demonstrated to the Surveyor's satisfaction.

9.1.2 The actual values of steering torque are to be verified during sea trials to confirm that the design maximum dynamic duty torque has not been exceeded.

9.1.3 Electric motor cooling systems are to be verified, as far as possible, to ensure that they are capable of limiting the extremes of ambient temperature to those specified in 2.3.1.

9.1.4 Any trials and testing identified from the FMEA report, *see* 2.5.4(f), are also to be carried out.

Section 10
Installation, maintenance and replacement procedures

10.1 General

10.1.1 All podded propulsion units are to be supplied with a copy of the manufacturer's installation and maintenance manual that is pertinent to the actual equipment.

10.1.2 The manual required by 10.1.1 is to be placed on board and is to contain the following information:

(a) Description of the podded propulsion unit with details of function and design operating limits. This is also to include details of support systems such as lubrication, cooling and condition monitoring arrangements.
(b) Identification of all components together with details of any that have a defined maximum operating life.
(c) Instructions for installation of unit(s) on board ship with details of any required specialised equipment.
(d) Instructions for commissioning at initial installation and following maintenance.
(e) Maintenance and service instructions to include inspection/renewal of bearings, seals, motors, slip rings and other major components. This is also to include component fitting procedures, special environmental arrangements, clearance and push-up measurements and lubricating oil treatment where applicable.
(f) Actions required in the event of fault/failure conditions being detected.
(g) Precautions to be taken by personnel working during installation and maintenance.

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter are applicable to fusion welded pressure vessels and their mountings and fittings, for the following uses:

(a) Production or storage of steam.
(b) Heating of pressurised hot water above 120°C.
(c) Heating of pressurised thermal liquid.

The formulae in this Chapter may be used for determining the thickness of seamless pressure vessels using a joint factor of 1,0. Seamless pressure vessels are to be manufactured and tested in accordance with the requirements of Chapter 5 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.1.2 The scantlings of coil type heaters with pumped circulation, which are fired or heated by exhaust gas, are to comply with the appropriate requirements of this Chapter.

1.1.3 Where exhaust gas emissions abatement equipment is fitted to steam raising plant, it is to meet the requirements of Chapter 24.

1.2 Definition of symbols

1.2.1 The symbols used in the various formulae in Sections 2 to 8, unless otherwise stated, are defined as follows and are applicable to the specific part of the pressure vessel under consideration:

d = diameter of hole or opening, in mm
p = design pressure, *see* 1.3, in bar
r_i = inside knuckle radius, in mm
r_o = outside knuckle radius, in mm
s = pitch, in mm
t = minimum thickness, in mm
D_i = inside diameter, in mm
D_o = outside diameter, in mm
J = joint factor applicable to welded seams, *see* 1.9, or ligament efficiency between tube holes (expressed as a fraction, *see* 2.2)
R_i = inside radius, in mm
R_o = outside radius, in mm
T = design temperature, in °C
σ = allowable stress, *see* 1.8, in N/mm^2.

1.2.2 Where reference is made to calculated or actual plate thickness for the derivation of other values, these thicknesses are to be minus the standard Rule corrosion allowance of 0,75 mm, if not so stated.

1.3 Design pressure

1.3.1 The design pressure is the maximum permissible working pressure and is to be not less than the highest set pressure of any safety valve.

1.3.2 The calculations made to determine the scantlings of the pressure parts are to be based on the design pressure, adjusted where necessary to take account of pressure variations corresponding to the most severe operational conditions.

1.3.3 It is desirable that there should be a margin between the normal pressure at which the boiler or pressure vessel operates and the lowest pressure at which any safety valve is set to lift, to prevent unnecessary lifting of the safety valve.

1.4 Metal temperature

1.4.1 The metal temperature, T, used to evaluate the allowable stress, σ, is to be taken as the actual mean wall metal temperature expected under operating conditions for the pressure part concerned, and is to be stated by the manufacturer when plans of the pressure parts are submitted for consideration.

1.4.2 The following values are to be regarded as the minimum:

(a) For fired steam boilers, *T*, is to be taken as not less than 250°C.
(b) For steam heated generators, secondary drums of double evaporation boilers, steam receivers and pressure parts of fired pressure vessels, not heated by hot gases and adequately protected by insulation, *T*, is to be taken as the maximum temperature of the internal fluid.
(c) For pressure parts heated by hot gases, *T*, is to be taken as not less than 25°C in excess of the maximum temperature of the internal fluid.
(d) For boiler, superheater, reheater and economiser tubes, *T*, is to be taken as indicated in 7.1.2.
(e) For combustion chambers of the type used in horizontal wet-back boilers, *T*, is to be taken as not less than 50°C in excess of the maximum temperature of the internal fluid.
(f) For furnaces, fireboxes, rear tube plates of dry-back boilers and pressure parts subject to similar rates of heat transfer, *T*, is to be taken as not less than 90°C in excess of the maximum temperature of the internal fluid.

1.4.3 In general any parts of boiler drums or headers not protected by tubes, and exposed to radiation from the fire or to the impact of hot gases, are to be protected by a shield of good refractory material or by other approved means.

1.4.4 Drums and headers of thickness greater than 35 mm are not to be exposed to combustion gases having an anticipated temperature in excess of 650°C unless they are efficiently cooled by closely arranged tubes.

1.5 Classification of fusion welded pressure vessels

1.5.1 For Rule purposes, pressure vessels with fusion welded seams are graded as Class 1 if they comply with the following conditions:

(a) For pressure parts of fired steam boilers, fired thermal liquid heaters and exhaust gas heated shell type steam boilers where the design pressure exceeds 3,4 bar.
(b) For pressure parts of steam heated steam generators and separate steam receivers where the design pressure exceeds 11,3 bar, or where the pressure, in bar, multiplied by the internal diameter of the shell, in mm, exceeds 14 420.

1.5.2 For Rule purposes, pressure vessels with fusion welded seams, used for the production or storage of steam, the heating of pressurised hot water above 120°C or the heating of pressurised thermal liquid not included in Class 1 are graded as Class 2/1 and 2/2.

1.5.3 Pressure vessels which are constructed in accordance with Class 2/1 or Class 2/2 standards (as indicated above) will, if manufactured in accordance with requirements of a superior class, be approved with the scantlings appropriate to that class.

1.5.4 Pressure vessels which have only circumferential fusion welded seams, will be considered as seamless with no class being assigned. Preliminary weld procedure tests and non-destructive examination for the circumferential seam welds should be carried out for the equivalent class as determined by 1.5.1 and 1.5.2.

1.5.5 In special circumstances relating to service conditions, materials, operating temperature, the carriage of dangerous gases and liquids, etc., it may be required that certain pressure vessels be manufactured in accordance with the requirements of a superior class.

1.5.6 Details of heat treatment, non-destructive examination and routine tests (where required) are given in Chapter 13 of the Rules for Materials.

1.5.7 Hydraulic testing is required for pressure vessels of Class 1, 2/1 and 2/2.

1.6 Plans

1.6.1 Plans of boilers, superheaters and economisers are to be submitted in triplicate for consideration. When plans of water tube boilers are submitted for approval, particulars of the safety valves and their disposition on boilers and superheaters, together with the estimated pressure drop through the superheaters, are to be stated. The pressures proposed for the settings of boiler and superheater safety valves are to be indicated on the boiler plan.

1.6.2 Plans, in triplicate, showing full constructional features of fusion welded pressure vessels and dimensional details of the weld preparation for longitudinal and circumferential seams and attachments, together with particulars of the welding consumables and of the mechanical properties of the materials, are to be submitted before construction is commenced.

1.6.3 Plans, in triplicate, showing details of the air flow through the combustion chamber, boiler furnace and boiler uptake spaces, including measures taken to assure effective purging in all of the spaces, are to be submitted for consideration. *See also* Pt 5, Ch 10,18.3 and Ch 14,2.2.

1.6.4 Plans, in triplicate, showing all areas of refractory material in the combustion chamber and boiler furnace spaces, are to be submitted for consideration. *See* 1.12.1.

1.6.5 Calculations, in triplicate, showing that a minimum of 4 air changes of the combustion chamber, boiler furnace and boiler uptake spaces will be achieved during automatic purging operations, with details of the forced draft fans and arrangements of air flow from fan intake to flue outlet, are to be submitted for consideration, *see* 1.12.1.

1.6.6 Calculations, in triplicate, are to be submitted showing that the ventilation of machinery spaces containing boilers is adequate for the air consumers within the space with an unimpaired air supply, in accordance with the equipment manufacturer's recommendations, under operating conditions as defined in Ch 1,4.4.2.

1.7 Materials

1.7.1 Materials used in the construction are to be manufactured and tested in accordance with the requirements of the Rules for Materials.

1.7.2 The specified minimum tensile strength of carbon and carbon-manganese steel plates, pipes, forgings and castings is to be within the following general limits:

(a) For seamless, Class 1, Class 2/1 and Class 2/2 fusion welded pressure vessels:
340 to 520 N/mm^2.

(b) For boiler furnaces, combustion chambers and flanged plates:
400 to 520 N/mm^2.

1.7.3 The specified minimum tensile strength of low alloy steel plates, pipes, forgings and castings is to be within the general limits of 400 to 500 N/mm^2 and pressure vessels made in these steels are to be either seamless or Class 1 fusion welded.

1.7.4 The specified minimum tensile strength of boiler and superheater tubes is to be within the following general limits:

(a) Carbon and carbon-manganese steels:
320 to 460 N/mm^2.

(b) Low alloy steels:
400 to 500 N/mm^2.

1.7.5 Where it is proposed to use materials other than those specified in the Rules for Materials, details of the chemical compositions, heat treatment and mechanical properties are to be submitted for approval. In such cases the values of the mechanical properties used for deriving the allowable stress are to be subject to agreement by Lloyd's Register (hereinafter referred to as 'LR').

1.7.6 Where a fusion welded pressure vessel is to be made of alloy steel, and approval of the scantlings is required on the basis of the high temperature properties of the material, particulars of the welding consumables to be used, including typical mechanical properties and chemical composition of the deposited weld metal, are to be submitted for approval.

1.8 Allowable stress

1.8.1 The term 'allowable stress', σ, is the stress to be used in the formulae for the calculation of scantlings of pressure parts.

1.8.2 The allowable stress, σ, is to be the lowest of the following values:

$$\sigma = \frac{E_t}{1,5} \qquad \sigma = \frac{R_{20}}{2,7} \qquad \sigma = \frac{S_R}{1,5}$$

where

E_t = specified minimum lower yield stress or 0,2 per cent proof stress at temperature, T

R_{20} = specified minimum tensile strength at room temperature

S_R = average stress to produce rupture in 100 000 hours at temperature, T

T = metal temperature, *see* 1.4.

1.8.3 The allowable stress for steel castings is to be taken as 80 per cent of the value determined by the method indicated in 1.8.2, using the appropriate values for cast steel.

1.8.4 Where steel castings, which have been tested in accordance with the Rules for Materials, are also subjected to non-destructive tests, consideration will be given to increasing the allowable stress using a factor up to 90 per cent in lieu of the 80 per cent referred to in 1.8.3. Particulars of the non-destructive test proposals are to be submitted for consideration.

1.9 Joint factors

1.9.1 The following joint factors are to be used in the equations in Sections 2 to 8, where applicable. Fusion welded pressure parts are to be made in accordance with Chapter 17.

Class of pressure vessel	Joint factor
Class 1	1,0
Class 2/1	0,85
Class 2/2	0,75

1.9.2 The longitudinal and circumferential joints for all classes of pressure vessels for the purposes of this Chapter are to be butt joints. For typical acceptable methods of attaching dished ends, *see* Fig. 10.14.1.

1.10 Pressure parts of irregular shape

1.10.1 Where pressure parts are of such irregular shape that it is impracticable to design their scantlings by the application of formulae in Sections 2 to 8, the suitability of their construction is to be determined by hydraulic proof test of a prototype or by agreed alternative method.

1.11 Adverse working conditions

1.11.1 Where working conditions are adverse, special consideration may be required to be given to increasing the scantlings derived from the formulae. In this connection, where necessary, account should also be taken of any excess of loading resulting from:

(a) impact loads, including rapidly fluctuating pressures,
(b) weight of the vessel and normal contents under operating and test conditions,
(c) superimposed loads such as other pressure vessels, operating equipment, insulation, corrosion-resistant or erosion-resistant linings and piping,
(d) reactions of supporting lugs, rings, saddles or other types of supports, or
(e) the effect of temperature gradients on maximum stress.

1.12 Furnace explosion prevention

1.12.1 The design of combustion chamber and furnace arrangements is to incorporate measures to minimise the risk of explosion as far as practicable. Measures are to be taken to prevent the accumulation of flammable gases in spaces which may not effectively be reached by purging air. Measures are to be taken to minimise heat retaining surfaces e.g., refractory which can become sources of ignition in the furnace and uptakes.

1.13 Exhaust gas economiser/boiler arrangements

1.13.1 The design of exhaust gas economisers/boilers of the plain or extended surface fin tube types is to be compatible with the installed engine design parameters. The parameters which influence the build up of soot deposits and overheating such as fuel, exhaust gas temperature and efflux velocity are to be considered in the design of the exhaust gas economiser/boiler for use with the installed engine, in order to minimise the risk of fire and breakdown during operation.

1.13.2 A design statement demonstrating compliance with the requirements of 1.13.1 or alternative means of preventing the accumulation of soot or overheating, such as the use of exhaust gas bypass ducting with automatic flap valve arrangements and/or effective soot prevention and cleaning systems, is to be submitted for approval.

■ *Section 2* Cylindrical shells and drums subject to internal pressure

2.1 Minimum thickness

2.1.1 Minimum thickness, t, of a cylindrical shell is to be determined by the following formula:

$$t = \frac{p\,R_i}{10\sigma\,J - 0{,}5p} + 0{,}75 \text{ mm}$$

where

t, p, R_i and σ are defined in 1.2,

J = efficiency of ligaments between tube holes or other openings in the shell or the joint factor of the longitudinal joints (expressed as a fraction). *See* 1.9 or 2.2, whichever applies. In the case of seamless shells clear of tube holes or other openings, J = 1,0.

2.1.2 The formula in 2.1.1 is applicable only where the resulting thickness does not exceed half the internal radius, i.e. where R_o is not greater than 1,5R_i.

2.1.3 Irrespective of the thickness determined by the above formula, t is to be not less than:

(a) 6,0 mm for cylindrical shell plates.

(b) For tube plates, such thickness as will give a minimum parallel seat of 9,5 mm, or such greater width as may be necessary to ensure tube tightness, *see* 14.6.

2.2 Efficiency of ligaments between tube holes

2.2.1 Where tube holes are drilled in a cylindrical shell in a line or lines parallel to its axis, the efficiency, J, of the ligaments is to be determined as in 2.2.2, 2.2.3 and 2.2.4.

2.2.2 **Regular drilling**. Where the distance between adjacent tube holes is constant, *see* Fig. 10.2.1,

$$J = \frac{s - d}{s}$$

where

d = the mean effective diameter of the tube holes, in mm, after allowing for any serrations, counter-boring or recessing, or the compensating effect of the tube stub. *See* 2.3 and 2.4.

s = pitch of tube holes, in mm.

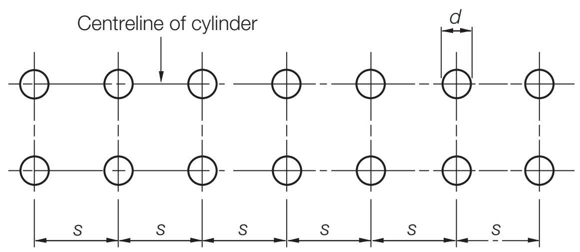


Fig. 10.2.1 Regular drilling

2.2.3 **Irregular drilling**. Where the distance between centres of adjacent tube holes is not constant, *see* Fig. 10.2.2:

$$J = \frac{s_1 + s_2 - 2d}{s_1 + s_2}$$

where d is as defined in 2.2.2

s_1 = the shorter of any two adjacent pitches, in mm

s_2 = the longer of any two adjacent pitches, in mm.

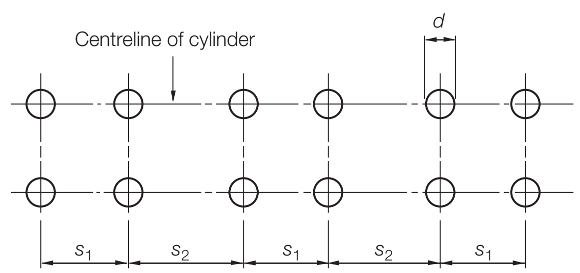


Fig. 10.2.2 Irregular drilling

2.2.4 When applying the formula in 2.2.3, the double pitch ($s_1 + s_2$) chosen is to be that which makes J, a minimum, and in no case is s_2 to be taken as greater than twice s_1.

2.2.5 Where the circumferential pitch between tube holes measured on the mean of the external and internal drum or header diameters is such that the circumferential ligament efficiency determined by the formulae in 2.2.2 and 2.2.3 is less than one-half of the ligament efficiency on the longitudinal axis, J in 2.1 is to be taken as twice the circumferential efficiency.

2.2.6 Where tube holes are drilled in a cylindrical shell along a diagonal line with respect to the longitudinal axis, the efficiency, J, of the ligaments is to be determined as in 2.2.7 to 2.2.10.

2.2.7 For spacing of tube holes on a diagonal line as shown in Fig. 10.2.3, or in a regular saw-tooth pattern as shown in Fig. 10.2.4, J is to be determined from the formula in 2.2.8, where a and b, as shown in Figs. 10.2.3 and 10.2.4, are measured, in mm, on the median line of the plate, and d, is as defined in 2.2.2.

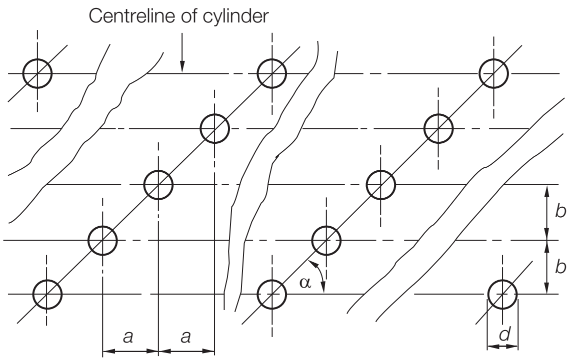


Fig. 10.2.3 Spacing of holes on a diagonal line

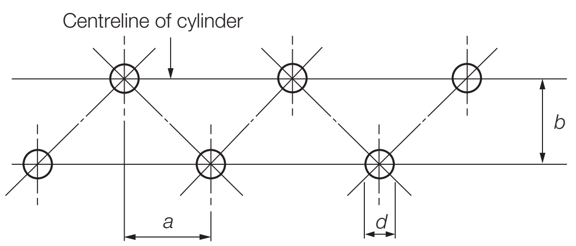


Fig. 10.2.4 Regular saw-tooth pattern of holes

2.2.8 For tube holes on a diagonal line:

$$J = \frac{2}{A + B + \sqrt{(A - B)^2 + 4C^2}}$$

where

$$A = \frac{\cos^2 \alpha + 1}{2\left(1 - \dfrac{d \cos \alpha}{a}\right)}$$

$$B = 0,5 \left(1 - \frac{d \cos \alpha}{a}\right) (\sin^2 \alpha + 1)$$

$$C = \frac{\sin \alpha \cos \alpha}{2\left(1 - \dfrac{d \cos \alpha}{a}\right)}$$

$$\cos \alpha = \frac{1}{\sqrt{1 + \dfrac{b^2}{a^2}}}$$

$$\sin \alpha = \frac{1}{\sqrt{1 + \dfrac{a^2}{b^2}}}$$

α = angle between centreline of cylinder and centreline of diagonal holes.

2.2.9 For regularly staggered spacing of tube holes as shown in Fig. 10.2.5, the smallest value of the efficiency, J, of all ligaments (longitudinal, circumferential and diagonal) is obtained from Fig. 10.2.6, where a and b as shown in Fig. 10.2.5 are measured, in mm, on the median line of the plate, and d is as defined in 2.2.2.

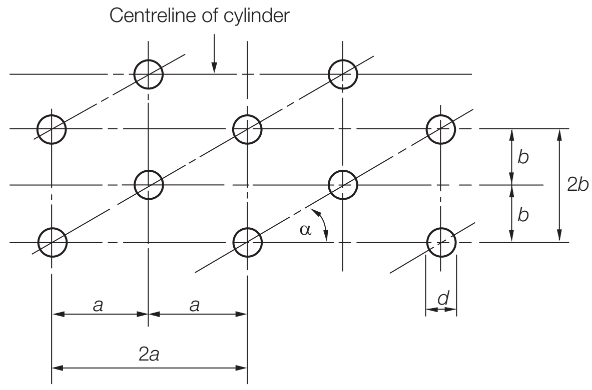


Fig. 10.2.5 Regular staggering of holes

2.2.10 For irregularly spaced tube holes whose centres do not lie on a straight line, the formula in 2.2.3 is to apply, except that an equivalent longitudinal width of the diagonal ligament is to be used. An equivalent longitudinal width is that width which gives, using the formula in 2.2.2, the same efficiency as would be obtained using the formula in 2.2.8 for the diagonal ligament in question.

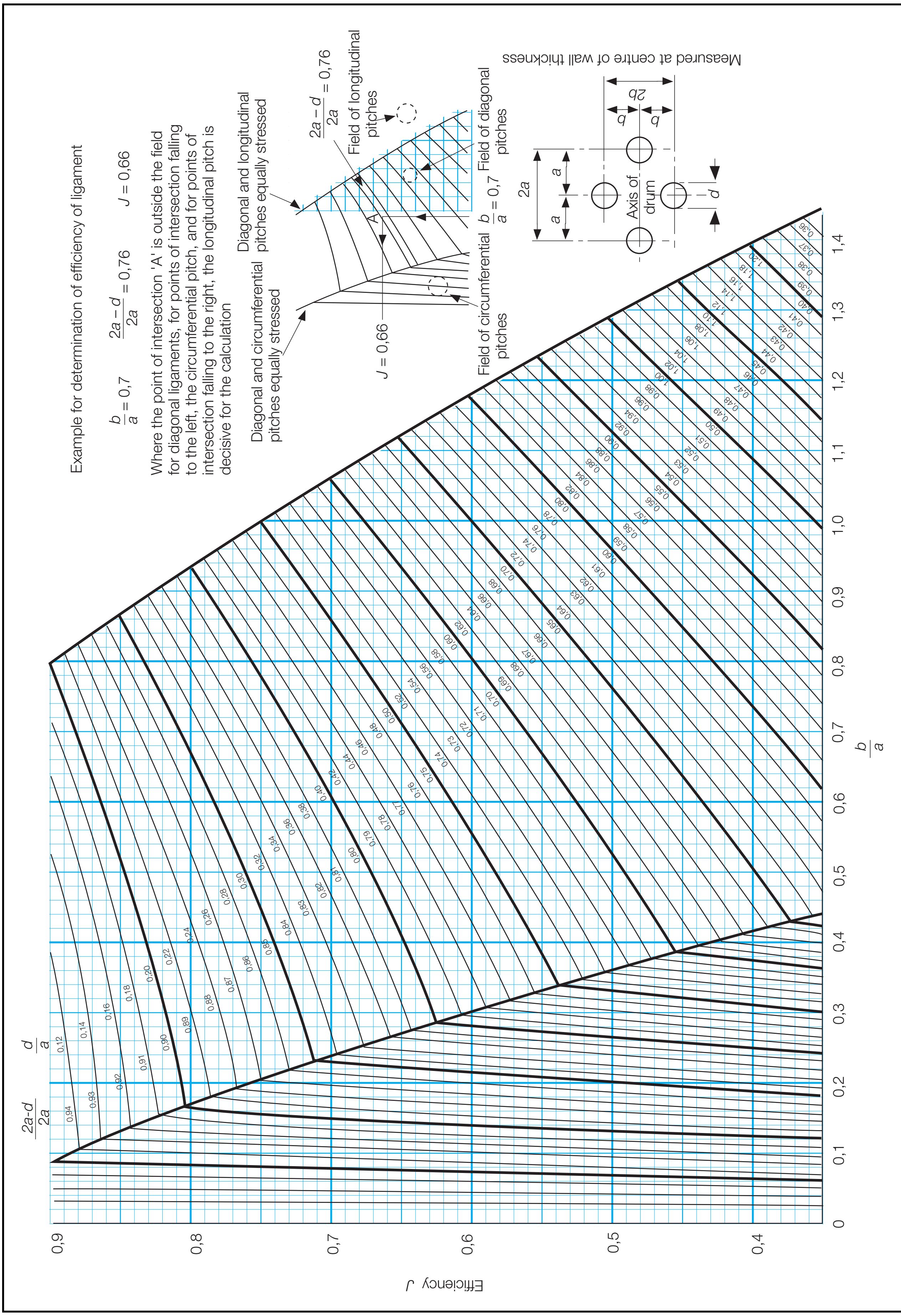


Fig. 10.2.6 Efficiency of ligaments between holes

2.3 Compensating effect of tube stubs

2.3.1 Where a drum or header is drilled for tube stubs fitted by strength welding, either in line or in staggered formation, the effective diameter of holes is to be taken as:

$$d_e = d_a - \frac{A}{t}$$

where

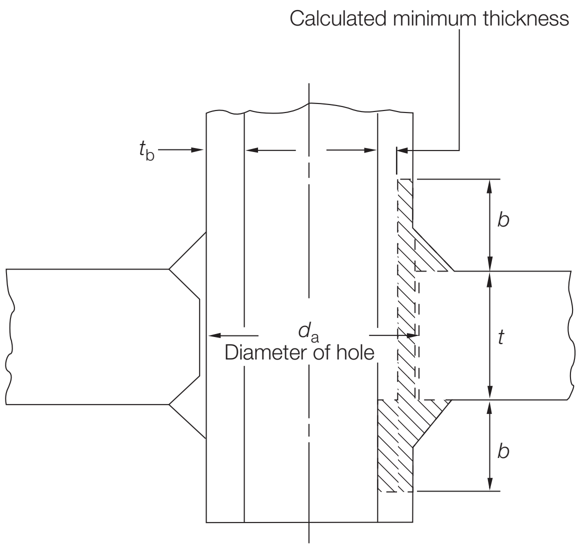
d_e = the equivalent diameter of the hole, in mm
d_a = the actual diameter of the hole, in mm
t = the thickness of the shell, in mm
A = the compensating area provided by each tube stub and its welding fillets, in mm^2.

2.3.2 The compensating area, *A*, is to be measured in a plane through the axis of the tube stub parallel to the longitudinal axis of the drum or header and is to be calculated as follows, *see* Figs. 10.2.7 and 10.2.8:

- The cross-sectional area of the stub, in excess of that required by 7.1 for the minimum tube thickness, from the interior surface of the shell up to a distance, *b*, from the outer surface of the shell;
- plus the cross-sectional area of the stub projecting inside the shell within a distance, *b*, from the inner surface of the shell;
- plus the cross-sectional area of the welding fillets inside and outside the shell;

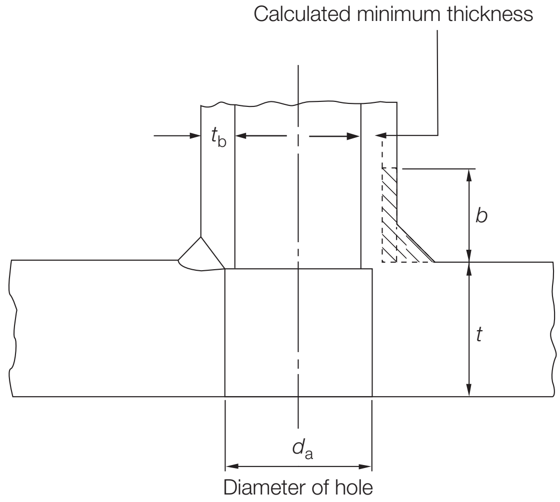
where

$b = \sqrt{d_a t_b}$
t_b = actual thickness of tube stub, in mm.



The area shown hatched is half the area *A*

Fig. 10.2.7 Compensation of welded tube stubs
The calculated minimum thickness is to satisfy 7.1.



The area shown hatched is half the area *A*

Fig. 10.2.8 Compensation of welded tube stubs
The calculated minimum thickness is to satisfy 7.1.

2.3.3 Where the material of the tube stub has an allowable stress lower than that of the shell, the compensating cross-sectional area of the stub is to be multiplied by the ratio:

$$\frac{\text{allowable stress of stub at design metal temperature}}{\text{allowable stress of shell at design metal temperature}}$$

2.4 Unreinforced openings

2.4.1 Openings in a definite pattern, such as tube holes, may be designed in accordance with the Rules for ligaments in 2.2, provided that the diameter of the largest hole in the group does not exceed that permitted by 2.4.2.

2.4.2 The maximum diameter, *d*, of any unreinforced isolated openings is to be determined by the following formula:

$$d = 8{,}08\ [D_o\ t\ (1 - K)]^{1/3} \quad \text{in mm}$$

The value of *K* to be used is calculated from the following formula:

$$K = \frac{p\ D_o}{18{,}2\ \sigma\ t}$$ but is not to be taken as greater than 0,99

where

p, D_o and σ are as defined in 1.2
t = actual thickness of shell, in mm.

2.4.3 For elliptical or oval holes, *d*, for the purposes of 2.4.2, refers to the major axis when this lies longitudinally or to the mean of the major and minor axes when the minor axis lies longitudinally.

2.4.4 No unreinforced opening is to exceed 200 mm in diameter.

2.4.5 Holes may be considered isolated if the centre distance between two holes on the longitudinal axis of a cylindrical shell is not less than:

$d + 1{,}1\sqrt{D\,t}$ with a minimum $5d$

d = diameter of openings in shell (mean diameter if dissimilarly sized holes involved)
D = mean diameter of shell
t = actual thickness of shell

Where the centre distance is less than so derived, the holes are to be fully compensated.

Where two holes are offset on a diagonal line, the diagonal efficiency from Fig. 10.2.6 may be used to derive an equivalent longitudinal centre distance for the purposes of this paragraph.

2.5 Reinforced openings

2.5.1 Openings larger than those permitted by 2.4 are to be compensated in accordance with Fig. 10.2.9(a) or (b). The following symbols are used in Fig. 10.2.9(a) and (b):

t_s = calculated thickness of a shell without joint or opening or corrosion allowance, in mm
t_d = thickness calculated in accordance with 7.1 without corrosion allowance, in mm
t_a = actual thickness of shell plate without corrosion allowance, in mm
t_b = actual thickness of standpipe without minus tolerances and corrosion allowance, in mm
t_r = thickness of added reinforcement, in mm
D_i = internal diameter of cylindrical shell, in mm
d_o = diameter of hole in shell, in mm
L = width of added reinforcement not exceeding D, in mm
C = $\sqrt{d_o\,t_b}$ in mm
D = $\sqrt{D_i\,t_a}$ and is not to exceed $0{,}5d_o$, in mm
σ = shell plate allowable stress, N/mm^2
σ_p = standpipe allowable stress, N/mm^2
σ_r = added reinforcement allowable stress, N/mm^2
σ_w = weld metal allowable stress, N/mm^2

NOTE
σ_p, σ_r and σ_w are not to be taken as greater than σ.

2.5.2 For elliptical or oval holes, the dimension on the meridian of the shell is to be used for d_o in 2.5.1.

2.5.3 Compensation is to be distributed equally on either side of the centreline of the opening.

2.5.4 The welds attaching standpipes and reinforcing plates to the shell are to be of sufficient size to transmit the full strength of the reinforcing areas and all other loadings to which they may be subjected.

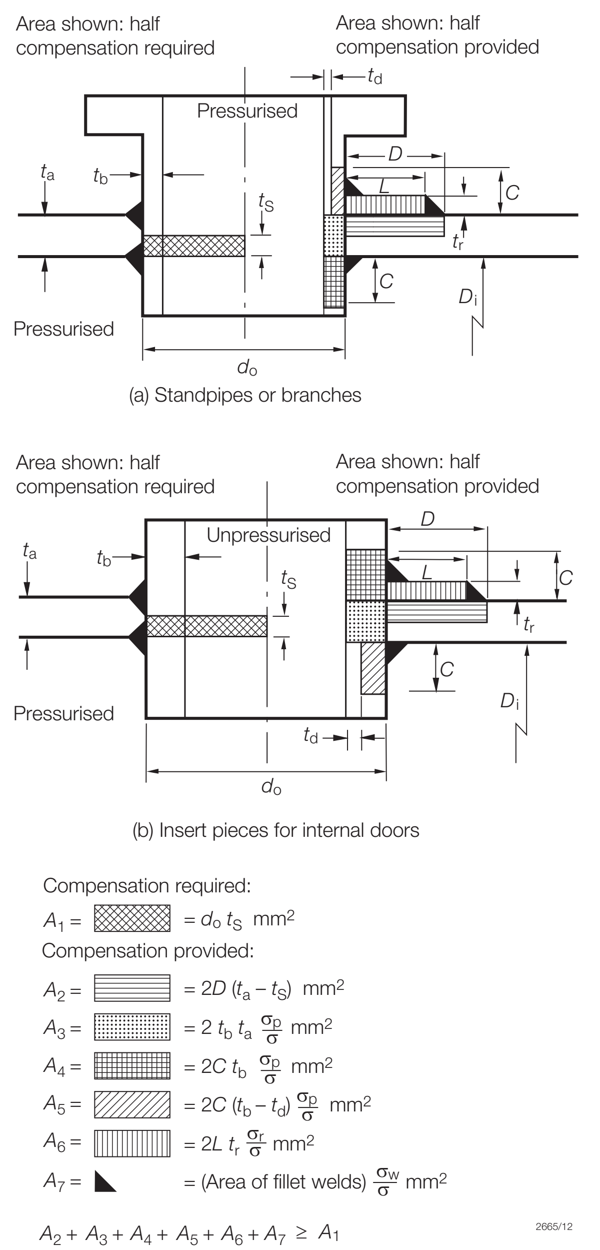


Fig. 10.2.9
Compensation for welded standpipes or branches in cylindrical shells

Section 3
Spherical shells subject to internal pressure

3.1 Minimum thickness

3.1.1 The minimum thickness of a spherical shell is to be determined by the following formula:

$$t = \frac{p\,R_i}{20\sigma\,J - 0{,}5p} + 0{,}75 \text{ mm}$$

where
t, p, R_i, σ and J are as defined in 1.2.

3.1.2 The formula in 3.1.1 is applicable only where the resulting thickness does not exceed half the internal radius.

3.1.3 Openings in spherical shells requiring compensation are to comply, in general, with 2.5, using the calculated and actual thicknesses of the spherical shell as applicable.

Section 4
Dished ends subject to internal pressure

4.1 Minimum thickness

4.1.1 The thickness, t, of semi-ellipsoidal and hemi-spherical unstayed ends, and the knuckle section of torispherical ends, dished from plate, having pressure on the concave side and satisfying the conditions listed below, is to be determined by the following formula:

$$t = \frac{p\,D_o\,K}{20\sigma\,J} + 0{,}75 \text{ mm}$$

where
t, p, D_o, σ and J are as defined in 1.2
K = a shape factor, *see* 4.2 and Fig. 10.4.1.

4.1.2 For semi-ellipsoidal ends:
the external height, $H \geq 0{,}18D_o$
where
D_o = the external diameter of the parallel portion of the end, in mm.

4.1.3 For torispherical ends:
the internal radius, $R_i \leq D_o$
the internal knuckle radius, $R_i \geq 0{,}1D_o$
the internal knuckle radius, $R_i \geq 3t$
the external height, $H \geq 0{,}18D_o$ and is determined as follows:

$$H = R_o - \sqrt{(R_o - 0{,}5D_o)(R_o + 0{,}5D_o - 2r_o)}\ .$$

4.1.4 In addition to the formula in 4.1.1 the thickness, t, of a torispherical head, made from more than one plate, in the crown section is to be not less than that determined by the following formula:

$$t = \frac{p\,R_i}{20\sigma\,J - 0{,}5p} + 0{,}75 \text{ mm}$$

where
t, p, R_i, σ and J are as defined in 1.2.

4.1.5 The thickness required by 4.1.1 for the knuckle section of a torispherical head is to extend past the common tangent point of the knuckle and crown radii into the cross-section for a distance not less than $0{,}5\sqrt{R_i\,t}$ mm, before reducing to the crown thickness permitted by 4.1.4, where
t = the required thickness from 4.1.1.

4.1.6 In all cases, H, is to be measured from the commencement of curvature, *see* Fig. 10.4.2.

4.1.7 The minimum thickness of the head, t, is to be not less than 6,0 mm.

4.1.8 For ends which are butt welded to the drum shell, *see* 1.8, the thickness of the edge of the flange for connection to the shell is to be not less than the thickness of an unpierced seamless or welded shell, whichever is applicable, of the same diameter and material and determined by 2.1.

4.2 Shape factors for dished ends

4.2.1 The shape factor, K, to be used in 4.1.1 is to be obtained from the curves in Fig. 10.4.1, and depends on the ratio of height to diameter $\frac{H}{D_o}$.

4.2.2 The lowest curve in the series provides the factor, K, for plain (i.e. unpierced) ends. For lower values of $\frac{H}{D_o}$, K depends upon the ratio of thickness to diameter, $\frac{t}{D_o}$, as well as on the ratio $\frac{H}{D_o}$, and a trial calculation may be necessary to arrive at the correct value of K.

4.3 Dished ends with unreinforced openings

4.3.1 Openings in dished ends may be circular, obround or approximately elliptical.

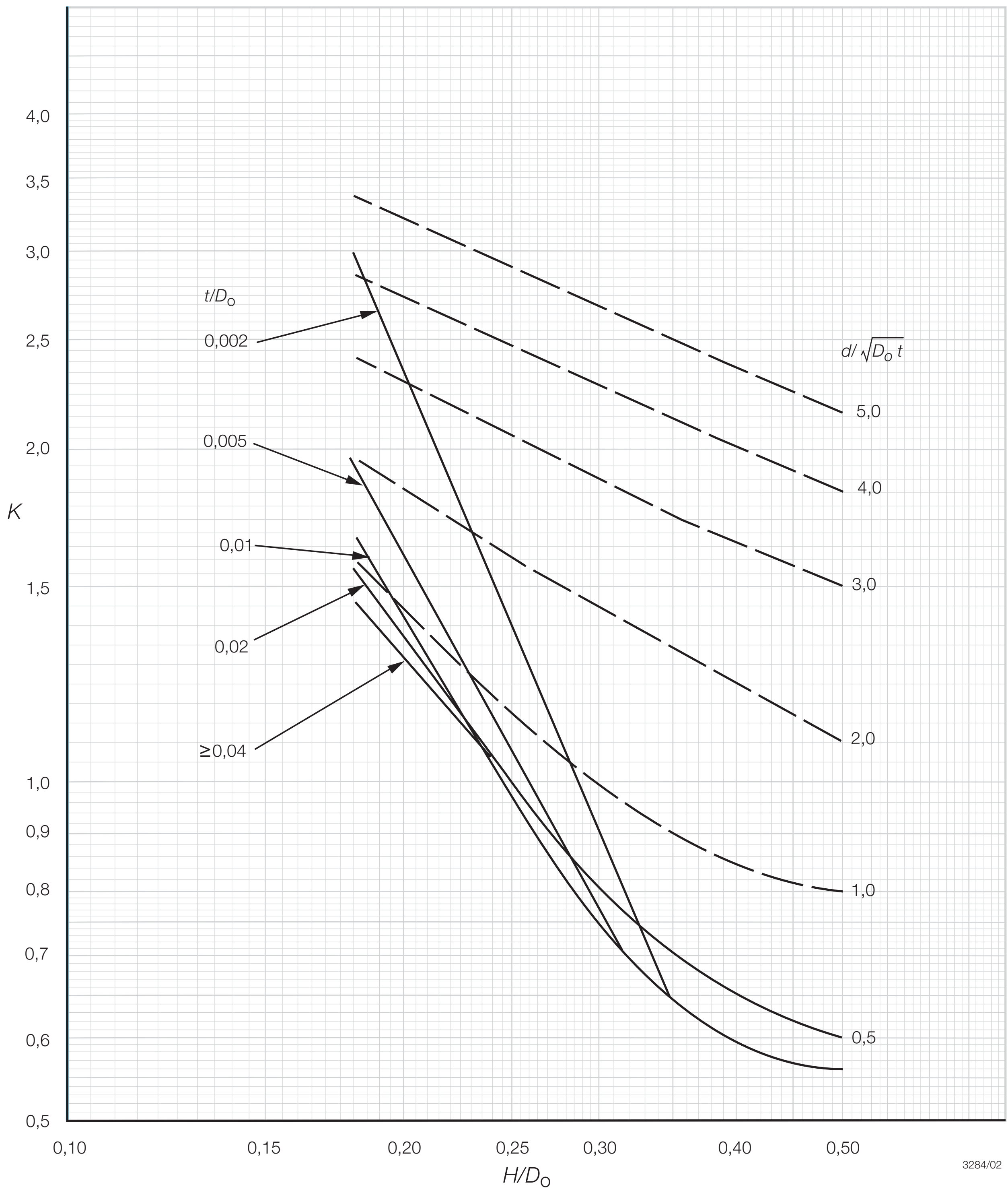


Fig. 10.4.1 Shape factor

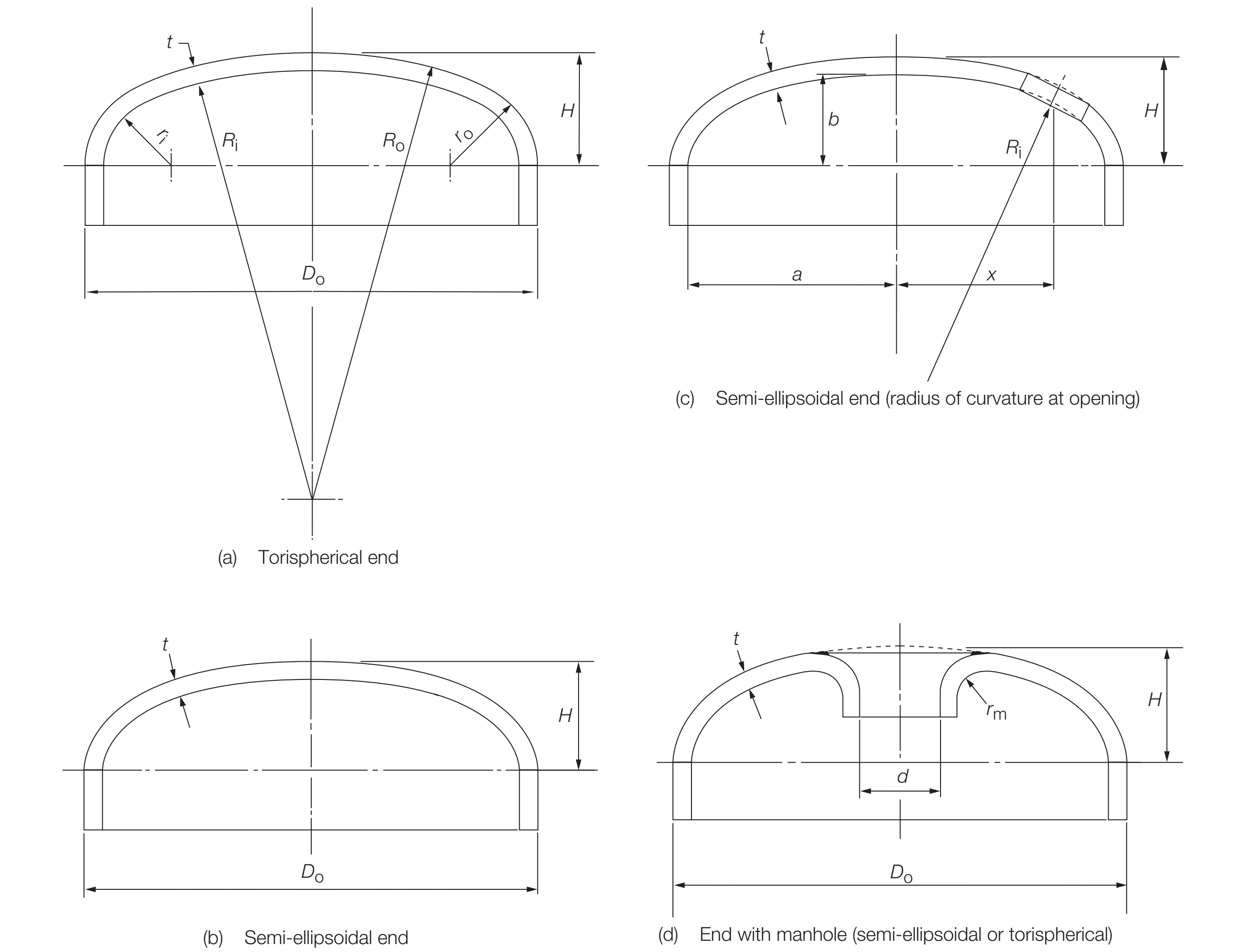


Fig. 10.4.2 Typical dished ends

4.3.2 The upper curves in Fig. 10.4.1 provide values of *K*, to be used in 4.1.1, for ends with unreinforced openings. The selection of the correct curve depends on the value $\frac{d}{\sqrt{D_o t}}$ and trial calculation is necessary to select the correct curve,

where

d = the diameter of the largest opening in the end plate, in mm (in the case of an elliptical opening, the larger axis of the ellipse)

t = minimum thickness, after dishing, in mm

D_o = outside diameter of dished end, in mm.

4.3.3 The following requirements must in any case be satisfied:

$$\frac{t}{D_o} \leq 0{,}1$$

$$\frac{d}{D_o} \leq 0{,}7.$$

4.3.4 From Fig.10.4.1 for any selected ratio of $\frac{H}{D_o}$ the curve for unpierced ends gives a value for $\frac{d}{\sqrt{D_o t}}$ as well as for *K*. Openings giving a value of $\frac{d}{\sqrt{D_o t}}$ not greater than the value so obtained may thus be pierced through an end designed as unpierced without any increase in thickness.

4.4 Flanged openings in dished ends

4.4.1 The requirements in 4.3 apply equally to flanged openings and to unflanged openings cut in the plate of an end. No reduction may be made in end plate thickness on account of flanging.

4.4.2 Where openings are flanged, the radius, r_m of the flanging is to be not less than 25 mm, *see* Fig. 10.4.2(d). The thickness of the flanged portion may be less than the calculated thickness.

4.5 Location of unreinforced and flanged openings in dished ends

4.5.1 Unreinforced and flanged openings in dished ends are to be so arranged that the distance from the edge of the hole to the outside edge of the plate and the distance between openings are not less than those shown in Fig. 10.4.3.

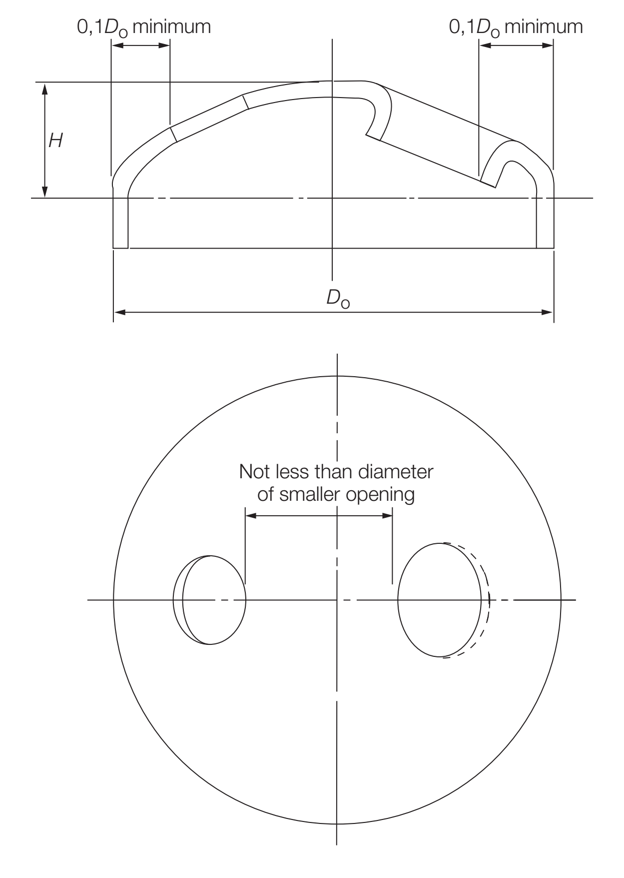


Fig. 10.4.3 Opening in dished ends

4.6 Dished ends with reinforced openings

4.6.1 Where it is desired to use a large opening in a dished end of less thickness than would be required by 4.3, the end is to be reinforced. This reinforcement may consist of a ring or standpipe welded into the hole, or of reinforcing plates welded to the outside and/or inside of the end in the vicinity of the hole, or a combination of both methods, *see* Fig. 10.4.4. Forged reinforcements may be used.

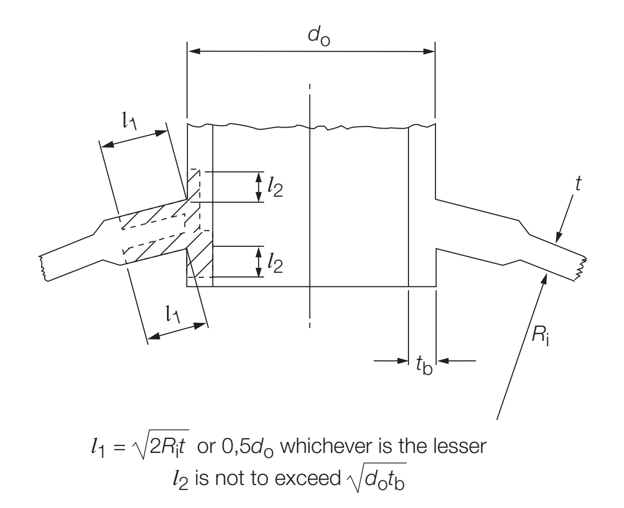


Fig. 10.4.4 Limits of reinforcement

4.6.2 Reinforcing material with the following limits may be taken as effective reinforcement:

(a) The effective width, l_1 of reinforcement is not to exceed $\sqrt{2R_i\, t}$ or 0,5d_o whichever is the lesser.

(b) The effective length, l_2 of a reinforcing ring is not to exceed $\sqrt{d_o\, t_b}$

where

R_i = the internal radius of the spherical part of a torispherical end, in mm, or

R_i = internal radius of the meridian of the ellipse at the centre of the opening, of a semi-ellipsoidal end, in mm, and is given by the following formula:

$$\frac{[a^4 - x^2\,(a^2 - b^2)]^{\ 3/2}}{a^4\, b}$$

where

a, b and x are shown in Fig. 10.4.2(c)

d_o = external diameter of ring or standpipe, in mm

l_1 and l_2 are shown in Fig. 10.4.4

t_b = actual thickness of ring or standpipe, in mm.

4.6.3 The shape factor, K, for a dished end having a reinforced opening can be read from Fig. 10.4.1 using the value obtained from:

$$\frac{d_o - \dfrac{A}{t}}{\sqrt{D_o\, t}} \quad \text{instead of from} \quad \frac{d}{\sqrt{D_o\, t}}$$

where

A = the effective cross-sectional area of reinforcement and is to be twice the area shown shaded on Fig. 10.4.4.

As in 4.3, a trial calculation is necessary in order to select the correct curve.

4.6.4 The area shown in Fig. 10.4.4 is to be obtained as follows:

- Calculate the cross-sectional area of reinforcement both inside and outside the end plate within the length, l_1
- plus the full cross-sectional area of that part of the ring or standpipe which projects inside the end plate up to a distance, l_2

- plus the full cross-sectional area of that part of the ring or standpipe which projects outside the internal surface of the end plate up to a distance, l_2 and deduct the sectional area which the ring or standpipe would have if its thickness were as calculated in accordance with 7.1.

4.6.5 If the material of the ring or the reinforcing plates has an allowable stress value lower than that of the end plate, then the effective cross-sectional area, *A*, is to be multiplied by the ratio:

$$\frac{\text{allowable stress of reinforcing plate at design temperature}}{\text{allowable stress of end plate at design temperature}}$$

4.7 Torispherical dished ends with reinforced openings

4.7.1 If an opening and its reinforcement are positioned entirely within the crown section, the compensation requirements are to be as for a spherical shell, using the crown radius as the spherical shell radius. Otherwise the requirements of 4.6 are to be applied.

Section 5
Conical ends subject to internal pressure

5.1 General

5.1.1 Conical ends and conical reducing sections, as shown in Fig. 10.5.1, are to be designed in accordance with the equations given in 5.2.

5.1.2 Connections between cylindrical shell and conical sections and ends should preferably be by means of a knuckle transition radius. Typical permitted details are shown in Fig. 10.5.1. Alternatively, conical sections and ends may be butt welded to cylinders without a knuckle radius where the change in angle of slope, ψ, between the two sections under consideration does not exceed 30°.

5.1.3 Conical ends may be constructed of several ring sections of decreasing thickness, as determined by the corresponding decreasing diameter.

5.2 Minimum thickness

5.2.1 The minimum thickness, *t*, of cylinder, knuckle and conical section at the junction and within the distance, *L*, from the junction is to be determined by the following formula:

$$t = \frac{p\,D_o\,K}{20\sigma\,J} + 0{,}75 \text{ mm}$$

where

t, p, σ and J are as defined in 1.2

K = a factor, taking into account the stress in the knuckle, *see* Table 10.5.1.

D_o = outside diameter, in mm, of the conical section or end, *see* Fig. 10.5.1.

5.2.2 If the distance of a circumferential seam from the knuckle or junction is not to be less than *L*, then *J* is to be taken as 1,0; otherwise *J* is to be taken as the weld joint factor appropriate to the circumferential seam,

where

L = distance, in mm, from the knuckle or junction within which meridional stresses determine the required thickness, *see* Fig. 10.5.1

$$= 0{,}5\sqrt{\frac{D_o\,t}{\cos\psi}}$$

r_i = inside radius of transition knuckle, in mm, which is to be taken as $0{,}01D_c$ in the case of conical sections without knuckle transition.

ψ = difference between angle of slope of two adjoining conical sections, *see* Fig. 10.5.1.

5.2.3 The minimum thickness, *t*, of those parts of conical sections not less than a distance, *L*, from the junction with a cylinder or other conical section is to be determined by the following formula:

$$t = \frac{p\,D_c}{(20\sigma\,J - p)}\;\frac{1}{\cos\alpha} + 0{,}75 \text{ mm}$$

where

D_c = inside diameter, in mm of conical section or end at the position under consideration, *see* Fig. 10.5.1

$\alpha, \alpha_1, \alpha_2$ = angle of slope of conical section (at the point under consideration) to the vessel axis, *see* Fig. 10.5.1.

5.2.4 The greater of the two thicknesses determined by the formulae in 5.2.1 and 5.2.3 is to apply at the junction or knuckle and within the limits of reinforcement.

Table 10.5.1 Values of *K* as a function of ψ and r_i/D_o

ψ	Values of *K* for r_i/D_o ratios of 0,01	0,02	0,03	0,04	0,06	0,08	0,10	0,15	0,20	0,30	0,40	0,50
10°	0,70	0,65	0,60	0,60	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55
20°	1,00	0,90	0,85	0,80	0,70	0,65	0,60	0,55	0,55	0,55	0,55	0,55
30°	1,35	1,20	1,10	1,00	0,90	0,85	0,80	0,70	0,65	0,55	0,55	0,55
45°	2,05	1,85	1,65	1,50	1,30	1,20	1,10	0,95	0,90	0,70	0,55	0,55
60°	3,20	2,85	2,55	2,35	2,00	1,75	1,60	1,40	1,25	1,00	0,70	0,55
75°	6,80	5,85	5,35	4,75	3,85	3,50	3,15	2,70	2,40	1,55	1,00	0,55

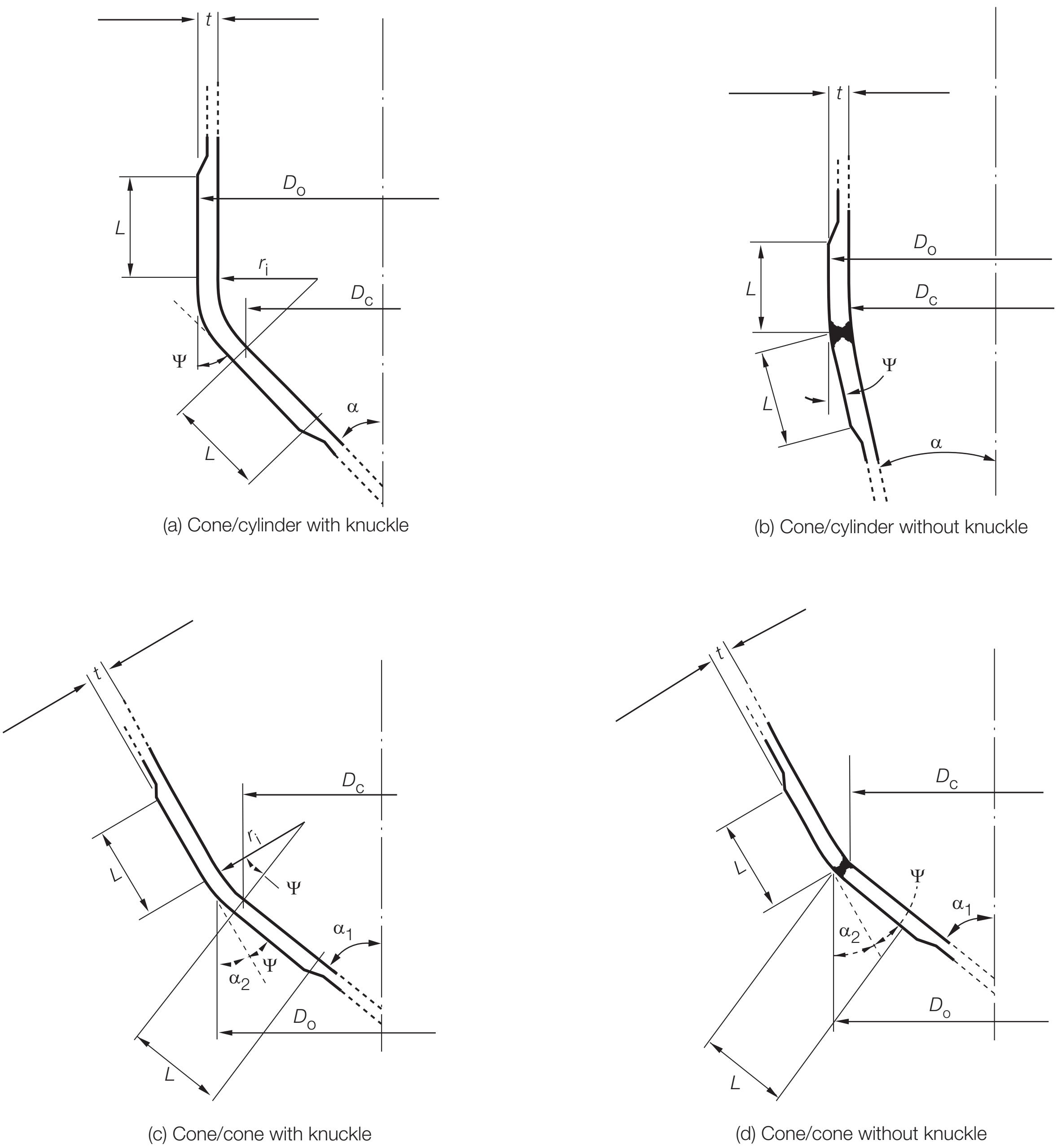


Fig. 10.5.1 Conical ends and conical reducing sections

5.2.5 The thickness of conical sections having an angle of inclination to the vessel axis of more than 75° is to be determined as for a flat plate.

Section 6 Standpipes and branches

6.1 Minimum thickness

6.1.1 The minimum wall thickness of standpipes and branches is to be not less than that determined by 7.1 increased by the addition of a corrosion allowance of 0,75 mm, making such additions as may be necessary on account of bending, static loads and vibration. The wall thickness, however, is to be not less than:

$$t = 0{,}015D_o + 3{,}2 \text{ mm}$$

This thickness need only be maintained for a length, L, from the outside surface of the vessel, but need not extend past the first connection, butt weld or flange, where:

$$L = 3{,}5\sqrt{D_o\, t} \text{ mm}$$

where

t and D_o are as defined in 1.2.

6.1.2 For boilers having a working pressure exceeding 50 bar and safety valves of full lift or full bore type, the thickness of the branch pipe carrying the superheater or drum safety valves is to be not less than:

$$t = \frac{1}{\sigma}\left[1{,}7d + \frac{DWK}{1{,}3d^2}\right] \text{ mm}$$

where

t and σ are as defined in 1.2
d = inside diameter of branch, in mm
D = inside diameter of safety valve discharge, in mm
K = 2 for superheater safety valves
= 1 for drum safety valves
W = total valve throughput, in kg/h.

6.1.3 The offset from the centreline of the waste steam pipe to the centreline of the safety valve is not to exceed four times the outside diameter of the safety valve discharge pipe. The waste steam pipe system is to be supported and arrangements made for expansion such that no direct loading is imposed on the safety valve chests and the effects of vibration are to be minimised.

6.1.4 The pipe or header which carries the superheater safety valve is to be suitably thickened but is to be not less than the thickness required for the branch for a distance of $\sqrt{D_2\, t}$ on either side of the opening

where

t = thickness required for the branch
D_2 = inside diameter of the pipe or header.

6.1.5 Except as required by 6.1.4, in no case need the wall thickness exceed the minimum shell thickness as required by 2.1, 3.1 or 4.1 as applicable.

6.1.6 Where a standpipe or branch is connected by screwing, the thickness is to be measured at the root of the thread.

6.1.7 For boiler, superheater or economiser tubes, the minimum thickness of the drum or the header connection or tube stub is to be calculated as part of the tube in accordance with 7.1.

Section 7 Boiler tubes subject to internal pressure

7.1 Minimum thickness

7.1.1 The minimum wall thickness of straight tubes subject to internal pressure is to be determined by the following formula:

$$t = \frac{p\, D_o}{20\sigma + p} \text{ mm}$$

where

t, p, D_o and σ are as defined in 1.2.

NOTES

1. Provision must be made for minus tolerances where necessary and also in cases where abnormal corrosion or erosion is expected in service. For bending allowances, *see* 7.2.
2. Thickness is in no case to be less than the minimum shown in Table 10.7.1.

Table 10.7.1 Minimum thickness of tubes

Nominal outside diameter of tube, in mm	Minimum thickness. in mm
≤ 38	1,75
> 38 > 50	2,16
≤ 50 ≤ 70	2,40
> 70 ≤ 75	2,67
> 75 ≤ 95	3,05
> 95 ≤ 100	3,28
> 100 ≤ 125	3,50

7.1.2 The minimum thickness of boiler, superheater, reheater and economiser tubes is to be determined by using the design stress appropriate to the mean wall temperature, which will be considered to be the metal temperature. Unless it is otherwise agreed between the manufacturer and LR, the metal temperature used to decide the value of σ for these tubes is to be determined as follows:

(a) The calculation temperature for boiler tubes is to be taken as not less than the saturated steam temperature, plus 25°C for tubes mainly subject to convection heat, or plus 50°C for tubes mainly subject to radiant heat.
(b) The calculation temperature for superheater and reheater tubes is to be generally taken as not less than the steam temperature expected in the part being considered, plus 35°C for tubes mainly subject to convection heat. For tubes mainly subject to radiant heat the calculation temperature is generally to be taken as not less than the steam temperature expected in the part being considered, plus 50°C, but the actual metal temperature expected is to be stated when submitting plans.
(c) The calculation temperature for economiser tubes is to be taken as not less than 35°C in excess of the maximum temperature of the internal fluid.

7.1.3 The minimum thickness of downcomer tubes and pipes which form an integral part of the boiler and which are not exposed to combustion gases is to comply with the requirements for steam pipes.

7.2 Tube bending

7.2.1 Where boiler, superheater, reheater and economiser tubes are bent, the resulting thickness of the tubes at the thinnest part is to be not less than that required for straight tubes, unless it can be demonstrated that the method of forming the bend results in no decrease in strength at the bend. The manufacturer is to demonstrate in connection with any new method of tube bending that this condition is satisfied.

7.2.2 Tube bending, and subsequent heat treatment, where necessary, is to be carried out as to ensure that residual stresses do not adversely affect the strength of the tube for the design purpose intended.

■ *Cross-references*

For details of manholes, sight holes and doors, *see* 14.1.
For details of tube holes and fitting of tubes, *see* 14.6.

■ *Section 8* **Headers**

8.1 Circular section headers

8.1.1 The minimum thickness of circular section headers is to be calculated in accordance with the formula for cylindrical shells in 2.1.

8.2 Rectangular section headers

8.2.1 The thickness of the flat walls of rectangular section headers is to be determined at the centre of the sides, at all the lines of holes and at the corners. The minimum required is to be the greatest thickness determined by the following formula:

$$t = \frac{pn}{20\sigma J} + \sqrt{\frac{0{,}4Yp}{\sigma J_1}} + 0{,}75 \text{ mm}$$

where

t, p and σ are as defined in 1.2

n = one half of the internal width of the wall perpendicular to that under consideration, in mm, *see* Fig. 10.8.1(b)

J = ligament efficiency for membrane stresses determined in accordance with 8.2.3

J_1 = ligament efficiency for bending stresses determined in accordance with 8.2.3.

Y = a coefficient determined in accordance with 8.2.2. In all cases if the value of Y is negative, the sign is to be ignored.

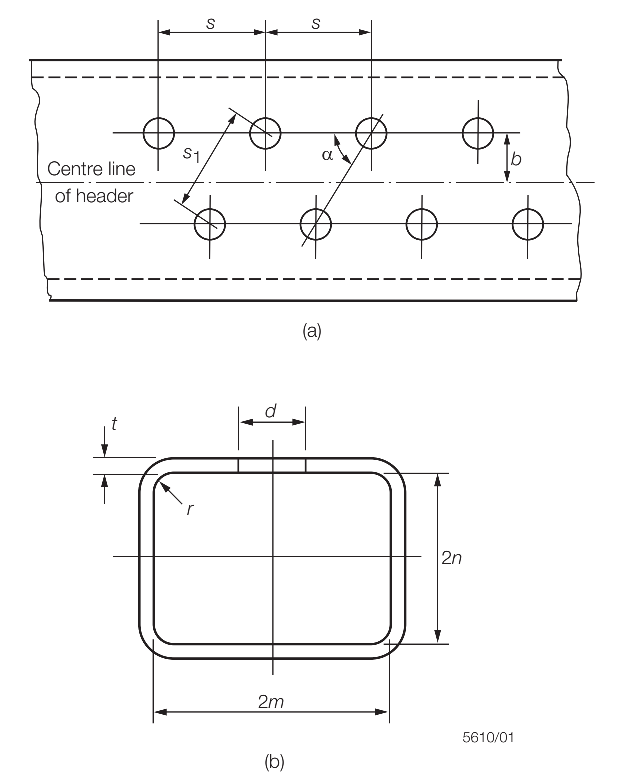


Fig. 10.8.1 Rectangular section headers

8.2.2 The coefficient Y for use in 8.2.1 is to be determined as follows:

(a) at the centre of the side with internal width, $2m$:

$$Y = \frac{1}{3}\left(\frac{m^3 + n^3}{m + n}\right) - \frac{1}{2}\ m^2$$

where

m = one half of the internal width of the wall under consideration, in mm, *see* Fig. 10.8.1(b)

(b) at a line of holes parallel to the longitudinal axis of the header on the wall of width, $2m$:

$$Y = \frac{1}{3}\left(\frac{m^3 + n^3}{m + n}\right) - \frac{m^2 - b^2}{2}$$

where

b = distance from the centre of the holes to the centreline of the wall, in mm, *see* Fig. 10.8.1(a)

(c) to check the effect of the off-set on a staggered hole arrangement where the holes are positioned equidistant from the centreline of the wall:

$$Y = \cos\alpha\left\{\frac{1}{3}\left(\frac{m^3 + n^3}{m + n}\right) - \frac{m^2}{2}\right\}$$

where

α = the angle subtended by the diagonal ligament on the longitudinal ligament, *see* Fig.10.8.1(a)

(d) at the corners:

$$Y = \frac{1}{3}\left(\frac{m^3 + n^3}{m + n}\right)$$

8.2.3 The ligament efficiencies J and J_1 are to be determined as follows:

(a) for a line of holes parallel to the longitudinal axis of the header:

$$J = \frac{s - d}{s}$$

Symbols are as defined in 8.2.4.

(b) for the diagonals:

$$J = \frac{s_1 - d}{s_1}$$

Symbols are as defined in 8.2.4.

(c) for a line of holes parallel to the longitudinal axis of the header:

$$J_1 = \frac{s - d}{s} \text{ when } d < 0{,}6m$$

or

$$J_1 = \frac{s - 0{,}6m}{s} \text{ when } d \geq 0{,}6m$$

Symbols are as defined in 8.2.4.

(d) for the diagonals:

$$J_1 = \frac{s_1 - d}{s_1} \text{ when } d < 0{,}6m$$

or

$$J_1 = \frac{s_1 - 0{,}6m}{s_1} \text{ when } d \geq 0{,}6m$$

Symbols are as defined in 8.2.4.

8.2.4 Symbols, as used in 8.2.3, are defined as follows:

d = diameter of the hole in the header, in mm

m, s and s_1, in mm, are as shown in Fig. 10.8.1.

8.2.5 In the case of elliptical holes the value of d to be used in the equations for J and J_1 is to be the inside dimension of the hole measured parallel to the longitudinal axis of the header. For evaluating the two limiting values of d in the equations for J_1, the value of d is to be the inside dimension of the hole measured perpendicular to the longitudinal axis of the header.

8.2.6 The internal corner radius, r, is to be not less than one third of the mean of the nominal thicknesses of the two sides, but in no case to be less than 6,5 mm.

8.3 Toroidal furnace headers

8.3.1 The minimum thickness of a toroidal header forming the lower end of a waterwall furnace, and supporting the weight of the boiler and water, is to be determined by the following formula:

$$t = A + \sqrt{A^2 + \frac{4M}{JS\sigma}} + 0{,}75 \text{ mm}$$

where

$$A = \frac{pr}{30J\sigma} \text{ mm}$$

t, p and σ are as defined in 1.2

d_e = equivalent diameter of the tube hole in accordance with 2.3

r = inside radius of toroid circular cross-section, in mm, *see* Fig. 10.8.3

J = ligament efficiency of tube holes around toroid

$$= \frac{S - d_e}{S}$$

S = pitch of tubes around the toroid, in mm

$$M = \frac{Wr}{3} - \frac{pd^2 r}{40} \text{ Nmm}$$

where

W = imposed loading on each water wall tube due to the weight of the boiler and water, in N

d = minimum diameter of the tube hole in the toroid, in mm

The calculation is to be performed at design pressure using the allowable stress at saturation temperature, and also at zero pressure using the allowable stress at 100°C.

8.4 Header ends

8.4.1 The shape and thickness of ends forged integrally with the bodies of headers are to be the subject of special consideration.

8.4.2 Where sufficient experience of previous satisfactory service of headers with integrally forged ends cannot be shown, the suitability of a proposed form of end is to be proved in accordance with the provisions of 1.10.

8.4.3 Ends attached by welding are to be designed as follows:

- Dished ends: these are to be in accordance with 4.1.
- Flat ends: the minimum thickness of flat end plates is to be determined by the following formula:

$$t = d_i \sqrt{\frac{pC}{\sigma}} + 0{,}75 \text{ mm}$$

where

p and σ are as defined in 1.2.

t = minimum thickness of end plate, in mm

d_i = internal diameter of circular header or least width between walls of rectangular header, in mm

C = a constant depending on method of end attachment, *see* Fig. 10.8.2.

- For end plates welded as shown in Fig. 10.8.2(a):

C = 0,019 for circular headers

= 0,032 for rectangular headers.

- For end plates welded as shown in Figs. 10.8.2(b) and (c):

C = 0,028 circular headers

= 0,040 for rectangular headers.

8.4.4 Where flat end plates are bolted to flanges attached to the ends of headers, the flanges and end plates are to be in accordance with recognised pipe flange standards.

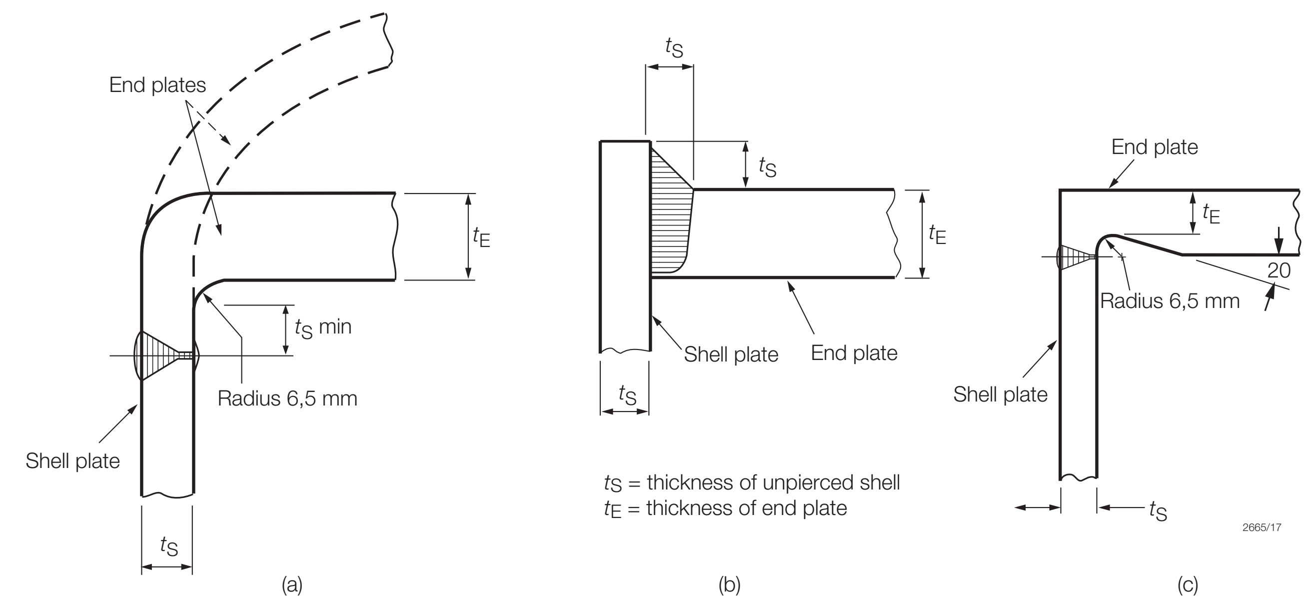


Fig. 10.8.2 Typical methods of attachment of header end closures

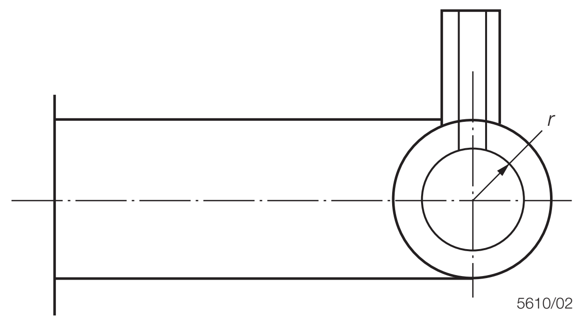


Fig. 10.8.3 Toroidal furnace headers

8.4.5 Openings in flat plates are to be compensated in accordance with Fig. 10.2.9 (a) or (b), with the value of A_1 the compensation required, calculated as follows:

$$A_1 = \frac{d_o}{2,4} t_f \text{ mm}$$

where

d_o = diameter of hole in flat plate, in mm

t_f = required thickness of the flat plate in the area under consideration, in mm, calculated in accordance with 8.4.3, 8.3.3 or 9.1.6, as applicable, without corrosion allowance

Limit D = $0,5d_o$.

Section 9
Flat surfaces and flat tube plates

9.1 Stayed flat surfaces

9.1.1 Where flat end plates are flanged for connection to the shell, the inside radius of flanging is to be not less than 1,75 times the thickness of the plate, with a minimum of 38 mm.

9.1.2 Where combustion chamber or firebox plates are flanged for connection to the wrapper plate, the inside radius of flanging is to be equal to the thickness of the plate, with a minimum of 25 mm.

9.1.3 Where unflanged flat plates are connected to the shell by welding, typical methods of attachment are shown in Fig. 10.9.1. Similar forms of attachment may be used where unflanged combustion chamber or firebox plates are connected to the wrapper plate by welding.

9.1.4 Where the flange curvature is a point of support, this is to be taken at the commencement of curvature, or at a line distant 3,5 times the thickness of the plate from the outside of the plate, whichever is nearer to the flange.

9.1.5 Where a flat plate is welded directly to a shell or wrapper plate, the point of support is to be taken at the inside of the shell or wrapper plate.

9.1.6 The thickness, t, of those portions of flat plates supported by stays and around tube nests is to be determined by the following formula:

$$t = Cd \sqrt{\frac{p}{\sigma}} + 0,75 \text{ mm}$$

where

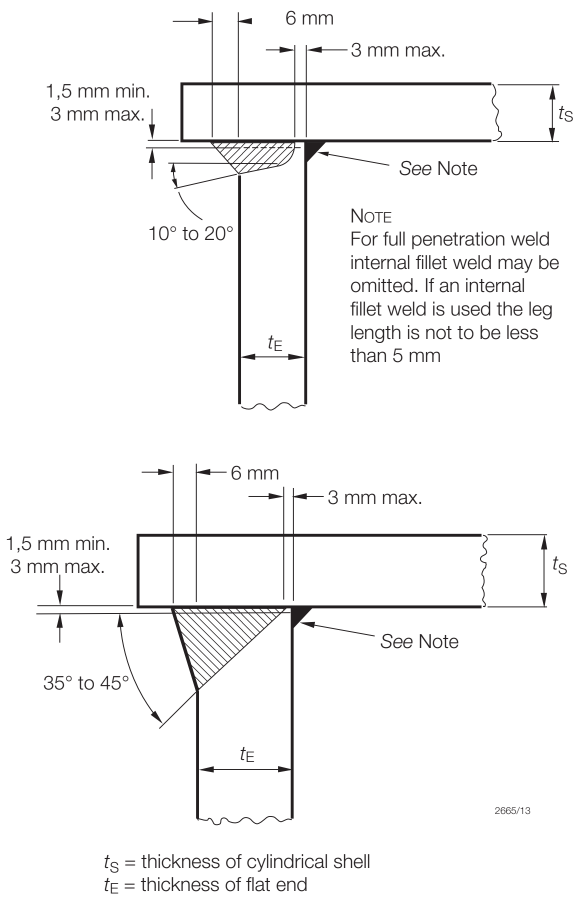


Fig. 10.9.1
Typical attachment of unflanged flat end plates to shell

t, *p* and σ are as defined in 1.2

d = diameter of the largest circle which can be drawn through at least three points of support. At least one point of support must lie on one side of any diameter of the circle

C = a constant, dependent on the method of support as detailed in 9.1.7. Where various forms of support are used, *C* is to be the mean of the values for the respective methods adopted.

9.1.7 The value of *C* in the formula in 9.1.6 is to be as follows:

(a) Where plain bar stays are strength welded into the plates as shown in Fig. 10.9.2
C = 0,134

(b) Where plain bar stays pass through holes in the plates and are fitted on the outside with washers as shown in Fig. 10.9.3
C = 0,12 where the diameter of the washer is 3,5 times the diameter of the stay
C = 0,113 where the diameter of the washer is 0,67 times the pitch of the stays.

(c) Where the flat plate is flanged for attachment to the shell, flue, furnace or wrapper or, alternatively, is welded directly to shell, flue, furnace or wrapper, *see* 9.1.4 and 9.1.5:
C = 0,113

(d) Where the support is a gusset stay
C = 0,134

(e) Where the support is a tube secured as shown in Fig. 10.9.4
C = 0,144.

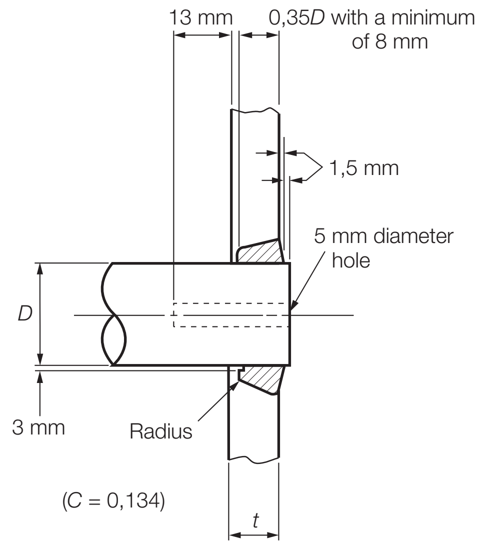
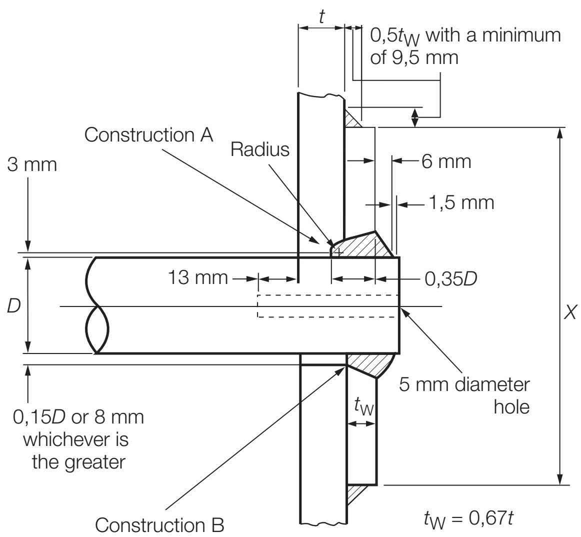


Fig. 10.9.2
Typical attachment of firebox, combustion chamber stays and bar stays

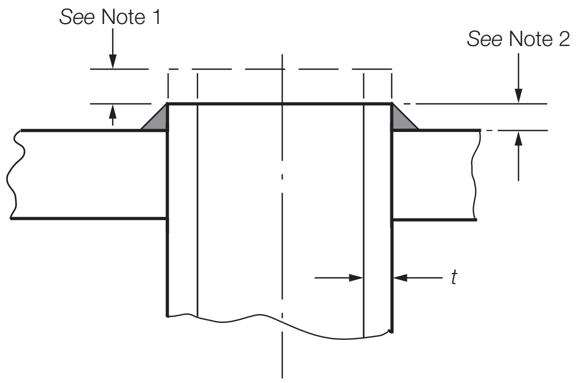


Method of construction 'A' or 'B' may be used, except where t_W < 0,35*D*, construction 'A' is to be used.

where *X* = 3,5*D*, *C* = 0,12;
where *X* = 0,67 x pitch of stays, *C* = 0,113

Fig. 10.9.3 Typical attachment of bar stays

9.1.8 Where tubes are fixed by expanding only, sufficient tubes welded at both ends in accordance with Fig. 10.9.4 are to be provided within the tube nest to comply with 9.1.6, to carry the flat plate loading within the tube nest. Tubes welded in accordance with Fig. 10.9.4 are also to be provided in the boundary rows in sufficient numbers to carry the flat plate loading outside the tube areas.



NOTE
1. The ends of the tubes are to be dressed flush with the welds when exposed to flame. When not exposed to flame the ends of the tubes may extend a maximum of 10 mm beyond the weld.
2. 3 mm minimum, but stress in weld due to nominal flat plate load carried by the tube not to exceed 70 N/mm^2. An equivalent recessed weld may be used.
3. Weld stress area is to be based on the weld throat area.

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Fig. 10.9.4 Detail of weld for tube

9.1.9 In the case of small boilers with a single tube nest of expanded tubes which does not exceed an area of 0,65 m^2, welded tubes need not be fitted provided the tubes are beaded at the inlet end. In this instance the support afforded by the expanded tubes is not to be taken to extend beyond the line enclosing the outer surfaces of the tubes except that, between the outside of the nest and the attachment of the end plate to shell, there may be an unsupported width equal to the flat plate margin, as given by the formula in 9.4.1. The required tube plate thickness within such a tube nest is to be determined using the formula in 9.1.6, where:

C = 0,154
d = four times the mean pitch, in mm, of the expanded tubes in the nest.

9.1.10 The thickness, t, of any tube plate in the tube area is to be not less than that required for the surrounding plate determined by 9.1.6 and in no case less than:

(a) 12,5 mm where the diameter of the tube hole does not exceed 50 mm, or
(b) 14 mm where the diameter of the tube hole is greater than 50 mm.

9.1.11 Alternative methods of support will be specially considered.

9.1.12 The spacing of tube holes is to be such that the minimum width, b, in mm of any ligament between tube holes is not less than:

for expanded tubes:
$b = 0{,}125d + 12{,}5$ mm
for welded tubes:
$b = 0{,}125d + 8$ mm
where
d = diameter of the hole drilled in the plate, in mm.

9.1.13 Where a flat plate has a manhole or sight hole and the opening is strengthened by flanging, the total depth, H, of the flange, measured from the outer surface of the plate, is to be not less than:

$H = \sqrt{t\,W}$

where
t = thickness of plate, in mm
H = depth of flange, in mm
W = minor axis of manhole or sight hole, in mm.

9.1.14 Where the flat top plates of combustion chambers are supported by welded-on girders, the equation in 9.1.6 is to apply as follows:

(a) In the case of welded-on girders provided with waterways
C = 0,144
$d = \sqrt{X^2 + Y^2}$
where
X = width of waterway in the girder plus the thickness of the girder, in mm
Y = pitch of girders, in mm.

(b) In the case of continuously welded-on girders
C = 0,175
$d = D$
where
D = distance between inside faces of girders, in mm.

9.2 Combustion chamber tube plates under compression

9.2.1 The thickness of combustion chamber tube plates under compression due to the pressure on the top plate, based on a compressive stress not exceeding 96 N/mm^2 is to be determined by the following formula:

$$t = \frac{pWs}{1930\,(s - d)} \text{ mm}$$

where
t and p are as defined in 1.2
d = internal diameter of the plain tubes, in mm
s = pitch of tubes, in mm, measured horizontally where tubes are chain pitched, or diagonally where the tubes are staggered pitched and the diagonal pitch is less than the horizontal pitch
W = internal width of the combustion chamber, in mm, measured from tube plate to back chamber plate.

9.3 Girders for combustion chamber top plates

9.3.1 The formula in 9.3.2 is applicable to plate girders welded to the top combustion chamber plate by means of a full penetration weld.

9.3.2 The thickness of steel plate girders supporting the tops of combustion chambers is to be determined by the following formula:

$$t = \frac{0{,}32p\, l^2\, s}{d^2\, R_{20}} \text{ mm}$$

where

t and p are as defined in 1.2
d = effective depth of girder, in mm
l = length of girder measured internally from tube plate to back chamber plate, in mm
s = pitch of the girders, in mm
R_{20} = specified minimum tensile strength of the girder plate, in N/mm^2.

9.4 Flat plate margins

9.4.1 The width of margin, b, of a flat plate which may be regarded as being supported by the shell, furnaces or flues to which the flat plate is attached is not to exceed that determined by the following formula:

$$b = C\,(t - 0{,}75)\sqrt{\frac{\sigma}{p}} \text{ mm}$$

where

p and σ are as defined in 1.2
t = thickness of the flat plate, in mm
b = width of margin, in mm
C = 3,12.

9.4.2 Where an unflanged flat plate is welded directly to the shell, furnaces or flues and it is not practicable to effect the full penetration weld from both sides of the flat plate, the constant C used in the formula in 9.4.1 is to be:
C = 2,38.

9.4.3 In the case of plates which are flanged, the margin is to be measured from the commencement of curvature of flanging, or from a line 3,5 times the thickness of the plate measured from the outside of the plate, whichever is nearer to the flange.

9.4.4 Where the flat plate is not flanged for attachment to the shell, furnaces or flues, the margin is to be measured from inside of the shell or the outside of the furnaces or flues, whichever is applicable.

9.4.5 In no case is the diameter D, in mm, of the circle forming the boundary of the margin supported by the uptake of a vertical boiler to be greater than determined by the following formula:

$$D = \sqrt{\frac{345A}{p} + d^2}$$

where

p is as defined in 1.2
d = external diameter of uptake, in mm
d_i = internal diameter of uptake, in mm
A = cross-sectional area of the uptake tube material, i.e. $\frac{\pi}{4}\,(d^2 - d_i^2)$ mm^2.

Section 10
Flat plates and ends of vertical boilers

10.1 Tube plates of vertical boilers

10.1.1 Where vertical boilers have a nest or nests of horizontal tubes, so that there is direct tension on the tube plates due to the vertical load on the boiler ends or to their acting as horizontal ties across the shell, the thickness of the tube plates in way of the outer rows of tubes is to be determined by the following formula:

$$t = \frac{pD}{5J\, R_{20}} + 0{,}75 \text{ mm}$$

where

t and p are as defined in 1.2
D = twice the radial distance of the centre of the outer row of tube holes from the axis of the shell, in mm
J = efficiency of ligaments between tube holes in the outer vertical rows (expressed as a fraction)
$= \frac{s - d}{s}$
R_{20} = specified minimum tensile strength of tube plate, in N/mm^2

where

d = diameter of tube holes, in mm
s = vertical pitch of tubes, in mm.

10.1.2 Each alternate tube in the outer vertical rows of tubes is to be a tube welded at both ends as shown in Fig. 10.9.4. Further, the arrangement of tubes in the nests is to be such that the thickness of the tube plates meets the requirements of 9.1.

10.1.3 Where the vertical height of the tube plates between the top and bottom shelves exceeds 0,65 times the internal diameter of the boiler, the staying of the tube plates, and the scantlings of the tube plates and shell plates to which the sides of the tube plates are connected, will require to be specially considered. It is recommended, however, that for this type of boiler the vertical height of the tube plates between the top and bottom shelves should not exceed 1,25 times the internal diameter of the boiler.

10.2 Horizontal shelves of tube plates forming part of the shell

10.2.1 For vertical boilers of the type referred to in 10.1, in order to withstand vertical load due to pressure on the boiler ends, the horizontal shelves of the tube plates are to be supported by gussets in accordance with the following formula:

$$C = \frac{AD_i\, p}{t}$$

where

p = design pressure, in bar
t = thickness of the tube plate, in mm
A = maximum horizontal dimension of the shelf from the inside of the shell plate to the outside of the tube plate, in mm
D_i = inside diameter of the boiler, in mm.

10.2.2 For the combustion chamber tube plate the minimum number of gussets is to be:

1 gusset, where C exceeds 255 000
2 gussets, where C exceeds 350 000
3 gussets where C exceeds 420 000.

10.2.3 For the smokebox tube plate the minimum number of gussets is to be:

1 gusset where C exceeds 255 000
2 gussets where C exceeds 470 000.

10.2.4 The shell plates to which the sides of the tube plates are connected are to be not less than 1,6 mm thicker than is required by the formula applicable to shell plates with continuous circularity, and where gussets or other stays are not fitted to the shelves, the strength of the parts of the circumferential seams at the top and bottom of these plates from the outside of one tube plate to the outside of the other, is to be sufficient to withstand the whole load on the boiler end with a factor of safety of not less than 4,5 related to R_{20} (where R_{20} is the specified minimum tensile strength of the shell plates, in N/mm^2).

10.3 Dished and flanged ends for vertical boilers

10.3.1 The minimum thickness, t, of dished and flanged ends for vertical boilers which are subject to pressure on the concave side and are supported by central uptakes is to be determined by the following formula:

$$t = \frac{pR_i}{13\sigma} + 0,75 \quad \text{mm}$$

where
t, p, R_i and σ are as defined in 1,2.

10.3.2 The inside radius of curvature, R_i, of the end plate is to be not greater than the external diameter of the cylinder to which it is attached.

10.3.3 The inside knuckle radius, r_i, *see* Fig. 10.4.2(a), of the arc joining the cylindrical flange to the spherical surface of the end is to be not less than four times the thickness of the end plate, and in no case less than 65 mm.

10.3.4 The inside radius of curvature of flange to uptake is to be not less than twice the thickness of the end plate, and in no case less than 25 mm.

10.3.5 If the dished end has a manhole, the opening is to be strengthened by flanging. The total depth, H, of the flange, measured from the outer surface of the plate on the minor axis, is to be not less than:

$$H = \sqrt{t\,W}$$

where
t = thickness of the flange, in mm
H = depth of flange, in mm
W = minor axis of the manhole, in mm.

10.4 Flat crowns of vertical boilers

10.4.1 The minimum thickness of flat crown plates of vertical boilers is to be determined as in 9,1; d and C are defined as follows:

- Where the crown is supported by an uptake only,
  d = diameter, in mm, of the largest circle which can be drawn between the connections to the shell or firebox and uptake, *see* 9.1.1 to 9.1.5
  C = 0,161
- Where bar stays are fitted in accordance with 9.1.6 and 9.1.7:
  d = diameter of the largest circle which can be drawn through at least three points of support, in mm
  C = the mean of the values for the respective points of support through which the circle passes.

■ *Section 11* Furnaces subject to external pressure

11.1 Maximum thickness

11.1.1 Furnaces, plain or corrugated, are not to exceed 22,5 mm in thickness.

11.2 Corrugated furnaces

11.2.1 The minimum thickness, t, of corrugated furnaces is to be determined by the following formula:

$$t = \frac{pD_o}{C} + 0,75 \quad \text{mm}$$

where
p is as defined in 1.2
t = thickness of the furnace plate measured at the bottom of the corrugations, in mm
C = 1060 for Fox, Morison and Deighton corrugations
= 1130 for Suspension Bulb corrugations
D_o = external diameter of the furnace measured at the bottom of the corrugations, in mm.

11.3 Plain furnaces, flue sections and combustion chamber bottoms

11.3.1 The minimum thickness, t, between points of substantial support, of plain furnaces or furnaces strengthened by stiffening rings, of flue sections and of the cylindrical bottoms of combustion chambers is to be determined by the following formulae, the greater of the two thicknesses obtained being taken:

$$t = \sqrt{\frac{pD_o\,(L + 610)}{102\,400}} + 0,75 \quad \text{mm}$$

$$t = \frac{C\,p\,D_o}{1100} + \frac{L}{320} + 0,75 \quad \text{mm}$$

where

t and p are as defined in 1.2

$C = \dfrac{2x}{x + \sigma}$ or 0,85 whichever is the greater

D_o = external diameter of the furnace, flue or combustion chamber, in mm

L = length of section between the centres of points of substantial support, in mm

x and σ are as defined in 11.7.1.

11.3.2 Where stiffeners are used for strengthening plain cylindrical furnaces, or combustion chambers, the second moment of area, I, of the stiffener is to be determined by the following formula:

$$I = \frac{pD_o^3 L}{13,3 \times 10^6} \text{ mm}^4$$

where

p is as defined in 1.2

D_o = external diameter of the furnace flue or combustion chamber, in mm

L = length of section between the centres of points of substantial support, in mm

For proportion of stiffening rings, *see* Fig. 10.11.1.

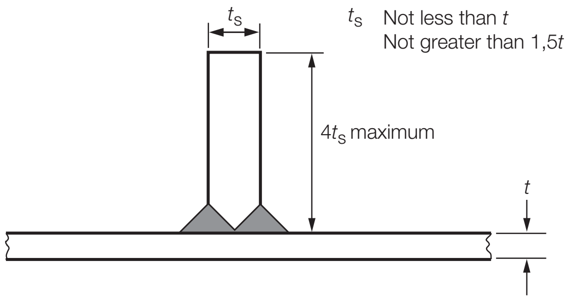
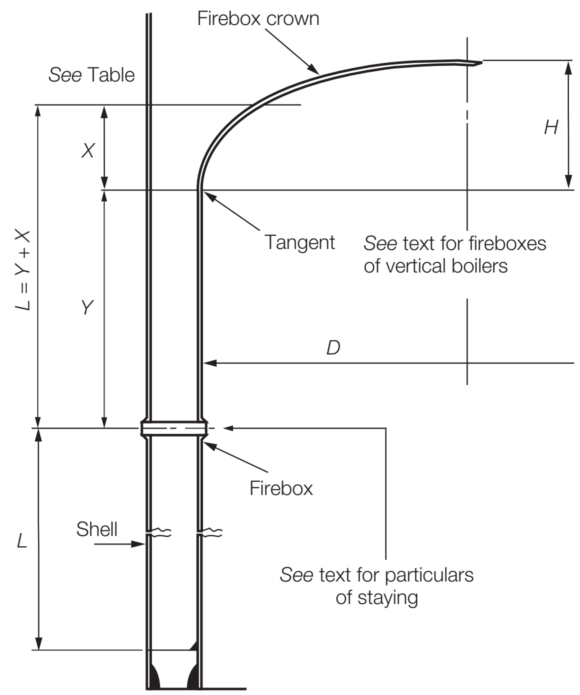
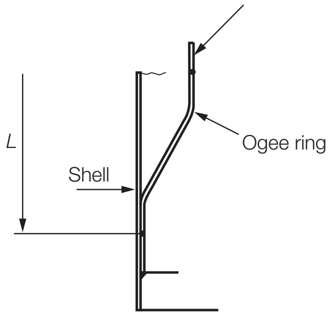


Fig. 10.11.1
Furnace, flue and combustion chamber stiffeners





H/D	X/D
0,169	0,07
0,2	0,08
0,25	0,1
0,3	0,12
0,4	0,16
0,5	0,2

Fig. 10.11.2 Effective length, *L*, for use in 11.4

11.4 Plain furnaces of vertical boilers

11.4.1 The thickness of plain furnaces not exceeding 2000 mm in external diameter is to be determined by the formulae given in 11.3.1, the greater of the two thicknesses being taken:

where

D_o = external diameter of the furnace, in mm. Where the furnace is tapered, the diameter to be taken for calculation purposes is to be the mean of that at the top and that at the bottom where it meets the substantial support from flange, ring or row of stays

L = effective length, in mm, of the furnace between the points of substantial support as indicated in Fig. 10.11.2.

11.4.2 For furnaces under 760 mm in external diameter, the thickness is to be not less than 8 mm, and for furnaces 760 mm in external diameter and over, the thickness is to be not less than 9,5 mm.

11.4.3 A circumferential row of stays connecting the furnace to the shell will be considered to provide substantial support to the furnace, provided that:

- The diameter of the stay is not less 22,5 mm or twice the thickness of the furnace, whichever is the greater.
- The pitch of the stays at the furnace does not exceed 14 times the thickness of the furnace.

11.5 Hemispherical furnaces

11.5.1 The minimum thickness, t, of unsupported hemispherical furnaces subject to pressure on the convex surface is to be determined by the following formula:

$$t = \frac{C\,p\,R_o}{608} + 0{,}75 \text{ mm}$$

where

t and p are as defined in 1.2

x and σ are as defined in 11.7.1

$C = \frac{2x}{x + \sigma}$ or 0,85 whichever is the greater

R_o = outer radius of curvature of the furnace, in mm.

11.5.2 In no case is the maximum thickness to exceed 22,5 mm, or the ratio $\frac{R_o}{t - 0{,}75}$ to exceed 100.

11.6 Dished and flanged ends for supported vertical boiler furnaces

11.6.1 The minimum thickness, t, of dished and flanged ends for vertical boiler furnaces that are subject to pressure on the convex side and are supported by central uptakes, is to be determined by the following formula:

$$t = \frac{p\,R_o}{10\sigma} + 0{,}75 \text{ mm}$$

where

t, p, R_o and σ are as defined in 1.2.

11.6.2 The inside radius of dishing and flanging are to be as required by 10.3.

11.7 Dished and flanged ends for unsupported vertical boiler furnaces

11.7.1 The minimum thickness, t, of dished and flanged ends for vertical boiler furnaces that are subject to pressure on the convex side and are without support from stays of any kind, is to be determined by the following formula, but is in no case to be less than the thickness of the firebox:

$$t = \frac{CpR_o}{660} + 0{,}75 \text{ mm}$$

where

t and p are as defined in 1.2.

x = specified minimum lower yield stress or 0,2 per cent proof stress in N/mm^2 at a temperature 90°C above the saturated steam temperature corresponding to the design pressure for carbon and carbon manganese steel with a specified minimum tensile strength of 400 N/mm^2

$C = \frac{2x}{x + \sigma}$ or 0,85 whichever is the greater

R_o = outside radius of the crown plate, in mm

$\left(\text{in no case is } \frac{R_o}{t} \text{ to exceed 88}\right)$

σ = specified minimum lower yield stress or 0,2 per cent proof stress in N/mm^2 at a temperature 90°C above the saturated steam temperature corresponding to the design pressure for the steel actually used

11.7.2 The inside radius of curvature, R_i, of the end plate is to be not greater than the external diameter of the cylinder to which it is attached.

11.7.3 The inside knuckle radius, r_i, *see* Fig.10.4.2(a), of the arc joining the cylindrical flange to the spherical surface of the end is to be not less than four times the thickness of the end plate and in no case less than 65 mm.

11.8 Ogee rings

11.8.1 The minimum thickness, t, of the ogee ring which connects the bottom of the furnace to the shell of a vertical boiler and sustains the whole vertical load on the furnace is to be determined by the following formula:

$$t = \sqrt{\frac{p\,D_i\,(D_i - D_o)}{9\,900}} + 0{,}75 \text{ mm}$$

where

t and p are as defined in 1.2

D_i = inside diameter of boiler shell, in mm

D_o = outside diameter of the lower part of the furnace where it joins the ogee ring, in mm.

11.8.2 Proposals to use a flat plate annular ring which connects the bottom of the furnace to the shell of a vertical boiler and sustains any unbalanced vertical load on the furnace will be the subject of special consideration.

11.9 Uptakes of vertical boilers

11.9.1 The minimum thickness, t, of internal uptakes of vertical boilers is to be determined by the following formulae, the greater of the two thicknesses obtained being taken:

$$t = \sqrt{\frac{p\,D_o\,(L + 610)}{102\,400}} + 4 \text{ mm}$$

$$t = \frac{p\,D_o}{1100} + \frac{L}{320} + 4 \text{ mm}$$

where

t and p are as defined in 1.2

D_o = external diameter of uptake, in mm

L = length of uptake between the centres of points of substantial support, in mm.

Section 12
Boiler tubes subject to external pressure

12.1 Tubes

12.1.1 The thickness of tubes is to be in accordance with Table 10.12.1 for the appropriate outside diameter and design pressure.

12.1.2 Tubes may be welded at both ends, welded at the inlet end and expanded at the outlet end, or expanded at both ends. In addition to expanding, tubes may be bell mouthed or beaded at the inlet end. Where tubes are welded, the weld detail is to be as shown in Fig. 10.9.4 and the tubes are to be expanded into the tube plates in addition to welding, except as permitted by 12.1.3.

12.1.3 For tubes of thickness greater than 6,0 mm, expanding in addition to welding is not required if a recessed weld of depth not less than the tube thickness is provided.

Section 13
Tubes welded at both ends and bar stays for cylindrical boilers

13.1 Loads on tubes welded at both ends and bar stays

13.1.1 Each tube or bar stay is to be designed to carry its due proportion of the load on the plates which it supports.

13.1.2 For a tube or bar stay, the net area to be supported is to be the area, in mm^2, enclosed by the lines bisecting at right angles the lines joining the stay and the adjacent points of support, less the area of any tubes or stays enclosed. In the case of a tube or bar stay in the boundary rows, the support afforded by the flat plate margin, where applicable, should be taken into account. Where flat margins overlap stays are not required.

13.1.3 The thickness of tubes welded at both ends to tube plates is to be such that the longitudinal stress due to the flat plate loading does not exceed 70 N/mm^2.

13.1.4 Tubes may be welded into the boiler after post-weld heat treatment has been carried out.

13.1.5 The permissible longitudinal stress in combustion chamber bar stays or similar stays where an end is heated by flame, is not to exceed 70 N/mm^2, and the diameter of this type of bar stay is not to be less than 19 mm.

13.1.6 The permissible longitudinal stress in longitudinal bar stays not subject to heating, is not to exceed 20 per cent of the minimum specified tensile strength, in N/mm^2, and the diameter of this type of bar stay is not to be less than 25 mm.

Table 10.12.1 Thickness of plain tubes under external pressure

Design pressure, in bar											Thickness, in mm
Outside diameter, in mm											
38	44,5	51	57	63,5	70	76	82,5	89	95	102	
–	–	–	–	–	–	–	–	–	26,9	25,2	5,89
–	–	–	–	–	–	–	26,2	24,1	22,8	21,4	5,38
–	–	–	–	–	–	24,1	22,1	20,7	19,3	17,9	4,88
–	–	–	27,6	24,8	22,8	20,7	19,3	17,9	16,6	15,9	4,47
–	29,3	25,5	22,8	20,7	18,9	17,3	15,9	14,8	13,7	12,7	4,06
26,6	22,8	20,7	17,9	15,9	14,8	13,1	12,4	11,4	10,3	9,6	3,66
20,3	16,9	14,8	13,1	12,1	11,0	9,6	8,9	8,2	7,6	6,9	3,25
14,8	12,4	10,7	9,6	8,6	7,6	—	—	—	—	—	2,95

Section 14 Construction

14.1 Access arrangements

14.1.1 In watertube boilers, manholes are to be provided in all drums of sufficient size to allow access for internal examination and cleaning, and for fitting and expanding the tubes. In the case of headers for water walls, superheaters or economisers, and of drums which are too small to permit entry, sight holes or mudholes sufficiently large and numerous for these purposes are to be provided.

14.1.2 Cylindrical boilers are to be provided, where possible with means for ingress to permit examination and cleaning of the inner surfaces of plates and tubes exposed to flame. Where the boilers are too small to permit this, there are to be sight holes and mudholes sufficiently large and numerous to allow the inside to be satisfactorily cleaned.

14.1.3 Where the cross tubes of vertical boilers are large, there is to be a sight hole in the shell opposite to one end of each tube sufficiently large to allow the tube to be examined and cleaned. These sight holes are to be in positions accessible for that purpose.

14.1.4 Manholes in cylindrical shells should preferably have their shorter axes arranged longitudinally.

14.1.5 Doors for manholes, mudholes and sight holes are to be formed from steel plate or other approved construction, and all jointing surfaces are to be machined.

14.1.6 Doors of the internal type are to be provided with spigots which have a clearance of not more than 1,5 mm all round, i.e. the axes of the opening are not to exceed those of the door by more than 3 mm. The width of the manhole gasket seat is to be not less than 16 mm.

14.1.7 Doors of the internal type for openings not larger than 230 mm x 180 mm need be fitted with one stud only, which may be forged integral with the door. Doors for openings larger than 230 mm x 180 mm are to be fitted with two studs or bolts. The strength of the attachment to the door is to be not less than the strength of the stud or bolt.

14.1.8 The crossbars or dogs for doors are to be of steel.

14.1.9 For smaller circular openings in headers and similar fittings, an approved type of plug may be used.

14.1.10 Circular flat cover plates may be fitted to raised circular manhole frames not exceeding 400 mm diameter, and for an approved design pressure not exceeding 18 bar.

14.1.11 External circular flat cover plates are to be in accordance with a recognised National Standard.

14.2 Torispherical and semi-ellipsoidal ends

14.2.1 For typical acceptable types of attachment for dished ends to cylindrical shells, *see* Fig. 10.14.1.

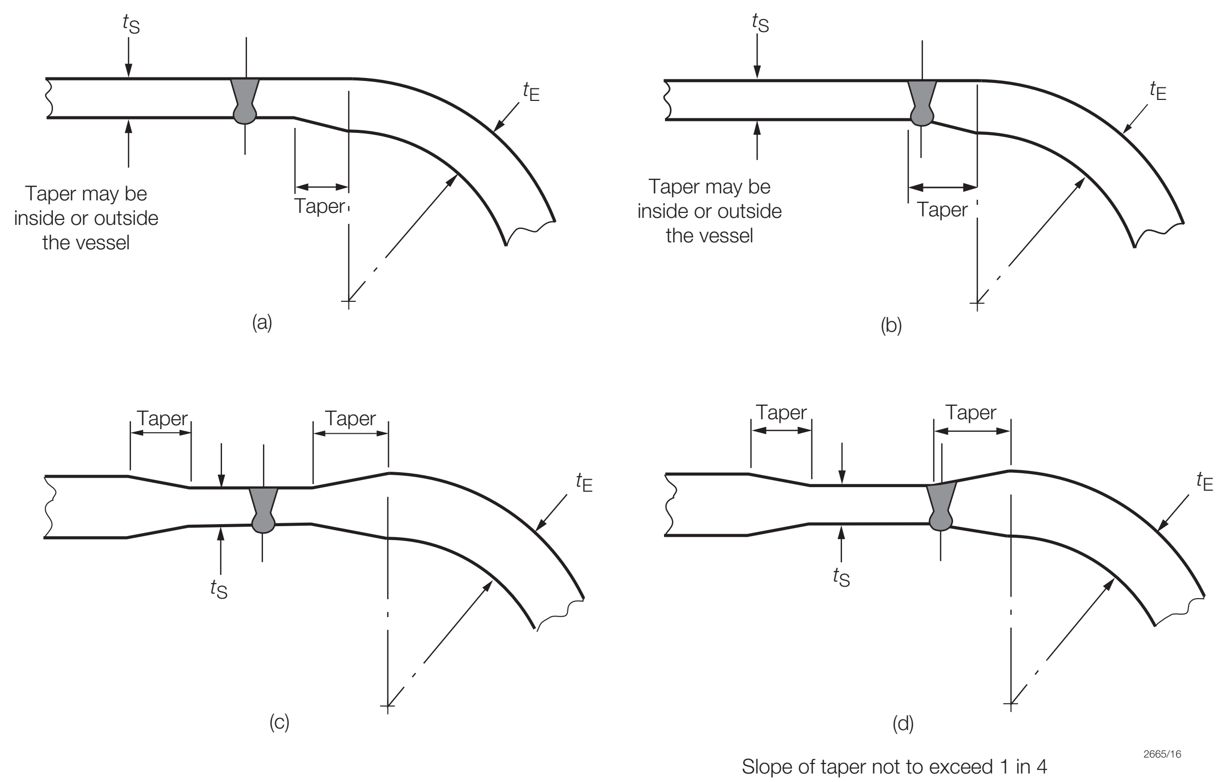


Fig. 10.14.1 Typical attachments of dished ends to cylindrical shells

14.2.2 Where the difference in thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate.

14.2.3 The thickness of the plates at the position of the circumferential weld is to be not less than that of an unpierced cylindrical shell of seamless or welded construction, whichever is applicable, of the same diameter and material, *see* 4.1.

14.3 Hemispherical ends

14.3.1 Where hemispherical ends are butt welded to cylindrical shells, the thickness of the shell is to be reduced by taper to that of the end, and the centre of the hemisphere is to be so located that the entire tapered portion of the shell and the butt weld are within the hemisphere, *see* Fig. 10.14.2.

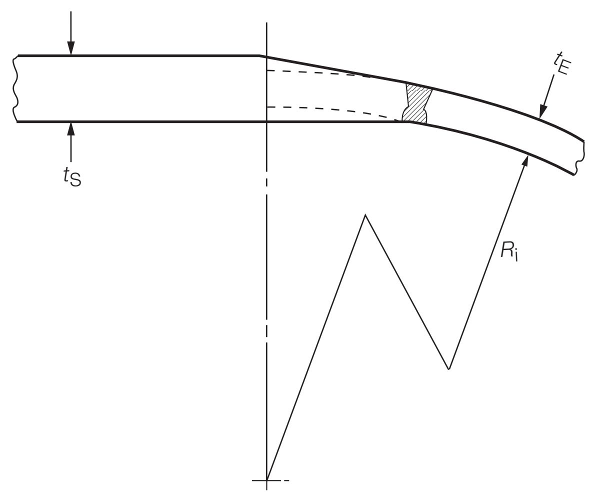


Fig. 10.14.2
Attachment of hemispherical end to cylindrical shell

14.3.2 If the hemispherical end is provided with a parallel portion, the thickness of this portion is to be not less than that of a seamless or welded shell, whichever is applicable, of the same diameter and material.

14.4 Welded-on flanges, butt welded joints and fabricated branch pieces

14.4.1 Flanges may be cut from plates or may be forged or cast. Hubbed flanges are not to be machined from plate. Flanges are to be attached to branches by welding. Alternative methods of flange attachment will be subject to special consideration.

14.4.2 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the branches are intended.

14.4.3 Flange attachments and pressure-temperature ratings in accordance with materials and design of recognised Standards will be accepted.

14.4.4 Typical examples of welded-on flange connections are shown in Fig. 10.14.3(a) to (f), and limiting design conditions for the flange types are shown in Table 10.14.1. In Fig. 10.14.3 *t* is the minimum Rule thickness of the standpipe or branch.

14.4.5 Welded-on flanges are not to be a tight fit on the branch. The maximum clearance between the bore of the flange and the outside diameter of the branch is to be 3 mm at any point, and the sum of the clearances diametrically opposite is not to exceed 5 mm.

14.4.6 Where butt welds are employed in the attachment of flange type (a), or in the construction of standpipes or branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to that of the thinner at the butt joint.

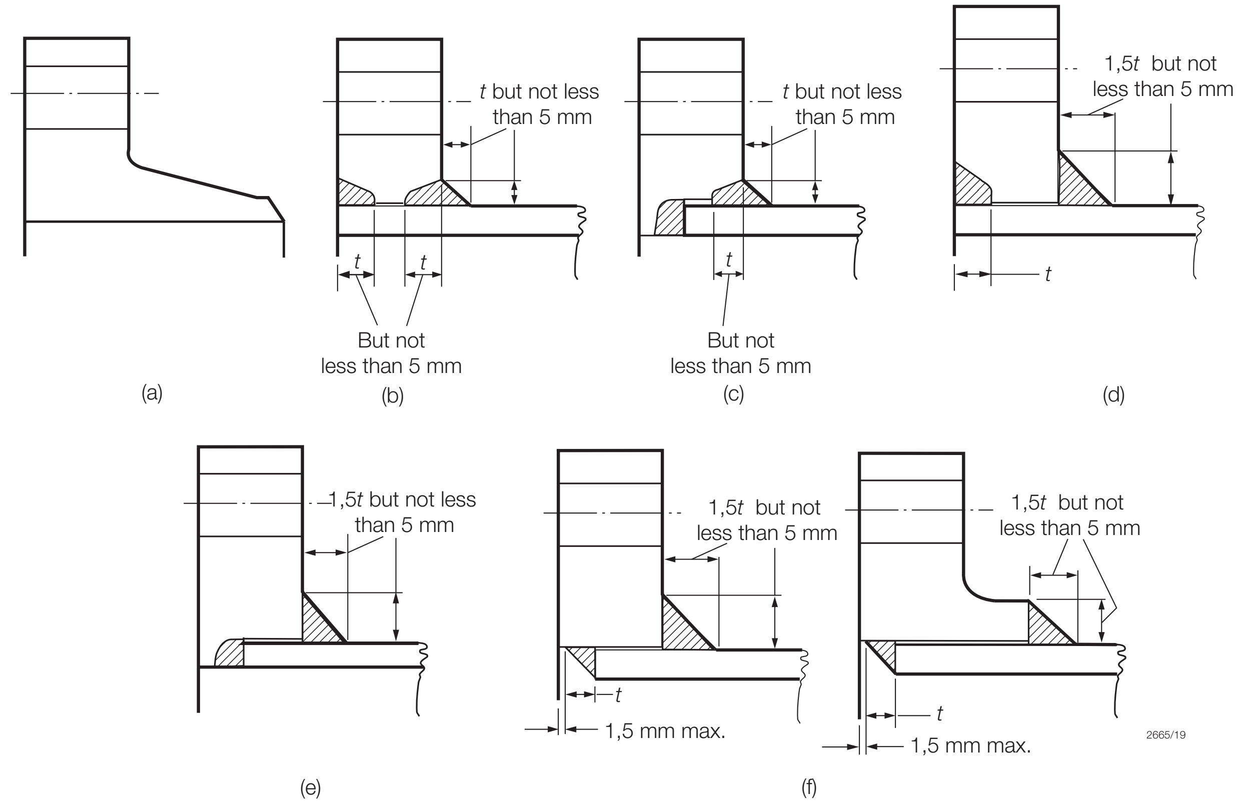
14.4.7 Welding may be carried out by means of the shielded metal arc, inert gas metal arc, oxy-acetylene or other approved process, but in general, oxy-acetylene welding is suitable only for flange type (a) and is not to be applied to branches exceeding 100 mm diameter or 9,5 mm thick. The welding is to be carried out in accordance with the appropriate paragraphs of Chapter 17.

14.4.8 Threaded sleeve joints complying with Ch 12,2.8.1 may be used on the steam and water piping of small oil fired package boilers of the once through coil type, used for auxiliary or domestic purposes, where the feed pump capacity limits the output.

14.4.9 Socket weld joints are not to be used where fatigue, severe erosion, crevice corrosion or stress corrosion is expected to occur, for example, blow down, drain, scum and chemical dosing connections.

14.5 Welded attachments to pressure vessels

14.5.1 Unless the actual thickness of the shell or end is at least twice that required by calculation for a seamless shell or end, whichever is applicable, doubling plates with well rounded corners are to be fitted in way of attachments such as lifting lugs, supporting brackets and feet, to minimise load concentrations on pressure shells and ends. Compensating plates, pads, brackets and supporting feet are to be bedded closely to the surface before being welded, and are to be provided with a 'tell-tale' hole not greater than 9,5 mm in diameter, open to the atmosphere to provide for the release of entrapped air during heat treatment of the vessel, or as a means of indicating any leakage during hydraulic testing and in service, *see* Chapter 17.



'*t*' is the minimum Rule thickness of standpipe or branch

Fig. 10.14.3 Typical examples of welded flange connections

Table 10.14.1 Limiting design conditions for flanges

Flange type	Maximum pressure	Maximum temperature	Maximum pipe o.d.	Minimum pipe bore
		°C	mm	mm
(a)		No restriction	No restriction	No restriction
(b)		No restriction	168,3 for alloy steels*	No restriction
(c)	Pressure-temperature ratings to be in accordance with a recognised standard	No restriction	168,3 for alloy steels*	75
(d)		425	No restriction	No restriction
(e)		425	No restriction	75
(f)		425	No restriction	No restriction

* No restriction for carbon steels

14.5.2 For acceptable methods of attaching standpipes, branches, compensating plates and pads, *see* Fig. 10.14.4. Alternative methods of attachment may be accepted provided details are submitted for consideration.

14.5.3 Where fillet welds are used to attach standpipes or set-in pads, there are to be equal sized welds both inside and outside the vessel, *see* Fig 10.14.4(a) and (l). The leg length of each of the fillet welds is to be not less than 1,4 times the actual thickness of the thinner of the parts being joined.

14.6 Fitting of tubes in water tube boilers

14.6.1 The tube holes in drums or headers are to be formed in such a way that the tubes can be effectively tightened in them. Where the tube ends are not normal to the tube plates, there is to be a neck or belt of parallel seating of at least 13 mm in depth, measured in a plane through the axis of the tube at the holes. Where the tubes are practically normal to their plates, this parallel seating is to be not less than 9,5 mm in depth.

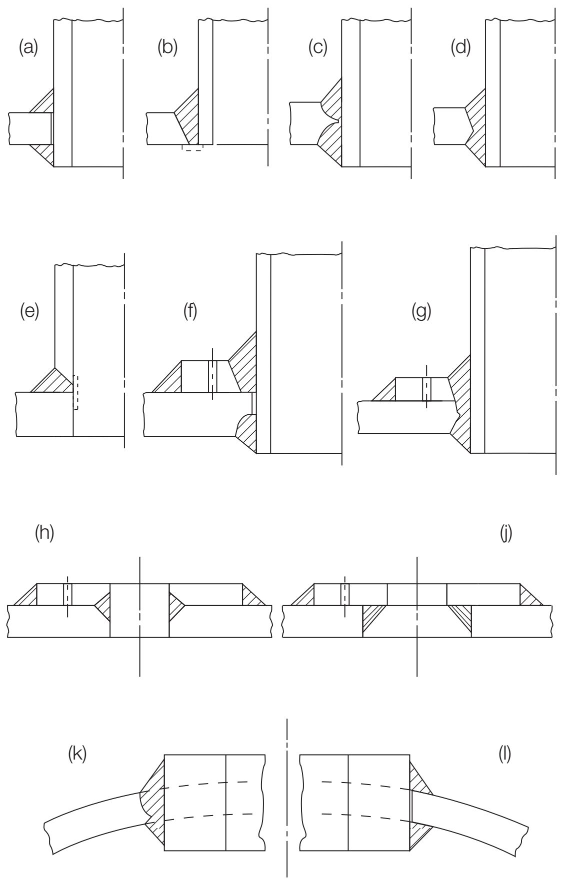


Fig. 10.14.4
Typical acceptable methods of attaching branches and pads

14.6.2 Tubes are to be carefully fitted in the tube holes and secured by means of welding, expanding and belling or by other approved methods. Tubes are to project through the neck or belt of parallel seating by at least 6 mm and where they are secured from drawing out by means of bellmouthing only, the included angle of belling is to be not less than 30°.

■ *Section 15* Mountings and fittings for cylindrical and vertical boilers, steam generators, pressurised thermal liquid and pressurised hot water heaters

15.1 General

15.1.1 Valves over 38 mm diameter are to be fitted with outside screws, and the covers are to be secured by bolts or studs. All valves are to be arranged to shut with a right-hand (clockwise) motion of the wheels.

15.1.2 All valves and cocks connected to the boiler are to be such that it is seen without difficulty whether they are open or shut. Where boiler mountings are secured by studs, the studs are to have a full thread holding in the plate for a length of at least one diameter.

15.1.3 Where a superheater is fitted which can be shut-off from the boiler, it is to be provided with a separate safety valve fitted with easing gear. The valve as regards construction is to comply with the regulations for ordinary safety valves, but the easing gear may be fitted to be workable from the stokehold only. The superheater is also to be fitted with a drain valve or cock to free it from water when necessary.

15.1.4 Safety valve chests and other boiler and superheater mountings subjected to pressures exceeding 13,0 bar or to steam temperatures exceeding 220°C, and boiler blow-down fittings, are to be made of steel or other approved material.

15.2 Safety valves

15.2.1 Boilers and steam generators are to be fitted with not less than two safety valves, each having a minimum internal diameter of 25 mm, but those having a total heating surface of less than 50 m^2 may have one valve not less than 50 mm diameter. Small oil fired package boilers of the once through coil type used for auxiliary or domestic purposes, where the feed pump capacity limits the output, may have one safety valve not less than 19 mm internal diameter, or two safety valves with internal diameters not less than 16 mm, provided the capacity is in accordance with 15.2.13.

15.2.2 The valves, spindles, springs and compression screws are to be so encased and locked or sealed that the safety valves and pilot valves, after setting to the working pressure, cannot be tampered with or overloaded in service.

15.2.3 Valves are to be so designed that in the event of fracture of springs they cannot lift out of their seats.

15.2.4 Easing gear is to be provided for lifting the safety valves and is to be operable by mechanical means at a safe position from the boiler or engine room platforms.

15.2.5 Safety valves are to be made with working parts having adequate clearances to ensure complete freedom of movement.

15.2.6 Valve seats are to be effectively secured in position. Any adjusting devices which control discharge capacity are to be positively secured so that the adjustment will not be affected when the safety valves are dismantled at surveys.

15.2.7 All the safety valves of each boiler and steam generator may be fitted in one chest, which is to be separate from any other valve chest and is to be connected directly to the shell by a strong and stiff neck, the passage through which is to be of cross-sectional area not less than the aggregate area of the safety valves in the chest in the case of full lift valves, and one-half of that area in the case of other valves. For the meaning of aggregate area, *see* 15.2.13.

15.2.8 For each safety valve, an individual unrestricted drain is to be provided. The drain pipe is to be fitted to the lowest part of the safety valve and is to be independently led with a continuous fall to a place where the high temperature steam and/or condensate can discharge, visibly clear of the boilers and where it cannot cause injury. No valves or cocks are to be fitted to these drain pipes. The bore of the drain pipes is not to be less than 19 mm.

15.2.9 Safety valves for shell type exhaust gas steaming economisers are to incorporate fail safe features which will ensure operation of the valve even with solid matter deposits on the valve and guide, or features that will prevent the accumulation of solid matter in way of the valve and in the clearance between the valve spindle and guide. Alternatively, if the fitted valves do not incorporate the features described then a bursting disc discharging to a suitable waste steam pipe is to be fitted in addition to the valves. These bursting discs are to function at a pressure not exceeding 1,25 times the economiser approved design pressure and are to have sufficient capacity to prevent damage to the economiser when operating at its design heat input level.

15.2.10 To avoid the accumulation of solid matter deposits on the outlet side of the safety valves and bursting discs required by 15.2.9, the discharge pipes and safety valve/ bursting disc housings are to be fitted with drainage arrangements from the lowest part, directed with continuous fall to a position clear of the economiser where it will not pose a threat to either personnel or machinery. No valves or cocks are to be fitted in the drainage arrangements. The drainage arrangements required by 15.2.8 may be accepted as meeting these requirements where the arrangements comply with this paragraph.

15.2.11 Full particulars of the proposed arrangements are to be submitted for consideration.

15.2.12 Where the receiver is fitted with safety valves to relieve the steam output of the economiser and the economiser cannot be isolated from the receiver the requirements of 15.2.9 may be waived.

15.2.13 The designed discharge capacities of the safety valves on each boiler and steam generator are to be found from the following formulae:

Saturated steam safety valves:

$$E = \frac{AC\,(p + 1{,}03)}{98{,}1}$$

Superheated steam safety valves:

$$E = \frac{AC\,(p + 1{,}03)}{98{,}1}\sqrt{\frac{V_S}{V_H}}$$

where

p = set pressure, in bar gauge

A = for ordinary, high lift or improved high lift safety valves, the aggregate area, in mm^2, of the orifices through the seatings of the valves, neglecting the area of guides and other obstructions

= for full lift safety valves, the net aggregate area, in mm^2, through the seats after deducting the area of the guides or other obstructions when the valves are fully lifted

C = 4,8 for valves of ordinary type having a minimum lift of $\frac{D}{24}$

= 7,2 for valves of high lift type, having a minimum lift of $\frac{D}{16}$

= 9,6 for valves of improved high lift type having a minimum lift of $\frac{D}{12}$

= 19,2 for valves of full lift type having a minimum lift of $\frac{D}{4}$

D = bore of valve seat, in mm

E = the maker's specified peak load evaporation, in kg/hour (including all evaporation from water walls, integral, or steaming economisers and other heating surfaces in direct communication with the boiler)

V_H = specific volume of superheated steam (m^3/kg)

V_S = specific volume of saturated steam (m^3/kg).

15.2.14 When the discharge capacity of a safety valve of approved design has been established by type tests, carried out in the presence of the Surveyors or by an independent authority recognised by LR, on valves representative of the range of sizes and pressures intended for marine application, consideration will be given to the use of a constant higher than C = 19,2, based on 90 per cent of the measured capacity up to a maximum of C = 45 for full lift safety valves.

15.2.15 Pressurised thermal liquid and pressurised hot water heaters are to be provided with a safety relief device. The safety valve is to be designed and constructed in accordance with a relevant National or International Standard acceptable to LR.

15.3 Waste steam pipes

15.3.1 For ordinary, high lift and improved high lift type valves, the cross-sectional area of the waste steam pipe and passages leading to it is to be at least 10 per cent greater than the aggregate area of the safety valves as used in the formulae in 15.2.13. For full lift and other approved valves of high discharge capacity, the cross-sectional area of the waste steam pipe and passages is to be not less than 0,1C times the aggregate valve area.

15.3.2 The cross-sectional area of the main waste steam pipe is to be not less than the combined cross-sectional areas of the branch waste steam pipes leading thereto from the boiler safety valves.

15.3.3 Waste steam pipes are to be led to the atmosphere and are to be adequately supported and provided with suitable expansion joints, bends or other means to relieve the safety valve chests of undue loading.

15.3.4 The scantlings of waste steam pipes and silencers are to be suitable for the maximum pressure to which the pipes may be subjected in service, and in any case not less than 10 bar.

15.3.5 Silencers fitted to waste steam pipes are to be so designed that the clear area through the baffle plates is not less than that required for the pipes.

15.3.6 The safety valves of each exhaust gas heated economiser and exhaust gas heated boiler which may be used as an economiser are to be provided with entirely separate waste steam pipes.

15.3.7 External drains and exhaust steam vents to atmosphere are not to be led to waste steam pipes.

15.3.8 It is recommended that a scale trap and means for cleaning be provided at the base of each waste steam pipe.

15.4 Adjustment and accumulation tests

15.4.1 All safety valves are to be set under steam to a pressure not greater than the approved pressure of the boiler. As a working tolerance the setting is acceptable provided the valves lift at not more than 103 per cent of the approved design pressure. During a test of 15 minutes with the stop valves closed and under full firing conditions the accumulation of pressure is not to exceed 10 per cent of the design pressure. During this test no more feed water is to be supplied than is necessary to maintain a safe working water level.

15.5 Stop valves

15.5.1 One main stop valve is to be fitted to each boiler and secured directly to the shell. There are to be as few auxiliary stop valves as possible so as to avoid piercing the boiler shell more than is absolutely necessary.

15.5.2 Where two or more boilers are connected together:
- Stop valves of self-closing or non-return type are to be fitted.
- Essential services are to be capable of being supplied from at least two boilers.

15.6 Water level indicators

15.6.1 Every boiler designed to contain water at a specified level is to be fitted with at least two means for indicating its water level, at least one of which is to be a direct reading gauge glass. The other means is to be either an additional gauge glass or an approved equivalent device. The required water level indicators are to be independent of each other.

15.6.2 Where a pair of gauge glasses are set at different levels to provide an extended range of water level indication they will only be considered as one water level indicator.

15.6.3 An approved equivalent device for level indication may derive its level input signal from one of the low water level detection systems required by 15.7.1 provided that in the event of a power supply failure to that system an alarm is initiated and the oil fuel supply to the burners, or any other fuel used to fire the boiler, is automatically shut-off. The fuel supply shut-off will only be required if the power supply failure results in the direct reading gauge glass being the only functioning water level indicator.

15.6.4 The water gauges are to be readily accessible and placed so that the water level is clearly visible. The lowest visible parts of water gauges are to be situated at the lowest safe working level.

15.6.5 The level of the highest part of the effective heating surfaces, e.g. combustion chamber top of a horizontal boiler and the furnace crown of a vertical boiler, is to be clearly marked in a position adjacent to the glass water gauge.

15.6.6 The cocks of all water gauges are to be operable from positions free from danger in the event of the glass breaking.

15.7 Low water level fuel shut-off and alarm

15.7.1 Every fired boiler designed to contain water at a specified level is to be fitted with two systems of water level detection which are to be independent of each other, and which will operate an alarm and shut-off automatically the fuel supply to the burners, or any other fuel used to fire the boiler, when the water level falls to a predetermined low level. These level detectors, in addition, may be used for other functions, e.g. high level alarm, feed pump control, etc.

15.8 Feed check valves

15.8.1 Two feed check and stop valves, connected to separate feed lines, are to be provided for all main and auxiliary boilers which are required for essential services. The feed check and stop valves may be connected to a single standpipe at the shell. In the case of steam/steam generators one feed check valve is acceptable provided steam for essential services is simultaneously available from another source.

15.9 Pressure gauges

15.9.1 Each boiler is to be provided with a separate steam pressure gauge.

15.9.2 The gauges are to be placed where they are easily read.

15.10 Blow-down and scum valves

15.10.1 Each boiler is to be fitted with at least one blow-down valve.

15.10.2 The blow-down valve is to be attached, wherever practicable, direct to the lower part of the boiler. Where it is not practicable to attach the blow-down valve directly, a steel pipe supported from the boiler may be fitted between the boiler and valve.

15.10.3 The blow-down valve and its connections to the sea need not be more than 38 mm, and is to be not less than 19 mm internal diameter. For cylindrical boilers the size of the valve may be generally 0,0085 times the diameter of the boiler.

15.10.4 Blow-down valves and scum valves (where the latter are fitted) of two or more boilers may be connected to one common discharge, but where thus arranged there are to be screw-down non-return valves fitted for each boiler to prevent the possibility of the contents of one boiler passing to another.

15.10.5 For blow-down valves or cocks on the ship's side and attachments, *see* Ch 13,2.

15.11 Sampling valve or cock

15.11.1 Each boiler is to be provided with a sampling valve or cock secured direct to the boiler in a convenient position. The valve or cock is not to be on the water gauge standpipe.

15.12 Additional requirements for shell type exhaust gas steaming economisers

15.12.1 The design and construction of shell type economisers are to pay particular attention to the welding, heat treatment and inspection arrangements at the tube plate connection to the shell.

15.12.2 Every shell type economiser is to be provided with removable lagging at the circumference of the tube end plates to enable ultrasonic examination of the tube plate to shell connection.

15.12.3 Every economiser is to be provided with arrangements for pre-heating and de-aeration, and addition of water treatment or combination thereof, to control the quality of feed water to within the manufacturer's recommendations.

15.12.4 The manufacturer is to provide operating instructions for each economiser which is to include reference to:

- Feed water treatment and sampling arrangements.
- Operating temperatures – exhaust gas and feed water temperatures.
- Operating pressure.
- Inspection and cleaning procedures.
- Records of maintenance and inspection.
- The need to maintain adequate water flow through the economiser under all operating conditions.
- Periodical operational checks of the safety devices to be carried out by the operating personnel and to be documented accordingly.
- Procedures for using the exhaust gas economiser in the dry condition.
- Procedures for maintenance and overhaul of safety valves.
- Emergency operating procedures.

■ *Section 16* Mountings and fittings for water tube boilers

16.1 General

16.1.1 Mountings and fittings not mentioned in this Section are to be in accordance with the requirements in Section 15.

16.2 Safety valves

16.2.1 Water tube boilers are to be fitted with not less than two safety valves of area and design in general accordance with the requirements of 15.2.

16.2.2 Each saturated steam drum and each superheater are to be provided with at least one safety valve.

16.2.3 Where the superheater forms an integral part of the boiler, the relieving capacity of the superheater safety valve(s), based on the reduced pressure at the superheater outlet, may be included as part of the total relieving capacity required for the boiler. As some National Authorities limit the proportion of the superheater safety valve relieving capacity which may be credited towards the total capacity for the boiler, builders should give attention to any relevant Statutory Requirements of the National Authority of the country in which the ship is to be registered.

16.2.4 The boiler and superheater valves are to be so disposed and proportioned between saturated steam drum and superheater outlet that the superheater will be protected from overheating under all service conditions, including an emergency stop of the ship at full power.

16.2.5 Where it is proposed to fit full bore safety valves operated by independent pilot valves, the arrangements are to be submitted for consideration. The pipes connecting pilot valves and main valves are to be of ample bore and wall thickness to minimise the possibility of obstruction and damage.

16.2.6 Where it is impracticable to attach safety valves directly to the superheater, the valves are to be located as near as possible thereto and fitted to a branch piece connected to the superheater outlet pipe.

16.2.7 In high temperature installations the drains from safety valves are to be led to a tank or other place where high temperature steam can be safely discharged.

16.3 Safety valve settings

16.3.1 All boiler and superheater safety valves are to be set under steam to their respective working pressures, which are not to be greater than the approved design pressure of the boiler. As a working tolerance the setting is acceptable provided the valves lift at not more than 103 per cent of the approved pressure.

16.3.2 In the setting of superheater safety valves, allowance is to be made for the pressure drop through the superheater so that under discharge conditions the pressure in the boiler will not exceed the approved boiler pressure.

16.3.3 In no case is the superheater safety valve setting to exceed by more than three per cent the pressure for which the steam piping is approved.

16.4 Waste steam pipes

16.4.1 The waste steam pipe and passages leading to it from the safety valves are to be in general accordance with the requirements of 15.3.

16.4.2 In installations operating with a high degree of superheat, consideration is to be given to the high temperatures which waste steam pipes, silencers and surrounding spaces will attain when the superheater safety valves are blowing during accumulation tests and in service, adequate protection against heat effects is to be provided to the Surveyor's satisfaction.

16.4.3 Waste steam pipes are to be led well clear of electric cables and any parts or structures sensitive to heat or likely to distort; the pipes are to be insulated where necessary. In these installations each boiler should have a separate waste steam pipe system to atmosphere, with supporting and expansion arrangements such that no direct loading is imposed on the safety valve chests.

16.5 Accumulation tests

16.5.1 Tests for accumulation of pressure are to be carried out with the stop valve closed and under full firing conditions for a period not exceeding seven minutes. The accumulation is not to exceed 10 per cent of the design pressure.

16.5.2 Where accumulation tests might endanger the superheaters, consideration will be given in cases of fired boilers to the omission of these tests, provided that application is made when the boiler plan and sizes of safety valves are submitted for approval, and that the safety valves are of an approved type for which the capacity has been established by test in the presence of the Surveyors or an approved independent authority, or for which LR is satisfied, by long experience of accumulation tests, that the capacity is adequate. When it is agreed to waive accumulation tests, it will be required that the valve makers provide a certificate for each safety valve, stating its rated capacity at the approved working conditions of the boilers and that the boiler makers provide a certificate for each boiler stating its maximum evaporation.

16.5.3 The safety valves are to be found satisfactory in operation under working conditions during the trials of the machinery on board ship.

16.6 Water level indicators

16.6.1 Every boiler designed to contain water at a specified level is to be fitted with at least two means for indicating its water level, at least one of which is to be a direct reading gauge glass. The other means is to be either an additional gauge glass or an approved equivalent device. The required water level indicators are to be independent of each other.

16.6.2 Where a pair of gauge glasses are set at different levels to provide an extended range of water level indication they will only be considered as one water level indicator.

16.6.3 An approved equivalent device for level indication may derive its level input signal from one of the low water level detection systems required by 16.7.1 provided that, in the event of a power supply failure to that system, an alarm is initiated and the oil fuel supply to the burners, or any other fuel used to fire the boiler, is automatically shut-off. The fuel supply shut-off will only be required if the power supply failure results in the direct reading gauge glass being the only functioning water level indicator.

16.6.4 Where a steam and water drum exceeding 4 m in length is fitted athwartships, two glass water gauges are to be fitted in suitable positions, one near each end of the drum.

16.6.5 The position of the glass water gauge of boilers in which the tubes are entirely drowned when cold is to be such that water is just showing in the glass when the water level in the steam drum is just above the top of the uppermost tubes when the boiler is cold.

16.6.6 In boilers, the tubes of which are not entirely drowned when cold, the glass water gauges are to be placed, to the Surveyor's satisfaction, in the positions which have been found by experience to indicate satisfactorily that the water content is sufficient for safety when the boiler is worked under all service conditions.

16.7 Low water level fuel shut-off and alarm

16.7.1 Every fired boiler designed to contain water at a specified level is to be fitted with two systems of water level detection which are to be independent of each other, and which will operate an alarm and shut-off automatically the fuel supply to the burners when the water level falls to a predetermined low level. These level detectors may be used for other functions, e.g. high level alarm, feed pump control, etc.

16.7.2 Any proposals to depart from these requirements in the case of small auxiliary boilers will be the subject of special consideration.

16.7.3 *See* Pt 6, Ch 1 for requirements for control, alarm and safety systems, and additional requirements for unattended operation.

16.8 Feed check valves and water level regulators

16.8.1 Two feed check and stop valves, connected to separate feed lines, are to be provided for each boiler and are to be attached, wherever practicable, direct to the boiler or to an economiser which forms an integral part of the boiler.

16.8.2 Where the arrangements necessitate the use of a common inlet pipe on the economiser for both main and auxiliary feed systems, this pipe is to be as short as practicable, and the arrangements of check valves are to be such that either feed line can be effectively isolated without interruption of the feed water supply to the boiler.

16.8.3 At least one of the feed water systems is to be fitted with an approved feed water regulator whereby the water level in the boilers is controlled automatically. *See* Ch 14,6 for arrangements and details of boiler feed systems.

16.8.4 The feed check valves are to be fitted with efficient gearing, whereby they can be satisfactorily worked from the stokehold floor, or other convenient position.

16.8.5 Standpipes on boilers, for feed inlets, are to be designed with an internal pipe to prevent direct contact between the feed pipe and the boiler shell or end plates with the object of minimising thermal stresses in these plates. Similar arrangements are to be provided for desuperheater and other connections where significant temperature differences occur in service.

■ *Section 17* Hydraulic tests

17.1 General

17.1.1 Boilers and pressure vessels, together with their components are to withstand the following hydraulic tests without any sign of weakness or defect.

17.1.2 Having regard to the variation in the types and design of boilers, the hydraulic test may be carried out by either of the methods indicated below:
(a) boilers are to be tested on completion to a pressure 1,5 times the approved design pressure, or
(b) where construction permits, all components of the boiler are to be tested on completion of the work including heat treatment to 1,5 times the design pressure. In the case of components such as drums or headers, which are to be drilled for tube holes, the test may be before drilling the tube holes, but is to be after the attachment of standpipes, stubs and similar fittings and also after heat treatment has been carried out. Where all the components have been tested as above, each completed boiler after assembly is to be tested to 1,25 times the design pressure.

17.2 Mountings

17.2.1 All boiler mountings are to be subjected to a hydraulic test of twice the approved design pressure with the exception of feed check valves and other mountings connected to the main feed system which are to be tested to 2,5 times the approved boiler design pressure, or twice the maximum pressure which can be developed in the feed line in normal service, whichever is greater.

■ *Section 18* Control and monitoring

18.1 General

18.1.1 Control engineering systems are to be in accordance with the requirements of Pt 6, Ch 1.

18.2 Unattended machinery

18.2.1 Where boilers are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by 18.2 to 18.3, as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

18.2.2 Where machinery is arranged to start automatically or from a remote control station, interlocks are to be provided to prevent start-up under conditions which could hazard the machinery.

18.2.3 Where machinery specified in this Section is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

18.2.4 Where a first stage alarm together with a second stage alarm and automatic shut-down of machinery are required in the relevant Tables of this Section, the sensors and circuits utilised for the second stage alarm and automatic shut-down are to be independent of those required for the first stage alarm.

18.3 Main, auxiliary and other boilers

18.3.1 Alarms and safeguards are indicated in 18.3.2 to 18.3.9 and Table 10.18.1.

18.3.2 The following boiler services are to be fitted with automatic controls so as to maintain steady state conditions throughout the normal operating range of the boiler:
(a) Combustion system.
(b) Oil fuel supply temperature or viscosity, heavy oil only.
(c) Boiler drum water level.
(d) De-aerator water level, where applicable.
(e) Superheated steam pressure, where applicable.
(f) Superheated steam temperature, where applicable.

Table 10.18.1 Main, auxiliary and other boilers: Alarms and safeguards

Item	Alarm	Note
Water level*	Low	Two water level sensors are to be provided, each to operate independently, and automatically to shut off the oil fuel to the burners and operate alarms, *see* Notes 1 to 3 and 5
Water level	1st stage high 2nd stage high	— Where applicable, automatic closure of turbine steam inlet valves, *see* 18.2.4
Steam drum or superheater outlet pressure*	High and Low	—
Superheated steam temperature	High	—
De-superheated steam temperature*	High	—
Feed water or water forced circulation flow (if fitted)	Low	Oil fuel to burners to be shut off automatically, *see* Notes 5 and 6
Feed water pH	Low	When automatic dosing of feed water fitted
Feed water salinity	High	Fitted in boiler feed system
Feed water temperature	Low	When automatic temperature control fitted
Combustion air pressure*	Low	Oil fuel burners to be shut off automatically in operation or not released during start up, *see* Note 5. Purge sequences to be inhibited, *see* Ch 14,3.1.9
Oil fuel pressure*	Low	—
Oil fuel temperature or viscosity*	High and Low	Heavy oil only
Oil fuel atomising steam/air pressure	Low	—
Burner flame*	Failure	Each burner to be monitored. Oil fuel to burner(s) to be shut off automatically, *see* Ch 14,3.1.11 and 3.1.12 and Note 5
Flame monitoring device(s)*	Failure	*See* 18.3.7 and Note 5
Igniter power supply*	Failure	Each igniter to be checked before oil fuel is supplied to burner, *see* 18.3.6 and Note 5
Forced draft fan*	Power failure	Oil fuel to burners to be shut off automatically. Control using alternative arrangements is to remain available, *see* Pt 6, Ch 1,2.5.7
Air registers and dampers (including those in the uptake)*	Not fully open	Purge sequence to be inhibited, *see* Ch 14,3.1.9
Control system*	Power failure	Oil fuel burners to be shut off automatically. Control using alternative arrangement is to remain available, *see* Pt 6, Ch 1,2.5.8
Uptake temperature	High	Where economiser and/or gas air heaters are integral with the boiler and also for independent exhaust gas boilers/economisers, to monitor for soot fires. *See* Note 7

NOTES

1. For dual-evaporation boilers, the primary circuit is to be fitted with two independent low water level detectors which will operate alarms and shut off the oil fuel to the burners automatically. The secondary circuit is to be fitted with one low water level detector which will operate alarms and shut off the oil fuel to the burners automatically. Additionally one high water level alarm is to be fitted on the secondary circuit which may be operated by the same detector as that provided for low water level detection.
2. Only one independent system of low water level detection, alarm and automatic oil fuel shut-off need be fitted in the case of small forced circulation or re-circulation coiled water tube `package' type boilers when evaporation is less than 2900 kg/hr or the heating surface is less than 100 m^2.
3. Where two level sensors are provided these may be used for other functions, e.g., high level alarm, level control, trip systems, etc.
4. For boilers not supplying steam for propulsion or for services essential for the safety or operation of the ship at sea, only the items marked * are required.
5. These safeguards are to remain operative during automatic, manual and emergency operation.
6. For exhaust gas economisers/boilers requiring feed water or forced water circulation, the low flow alarm is to be fitted with provision to override the alarm if the exhaust gas economiser/boiler is to be operated in the dry condition. *See also* Ch 14,6.2.5.
7. Alternatively, details of an appropriate fire detection system are to be submitted for consideration.

(g) De-superheated steam pressure, where applicable.
(h) De-superheated steam temperature, where applicable.

18.3.3 Safety systems and overrides are to comply with the requirements of Pt 6, Ch 1,2.4.8.

18.3.4 Burner controls are to be arranged such that light off is only possible at the minimum firing rate compatible with flame establishment. If ignition is set to occur at a fuel rich condition then the burner is to revert to the correct operating air/fuel ratio on establishment of a stable flame.

18.3.5 Where water level indicators are dependent upon an external power supply, the oil fuel supply to the burners is to be automatically shut off in the event of power or signal failure.

18.3.6 Arrangements are to be such that burner oil fuel valve(s) do not open:
(a) prior to completion of required warm up times for residual fuel oil; or
(b) when the power supply to the igniter has failed, as applicable; or
(c) until a pilot flame is established, as applicable; or
(d) prior to the completion of furnace purging, *see* Ch 14,3.1.7.

18.3.7 Arrangements for flame failure detection are to be provided with self-monitoring capabilities which ensure that the flame detector is not erroneously indicating the presence of a flame. In the event of failure being detected by these self-monitoring capabilities:
- an alarm is to be activated;
- in the event of loss of flame detection capability for a burner;
- oil fuel to the burner is to be shut off automatically; and
- an alarm is to be activated.

18.3.8 Where established as necessary by Ch 14,3.1.8, means are to be provided to prevent starting of the ignition sequence following multiple flame failures until completion of the identified lock-out period.

18.3.9 Following burner shut-down, the furnace is to be purged automatically for at least the required pre-purging time. In the event of shut-down due to activation of a required safeguard, this purging is to be manually initiated.

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter are applicable to fusion welded pressure vessels and plate heat exchangers, intended for marine purposes but not included in Chapter 10. The equations in this Chapter may be used for determining the thickness of seamless pressure vessels using a joint factor of 1,0. Seamless pressure vessels are to be manufactured and tested in accordance with the requirements of Chapter 5 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). For the construction and design of pressure vessels and plate heat exchangers for liquefied gas or chemical cargo applications, *see* the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk* (hereinafter referred to as the Rules for Ships for Liquefied Gases) or the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquid Chemicals in Bulk* (hereinafter referred to as the Rules for Ships for Liquid Chemicals) as applicable.

1.1.2 Where the required design criteria for pressure vessels are not indicated within this Chapter, the relevant Sections of Chapter 10 are applicable.

1.1.3 Seamless pressure vessels are to be manufactured in accordance with the requirements of the Rules for Materials where applicable.

1.2 Definition of symbols

1.2.1 The symbols used in the various formulae in Sections 2 to 7 inclusive, unless otherwise stated, are defined as follows, and are applicable to the specific part of the pressure vessel under consideration:

d = diameter of hole, or opening, in mm
p = design pressure, *see* 1.3, in bar
r_i = inside knuckle radius, in mm
r_o = outside knuckle radius, in mm
s = pitch, in mm
t = minimum thickness, in mm
D_i = inside diameter, in mm
D_o = outside diameter, in mm
J = joint factor applicable to welded seams, *see* 1.9, or ligament efficiency between tube holes (expressed as a fraction, *see* Ch 10,2.2)
R_i = inside radius, in mm
R_o = outside radius, in mm
T = design temperature, in °C
σ = allowable stress, *see* 1.8, in N/mm^2.

1.2.2 Where reference is made to calculated or actual plate thickness for the derivation of other values, these thicknesses are to be minus the standard Rule corrosion allowance of 0,75 mm, if not so stated.

1.3 Design pressure

1.3.1 The design pressure is the maximum permissible working pressure, and is to be not less than the highest set pressure of any relief valve.

1.3.2 Calculations made to determine the scantlings of the pressure parts are to be based on the design pressure, adjusted where necessary to take account of pressure variations corresponding to the most severe operational conditions.

1.3.3 It is desirable that there should be a margin between the normal pressure at which the pressure vessel operates and the lowest pressure at which any relief valve is set to lift, to prevent unnecessary lifting of the relief valve.

1.4 Metal temperature

1.4.1 The metal temperature, T, used to evaluate the allowable stress, σ, is to be taken as the actual metal temperature expected under operating conditions for the pressure part concerned, and is to be stated by the manufacturer when plans of the pressure parts are submitted for consideration.

1.4.2 The design temperature, T, for calculation purposes is to be not less than 50°C.

1.5 Classification of fusion welded pressure vessels

1.5.1 For Rule purposes, pressure vessels are graded as Class 1 where the shell thickness exceeds 38 mm.

1.5.2 For Rule purposes, pressure vessels are graded as Class 2/1 and Class 2/2 if they comply with the following conditions:

(a) where the design pressure exceeds 17,2 bar, or
(b) where the metal temperature exceeds 150°C, or
(c) where the design pressure, in bar, multiplied by the actual thickness of the shell, in mm, exceeds 157, or
(d) where the shell thickness does not exceed 38 mm.

1.5.3 For Rule purposes, Class 3 pressure vessels are to have a maximum shell thickness of 16 mm, and are pressure vessels not included in Classes 1, 2/1 or 2/2.

1.5.4 Pressure vessels which are constructed in accordance with Classes 2/1, 2/2 or 3 standards (as indicated above) will, if manufactured in accordance with the requirements of superior Class, be approved with the scantlings appropriate to that Class.

1.5.5 Pressure vessels which only have circumferential fusion welded seams, will be considered as seamless with no Class being assigned. Preliminary weld procedure tests and non-destructive examination for the circumferential seam welds should be carried out for the equivalent Class as determined by 1.5.1, 1.5.2 and 1.5.3.

1.5.6 In special circumstances relating to service conditions, materials, operating temperature, the carriage of dangerous gases and liquids, etc., it may be required that certain pressure vessels be manufactured in accordance with the requirements of a superior Class.

1.5.7 Details of heat treatment, non-destructive examination and routine tests (where required) are given in Chapter 13 of the Rules for Materials.

1.5.8 Hydraulic testing is required for all Classes of pressure vessels.

1.5.9 For a full definition of Classes of pressure vessels relating to boilers and associated pressure vessels, *see* Ch 10,1.

1.6 Plans

1.6.1 Plans of pressure vessels are to be submitted in triplicate for consideration where all the conditions in (a) or (b) are satisfied:

(a) The vessel contains vapours or gases, e.g. air receivers, hydrophore or similar vessels and gaseous CO_2 vessels for fire-fighting, and
   $pV > 600$
   $p > 1$
   $V > 100$
   V = volume (litres) of gas or vapour space
(b) The vessel contains liquefied gases, or flammable liquids
   $p > 7$
   $V > 100$
   V = volume (litres)
   p is as defined in 1.2.1.

1.6.2 Plans of full constructional features of the vessel and dimensional details of the weld preparations for longitudinal and circumferential seams and attachments, together with particulars of the welding consumables and of the mechanical properties of the materials, are to be submitted before construction is commenced.

1.7 Materials

1.7.1 Materials used in the construction of Class 1, 2/1 and 2/2 pressure vessels are to be manufactured, tested and certified in accordance with the requirements of the Rules for Materials. Materials used in the construction of Class 3 pressure vessels may be in accordance with the requirements of an acceptable national or international specification. The manufacturer's certificate will be accepted in lieu of Lloyd's Register's (hereinafter referred to as LR) material certificate for such materials.

1.7.2 The specified minimum tensile strength of carbon and carbon-manganese steel plates, pipes, forgings and castings is to be within the general limits of 340 to 520 N/mm^2.

1.7.3 The specified minimum tensile strength of low alloy steel plates, pipes, forgings and castings is to be within the general limits of 400 to 500 N/mm^2, and pressure vessels made in these steels are to be either seamless or Class 1 fusion welded.

1.7.4 Where it is proposed to use materials other than those specified in the Rules for Materials, details of the chemical compositions, heat treatment and mechanical properties are to be submitted for approval. In such cases, the values of the mechanical properties used for deriving the allowable stress are to be subject to agreement by LR.

1.8 Allowable stress

1.8.1 The term 'allowable stress', σ, is the stress to be used in the formulae for the calculation of scantlings of pressure parts.

1.8.2 The allowable stress, σ, is to be the lowest of the following values:

$$\sigma = \frac{E_t}{1,5} \qquad \sigma = \frac{R_{20}}{2,7} \qquad \sigma = \frac{S_R}{1,5}$$

where

E_t = specified minimum lower yield stress or 0,2 per cent proof stress at temperature, T, for carbon and carbon-manganese steels. In the case of austenitic steels, the 1,0 per cent proof stress at temperature, T, is to be used
R_{20} = specified minimum tensile strength at room temperature
S_R = average stress to produce rupture in 100 000 hours at temperature, T
T = metal temperature, *see* 1.4.

1.8.3 The allowable stress for steel castings is to be taken as 80 per cent of the value determined by the method indicated in 1.8.2 using the appropriate values for cast steel.

1.8.4 Where steel castings, which have been tested in accordance with the Rules for Materials are also subjected to non-destructive tests, consideration will be given to increasing the allowable stress using a factor up to 90 per cent in lieu of the 80 per cent referred to in 1.8.3. Particulars of the non-destructive test proposals are to be submitted for consideration.

1.9 Joint factors

1.9.1 The following joint factors are to be used in the equations in Sections 2 to 6, where applicable. Fusion welded pressure parts are to be made in accordance with Chapter 17.

Class of pressure vessel	Joint factor
Class 1	1,0
Class 2/1	0,85
Class 2/2	0,75
Class 3	0,60

1.9.2 The longitudinal joints for all Classes of vessels are to be butt joints. Circumferential joints for Class 1 vessels are also to be butt welds. Circumferential joints for Classes 2/1, 2/2 and 3 vessels should also be butt joints with the following exceptions:

(a) Circumferential joints for Classes 2/1, 2/2 and 3 vessels may be of the joggle type provided neither plate at the joints exceeds 16 mm thickness.
(b) Circumferential joints for Class 3 vessels may be of the lap type provided neither plate at the joint exceeds 16 mm thickness nor the internal diameter of the vessel exceeds 610 mm.

For typical acceptable methods of attaching flat ends, *see* Fig. 10.8.2 and Fig. 10.9.1 in Chapter 10.
For typical acceptable methods of attaching dished ends, *see* Fig 11.8.1.

1.9.3 Where a pressure vessel is to be made of alloy steel, particulars of the welding consumables to be used, including typical mechanical properties and chemical composition of the deposited weld metal, are to be submitted for approval.

1.10 Pressure parts of irregular shape

1.10.1 Where pressure parts are of such irregular shape that it is impracticable to design their scantlings by the application of the formulae in Sections 2 to 7, the suitability of their construction is to be determined by hydraulic proof test of a prototype or by an agreed alternative method.

1.11 Adverse working conditions

1.11.1 Where working conditions are adverse, special consideration may require to be given to increasing the scantlings derived from the formulae. In this connection, where necessary, account should also be taken of any excess of loading resulting from:

(a) impact loads, including rapidly fluctuating pressures,
(b) weight of the vessel and normal contents under operating and test conditions,
(c) superimposed loads, such as other pressure vessels, operating equipment, insulation, corrosion-resistant or erosion-resistant linings and piping,
(d) reactions of supporting lugs, rings, saddles or other types of supports, or
(e) the effect of temperature gradients on maximum stress.

Section 2
Cylindrical shells and drums subject to internal pressure

2.1 Minimum thickness

2.1.1 The minimum thickness, t, of a cylindrical shell is to be determined by the following formula:

$$t = \frac{p\,R_i}{10\sigma\,J - 0{,}5p} + 0{,}75 \quad \text{mm}$$

where

t, p, R_i and σ are as defined in 1.2
J = the joint factor of the longitudinal joints (expressed as a fraction). *See* 1.9 in the case of seamless shells clear of openings $J = 1{,}0$.

2.1.2 The formula in 2.1.1 is applicable only where the resulting thickness does not exceed half the internal radius, i.e. where R_o is not greater than $1{,}5R_i$.

2.1.3 Irrespective of the thickness determined by the formula in 2.1.1, t is to be not less than $3 + \frac{D_i}{1500}$ mm, where D_i is as defined in 1.2. The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

Cross-references

For efficiency of ligaments between tube holes, *see* Ch 10,2.2.
For compensating effect of tube stubs, *see* Ch 10,2.3.
For unreinforced openings, *see* Ch 10,2.4.
For reinforced openings, *see* Ch 10,2.5.

Section 3
Spherical shells subject to internal pressure

3.1 Minimum thickness

3.1.1 The minimum thickness, t, of a spherical shell is to be determined by the following formula:

$$t = \frac{p\,R_i}{20\sigma\,J - 0{,}5p} + 0{,}75 \quad \text{mm}$$

where

t, p, R_i, σ and J are as defined in 1.2.

3.1.2 The formula in 3.1.1 is applicable only where the resulting thickness does not exceed half the internal radius.

3.1.3 Irrespective of the thickness determined by the formula in 3.1.1, t is to be not less than $3 + \frac{D_i}{1500}$ mm, where D_i is as defined in 1.2. The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

3.1.4 Openings in spherical shells requiring compensation are to comply, in general, with Ch 10,2.5, using the calculated and actual thickness of the spherical shell as applicable.

Section 4
Dished ends subject to internal pressure

4.1 Minimum thickness

4.1.1 The thickness, t, of semi-ellipsoidal and hemispherical unstayed ends and the knuckle section of torispherical ends, dished from plate, having pressure on the concave side and satisfying the conditions listed below, is to be determined by the following formula:

$$t = \frac{p\,D_o\,K}{20\sigma\,J} + 0{,}75 \quad \text{mm}$$

where

t, p, D_o, σ and J are as defined in 1.2

K = a shape factor, *see* Ch 10,4.2 and Fig. 10.4.1.

4.1.2 For semi-ellipsoidal ends:

the external height, $H \geq 0{,}18D_o$

where

D_o = the external diameter of the parallel portion of the end, in mm.

4.1.3 For torispherical ends:

the internal radius, $R_i \leq D_o$

the internal knuckle radius, $r_i \geq 0{,}1D_o$

the internal knuckle radius, $r_i \geq 3t$

the external height, $H \geq 0{,}18D_o$, and is determined as follows:

$$H = R_o - \sqrt{(R_o - 0{,}5D_o)(R_o + 0{,}5D_o - 2r_o)}$$

4.1.4 In addition to the formula in 4.1.1 the thickness, t, of a torispherical head, made from more than one plate, in the crown section, is to be not less than that determined by the following formula:

$$t = \frac{p\,R_i}{20\sigma\,J - 0{,}5p} + 0{,}75 \quad \text{mm}$$

where

t, p, R_i, σ, and J are as defined in 1.2.

4.1.5 The thickness required by 4.1.1 for the knuckle section of a torispherical head is to extend past the common tangent point of the knuckle and crown radii into the crown section for a distance not less than $0{,}5\sqrt{R_i\,t}$ mm, before reducing to the crown thickness permitted by 4.1.4

where

t = the required thickness from 4.1.1.

4.1.6 In all cases, H is to be measured from the commencement of curvature, shown in Fig. 10.4.2, in Chapter 10.

4.1.7 The minimum thickness of the head, t, is in no case to be less than $3 + \frac{D_i}{1500}$ mm, where D_i is as defined in 1.2. The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

4.1.8 For ends which are butt welded to the drum shell, *see* 1.9, the thickness of the edge of the flange for connection to the shell is to be not less than the thickness of an unpierced seamless or welded shell, whichever is applicable, of the same diameter and material and determined by 2.1.

Cross-references

For shape factors for dished ends, *see* Ch 10,4.2.
For dished ends with unreinforced openings, *see* Ch 10,4.3.
For flanged openings in dished ends, *see* Ch 10,4.4.
For location of unreinforced and flanged openings in dished ends, *see* Ch 10,4.5.
For dished ends with reinforced openings, *see* Ch 10,4.6 and 4.7.

Section 5
Dishea ends for Class 3 pressure vessels

5.1 Minimum thickness

5.1.1 As an alternative to the formula in 4.1.1, for Class 3 vessels only, the minimum thickness, t, of a torispherical unstayed end dished from plate and having pressure on the concave or convex side is to be determined by the following formula:

$$t = \frac{p\,R_i}{CS}$$

where

t, p, and R_i are as defined in 1.2

C = 2,57 for ends concave to pressure

= 1,65 for ends convex to pressure

S = specified minimum tensile strength of plate, in N/mm^2, which should be not less than 410 N/mm^2.

5.1.2 The inside radius of curvature, R_i, of the end plate is to be not greater than the external diameter of the cylinder to which it is attached.

5.1.3 The inside knuckle radius, r_i, of the arc joining the cylindrical flange to the spherical surface of the end is to be not less than four times the thickness of the end plate, and in no case less than 65 mm.

5.1.4 Ends convex to pressure are not to be used for vessels exceeding 610 mm internal diameter.

5.1.5 Where the end is provided with a flanged manhole, the thickness of the end, in mm, determined by 5.1.1, is to be increased by 3 mm, and the total depth, H, of the manhole flange, measured from the outer surface of the plate on the minor axis, is to be not less than:

$$H = \sqrt{t_1\,W}$$

where

t_1 = required thickness of the plate, in mm

H = depth of flange, in mm

W = minor axis of the manhole, in mm.

Section 6
Conical ends subject to internal pressure

6.1 General

6.1.1 Conical ends and conical reducing sections, as shown in Fig. 10.5.1 in Chapter 10, are to be designed in accordance with the equations given in 6.2.

6.1.2 Connections between cylindrical shell and conical sections and ends should preferably be by means of a knuckle transition radius. Typical permitted details are shown in Fig. 10.5.1 in Chapter 10. Alternatively, conical sections and ends may be butt welded to cylinders without a knuckle radius when the change in angle of slope, ψ, between the two sections under consideration does not exceed 30°.

6.1.3 Conical ends may be constructed of several ring sections of decreasing thickness as determined by the corresponding decreasing diameter.

6.2 Minimum thickness

6.2.1 The minimum thickness, t, of the cylinder, knuckle and conical section at the junction and within the distance L from the junction is to be determined by the following formula:

$$t = \frac{p\,D_o\,K}{20\sigma\,J} + 0{,}75 \quad \text{mm}$$

where

t, p, σ and J are as defined in 1.2

D_o = outside diameter, in mm of the conical section or end, *see* Fig. 10.5.1 in Chapter 10

K = a factor, taking into account the stress in the knuckle, *see* Table 10.5.1 in Chapter 10.

6.2.2 If the distance of a circumferential seam from the knuckle or junction is not less than L, then J is to be taken as 1,0; otherwise J is to be taken as the weld joint factor appropriate to the circumferential seam,

where

r_i = inside radius of transition knuckle, in mm, which is to be taken as $0{,}01D_c$ in the case of conical sections without knuckle transition

L = distance, in mm, from knuckle or junction within which meridional stresses determine the required thickness, *see* Fig. 10.5.1 in Chapter 10

$$= 0{,}5\sqrt{\frac{D_o\,t}{\cos\psi}}$$

ψ = difference between angle of slope of two adjoining conical sections, *see* Fig. 10.5.1 in Chapter 10.

6.2.3 The minimum thickness, t, of those parts of conical sections not less than a distance L from the junction with a cylinder or other conical section, is to be determined by the following formula:

$$t = \frac{p\,D_c}{20\sigma\,J - p}\;\frac{1}{\cos\alpha} + 0{,}75 \quad \text{mm}$$

where

D_c = inside diameter, in mm, of conical section or end at the position under consideration, *see* Fig. 10.5.1 in Chapter 10

$\alpha, \alpha_1, \alpha_2$ = angle of slope of conical section (at the point under consideration) to the vessel axis, *see* Fig. 10.5.1 in Chapter 10.

6.2.4 The thickness of conical sections having an angle of inclination to the vessel axis of more than 75° is to be determined as for a flat plate.

Section 7
Standpipes and branches

7.1 Minimum thickness

7.1.1 The minimum wall thickness, *t*, of standpipes and branches is to be not less than the greater of the two values determined by the following formulae, making such additions as may be necessary on account of bending, static loads and vibrations:

$$t = \frac{p\, D_o}{20\sigma + p} + 0{,}75 \text{ mm, or}$$

$$t = 0{,}015 D_o + 3{,}2 \text{ mm}$$

where

t, p, D_o and σ are defined in 1.2.

If the second formula applies, the thickness need only be maintained for a length, L, from the outside surface of the vessel, but need not extend past the first connection, butt weld or flange, where:

$$L = 3{,}5 \sqrt{D_o\, t} \text{ mm}$$

7.1.2 In no case need the wall thickness exceed the minimum shell thickness as required by 2.1, 3.1 or 4.1 as applicable.

Section 8
Construction

8.1 Access arrangements

8.1.1 Pressure vessels are to be so made that the internal surfaces may be examined. Wherever practicable, the openings for this purpose are to be sufficiently large for access and for cleaning the inner surfaces.

8.1.2 Manholes in cylindrical shells should preferably have their shorter axes arranged longitudinally.

8.1.3 Doors for manholes and sightholes are to be formed from steel plate or of other approved construction, and all jointing surfaces are to be machined.

8.1.4 Doors of the internal type are to be provided with spigots which have a clearance of not more than 1,5 mm all round, i.e. the axes of the opening are not to exceed those of the door by more than 3 mm. The width of the manhole gasket seat is not to be less than 16 mm.

8.1.5 Doors of the internal type for openings not larger than 230 x 180 mm need be fitted with only one stud, which may be forged integral with the door. Doors for openings larger than 230 mm x 180 mm are to be fitted with two studs or bolts. The strength of the attachment to the door is not to be less than the strength of the stud or bolt.

8.1.6 The crossbars or dogs for doors are to be of steel.

8.1.7 External circular flat cover plates are to be in accordance with a Recognised Standard.

8.2 Torispherical and semi-ellipsoidal ends

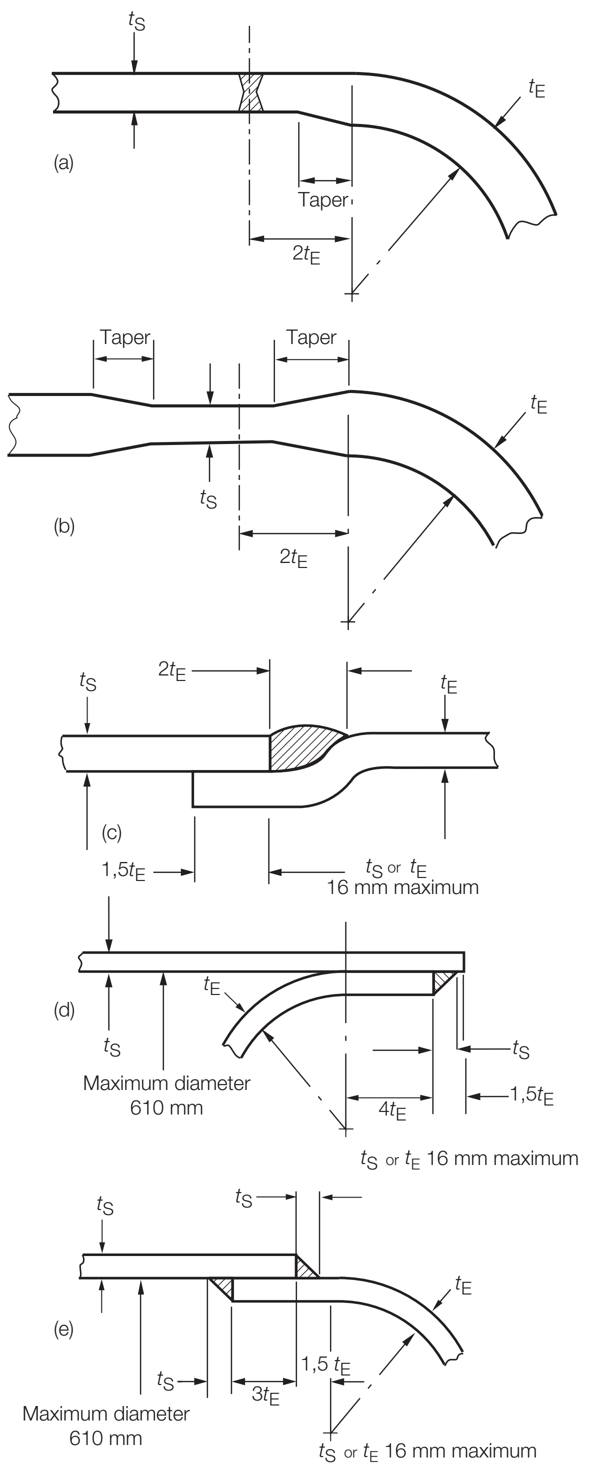
8.2.1 For typical acceptance types of attachment for dished ends to cylindrical shells, *see* Fig. 11.8.1. Types (d) and (e) are to be made a tight fit in the cylindrical shell.

8.2.2 Where the difference in thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate.

8.2.3 The thickness of the plates at the position of the circumferential weld is to be not less than that of an unpierced cylindrical shell of seamless or welded construction, whichever is applicable, of the same diameter and material, *see* 2.1.

Cross-references

For hemispherical ends, *see* Ch 10,14.3.
For openings in flat ends, *see* Ch 10,8.4.
For unstayed circular flat end plates, *see* Ch 10,8.4.
For welded-on flanges, butt joints and fabricated branch pieces, *see* Ch 10,14.4.
For welded attachments to pressure vessels, *see* Ch 10,14.5.



Type of end attachment	Acceptable for
(a) and (b)	All classes
(c)	2/1, 2/2 and 3
(d) and (e)	Class 3 only

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Fig. 11.8.1
Typical attachment of dished ends to cylindrical shell

■ *Section 9*
Mountings and fittings

9.1 General

9.1.1 Each pressure vessel or system is to be fitted with a stop valve situated as close as possible to the shell.

9.1.2 Adequate arrangements are to be provided to prevent over-pressure of any part of a pressure vessel which can be isolated. Pressure gauges are to be fitted in positions where they can be easily read.

9.1.3 Adequate arrangements are to be provided for draining and venting the separate parts of each pressure vessel.

9.2 Receivers containing pressurised gases

9.2.1 Each air receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

9.2.2 Each receiver which can be isolated from a relief valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C, *see also* 9.2.3 and 9.2.4.

9.2.3 Where a fixed system utilising fire-extinguishing gas is fitted, to protect a machinery space containing an air receiver(s), fitted with a fusible plug, it is recommended that the discharge from the fusible plug be piped to the open deck.

9.2.4 Receivers used for the storage of air for the control of remotely operated valves are to be fitted with relief valves and not fusible plugs.

■ *Cross-references*

For starting air pipe systems and safety fittings, *see* Ch 2,8.
For mountings for liquefied gas vessels, *see* the Rules for Ships for Liquefied Gases.

Section 10
Hydraulic tests

10.1 General

10.1.1 Pressure vessels covered by this Chapter are to be tested on completion to a pressure, p_T, determined by the following formula, without showing signs of weakness or defect:

$$p_T = 1{,}3\,\frac{\sigma_{50}}{\sigma_T}\,\frac{t}{(t-0{,}75)}\,p$$

but in no case is to exceed

$$= 1{,}5\,\frac{t}{(t-0{,}75)}\,p$$

where

p = design pressure, in bar
p_T = test pressure, in bar
t = nominal thickness of shell as indicated on the plan, in mm
σ_T = allowable stress at design temperature, in N/mm^2
σ_{50} = allowable stress at 50°C, in N/mm^2.

10.2 Mountings

10.2.1 Mountings are to be subjected to a hydraulic test of twice the approved design pressure.

Section 11
Plate heat exchangers

11.1 General

11.1.1 Plate heat exchangers are to be classed as follows.
Class 2 where either of the following conditions apply:

(a) the maximum metal design temperature is 150°C or greater, or
(b) design pressure is 17,2 bar or greater.

Class 3 in all other cases.

11.1.2 Where the design temperature is equal to or lower than minus 10°C, a higher class is to apply.

Section 1 General

1.1 Application

1.1.1 The requirements of this Chapter apply to the design and construction of piping systems, including pipe fittings forming parts of such systems.

1.1.2 The materials used for pipes, valves and fittings are to be suitable for the medium and the service for which the piping is intended.

1.1.3 The piping systems for LPG and LNG carriers, gas fuelled ships and classed refrigeration systems are to comply with the relevant Sections of this Chapter where applicable and the additional requirements in Section 9 as well as the requirements contained in the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk* (hereinafter referred to as the Rules for Ships for Liquefied Gases).

1.2 Design symbols

1.2.1 The symbols used in this Chapter are defined as follows:

a = percentage negative manufacturing tolerance on thickness
c = corrosion allowance, in mm
d = inside diameter of pipe, in mm, *see* 1.2.3
e = weld efficiency factor, *see* 1.2.4
p = design pressure, in bar (kgf/cm^2), *see* 1.3
p_t = hydraulic test pressure, in bar (kgf/cm^2)
t = the minimum thickness of a straight pipe, in mm, including corrosion allowance and negative tolerance, where applicable
t_b = the minimum thickness of a straight pipe to be used for a pipe bend, in mm, including bending allowance, corrosion allowance and negative tolerance, where applicable
D = outside diameter of pipe, in mm, *see* 1.2.2
R = radius of curvature of a pipe bend at the centreline of the pipe, in mm
T = design temperature, in °C, *see* 1.4
σ = maximum permissible design stress, in N/mm^2 (kgf/cm^2).

1.2.2 The outside diameter, D, is subject to manufacturing tolerances, but these are not to be used in the evaluation of formulae.

1.2.3 The inside diameter, d, is not to be confused with nominal size, which is an accepted designation associated with outside diameters of standard rolling sizes.

1.2.4 The weld efficiency factor, e, is to be taken as 1 for seamless and electric resistance and induction welded steel pipes. Where other methods of pipe manufacture are proposed, the value of e will be specially considered.

1.3 Design pressure

1.3.1 The design pressure, p, is the maximum permissible working pressure and is to be not less than the highest set pressure of the safety valve or relief valve.

1.3.2 In water tube boiler installations, the design pressure for steam piping between the boiler and integral superheater outlet is to be taken as the design pressure of the boiler, i.e., not less than the highest set pressure of any safety valve on the boiler drum. For piping leading from the superheater outlet, the design pressure is to be taken as the highest set pressure of the superheater safety valves.

1.3.3 The design pressure of feed piping and other piping on the discharge from pumps is to be taken as the pump pressure at full rated speed against a shut valve. Where a safety valve or other protective device is fitted to restrict the pressure to a lower value than the shut valve load, the design pressure is to be the highest set pressure of the device.

1.3.4 For design pressure of steering gear components and piping, *see* Ch 19,3.1.5.

1.4 Design temperature

1.4.1 The design temperature is to be taken as the maximum temperature of the internal fluid, but in no case is it to be less than 50°C.

1.4.2 In the case of pipes for superheated steam, the temperature is to be taken as the designed operating steam temperature for the pipeline, provided that the temperature at the superheater outlet is closely controlled. Where temperature fluctuations exceeding 15°C above the designed temperature are to be expected in normal service, the steam temperature to be used for determining the allowable stress is to be increased by the amount of this excess.

1.5 Classes of pipes

1.5.1 Pressure piping systems are divided into three classes for the purpose of assigning appropriate testing requirements, types of joints to be adopted, heat treatment and weld procedure.

1.5.2 Dependent on the service for which they are intended, Class II and III pipes are not to be used for design pressure or temperature conditions in excess of those shown in Table 12.1.1. Where either the maximum design pressure or temperature exceeds that applicable to Class II pipes, Class I pipes are to be used. To illustrate this, *see* Fig. 12.1.1.

Table 12.1.1 Maximum pressure and temperature conditions for Class II and III piping systems

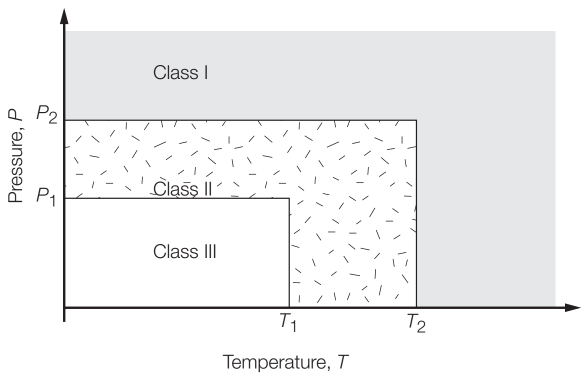
Piping system	Class II		Class III	
	p	T	p	T
	bar	°C	bar	°C
Steam	16,0	300	7,0	170
Thermal oil	16,0	300	7,0	150
Flammable Liquids, *see* Note 1	16,0	150	7,0	60
Other media	40,0	300	16,0	200
Cargo oil	40,0	300	16,0	200

NOTES
1. Flammable liquids include: oil fuel, lubricating oil and flammable hydraulic oil.
2. For grey cast iron, *see also* 4.2.2.

1.5.3 In addition to the pressure piping systems in Table 12.1.1, Class III pipes may be used for open ended piping, e.g., overflows, vents, boiler waste steam pipes, open ended drains, etc.

1.6 Materials

1.6.1 Materials for ferrous castings and forgings of Class I and Class II piping systems are to be produced at a works approved by Lloyd's Register (hereinafter referred to as 'LR') and are in general to be tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).



NOTE
T_1 and P_1 correspond to the maximum temperatures and pressures for a Class III piping system and T_2 and P_2 to those for a Class II piping system depending on the service.

Fig. 12.1.1 Classes of piping system

1.6.2 The Manufacturer's materials certificate will be accepted in lieu of an LR materials certificate for Class III piping systems and for all other classes of piping and associated components where the maximum design conditions are less than the values shown in Table 12.1.2. *See* Ch 1,3.1.3(c) of the Rules for Materials.

Table 12.1.2 Maximum conditions for pipes, valves and fittings for which manufacturer's materials test certificate is acceptable

Material	DN = nominal diameter, mm p_W = working pressure, bar
When the working temperature is less than 300°C: Carbon and low alloy steel, austenitic stainless steel and cast iron (spheroidal or nodular)	$DN < 50$ or $p_W \times DN < 2500$
Copper alloy intended for a working temperature of less than 200°C	$DN < 50$ or $p_W \times DN < 1500$

1.6.3 The manufacturer's certificate validated by LR for materials for ship-side valves and fittings and valves on the collision bulkhead equal to or less than 500 mm nominal diameter will be accepted in lieu of LR's materials certificate where the valves and fittings are in accordance with a recognised National Standard applicable to the intended application and are manufactured and tested in accordance with the appropriate requirements of the Rules for Materials. *See* Ch 1,3.1.3(b) of the Rules for Materials.

■ *Section 2* Carbon and low alloy steels

2.1 Carbon and low alloy steel pipes, valves and fittings

2.1.1 Materials for Class I and Class II piping systems, also for ship-side valves and fittings and valves on the collision bulkhead, are to be manufactured and tested in accordance with the appropriate requirements of the Rules for Materials, *see also* 1.6.

2.1.2 Materials for Class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable national specifications. Pipes having forge butt welded longitudinal seams are not to be used for oil fuel systems, for heating coils in oil tanks, or for pressures exceeding 4,0 bar (4,1 kgf/cm^2). The manufacturer's certificate will be acceptable and is to be provided for each consignment of material. *See* Ch 1,3.1.3(c) of the Rules for Materials.

2.1.3 Steel pipes, valves and fittings may be used within the temperature limits indicated in Tables 12.2.1 and 12.2.2. Where rimming steel is used for pipes manufactured by electric resistance or induction welding processes, the design temperature is limited to 400°C, *see* Ch 6,3 of the Rules for Materials.

2.2 Wrought steel pipes and bends

2.2.1 The maximum permissible design stress, σ, is to be taken as the lowest of the following values:

$$\sigma = \frac{E_t}{1,6} \qquad \sigma = \frac{R_{20}}{2,7} \qquad \sigma = \frac{S_R}{1,6}$$

where

E_t = specified minimum lower yield or 0,2 per cent proof stress at the design temperature; in the case of stainless steel, the 1,0 per cent proof stress at design temperature is to be used

R_{20} = specified minimum tensile strength at ambient temperature

S_R = average stress to produce rupture in 100 000 hours at the design temperature

Values of the maximum permissible design stress, σ, obtained from the properties of the steels specified in Chapter 6 of the Rules for Materials are shown in Tables 12.2.1 and 12.2.2. For intermediate values of specified minimum strengths and temperatures, values of the permissible design stress may be obtained by interpolation.

2.2.2 Where it is proposed to use, for high temperature service, alloy steels other than those detailed in Table 12.2.2 particulars of the tube sizes, design conditions and appropriate national or proprietary material specifications are to be submitted for consideration.

2.2.3 The minimum thickness, t, of straight steel pipes is to be determined by the following formula:

$$t = \left(\frac{pD}{20\sigma\, e + p} + c\right)\frac{100}{100 - a} \text{ mm}$$

$$\left(t = \left(\frac{pD}{2\sigma\, e + p} + c\right)\frac{100}{100 - a} \text{ mm}\right)$$

where

p, D, e and a are as defined in 1.2.1

c is obtained from Table 12.2.3

σ is defined in 2.2.1 and obtained from Table 12.2.1 or Table 12.2.2

For pipes passing through tanks, an additional corrosion allowance is to be added to take account of external corrosion; the addition will depend on the external medium and the value is to be in accordance with Table 12.2.3. Where the pipes are efficiently protected, the corrosion allowance may be reduced by not more than 50 per cent.

Table 12.2.1 Carbon and carbon-manganese steel pipes

Specified minimum tensile strength, N/mm^2 (kgf/mm^2)	Maximum permissible stress, N/mm^2 (kgf/cm^2)												
	Maximum design temperature, °C												
	50	100	150	200	250	300	350	400	410	420	430	440	450
320 (33)	107 (1091)	105 (1070)	99 (1010)	92 (938)	78 (795)	62 (632)	57 (581)	55 (561)	55 (561)	54 (551)	54 (551)	54 (551)	49 (500)
360 (37)	120 (1224)	117 (1193)	110 (1122)	103 (1050)	91 (928)	76 (775)	69 (704)	68 (693)	68 (693)	68 (693)	64 (653)	56 (571)	49 (500)
410 (42)	136 (1387)	131 (1336)	124 (1264)	117 (1193)	106 (1081)	93 (948)	86 (877)	84 (857)	79 (806)	71 (724)	64 (653)	56 (571)	49 (500)
460 (47)	151 (1540)	146 (1489)	139 (1417)	132 (1346)	122 (1244)	111 (1132)	101 (1030)	99 (1010)	98 (999)	85 (876)	73 (744)	62 (632)	53 (540)
490 (50)	160 (1632)	156 (1591)	148 (1509)	141 (1438)	131 (1336)	121 (1234)	111 (1132)	109 (1111)	98 (999)	85 (867)	73 (744)	62 (632)	53 (540)

Table 12.2.2 Alloy steel pipes

Type of steel	Specified minimum tensile strength, N/mm^2 (kgf/mm^2)	Maximum permissible stress, N/mm^2 (kgf/cm^2)									
		Maximum design temperature, °C									
		50	100	200	300	350	400	440	450	460	470
1 Cr $\frac{1}{2}$ Mo	440 (46)	159 (1621)	150 (1530)	137 (1397)	114 (1162)	106 (1081)	102 (1040)	101 (1030)	101 (1030)	100 (1020)	99 (1010)
2$\frac{1}{4}$ Cr 1 Mo annealed	410 (42)	76 (775)	67 (683)	57 (581)	50 (510)	47 (479)	45 (459)	44 (449)	43 (438)	43 (438)	42 (428)
2$\frac{1}{4}$ Cr 1 Mo normalised and tempered, *see* Note 1	490 (50)	167 (1703)	163 (1662)	153 (1550)	144 (1468)	140 (1428)	136 (1387)	130 (1326)	128 (1305)	127 (1295)	116 (1183)
2$\frac{1}{4}$ Cr 1 Mo normalised and tempered, *see* Note 2	490 (50)	167 (1703)	163 (1662)	153 (1560)	144 (1468)	140 (1428)	136 (1387)	130 (1326)	122 (1244)	114 (1162)	105 (1071)
$\frac{1}{2}$ Cr $\frac{1}{2}$ Mo $\frac{1}{4}$ V	460 (47)	166 (1693)	162 (1652)	147 (1499)	120 (1224)	115 (1173)	111 (1132)	106 (1081)	105 (1071)	103 (1050)	102 (1040)

Type of steel	Specified minimum tensile strength, N/mm^2 (kgf/mm^2)	Maximum design temperature, °C									
		480	490	500	510	520	530	540	550	560	570
1 Cr $\frac{1}{2}$ Mo	440 (46)	98 (999)	97 (989)	91 (928)	76 (775)	62 (632)	51 (520)	42 (428)	34 (347)	27 (275)	22 (224)
2$\frac{1}{4}$ Cr 1 Mo annealed	410 (42)	42 (428)	42 (428)	41 (418)	41 (418)	41 (418)	40 (408)	40 (408)	40 (408)	37 (377)	32 (326)
2$\frac{1}{4}$ Cr 1 Mo normalised and tempered, *see* Note 1	490 (50)	106 (1081)	96 (979)	86 (877)	76 (775)	67 (683)	58 (591)	49 (500)	43 (438)	37 (377)	32 (326)
2$\frac{1}{4}$ Cr 1 Mo normalised and tempered, *see* Note 2	490 (50)	96 (979)	88 (897)	79 (806)	72 (734)	64 (653)	56 (571)	49 (500)	43 (438)	37 (377)	32 (326)
$\frac{1}{2}$ Cr $\frac{1}{2}$ Mo $\frac{1}{4}$ V	460 (47)	101 (1030)	99 (1010)	97 (989)	94 (959)	82 (836)	72 (734)	62 (632)	53 (540)	45 (459)	37 (377)

NOTES
1. Maximum permissible stress values applicable when the tempering temperature does not exceed 750°C.
2. Maximum permissible stress values applicable when the tempering temperature exceeds 750°C.

Table 12.2.3 Values of *c* for steel pipes

Piping service	*c* mm
Superheated steam systems	0,3
Saturated steam systems	0,8
Steam coil systems in cargo tanks	2,0
Feed water for boilers in open circuit systems	1,5
Feed water for boilers in closed circuit systems	0,5
Blow down (for boilers) systems	1,5
Compressed air systems	1,0
Hydraulic oil systems	0,3
Lubricating oil systems	0,3
Oil fuel systems	1,0
Cargo oil systems	2,0
Refrigerating plants	0,3
Fresh water systems	0,8
Sea-water systems in general	3,0

2.2.4 The minimum thickness, t_b, of a straight steel pipe to be used for a pipe bend is to be determined by the following formula, except where it can be demonstrated that the use of a thickness less than t_b would not reduce the thickness below t at any point after bending:

$$t_b = \left[\left(\frac{pD}{20\sigma\, e + p}\right)\left(1 + \frac{D}{2{,}5R}\right) + c\right] \frac{100}{100 - a} \text{ mm}$$

$$\left(t_b = \left[\left(\frac{pD}{2\sigma\, e + p}\right)\left(1 + \frac{D}{2{,}5R}\right) + c\right] \frac{100}{100 - a} \text{ mm} \right)$$

where

p, D, R, e and a are as defined in 1.2.1

σ and c are as defined in 2.2.3. In general, R is to be not less than 3D.

2.2.5 Where the minimum thickness calculated by 2.2.3 or 2.2.4 is less than that shown in Table 12.2.4, the minimum nominal thickness for the appropriate standard pipe size shown in the Table is to be used. No allowance is required for negative tolerance, corrosion or reduction in thickness due to bending on this nominal thickness. For larger diameters, the minimum thickness will be considered. For threaded pipes, where permitted, the minimum thickness is to be measured at the bottom of the thread.

2.2.6 For sounding pipes, except those for cargo tanks with cargo having a flash point of less than 60°C, the minimum thickness is intended to apply to the part outside the tank.

2.2.7 For air, bilge, ballast, fuel, overflow, sounding and venting pipes as listed in Table 12.2.4, where the pipes are efficiently protected against corrosion, the thickness may be reduced by not more than 1 mm.

2.2.8 The internal diameter for bilge, venting and overflow pipes listed in Table 12.2.4 is to be not less than 50 mm. The internal diameter for sounding pipes is to be not less than 32 mm.

2.3 Pipe joints – General

2.3.1 Joints in pressure pipelines may be made by:

- Screwed-on or welded-on bolted flanges, *see* 2.5 and 2.6.
- Butt welds between pipes or between pipes and valve chests or other fittings, *see* 2.6.
- Socket weld joints, *see* 2.8.
- Welded sleeve joints, *see* 2.9.
- Threaded sleeve joints, *see* 2.10.
- Special types of approved joints that have been shown to be suitable for the design conditions. Details are to be submitted for consideration.

2.3.2 The dimensions and materials of flanges, gaskets and bolting, and the pressure – temperature rating of bolted flanges in pressure pipelines, are to be in accordance with National or other established Standards.

2.3.3 With the welded pressure piping systems referred to in 2.3.1 it is desirable that a few flanged joints be provided at suitable positions to facilitate installation, cold 'pull up' and inspection at Periodical Surveys.

2.3.4 Piping with joints is to be adequately adjusted, aligned and supported. Supports or hangers are not to be used to force alignment of piping at the point of connection.

2.3.5 Pipes passing through, or connected to, watertight decks are to be continuous or provided with an approved bolted or welded connection to the deck or bulkhead.

2.3.6 Consideration will be given to accepting joints in accordance with a recognised National Standard which is applicable to the intended service and media conveyed.

Table 12.2.4 Minimum thickness for steel pipes

External diameter, *D*, in mm	Pipes in general, in mm	Venting, overflow and sounding pipes for structural tanks, in mm	Bilge, ballast and general sea-water pipes, in mm	Bilge, air, overflow sounding pipes through ballast and fuel tanks, ballast lines through fuel tanks and fuel lines through ballast tanks, in mm	Air, overflow and sounding pipes for fuel oil tanks passing through cargo holds of bulk carriers, in mm
10,2–12	1,6	—	—	—	—
13,5–19	1,8	—	—	—	—
20	2,0	—	—	—	—
21,3–25	2,0	—	3,2	—	—
26,9-33,7	2,0	—	3,2	—	—
38–44,5	2,0	4,5	3,6	6,3	—
48,3	2,3	4,5	3,6	6,3	—
51–63,5	2,3	4,5	4,0	6,3	6,3
70	2,6	4,5	4,0	6,3	6,3
76,1–82,5	2,6	4,5	4,5	6,3	7,6
88,9–108	2,9	4,5	4,5	7,1	8,0
114,3–127	3,2	4,5	4,5	8,0	8,8
133–139,7	3,6	4,5	4,5	8,0	8,8
152,4–168,3	4,0	4,5	4,5	8,8	8,8
177,8	4,5	5,0	5,0	8,8	8,8
193,7	4,5	5,4	5,4	8,8	8,8
219,1	4,5	5,9	5,9	8,8	12,5
244,5–273	5,0	6,3	6,3	8,8	12,5
298,5–368	5,6	6,3	6,3	8,8	12,5
406,4–457,2	6,3	6,3	6,3	8,8	12,5

NOTE
The pipe diameters and wall thicknesses given in the Table are based on common International Standards. Diameter and thickness according to other National or International Standards will be considered.

2.4 Steel pipe flanges

2.4.1 Flanges may be cut from plates or may be forged or cast. The material is to be suitable for the design temperature. Flanges may be attached to the pipes by screwing and expanding or by welding. Alternative methods of flange attachment may be accepted provided details are submitted for consideration.

2.4.2 Flange attachments to pipes and pressure – temperature ratings in accordance with National or other approved Standards will be accepted.

2.5 Screwed-on flanges

2.5.1 Where flanges are secured by screwing, as indicated in Fig. 12.2.1, the pipe and flange are to be screwed with a vanishing thread and the diameter of the screwed portion of the pipe over the thread is not to be appreciably less than the outside diameter of the unscrewed pipe. After the flange has been screwed hard home the pipe is to be expanded into the flange.

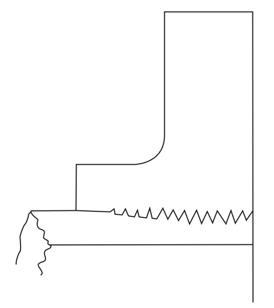


Fig. 12.2.1 Screwed-on flange

2.5.2 The vanishing thread on a pipe is to be not less than three pitches in length, and the diameter at the root of the thread is to increase uniformly from the standard root diameter to the diameter at the top of the thread. This may be produced by suitably grinding the dies, and the flange should be tapered out to the same formation.

2.5.3 Such screwed and expanded flanges may be used for steam for a maximum design pressure of 30,0 bar (30,5 kgf/cm^2) and a maximum design temperature of 370°C and for feed for a maximum design pressure of 50 bar (51 kgf/cm^2).

2.6 Welded-on flanges, butt welded joints and fabricated branch pieces

2.6.1 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the pipes are intended.

2.6.2 Typical examples of welded-on flange attachments are shown in Fig. 12.2.2, and limiting design conditions for flange types (a) to (f) are shown in Table 12.2.5.

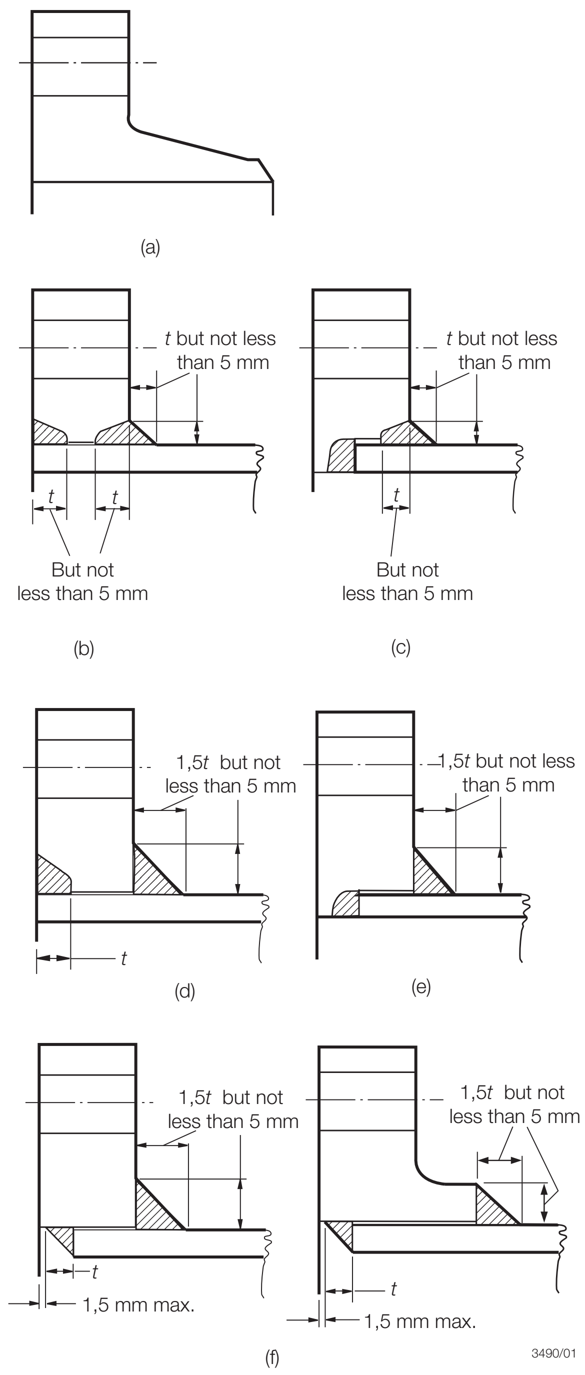


Fig. 12.2.2 Typical welded-on flanges

2.6.3 Butt welded joints are generally to be of the full penetration type and are to meet the requirements of Chapter 13 of the Rules for Materials.

Table 12.2.5 Limiting design conditions for flange types

Flange type	Maximum pressure	Maximum temperature, in °C	Maximum pipe o.d., in mm	Minimum pipe bore, in mm
(a)	Pressure-temperature ratings to be in accordance with a Recognised Standard	No restriction	No restriction	No restriction
(b)		No restriction	168,3 for alloy steels*	No restriction
(c)		No restriction	168,3 for alloy steels*	75
(d)		425	No restriction	No restriction
(e)		425	No restriction	75
(f)		425	No restriction	No restriction

* No restriction for carbon steels

2.6.4 Welded-on flanges are not to be a tight fit on the pipes. The maximum clearance between the bore of the flange and the outside diameter of the pipe is to be 3 mm at any point, and the sum of the clearances diametrically opposite is not to exceed 5 mm.

2.6.5 Where butt welds are employed in the attachment of flange type (a), in pipe-to-pipe joints or in the construction of branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided that the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to the thickness of the thinner at the butt joint. The welding necks of valve chests are to be sufficiently long to ensure that the valves are not distorted as the result of welding and subsequent heat treatment of the joints.

2.6.6 Where backing rings are used with flange type (a) they are to fit closely to the bore of the pipe and should be removed after welding. The rings are to be made of the same material as the pipes or of mild steel having a sulphur content not greater than 0,05 per cent.

2.6.7 Branches may be attached to pressure pipes by means of welding provided that the pipe is reinforced at the branch by a compensating plate or collar or other approved means, or, alternatively, that the thickness of pipe and branch is increased to maintain the strength of the pipe. These requirements also apply to fabricated branch pieces.

2.6.8 Welding may be carried out by means of the shielded metal arc, inert gas metal arc, oxy-acetylene or other approved process, but in general oxy-acetylene welding is suitable only for flange type (a) and is not to be applied to pipes exceeding 100 mm diameter or 9,5 mm thick. The welding is to be carried out in accordance with the appropriate paragraphs of Chapter 17.

2.7 Loose flanges

2.7.1 Loose flange designs as shown in Fig. 12.2.3 may be used provided they are in accordance with a recognised National or International Standard.

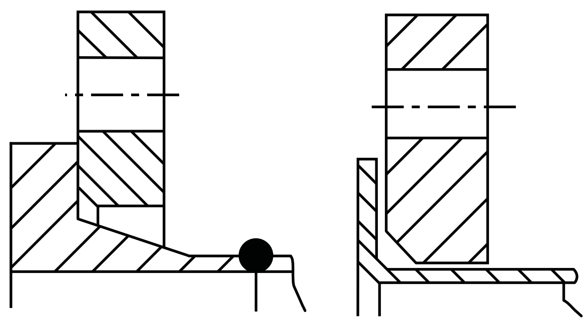


Fig. 12.2.3 Loose flange arrangements

2.7.2 Loose flange designs where the pipe end is flared as shown in Fig 12.2.3(b) are only to be used for water pipes and on open ended lines.

2.8 Socket weld joints

2.8.1 Socket weld joints may be used in Class III systems with carbon steel pipes of any outside diameter. Socket weld fittings are to be of forged steel and the material is to be compatible with the associated piping. In particular cases, socket welded joints may be permitted for piping systems of Class I and II having outside diameter not exceeding 88,9 mm. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur or where toxic or asphyxiating media are conveyed, other than for carbon dioxide fire-extinguishing distribution piping, *see also* Ch 10,14.4.9.

2.8.2 The thickness of the socket weld fittings is to meet the requirements of 2.2.3 but is to be not less than 1,25 times the nominal thickness of the pipe or tube. The diametrical clearance between the outside diameter of the pipe and the bore of the fitting is not to exceed 0,8 mm, and a gap of approximately 1,5 mm is to be provided between the end of the pipe and the bottom of the socket. *See also* Ch 13,5.2.9 of the Rules for Materials.

2.8.3 The leg lengths of the fillet weld connecting the pipe to the socket weld fitting are to be such that the throat dimension of the weld is not less than the nominal thickness of the pipe or tube.

2.8.4 Socket weld joints may be used in carbon dioxide fire-extinguishing system distribution piping only as permitted by 2.14.

2.9 Welded sleeve joints

2.9.1 Welded sleeve joints may be used in Class III systems with carbon steel pipes of any outside diameter. In particular cases, welded sleeve joints may be permitted for piping systems of Class I and II having outside diameter not exceeding 88,9 mm. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur or where toxic or asphyxiating media, other than for carbon dioxide fire-extinguishing distribution piping, are conveyed.

2.9.2 Welded sleeve joints are not to be used in the following locations:

- Bilge pipes in way of deep tanks.
- Cargo oil piping outside of the cargo area for bow or stern loading/discharge.
- Air and sounding pipes passing through cargo tanks.

2.9.3 Welded sleeve joints may be used in piping systems for the storage, distribution and utilisation of oil fuel, lubricating or other flammable oil systems in machinery spaces provided they are located in readily visible and accessible positions. *See also* Ch 14,2.9.2.

2.9.4 Welded sleeve joints may be used in carbon dioxide fire-extinguishing system distribution piping only as permitted by 2.14.

2.9.5 Welded sleeve joints are not to be used at deck/bulkhead penetrations that require continuous pipe lengths.

2.9.6 The thickness of the sleeve is to satisfy the requirements of 2.2.3 and Table 12.2.4 but is to be not less than 1,42 times the nominal thickness of the pipe in order to satisfy the throat thickness requirement in 2.9.7. The radial clearance between the outside diameter of the pipe and the internal diameter of the sleeve is not to exceed 1 mm for pipes up to a nominal diameter of 50 mm, 2 mm on diameters up to 200 mm nominal size and 3 mm for larger size pipes. The pipe ends are to be separated by a clearance of approximately 2 mm at the centre of the sleeve. Alternatively, consideration will be given to sleeve thickness in accordance with a relevant National Standard

2.9.7 The sleeve material is to be compatible with the associated piping and the leg lengths of the fillet weld connecting the pipe to the sleeve are to be such that the throat dimension of the weld is not less than the nominal thickness of the pipe or tube.

2.9.8 The minimum length of the sleeve is to conform to the following formula:

$$L_{si} = 0,14D + 36 \text{ mm}$$

where

L_{si} is the length of the sleeve
D is defined in 1.2.1.

2.10 Threaded sleeve joints

2.10.1 Threaded sleeve joints, in accordance with National or other established Standards, may be used with carbon steel pipes within the limits given in Table 12.2.6. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur or where flammable or toxic media is conveyed.

Table 12.2.6 Limiting design conditions for threaded sleeve joints

Thread type	Outside pipe diameter, in mm		
	Class I	Class II	Class III
Tapered thread	<33,7	<60,3	<60,3
Parallel thread	–	–	<60,3

2.11 Screwed fittings

2.11.1 Screwed fittings, including compression fittings, of an approved type may be used in piping systems for pipes not exceeding 51 mm outside diameter. Where the fittings are not in accordance with an acceptable standard then LR may require the fittings to be subjected to special tests to demonstrate their suitability for the intended service and working conditions.

2.12 Other mechanical couplings

2.12.1 Pipe unions, compression couplings, or slip-on joints, as shown in Fig. 12.2.4, may be used if Type Approved for the service conditions and the intended application. The Type Approval is to be based on the results of testing of the actual joints. The acceptable use for each service is indicated in Table12.2.7 and dependence upon the Class of piping, with limiting pipe dimensions, is indicated in Table 12.2.8.

2.12.2 Where the application of mechanical joints results in a reduction in pipe wall thickness due to the use of bite type rings or other structural elements, this is to be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.

2.12.3 Construction of mechanical joints is to prevent the possibility of tightness failure affected by pressure pulsation, piping vibration, temperature variation and other similar adverse effects occurring during operation on board.

2.12.4 Materials of mechanical joints are to be compatible with the piping material and internal and external media.

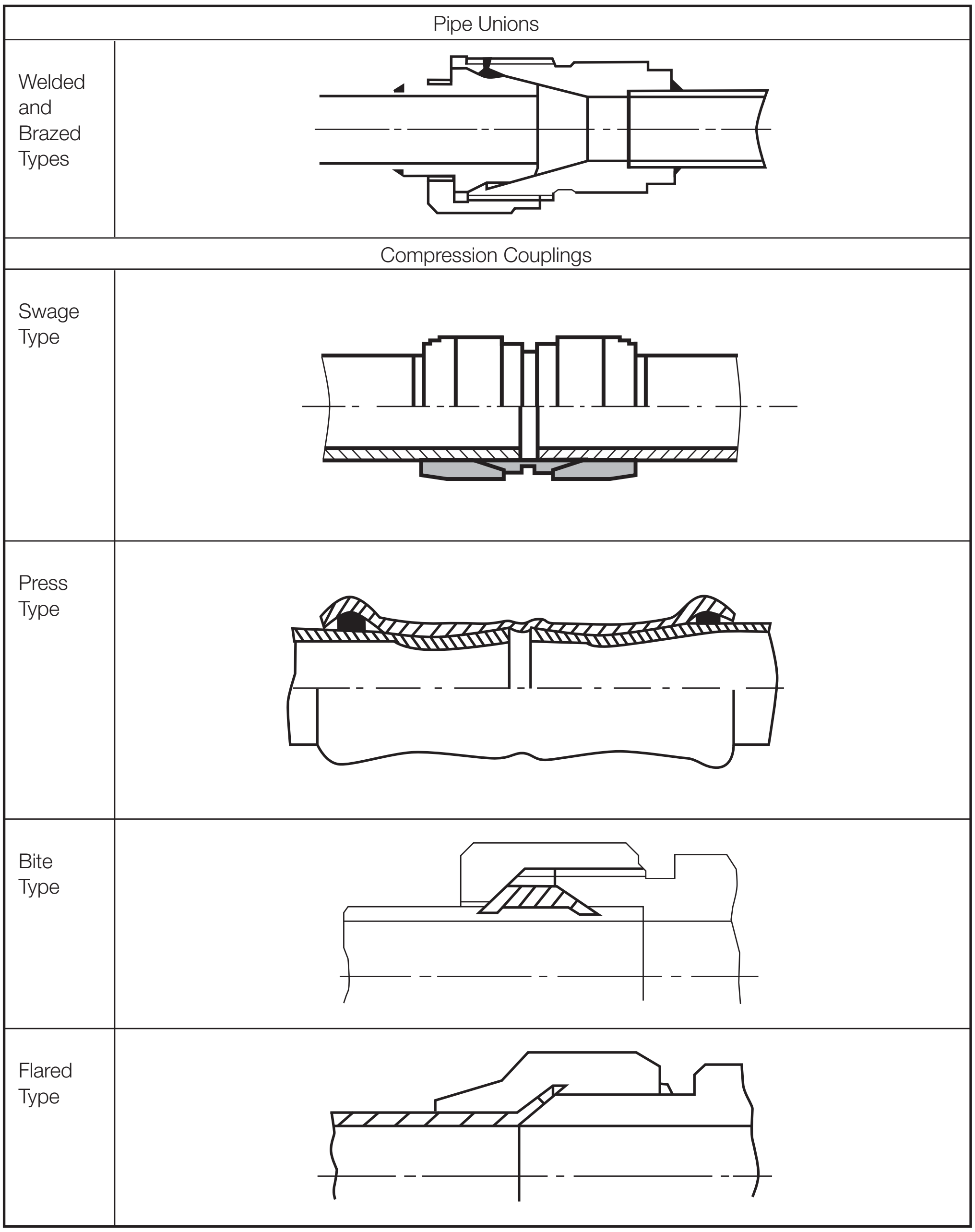


Fig. 12.2.4 Examples of mechanical joints (*see continuation*)

2.12.5 Mechanical joints for pressure pipes are to be tested to a burst pressure of 4 times the design pressure. For design pressures above 200 bar the required burst pressure will be specially considered.

2.12.6 In general, mechanical joints are to be of fire resistant type where required by Table 12.2.7.

2.12.7 Mechanical joints, which in the event of damage could cause fire or flooding, are not to be used in piping sections directly connected to the sea openings or tanks containing flammable fluids.

2.12.8 The mechanical joints are to be designed to withstand internal and external pressure as applicable and where used in suction lines are to be capable of operating under vacuum.

2.12.9 Generally, slip-on joints are not to be used in pipelines in cargo holds, tanks, and other spaces which are not easily accessible. Application of these joints inside tanks may only be accepted where the medium conveyed is the same as that in the tanks.

2.12.10 Unrestrained slip-on joints are only to be used in cases where compensation of lateral pipe deformation is necessary. Usage of these joints as the main means of pipe connection is not permitted.

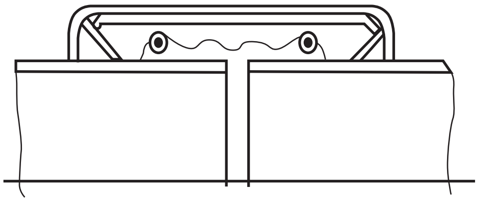
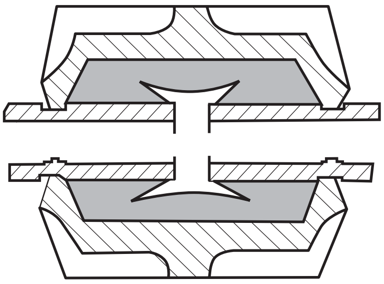
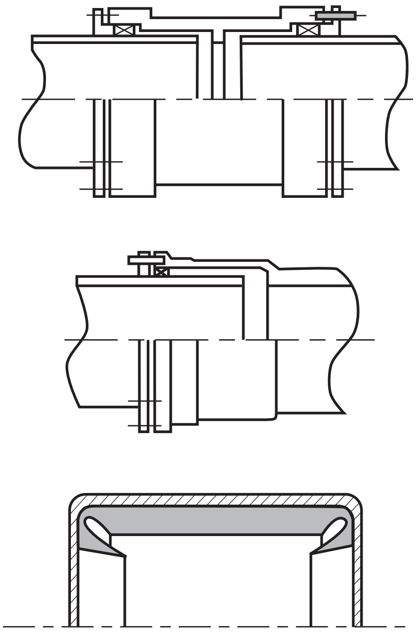
Slip-on Joints	
Grip Type	
Machine Grooved Type	
SlipType	

Fig. 12.2.4 Examples of mechanical joints (*conclusion*)

2.12.11 Restrained slip-on joints are permitted in steam pipes with a design pressure of 10 bar or less on the weather decks of oil and chemical tankers to accommodate axial pipe movement, *see* Ch 13,2.7.

2.12.12 Mechanical joints are to be tested in accordance with a program approved by LR, which is to include the following tests as relevant to the service conditions and the intended application:

- leakage test;
- vacuum test (where necessary);
- vibration (fatigue) test;
- fire endurance test (where necessary);
- burst pressure test;
- pressure pulsation test (where necessary);
- assembly test (where necessary);
- pull out test (where necessary);
- static displacement/misalignment test (where necessary).

Table 12.2.7 Application of mechanical joints

Systems	Kind of connections		
	Pipe unions	Compression couplings (6)	Slip-on joints
Flammable fluids (Flash point <60°)			
Cargo oil lines	+	+	+5
Crude oil washing lines	+	+	+5
Vent lines	+	+	+3
Inert gas			
Water seal effluent lines	+	+	+
Scrubber effluent lines	+	+	+
Main lines	+	+	+2,5
Distribution lines	+	+	+5
Flammable fluids (Flash point > 60°)			
Cargo oil lines	+	+	+5
Fuel oil lines	+	+	+2,3
Lubricating oil lines	+	+	+2,3
Hydraulic oil	+	+	+2,3
Thermal oil	+	+	+2,3
Sea-water			
Bilge lines	+	+	+1
Fire main and water spray	+	+	+3
Foam system	+	+	+3
Sprinkler system	+	+	+3
Ballast system	+	+	+1
Cooling water system	+	+	+1
Tank cleaning services	+	+	+
Non-essential systems	+	+	+
Fresh water			
Cooling water system	+	+	+1
Condensate return	+	+	+1
Non-essential system	+	+	+
Sanitary/Drains/Scuppers			
Deck drains (internal)	+	+	+4
Sanitary drains	+	+	+
Scuppers and discharge (overboard)	+	+	—
Sounding/vent			
Water tanks/Dry spaces	+	+	+
Oil tanks (f.p.> 60°C)	+	+	+2,3
Miscellaneous			
Starting/Control air (1)	+	+	—
Service air (non-essential)	+	+	+
Brine	+	+	+
CO_2 system	+	+	—
Steam	+	+	+7

KEY
+ Application is allowed
— Application is not allowed

NOTES
1. Inside machinery spaces of Category A – only approved fire resistant types.
2. Not inside machinery spaces of Category A or accommodation spaces. May be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions.
3. Approved fire resistant types. Fire resistant type is a type of connection which, when installed in the system and in the event of failure caused by fire, the failure would not result in fire spread, flooding or the loss of an essential service.
4. Above freeboard deck only.
5. In pump rooms and open decks – only approved fire resistant types.
6. If compression couplings include any components which are sensitive to heat, they are to be of approved fire resistant type as required for slip-on joints.
7. *See* 2.12.11.

Table 12.2.8 Application of mechanical joints depending on class of piping

Types of joints	Classes of piping systems		
	Class I	Class II	Class III
Pipe unions			
Welded and brazed type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Compression couplings			
Swage type	+	+	+
Bite type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Flared type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Press type	–	–	+
Slip-on joints			
Machine grooved type	+	+	+
Grip type	–	+	+
Slip type	–	+	+

KEY
+ Application is allowed
– Application is not allowed

2.13 Non-destructive testing

2.13.1 For details of non-destructive tests on piping systems, other than hydraulic tests, *see* Chapter 13 of the Rules for Materials.

2.14 Carbon dioxide (CO_2) fire-extinguishing system piping

2.14.1 The piping for carbon dioxide fire-extinguishing systems is to comply with the requirements of Chapter 5 of the FSS Code, as applicable. For purposes of Classification, any use of the word 'Administration' in the Regulation is to be taken to mean LR.

2.14.2 Materials for the distribution manifolds between the carbon dioxide storage bottles and the discharge valves to each section and associated pipes, valves and fittings of high pressure systems are to be manufactured and tested in accordance with the requirements for Class I piping systems. Pipes are to meet the minimum wall thickness requirements of Table 12.2.9 and the manifold system is to be hydraulically tested to a pressure of 190 bar. A high pressure system is defined as a system where the carbon dioxide is stored at ambient temperature.
Materials for the distribution manifolds between the carbon dioxide storage vessel(s) and the discharge valves to each section and associated pipes, valves and fittings of low pressure systems are to be manufactured and tested in accordance with the requirements for Class II piping systems and the manifold system is to be hydraulically tested to a pressure of 33 bar. A low pressure system is defined as a system where the carbon dioxide is stored at a working pressure in the range of 1,8 N/mm^2 to 2,2 N/mm^2.

2.14.3 Piping downstream of the distribution valve(s) for high pressure systems is to be manufactured and tested in accordance with the requirements for Class II piping and is to meet the minimum wall thickness requirements of Table 12.2.4. After installation the distribution system is to be leak tested at a pressure of 6 bar.
Piping downstream of the distribution valve(s) for low pressure systems is to be manufactured and tested in accordance with the requirements for Class III piping. After installation the distribution system is to be leak tested at a pressure of 6 bar. Class III piping may be used for open ended distribution piping downstream of the distribution valve(s) of high pressure systems where agreed by LR and where meeting the minimum wall thickness requirements of Table 12.2.4 and where a minimum of ten per cent of the piping is hydraulically tested at a pressure of 125 bar. This testing is to be carried out before installation.

2.14.4 Any part of the carbon dioxide fire-extinguishing system piping is to be of galvanised steel or of corrosion-resistant steel. Where full penetration butt welding is used, the pipe is to be protected against corrosion in the area of the weld seam after welding. The process for protecting the pipe internally against corrosion is to be of an approved type.
All pipes are to be arranged to be self-draining. Where pipes are to be led into refrigerated spaces, this is subject to special consideration. The ends of distribution pipes downstream of the distribution valve(s) are to extend at least 50 mm beyond the last nozzle and are to be fitted with a dirt trap consisting of an open ended tee with a capped nipple.

2.14.5 If it is necessary for carbon dioxide pipes to pass through accommodation spaces, the pipe is to be seamless and is to meet the requirements for Class II pipes. Joints are to be made only by welding and the pipes are to be hydraulically tested after installation at a pressure of 50 bar.

2.14.6 The following means are permitted for making joints on carbon dioxide fire-extinguishing system piping;
(a) Full penetration butt welding, where the pipe is galvanised, *see* 2.14.4.
(b) Couplings as permitted by Table 12.2.7.
(c) Cone connections.
(d) Tapered screw joints, where allowed by 2.14.10 and where meeting the requirements of 2.14.10.
(e) Flanged joints.
(f) Socket weld joints to acceptable National Standards and where allowed by 2.14.7 and where meeting the requirements of 2.14.9.

(g) Welded sleeve joints may be used where allowed by 2.14.8 and where meeting the requirements of 2.14.9.

2.14.7 Socket weld joints of an approved type may be used downstream of the distribution valve(s), provided that the requirements for materials and limitations on outside diameter applicable for Class II piping are applied.

2.14.8 Welded sleeve joints of an approved type may be used within the protected space, provided that the requirements for materials and limitations on outside diameter applicable for Class II piping are applied.

2.14.9 Where socket weld joints or welded sleeve joints are utilised, the pipes in way of the welded joints are to be adequately supported and the joints are to be located where they are visible. Where welding is to be carried out *in situ*, the piping is to be kept clear of adjacent structures to allow sufficient access for preheating and welding, which is to be carried out in accordance with approved procedures.

2.14.10 Threaded joints are only allowed inside the protected spaces and in carbon dioxide bottles storage rooms. They should have no exposed screw threads and any sealing medium should be selected as to ensure no protrusions or debris might be produced in the pipe.

■ Section 3
Copper and copper alloys

3.1 Copper and copper alloy pipes, valves and fittings

3.1.1 Materials for Class I and Class II piping systems, also for ship-side valves and fittings and valves on the collision bulkhead, are to be manufactured and tested in accordance with the requirements of Chapter 9 of the Rules for Materials, *see also* 1.6.

3.1.2 Materials for Class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable National Specifications. The manufacturer's certificate will be acceptable and is to be provided for each consignment of material. *See* Ch 1,3.1.3(c) of the Rules for Materials.

3.1.3 Pipes are to be seamless, and branches are to be provided by cast or stamped fittings, pipe pressings or other approved fabrications.

3.1.4 Brazing and welding materials are to be suitable for the operating temperature and for the medium being carried. All brazing and welding are to be carried out to the satisfaction of the Surveyors.

3.1.5 In general, the maximum permissible service temperature of copper and copper alloy pipes, valves and fittings is not to exceed 200°C for copper and aluminium brass, and 300°C for copper-nickel. Cast bronze valves and fittings complying with the requirements of Chapter 9 of the Rules for Materials may be accepted up to 260°C.

3.1.6 The minimum thickness, t, of straight copper and copper alloy pipes is to be determined by the following formula:

$$t = \left(\frac{pD}{20\sigma + p} + c\right)\frac{100}{100 - a}\ \text{mm}$$

$$\left(t = \left(\frac{pD}{2\sigma + p} + c\right)\frac{100}{100 - a}\ \text{mm}\right)$$

where

p, D and a are as defined in 1.2.1

c = corrosion allowance
 = 0,8 mm for copper, aluminium brass, and copper-nickel alloys where the nickel content is less than 10 per cent
 = 0,5 mm for copper-nickel alloys where the nickel content is 10 per cent or greater
 = 0 where the media are non-corrosive relative to the pipe material

σ = maximum permissible design stress, in N/mm^2 (kgf/cm^2), from Table 12.3.1. Intermediate values of stresses may be obtained by linear interpolation.

3.1.7 The minimum thickness, t_b, of a straight seamless copper or copper alloy pipe to be used for a pipe bend is to be determined by the formula below, except where it can be demonstrated that the use of a thickness less than t_b would not reduce the thickness below t at any point after bending:

$$t_b = \left[\left(\frac{p\,D}{20\sigma + p}\right)\left(1 + \frac{D}{2{,}5R}\right) + c\right]\frac{100}{100 - a}\ \text{mm}$$

$$\left(t_b = \left[\left(\frac{p\,D}{2\sigma + p}\right)\left(1 + \frac{D}{2{,}5R}\right) + c\right]\frac{100}{100 - a}\ \text{mm}\right)$$

where

p, D, R and a are as defined in 1.2.1
σ and c are as defined in 3.1.6. In general, R is to be not less than $3D$.

3.1.8 Where the minimum thickness calculated by 3.1.6 or 3.1.7 is less than shown in Table 12.3.2, the minimum nominal thickness for the appropriate standard pipe size shown in the Table is to be used. No allowance is required for negative tolerance or reduction in thickness due to bending on this nominal thickness. For threaded pipes, where permitted, the minimum thickness is to be measured at the bottom of the thread.

3.2 Heat treatment

3.2.1 Pipes which have been hardened by cold bending are to be suitably heat treated on completion of fabrication and prior to being tested by hydraulic pressure. Copper pipes are to be annealed and copper alloy pipes are to be either annealed or stress relief heat treated.

Table 12.3.1 Copper and copper alloy pipes

Pipe material	Condition of supply	Specified minimum tensile strength, N/mm^2 (kgf/mm^2)	Permissible stress, N/mm^2 (kgf/cm^2) Maximum design temperature, °C										
			50	75	100	125	150	175	200	225	250	275	300
Copper	Annealed	220 (22)	41,2 (420)	41,2 (420)	40,2 (410)	40,2 (410)	34,3 (350)	27,5 (280)	18,6 (190)	–	–	–	–
Aluminium brass	Annealed	320 (33)	78,5 (800)	78,5 (800)	78,5 (800)	78,5 (800)	78,5 (800)	51,0 (520)	24,5 (250)	–	–	–	–
90/10 Copper-nickel-iron	Annealed	270 (28)	68,6 (700)	68,6 (700)	67,7 (690)	65,7 (670)	63,7 (650)	61,8 (630)	58,8 (600)	55,9 (570)	52,0 (530)	48,1 (490)	44,1 (450)
70/30 Copper-nickel	Annealed	360 (37)	81,4 (830)	79,4 (810)	77,5 (790)	75,5 (770)	73,5 (750)	71,6 (730)	69,6 (710)	67,7 (690)	65,7 (670)	63,7 (650)	61,8 (630)

Table 12.3.2 Minimum thickness for copper and copper alloy pipes

Standard pipe sizes (outside diameter), in mm	Minimum overriding nominal thickness, in mm	
	Copper	Copper alloy
8 to 10	1,0	0,8
12 to 20	1,2	1,0
25 to 44,5	1,5	1,2
50 to 76,1	2,0	1,5
88,9 to 108	2,5	2,0
133 to 159	3,0	2,5
193,7 to 267	3,5	3,0
273 to 457,2	4,0	3,5
508	4,5	4,0

■ *Section 4* Cast iron

4.1 Spheroidal or nodular graphite cast iron

4.1.1 Spheroidal or nodular graphite iron may be accepted for bilge, ballast and cargo oil piping.

4.1.2 Spheroidal or nodular graphite iron castings for pipes, valves and fittings in Class II and Class III piping systems are to be made in a grade having a specified minimum elongation not less than 12 per cent on a gauge length of $5{,}65\sqrt{S_o}$, where S_o is the actual cross-sectional area of the test piece.

4.1.3 Castings for Class II systems, also for ship-side valves and fittings and valves on the collision bulkhead, are to be manufactured and tested in accordance with the requirements of Chapter 7 of the Rules for Materials.

4.1.4 Castings for Class III systems are to comply with the requirements of acceptable national specifications. A manufacturer's certificate will be accepted and is to be provided for each consignment of material for Class III systems, *see also* 1.6 and Ch 1,3.1.3(c) of the Rules for Materials.

4.1.5 Proposals for the use of this material in Class I piping systems will be specially considered, but in no case is the material to be used in systems where the design temperature exceeds 350°C.

4.1.6 Where the elongation is less than the minimum required by 4.1.2, the material is, in general, to be subject to the same limitations as grey cast iron.

4.2 Grey cast iron

4.2.1 Grey cast iron pipes, valves and fittings will, in general, be accepted in Class III piping systems except as stated in 4.2.3.

4.2.2 Grey cast iron is not to be used for pipes, valves and other fittings handling media having temperatures above 220°C or for piping subject to pressure shock, excessive strains or vibrations.

4.2.3 Grey cast iron is not to be used for the following:
- Pipes for steam systems and fire extinguishing systems.
- Pipes, valves and fittings for boiler blow-down systems and other piping systems subject to shock or vibration.
- Ship-side valves and fittings, *see* Ch 13,2.5.
- Valves fitted on the collision bulkhead, *see* Ch 13,3.5.
- Bilge lines in tanks.
- Pipes and fittings in flammable oil systems where the design pressure exceeds 7 bar or the design operating temperature is greater than 60°C.
- Valves fitted to tanks containing flammable oil under static pressure.
- Valve chests and fittings for starting air systems, *see* Ch 2,8.3.4.

4.2.4 Castings for Class III piping systems are to comply with acceptable National Specifications.

Section 5
Plastics pipes

5.1 General

5.1.1 Proposals to use plastics pipes in shipboard piping systems will be considered in relation to the properties of the materials, the operating conditions, the intended service and location. Details are to be submitted for approval. Special consideration will be given to any proposed service for plastics pipes not mentioned in these Rules.

5.1.2 Attention is also to be given to the *Guidelines for the Application of Plastic Pipes on Ships* contained in IMO Resolution A.753(18).

5.1.3 Plastics pipes and fittings will, in general, be accepted in Class III piping systems. Proposals for the use of plastics in Class I and Class II piping systems will be specially considered.

5.1.4 For Class I, Class II and any Class III piping systems for which there are Rule requirements, the pipes are to be of a type which has been approved by LR.

5.1.5 For domestic and similar services where there are no Rule requirements, the pipes need not be of a type which has been approved by LR. However, the fire safety aspects as referenced in 5.4, are to be considered.

5.1.6 The use of plastics pipes may be restricted by statutory requirements of the National Authority of the country in which the ship is to be registered.

5.2 Design and performance criteria

5.2.1 Pipes and fittings are to be of robust construction and are to comply with a National or other established Standard, consistent with the intended use. Particulars of pipes, fittings and joints are to be submitted for consideration.

5.2.2 The design and performance criteria of all piping systems, independent of service or location, are to meet the requirements of 5.3.

5.2.3 Depending on the service and location, the fire safety aspects are to meet the requirements of 5.4.

5.2.4 Plastics piping, connections and fittings are to be electrically conductive when:
(a) carrying fluids capable of generating electrostatic charges.
(b) passing through hazardous zones and spaces, regardless of the fluid being conveyed.

Suitable precautions against the build up of electrostatic charges are to be provided in accordance with the requirements of 5.5, *see also* Pt 6, Ch 2,1.13.

5.3 Design strength

5.3.1 The strength of pipes is to be determined by hydrostatic pressure tests to failure on representative sizes of pipe. The strength of fittings is to be not less than the strength of the pipes.

5.3.2 The nominal internal pressure, pN_i, of the pipe is to be determined by the lesser of the following:

$$pN_i \le \frac{p_{st}}{4}$$

$$pN_i \le \frac{p_{lt}}{2,5}$$

where

p_{st} = short term hydrostatic test failure pressure, in bar
p_{lt} = long term hydrostatic test failure pressure (100 000 hours), in bar

Testing may be carried out over a reduced period of time using suitable Standards, such as ASTM D2837 and D1598.

5.3.3 The nominal external pressure, pN_e, of the pipe, defined as the maximum total of internal vacuum and external static pressure head to which the pipe may be subjected, is to be determined by the following:

$$pN_e \le \frac{p_{col}}{3}$$

where

p_{col} = pipe collapse pressure, in bar

The pipe collapse pressure is not to be less than 3 bar.

5.3.4 Piping is to meet these design requirements over the range of service temperature it will experience.

5.3.5 High temperature limits and pressure reductions relative to nominal pressures are to be according to a recognised standard, but in each case the maximum working temperature is to be at least 20°C lower than the minimum temperature of deflection under load of the resin or plastics material without reinforcement. The minimum heat distortion temperature is not to be less than 80°C, *see also* Ch 14,4 of the Rules for Materials.

5.3.6 Where it is proposed to use plastics piping in low temperature services, design strength testing is to be made at a temperature 10°C lower than the minimum working temperature.

5.3.7 For guidance, typical temperature and pressure limits are indicated in Tables 12.5.1 and 12.5.2. The Tables are related to water service only. Transport of chemicals or other media is to be considered on a case by case basis.

5.3.8 The selection of plastics materials for piping is to take account of other factors such as impact resistance, ageing, fatigue, erosion resistance, fluid absorption and material compatibility such that the design strength of the piping is not reduced below that required by these Rules.

5.3.9 Design strength values may be verified experimentally or by a combination of testing and calculation methods.

Table 12.5.1 Typical temperature and pressure limits for thermoplastic pipes

Material	Nominal pressure, bar	Maximum permissible working pressure, bar						
		–20 to 0°C	30°C	40°C	50°C	60°C	70°C	80°C
PVC	10		7,5	6				
	16		12	9	6			
ABS	10	7,5	7,5	7	6			
	16	12	12	10,5	9	7,5	6	
HDPE	10	7,5	6					
	16	12	9,5	6				

Abbreviations
PVC Polyvinyl chloride
ABS Acrylonitrile – butadiene – styrene
HDPE High density polyethylene

Table 12.5.2 Typical temperature and pressure limits for glassfibre reinforced epoxy (GRE) and polyester (GRP) pipes

Minimum heat distortion temperature of resin	Nominal pressure, bar	Maximum permissible working pressure, bar							
		–50 to 30°C	40°C	50°C	60°C	70°C	80°C	90°C	95°C
80°C	10	10	9	7,5	6				
	16	16	14	12	9,5				
	25	16	16	16	15				
100°C	10	10	10	9,5	8,5	7	6		
	16	16	16	15	13,5	11	9,5		
	25	16	16	16	16	16	15		
135°C	10	10	10	10	10	9,5	8,5	7	6
	16	16	16	16	16	15	13,5	11	9,5
	25	16	16	16	16	16	16	16	15

5.4 Fire performance criteria

5.4.1 Where plastics pipes are used in systems essential to the safe operation of the ship, or for containing combustible liquids or sea-water where leakage or failure could result in fire or in the flooding of watertight compartments, the pipes and fittings are to be of a type which have been fire endurance tested in accordance with the requirements of Table 12.5.3.

5.4.2 Where a fire protective coating of pipes and fittings is necessary for achieving the fire endurance standards required, the coating is to be resistant to products likely to come into contact with the piping and be suitable for the intended application.

5.5 Electrical conductivity

5.5.1 Where a piping system is required to be electrically conductive for the control of static electricity, the resistance per unit length of the pipe, bends, elbows, fabricated branch pieces, etc., is not to exceed 0,1 MΩ/m, *see also* 5.2.4.

5.5.2 Electrical continuity is to be maintained across the joints and fittings and the system is to be earthed, *see also* Pt 6, Ch 2,1.13. The resistance to earth from any point in the piping system is not to exceed 1 MΩ.

5.6 Manufacture and quality control

5.6.1 All materials for plastics pipes and fittings are to be approved by LR, and are in general to be tested in accordance with Ch 14,4 of the Rules for Materials. For pipes and fittings not employing hand lay up techniques, the hydrostatic pressure test required by Ch 14,4.9 of the Rules for Materials may be replaced by testing carried out in accordance with the requirements stipulated in a National or International Standard, consistent with the intended use for which the pipe or fittings are manufactured, provided there is an effective quality system in place complying with the requirements of Ch 14,4.4 of the Rules for Materials and the testing is completed to the satisfaction of the LR Surveyor.

5.6.2 The material manufacturer's test certificate, based on actual tested data, is to be provided for each batch of material.

5.6.3 Plastics pipes and fittings are to be manufactured at a works approved by LR in accordance with agreed quality control procedures which shall be capable of detecting at any stage (e.g., incoming material, production, finished article, etc.) deviations in the material, product or process.

Table 12.5.3 Fire endurance requirements (*see continuation*)

Piping systems	Location A Machinery spaces of Category A	B Other machinery spaces and pump rooms	C Cargo pump rooms	D Ro–Ro cargo holds	E Other dry cargo holds	F Cargo tanks	G Fuel oil tanks	H Ballast water tanks	I Cofferdams void spaces pipe tunnel and ducts	J Accommodation service and control spaces	K Open decks
CARGO (FLAMMABLE CARGOES f.p. ≤ 60°C)											
1 Cargo lines	N/A	N/A	L1	N/A	N/A	0	N/A	0[10]	0	N/A	L1[2]
2 Crude oil washing lines	N/A	N/A	L1	N/A	N/A	0	N/A	0[10]	0	N/A	L1[2]
3 Vent lines	N/A	N/A	N/A	N/A	N/A	0	N/A	0[10]	0	N/A	X
INERT GAS											
4 Water seal effluent line	N/A	N/A	0[1]	N/A	N/A	0[1]	0[1]	0[1]	0[1]	N/A	0
5 Scrubber effluent line	0[1]	0[1]	N/A	N/A	N/A	N/A	N/A	0[1]	0[1]	N/A	0
6 Main line	0	0	L1	N/A	N/A	N/A	N/A	N/A	0	N/A	L1[6]
7 Distribution lines	N/A	N/A	L1	N/A	N/A	0	N/A	N/A	0	N/A	L1[2]
FLAMMABLE LIQUIDS (f.p. > 60°C)											
8 Cargo lines	X	X	L1	X	X	N/A[3]	0	0[10]	0	N/A	L1
9 Fuel oil	X	X	L1	X	X	N/A[3]	0	0	0	L1	L1
10 Lubricating oil	X	X	L1	X	X	N/A	N/A	N/A	0	L1	L1
11 Hydraulic oil	X	X	L1	X	X	0	0	0	0	L1	L1
SEA-WATER[1]											
12 Bilge main and branches	L1[7]	L1[7]	L1	X	X	N/A	0	0	0	N/A	L1
13 Fire main and water spray	L1	L1	L1	X	N/A	N/A	N/A	0	0	X	L1

Table 12.5.3 Fire endurance requirements *(continued)*

Piping systems	Location										
	A Machinery spaces of Category A	B Other machinery spaces and pump rooms	C Cargo pump rooms	D Ro–Ro cargo holds	E Other dry cargo holds	F Cargo tanks	G Fuel oil tanks	H Ballast water tanks	I Cofferdams void spaces pipe tunnel and ducts	J Accommodation service and control spaces	K Open decks
14 Foam system	L1	L1	L1	N/A	N/A	N/A	N/A	N/A	0	L1	L1
15 Sprinkler system	L1	L1	L3	X	N/A	N/A	N/A	0	0	L3	L3
16 Ballast	L3	L3	L3	L3	X	0[10]	0	0	0	L2	L2
17 Cooling water, essential services	L3	L3	N/A	N/A	N/A	N/A	N/A	0	0	N/A	L2
18 Tank cleaning services fixed machines	N/A	N/A	L3	N/A	N/A	0	N/A	0	0	N/A	L3[2]
19 Non-essential systems	0	0	0	0	0	N/A	0	0	0	0	0
FRESH WATER											
20 Cooling water essential services	L3	L3	N/A	N/A	N/A	N/A	0	0	0	L3	L3
21 Condensate return	L3	L3	L3	0	0	N/A	N/A	N/A	0	0	0
22 Non-essential systems	0	0	0	0	0	N/A	0	0	0	0	0
SANITARY/DRAINS/ SCUPPERS											
23 Deck drains (internal)	L1[4]	L1[4]	N/A	L1[4]	0	N/A	0	0	0	0	0
24 Sanitary drains (internal)	0	0	N/A	0	0	N/A	0	0	0	0	0
25 Scuppers and discharges (overboard)	0[1,8]	0[1,8]	0[1,8]	0[1,8]	0[1,8]	0	0	0	0	0[1,8]	0
SOUNDING/AIR											
26 Water tanks/dry spaces	0	0	0	0	0	0[10]	0	0	0	0	0[11]

Table 12.5.3 Fire endurance requirements *(continued)*

Piping systems	Location A Machinery spaces of Category A	B Other machinery spaces and pump rooms	C Cargo pump rooms	D Ro–Ro cargo holds	E Other dry cargo holds	F Cargo tanks	G Fuel oil tanks	H Ballast water tanks	I Cofferdams void spaces pipe tunnel and ducts	J Accommodation service and control spaces	K Open decks
27 Oil tanks (f.p. > 60°C)	X	X	X	X	X	X[3]	0	0[10]	0	X	X
MISCELLANEOUS 28 Control air	L1[5]	L1[5]	L1[5]	L1[5]	L1[5]	N/A	0	0	0	L1[5]	L1[5]
29 Service air (non-essential)	0	0	0	0	0	N/A	0	0	0	0	0
30 Brine	0	0	N/A	0	0	N/A	N/A	N/A	0	0	0
31 Auxiliary low pressure steam (≤ 7 bar)	L2	L2	0[9]	0[9]	0[9]	0	0	0	0	0[9]	0[9]

LOCATION DEFINITIONS

	Location	Definition
A	Machinery spaces of Category A	Machinery spaces of Category A as defined in SOLAS* regulation II–2/3.19.
B	Other machinery spaces and pump rooms	Spaces, other than Category A machinery spaces and cargo pump rooms, containing propulsion machinery, boilers, steam and internal combustion engines, generators and major electrical machinery, pumps, oil filling stations, refrigerating, stabilising, ventilation and air-conditioning machinery, and similar spaces, and trunks to such spaces.
C	Cargo pump rooms	Spaces containing cargo pumps and entrances and trunks to such spaces.
D	Ro-Ro cargo holds	Ro-Ro cargo holds are Ro-Ro cargo spaces and special category spaces as defined in SOLAS* regulation II–2/3.14 and 3.18.
E	Other dry cargo holds	All spaces other than Ro-Ro cargo holds used for non-liquid cargo and trunks to such spaces.
F	Cargo tanks	All spaces used for liquid cargo and trunks to such spaces.
G	Fuel oil tanks	All spaces used for oil fuel (excluding cargo tanks) and trunks to such spaces.
H	Ballast water tanks	All spaces used for ballast water and trunks to such spaces.
I	Cofferdams, voids, etc.	Cofferdams and voids are those empty spaces between two bulkheads separating two adjacent compartments.
J	Accommodation, service	Accommodation spaces, service spaces and control stations as defined in SOLAS* regulation II–2/3.10, 3.12, 3.22.
K	Open decks	Open deck spaces, as defined in SOLAS* regulation II–2/26.2.2(5).

* SOLAS 74 as amended by the 1978 SOLAS Protocol and the 1981 and 1983 amendments (consolidated text).

ABBREVIATIONS

L1	Fire endurance test in dry conditions, 60 minutes, IMO Resolution A.753(18) Appendix 1.
L2	Fire endurance test in dry conditions, 30 minutes, IMO Resolution A.753(18) Appendix 1.
L3	Fire endurance test in wet conditions, 30 minutes, IMO Resolution A.753(18) Appendix 2.
0	No fire endurance test required.
N/A	Not applicable.
X	Metallic materials having a melting point greater than 925°C.

Table 12.5.3 Fire endurance requirements *(conclusion)*

NOTES
1. Where non-metallic piping is used, remotely controlled valves to be provided at ship's side (valve is to be controlled from outside space).
2. Remote closing valves to be provided at the cargo tanks.
3. When cargo tanks contain flammable liquids with f.p. > 60°C, '0' may replace 'N/A' or 'X'.
4. For drains serving only the space concerned, '0' may replace 'L1'.
5. When controlling functions are not required by the Rules or statutory requirements, '0' may replace 'L1'.
6. For pipe between machinery space and deck water seal, '0' may replace 'L1'.
7. For passenger vessels, 'X' is to replace 'L1'.
8. Scuppers serving open decks in positions 1 and 2, as defined in regulation 13 of the *International Convention on Load Lines, 1966*, should be 'X' throughout unless fitted at the upper end with the means of closing capable of being operated from a position above the freeboard deck in order to prevent downflooding.
9. For essential services, such as oil fuel tank heating and ship's whistle, 'X' is to replace '0'.
10. For tankers where compliance with MARPOL Annex I, Regulation 19.3.6 is required, 'N/A' is to replace '0'.
11. Air and sounding pipes on open deck are to be of substantial construction, *see* Ch 13,10.2.2.

5.6.4 Plastics pipes are to be manufactured and tested in accordance with Ch 14,4 of the Rules for Materials. For Class III piping systems the pipe manufacturer's test certificate may be accepted in lieu of an LR Certificate and is to be provided for each consignment of pipe.

5.7 Installation and construction

5.7.1 All pipes are to be adequately but freely supported. Suitable provision is to be made for expansion and contraction to take place without unduly straining the pipes.

5.7.2 Pipes may be joined by mechanical couplings or by bonding methods such as welding and laminating.

5.7.3 Where bonding systems are used, the manufacturer or installer shall provide a written procedure covering all aspects of installation, including temperature and humidity conditions. The bonding procedure is to be approved by LR.

5.7.4 The person carrying out the bonding is to be qualified. Records are to be available to the Surveyor for each qualified person showing the bonding procedure and performance qualification, together with dates and results of the qualification testing.

5.7.5 In the case of pipes intended for essential services each qualified person is, at the place of construction, to make at least one test joint, representative of each type of joint to be used. The joined pipe section is to be tested to an internal hydrostatic pressure of four times the design pressure of the pipe system and the pressure held for not less than one hour, with no leakage or separation of joints. The bonding procedure test is to be witnessed by the Surveyor.

5.7.6 Conditions during installation, such as temperature and humidity, which may affect the strength of the finished joints, are to be in accordance with the agreed bonding procedure.

5.7.7 The required fire endurance level of the pipe is to be maintained in way of pipe supports, joints and fittings, including those between plastics and metallic pipes.

5.7.8 Where piping systems are arranged to pass through watertight bulkheads or decks, provision is to be made for maintaining the integrity of the bulkhead or deck by means of metallic bulkhead, or deck, pieces. The bulkhead pieces are to be protected against corrosion, and so constructed to be of a strength equivalent to the intact bulkhead; attention is drawn to 5.7.1, *see also* Ch 13,2.4.1. Details of the arrangements are to be submitted for approval.

5.7.9 Where a piping system is required to be electrically conductive, for the control of static electricity, continuity is to be maintained across the joints and fittings, and the system is to be earthed, *see also* Pt 6, Ch 2,1.13.

5.8 Testing

5.8.1 The hydraulic testing of pipes and fittings is to be in accordance with Section 8.

5.8.2 Where a piping system is required to be electrically conductive, tests are to be carried out to verify that the resistance to earth from any point in the system does not exceed 1 MΩ, *see also* Pt 6, Ch 2,21.2.3.

■ *Section 6* Valves

6.1 Design requirements

6.1.1 The design, construction and operational capability of valves is to be in accordance with an acceptable National or International Standard appropriate to the piping system. Where valves are not in accordance with an acceptable standard, details are to be submitted for consideration. Where valves are fitted, the requirements of 6.1.2 to 6.1.8 are to be satisfied.

6.1.2 Valves are to be made of steel, cast iron, copper alloy, or other approved material suitable for the intended purpose.

6.1.3 Valves having isolation or sealing components sensitive to heat are not to be used in spaces where leakage or failure caused by fire could result in fire spread, flooding or the loss of an essential service.

6.1.4 Where valves are required to be capable of being closed remotely in the event of fire, the valves, including their control gear, are to be of steel construction or of an acceptable fire tested design.

6.1.5 Valves are to be arranged for clockwise closing and are to be provided with indicators showing whether they are open or shut unless this is readily obvious. Legible nameplates are to be fitted.

6.1.6 Valves are to be so constructed as to prevent the possibility of valve covers or glands being slackened back or loosened when the valves are operated.

6.1.7 Valves are to be used within their specified pressure and temperature rating for all normal operating conditions, and are to be suitable for the intended purpose.

6.1.8 Valves intended for submerged installation are to be suitable for both internal and external media. Spindle sealing is to prevent ingress of external media at the maximum external pressure head expected in service.

■ *Section 7* Flexible hoses

7.1 General

7.1.1 A flexible hose assembly is a short length of metallic or non-metallic hose normally with prefabricated end fittings ready for installation.

7.1.2 For the purpose of approval for the applications in 7.2, details of the materials and construction of the hoses, and the method of attaching the end fittings together with evidence of satisfactory prototype testing, are to be submitted for consideration.

7.1.3 The use of hose clamps and similar types of end attachments are not be used for flexible hoses in piping systems for steam, flammable media, starting air systems or for sea-water systems where failure may result in flooding. In other piping systems, the use of hose clamps may be accepted where the working pressure is less than 5 bar and provided that there are two clamps at each end connection.

7.1.4 Flexible hoses are to be limited to a length necessary to provide for relative movement between fixed and flexibly mounted items of machinery/equipment or systems.

7.1.5 Flexible hoses are not to be used to compensate for misalignment between sections of piping.

7.1.6 Flexible hose assemblies are not to be installed where they may be subjected to torsional deformation (twisting) under normal operating conditions.

7.1.7 The number of flexible hoses in piping systems mentioned in this Section is to be kept to a minimum and to be limited for the purpose stated in 7.2.1.

7.1.8 Where flexible hoses are intended for conveying flammable fluids in piping systems that are in close proximity to hot surfaces, electrical installation or other sources of ignition, the risk of ignition due to failure of the hose assembly and subsequent release of fluids is to be mitigated as far as practicable by the use of screens or other suitable protection.

7.1.9 Flexible hoses are to be installed in clearly visible and readily accessible locations.

7.1.10 The installation of flexible hose assemblies is to be in accordance with the manufacturer's instructions and use limitations with particular attention to the following:
(a) Orientation.
(b) End connection support (where necessary).
(c) Avoidance of hose contact that could cause rubbing and abrasion.
(d) Minimum bend radii.

7.1.11 Flexible hoses are to be permanently marked by the manufacturer with the following details:
(a) Hose manufacturer's name or trademark.
(b) Date of manufacture (month/year).
(c) Designation type reference.
(d) Nominal diameter.
(e) Pressure rating
(f) Temperature rating.
Where a flexible hose assembly is made up of items from different manufacturers, the components are to be clearly identified and traceable to evidence of prototype testing.

7.2 Applications

7.2.1 Short joining lengths of flexible hoses complying with the requirements of this Section may be used, where necessary, to accommodate relative movement between various items of machinery connected to permanent piping systems. The requirements of this Section may also be applied to temporarily-connected flexible hoses or hoses of portable equipment.

7.2.2 Rubber or plastics hoses, with integral cotton or similar braid reinforcement, may be used in fresh and sea-water cooling systems. In the case of sea-water systems, where failure of the hoses could give rise to the danger of flooding, the hoses are to be suitably enclosed, as indicated in Ch 13,2.7.

7.2.3 Rubber hoses, with single, double or more closely woven integral wire braid or other suitable material reinforcement, or convoluted metal pipes with wire braid protection, may be used in bilge, ballast, compressed air, fresh water, sea-water, oil fuel, lubricating oil, Class III steam, hydraulic and thermal oil systems. Flexible hoses of plastics materials for the same purposes, such as Teflon or Nylon, which are unable to be reinforced by incorporating closely woven integral wire braid are to have suitable material reinforcement as far as practicable. Where rubber or plastics hoses are used for oil fuel supply to burners, the hoses are to have external wire braid protection in addition to the integral wire braid. Flexible hoses for use in steam systems are to be of metallic construction.

7.2.4 Flexible hoses are not to be used in high pressure fuel oil injection systems.

7.2.5 The requirements in this Section for flexible hose assemblies are not applicable to hoses intended to be used in fixed fire-extinguishing systems.

7.3 Design requirements

7.3.1 Flexible hose assemblies are to be designed and constructed in accordance with recognised National or International Standards acceptable to LR.

7.3.2 Flexible hoses are to be complete with approved end fittings in accordance with manufacturer's specification. End connections which do not have flanges are to comply with 2.12 as applicable and each type of hose/fitting combination is to be subject to prototype testing to the same standard as that required by the hose with particular reference to pressure and impulse tests.

7.3.3 Flexible hose assemblies intended for installation in piping systems where pressure pulses and/or high levels of vibration are expected to occur in service, are to be designed for the maximum expected impulse peak pressure and forces due to vibration. The tests required by 7.4 are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.

7.3.4 Flexible hose assemblies constructed of non-metallic materials intended for installation in piping systems for flammable media, and sea-water systems where failure may result in flooding, are to be of fire-resistant type. Fire resistance is to be demonstrated by testing to ISO 15540 and ISO 15541.

7.3.5 Flexible hose assemblies are to be suitable for the intended location and application, taking into consideration ambient conditions, compatibility with fluids under working pressure and temperature conditions consistent with the manufacturer's instructions and any other applicable requirements in the Rules.

7.4 Testing

7.4.1 Acceptance of flexible hose assemblies is subject to satisfactory prototype testing. Prototype test programmes for flexible hose assembles are to be submitted by the manufacturer and are to be sufficiently detailed to demonstrate performance in accordance with the specified Standards.

7.4.2 For a particular hose type complete with end fittings, the tests, as applicable, are to be carried out on different nominal diameters for pressure, burst, impulse and fire resistance in accordance with the requirements of the relevant Standard. The following Standards are to be used as applicable:

- ISO 6802 – *Rubber and plastics hoses and hose assemblies with wire reinforcements – Hydraulic impulse test with flexing*.
- ISO 6803 – *Rubber or plastics hoses and hose assemblies – Hydraulic-pressure impulse test without flexing*.
- ISO 15540 – *Ships and marine technology – Fire resistance of hose assemblies – Test methods*.
- ISO 15541 – *Ships and marine technology – Fire resistance of hose assemblies – Requirements for test bench*.
- ISO 10380 – *Pipework – Corrugated metal hoses and hose assemblies*.

Other Standards may be accepted where agreed by LR.

7.4.3 All flexible hose assemblies are to be satisfactorily prototype burst tested to an International Standard* to demonstrate they are able to withstand a pressure of not less than four times the design pressure without indication of failure or leakage.

Note

* The International Standards, e.g., EN or SAE for burst testing of non-metallic hoses, require the pressure to be increased until burst without any holding period at 4 x Maximum Working Pressure.

Section 8 Hydraulic tests on pipes and fittings

8.1 Hydraulic tests before installation on board

8.1.1 All Class I and II pipes and their associated fittings are to be tested by hydraulic pressure to the Surveyor's satisfaction. Further, all steam, feed, compressed air and oil fuel pipes, together with their fittings, are to be similarly tested where the design pressure is greater than 7,0 bar. The test is to be carried out after completion of manufacture and before installation on board and, where applicable, before insulating and coating.

8.1.2 Where the design temperature does not exceed 300°C, the test pressure is to be 1,5 times the design pressure, as defined in 1.3.

8.1.3 Where testing of systems or sub-systems following final assembly is specified, in addition to the requirements of 8.1.2 the lowest applicable pressure as defined in this sub-Section is to be used for testing.

8.1.4 For steel pipes and integral fittings for use in systems where the design temperature exceeds 300°C, the test pressure is to be as follows:

(a) For carbon and carbon-manganese steel pipes, the test pressure is to be twice the design pressure, as defined in 1.3.

(b) For alloy steel pipes, the test pressure is to be determined by the following formula, but need not exceed 2*p*:

$$p_t = 1{,}5 \frac{\sigma_{100}}{\sigma} p \quad \text{bar (kgf/cm}^2\text{)}$$

where

p_t and p are as defined in 1.2.1

σ = permissible stress for the design temperature, in N/mm^2 (kgf/cm^2), as stated in Table 12.2.2

σ_{100} = permissible stress for 100°C, in N/mm^2 (kgf/cm^2), as stated in Table 12.2.2.

8.1.5 Where alloy steels not included in Table 12.2.2 are used, the permissible stresses will be specially considered, as indicated in 2.2.2.

8.1.6 Consideration will be given to the reduction of the test pressure to not less than 1,5*p*, where it is necessary to avoid excessive stress in way of bends, branches, etc.

8.1.7 Valves and fittings non-integral with the piping system, intended for Classes I and II, are to be tested in accordance with recognised standards, but to not less than 1,5 times the design pressure. Where design features are such that modifications to the test requirements are necessary, alternative proposals for hydraulic tests are to be submitted for special consideration.

8.1.8 For requirements relating to valves and cocks intended to be fitted on the ship's side below the load water line, *see* Ch 13,2.5.10.

8.1.9 In no case is the membrane stress to exceed 90 per cent of the yield stress at the testing temperature.

8.2 Testing after assembly on board

8.2.1 Heating coils in tanks, gas fuel and oil fuel piping are to be tested by hydraulic pressure, after installation on board, to 1,5 times the design pressure but in no case to less than 4 bar (4,1 kgf/cm^2).

8.2.2 Where pipes specified in 8.1.1 are butt welded together during assembly on board, they are to be tested by hydraulic pressure in accordance with the requirements of 8.1 after welding. The pipe lengths may be insulated, except in way of the joints made during installation and before the hydraulic test is carried out.

8.2.3 The hydraulic test required by 8.2.2 may be omitted provided non-destructive tests by ultrasonic or radiographic methods are carried out on the entire circumference of all butt welds with satisfactory results. Where ultrasonic tests have been carried out, the manufacturer is to provide the Surveyor with a signed statement confirming that ultrasonic examination has been carried out by an approved operator and that there were no indications of defects which could be expected to have a prejudicial effect on the service performance of the piping.

8.2.4 Where bilge pipes are accepted in way of double bottom tanks or deep tanks, *see* Ch 13,7.9 and 7.10, the pipes after fitting are to be tested by hydraulic pressure to the same pressure as the tanks through which they pass.

Cross-reference

See also Ch 13,2.10 for testing after installation.

Section 9 Piping for LPG/LNG carriers, gas fuelled ships and classed refrigeration systems

9.1 Scope

9.1.1 This Section is applicable to piping systems installed in LPG/LNG carriers, gas fuelled ships and classed refrigeration systems for the following pipes and piping system components:

(a) Pipework – stainless steel, carbon steel and copper.

(b) Valves – normal and cryogenic service (below minus 55°C).

(c) Bellows – normal and cryogenic service (below minus 55°C).

(d) Pipe fittings – elbows, reducers, tee connections, etc.

(e) Ancillary fittings – weldolets, threadolets, thermo-pockets.

9.1.2 The following piping systems are covered by this Section:

(a) LPG/LNG cargo systems – normal cargo operations.
(b) LPG/LNG cargo systems – cargo gas to reliquefaction system.
(c) LNG cargo systems – gas burning and use of cargo as fuel.
(d) LNG Regasification system – high and low pressure.
(e) Cargo Reliquefaction system – nitrogen or mixed refrigerant.
(f) Refrigeration – independent plant used in cascade systems.
(g) Gas storage and supply systems for gas fuelled ships.

9.2 Application

9.2.1 The requirements of this Section apply to pipes and piping system components, such as valves, elbows and bellows, which are to be used on gas carriers, gas fuelled ships or classed refrigeration/reliquefaction systems. The requirements are also applicable to other gas cargo services such as regasification systems and gas combustion units, and are in addition to those contained in both the Rules for Ships for Liquefied Gases and relevant Sections of this Chapter where appropriate.

9.3 Classes of pipe

9.3.1 The material requirements for piping systems vary depending on the Class of the piping system. The Class of the piping system is dependent on the design pressure or temperature of the system and the pipe material used as shown in Table 12.1.1.

9.3.2 Table 12.1.1 piping systems containing LPG/LNG, cargo or fuel gas as the conveyed medium are to be treated as 'Flammable liquids'. These piping systems are to be categorised as Class II. Vapour lines are also to be categorised as Class II systems but the upper limit on pressure may be increased to 40 bar in accordance with the 'Other media'. Where higher design pressures are applied, such as in a regasification system, liquid lines above 16 bar and vapour lines above 40 bar are to be categorised as Class I. All open ended pipes, such as vent lines and pipes inside the cargo tanks may be categorised as Class III.

9.3.3 For reliquefaction and refrigeration systems Table 12.1.1 is to be applied. Nitrogen and non-toxic or non-flammable refrigerants are to be considered under the 'Other media' heading. Refrigeration systems containing ammonia are to be considered as Class I systems irrespective of the operational pressure.

9.4 Materials

9.4.1 Stainless steel pipes, valves and fittings for welded fabrication are to be grades 304L, 316L, 321 or 347 in accordance with Ch 6,5 of the Rules for Materials. For non-welded fabrications the grades 304 and 316 may be accepted.

9.4.2 The materials used in Class I and Class II systems are to be produced at a works approved by LR. Testing is to be in accordance with the Rules for Materials and Tables 6.1 and 6.4 in chapter 6 of the Rules for Ships for Liquefied Gases.

9.4.3 For stainless steel pipes, valve castings and forgings intended for service temperatures down to minus 55°C, a LR materials certificate is required unless

- *DN* <50 or
- *DN* ≤150 and *DN* x *P* <2500

where a manufacturer's material certificate is acceptable.

9.4.4 For pipe systems operating at cryogenic temperatures lower than minus 55°C, a LR materials certificate is required.

9.5 Valves and piping components independent of temperature

9.5.1 For valves and piping components fitted in the cargo piping system of LPG/LNG gas carriers, each type of valve and piping component is to have evidence of satisfactory type testing.

9.6 Valves for cryogenic temperature service

9.6.1 Each size and type of valve intended to be used at a working temperature below –55°C shall be approved through design appraisal and prototype testing.

9.6.2 The tightness test required by 5.3.2.1 of the Rules for Ships for Liquefied Gases is to be conducted in accordance with a recognised National or International Code or Standard.

9.7 Valves for refrigeration service

9.7.1 For valves intended for installation in a refrigeration system with a nominal diameter equal to or less than 150 mm, a manufacturer's certificate is acceptable. The certificate is to include details of the maximum working pressure and test pressure, and sufficient information for the LR Surveyor to assess the suitability of the equipment for the intended use. Each size and type of valve is to be supplied with its own certificate and is to be signed by a responsible person in the manufacturer's quality control department.

9.7.2 Valves with nominal diameters above 150 mm are to be supplied with a LR materials certificate in accordance with the Rules for Materials.

9.7.3 Where valves are fitted to pressure vessels, the requirements of Chapters 10 and 11 are applicable for the Class of pressure vessel. Mountings for liquefied gas pressure vessels are to comply with the Rules for Ships for Liquefied Gases. Any acceptance of manufacturer's certification in other Sections of this Chapter is not applicable to the valves fitted to pressure vessels in chapters 10 and 11 of the Rules for Ships for Liquefied Gases.

9.7.4 Any valve fitted directly onto a pressure vessel is to be considered a mounting and is required to be hydraulically pressure tested to twice the approved design pressure. *See* Ch 11,10.2.1.

9.8 Expansion bellows

9.8.1 The following plans and particulars are to be submitted:

(a) Dimensioned drawings of each type of bellows.
(b) Design calculations to show that the bellows are suitable for the intended design conditions, carried out to EJMA (Expansion Joint Manufacturers Association) standards (latest edition) or equivalent.
(c) A proposed prototype test program covering the tests detailed in 5.3.2.2 of the Rules for Ships for Liquefied Gases.
(d) Calculations to EJMA standards may be accepted, together with sample testing detailed above, in order to cover the entire size range for the type.

9.8.2 In accordance with 5.3 of the Rules for Ships for Liquefied Gases, the requirements for type testing in 9.8.3 to 9.8.7 are to be performed on each type of expansion bellows intended for use on LPG/LNG piping.

9.8.3 For each type of expansion bellows, an element of the bellows, not pre-compressed, is to be pressure tested at not less than five times the design pressure without bursting. This test is to be conducted at room temperature on each 'type' of element and need not be the complete bellows unit. A test on one element can cover other sized bellows with the same cross-sectional bellows form. The design pressure is to be at least 10 bar; bellows fitted to safety valves and vent lines may have a minimum design pressure of 5 bar in accordance with 5.2.3.3 of the Rules for Ships for Liquefied Gases. The required test duration is not to be less than 5 minutes.

9.8.4 A pressure test is to be performed on each type of expansion joint complete with all the accessories such as flanges, stays and articulations, at twice the design pressure at the extreme displacement conditions recommended by the manufacturer without permanent deformation. The test is to be undertaken at the minimum design temperature, unless the bellows material is stainless steel for which this test may be carried out at ambient temperature. The test duration is to be 30 minutes unless otherwise agreed with LR.

9.8.5 A cyclic thermal movement test, replicating the cooling down and warming up cycle which occurs during cargo loading and discharge, is to be performed on a complete expansion joint, by the application of representative external deflection resulting in bellow movement. This is to successfully withstand at least as many cycles, under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement, as it will encounter in actual service. The number of cycles is to be estimated by the builder and depends on the ship's intended trading pattern and life expectancy. As a minimum, testing to 7000 cycles is to be carried out. The test is to be carried out at between 2-5 cycles per second. Testing at ambient temperature is permitted when this testing is at least as severe as testing at the service temperature. The maximum movements on the horizontal and vertical axis are to be provided by the builders and obtained from their stress analysis; however, the test can be extended to any value which is greater than that expected, or to the maximum deflection for which the bellows unit is suitable. Movements in the test need not be in both horizontal and vertical directions; but the horizontal-vertical box diagonal distance may be used. NDE testing is required after cyclic testing.

9.8.6 A cyclic fatigue test, representing ship deformation, is to be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length, for at least 2,000,000 cycles at a frequency not higher than 5 cycles per second. The test may be waived if the piping arrangement, experiences ship deformation loads. NDE is required after cyclic testing.

9.8.7 The cyclic thermal movement test and cyclic fatigue test may be waived by LR if satisfactory documentation is provided to establish the suitability of the expansion joints to withstand the expected working conditions. Where the maximum internal pressure exceeds 1,0 bar gauge, this documentation is to include sufficient test data to justify the design method used, with particular reference to correlation between calculation and test results.

9.9 Pressure testing of piping and other piping components

9.9.1 Pressure testing is to be undertaken in accordance with specific Rule requirements relating to the system in which the component is to be located.

9.9.2 The duration for which pressure tests are to be held is to be in conjunction with an applicable and recognised code or standard acceptable to LR.

9.10 Equipment documentation

9.10.1 A certificate is required for each piping component supplied to be fitted in a Class I or Class II system. This certification is required for each size and type of equipment delivered. A single certificate may cover a number of valves, provided that they are of the same type and size, and serial numbers have been included on the certificate. If the piping components are part of a system fitted to a skid or packaged unit, then the complete skid may be supplied with a single certificate stating that the package has been constructed using approved materials, approved and tested in accordance with LR Rule requirements.

9.11 Relief valves for LPG/LNG cargo and deck tanks

9.11.1 Relief valves fitted to cargo tanks and deck tanks are to be of a type tested design. Type testing is to include:

- flow or capacity verification to a recognised Standard acceptable to the Administration;
- cryogenic testing when operating at design temperatures colder than minus 55°C;
- seat tightness testing to a recognised Standard or manufacturers' procedure acceptable to the Administration; and
- pressure testing of pressure-containing parts to at least 1,5 times the design pressure.

9.11.2 The materials used for construction of relief valves fitted to cargo tanks and deck tanks are to be produced in a works approved by LR and be provided with a Lloyd's Register Material Certificate.

■ *Section 10* Austenitic stainless steels

10.1 Pipe thickness

10.1.1 The minimum thickness of austenitic stainless steel pipes is to be determined from the formula given in 2.2.1 and either 2.2.3 or 2.2.4 using a corrosion allowance of 0,8 mm. Values of 1,0 per cent proof stress and tensile strength of the material for use in the formula in 2.2.1 may be obtained from Table 6.5.2 in Chapter 6 of the Rules for Materials.

10.1.2 Where stainless steel is used in lubricating oil, hydraulic oil and refrigeration systems, the corrosion allowance may be reduced to 0 mm. For pipes passing through tanks, an additional corrosion allowance is to be added to take account of external corrosion; the addition will depend on the external medium and the value is to be in accordance with Table 12.2.3. Where he pipes are efficiently protected, the corrosion allowance may be reduced by not more than 50 per cent.

10.1.3 In no case is the thickness of austenitic stainless steel pipes to be less than that shown in Table 12.10.1.

Table 12.10.1 Minimum thickness for austenitic stainless steel pipes

Standard pipe sizes (outside diameter) in mm	Min. thickness in mm
10,2 to 17,2	1,0
21,3 to 48,3	1,6
60,3 to 88,9	2,0
114,3 to 168,3	2,3
219,1	2,6
273,0	2,9
323,9 to 406,4	3,6
over 406,4	4,0

APPENDIX

■ *Section 11* Guidance notes on metal pipes for water services

11.1 General

11.1.1 These guidance notes, except where it is specifically stated, apply to sea-water piping systems.

11.1.2 In addition to the selection of suitable materials, careful attention should be given to the design details of the piping system and the workmanship in fabrication, construction and installation of the pipework in order to obtain maximum life in service.

11.2 Materials

11.2.1 Materials used in sea-water piping systems include:

- Galvanised steel.
- Steel pipes lined with rubber, plastics or stoved coatings.
- Copper.
- 90/10 copper-nickel-iron.
- 70/30 copper-nickel.
- Aluminium brass.

11.2.2 Selection of materials should be based on:

- the ability to resist general and localised corrosion, such as pitting, impingement attack and cavitation throughout all the flow velocities likely to be encountered;
- compatibility with the other materials in the system, such as valve bodies and casings, (e.g., in order to minimise bimetallic corrosion);
- the ability to resist selective corrosion, e.g., dezincification of brass, dealuminification of aluminium brass and graphitisation of cast iron;
- the ability to resist stress corrosion and corrosion fatigue; and
- the amenability to fabrication by normal practices.

11.3 Steel pipes

11.3.1 Steel pipes should be protected against corrosion, and protective coatings should be applied on completion of all fabrication, i.e., bending, forming and welding of the steel pipes.

11.3.2 Welds should be free from lack of fusion and crevices. The surfaces should be dressed to remove slag and spatter and this should be done before coating. The coating should be continuous around the ends of the pipes and on the faces of flanges.

11.3.3 Galvanising the bores and flanges of steel pipes as protection against corrosion is common practice, and is recommended as the minimum protection for pipes in sea-water systems, including those for bilge and ballast service.

11.3.4 Austenitic stainless steel pipes are not recommended for salt-water services as they are prone to pitting, particularly in polluted waters.

11.3.5 Rubber lined pipes are effective against corrosion and suitable for higher water velocities. The rubber lining should be free from defects, e.g., discontinuities, pinholes, etc., and it is essential that the bonding of the rubber to the bore of the pipe and flange face is sound. Rubber linings should be applied by firms specialising in this form of protection.

11.3.6 The foregoing comments on rubber lined pipes also apply to pipes lined with plastics.

11.3.7 Stove coating of pipes as protection against corrosion should only be used where the pipes will be efficiently protected against mechanical damage.

11.4 Copper and copper alloy pipes

11.4.1 Copper pipes are particularly susceptible to perforation by corrosion/erosion and should only be used for low water velocities and where there is no excessive local turbulence.

11.4.2 Aluminium brass and copper-nickel-iron alloy pipes give good service in reasonably clean sea-water. For service with polluted river or harbour waters, copper-nickel-iron alloy pipes with at least 10 per cent nickel are preferable. Alpha-brasses, i.e., those containing 70 per cent or more copper, must be inhibited effectively against dezincification by suitable additions to the composition. Alpha beta-brasses, (i.e., those containing less than 70 per cent copper), should not be used for pipes and fittings.

11.4.3 New copper alloy pipes should not be exposed initially to polluted water. Clean sea-water should be used at first to allow the metals to develop protective films. If this is not available the system should be filled with inhibited town mains water.

11.5 Flanges

11.5.1 Where pipes are exposed to sea-water on both external and internal surfaces, flanges should be made, preferably, of the same material. Where sea-water is confined to the bores of pipes, flanges may be of the same material or of less noble metal than that of the pipe, *see also* 2.3.

11.5.2 Fixed or loose type flanges may be used. The fixed flanges should be attached to the pipes by fillet welds or by capillary silver brazing. Where welding is used, the fillet weld at the back should be a strength weld and that in the face, a seal weld.

11.5.3 Inert gas shielded arc welding is the preferred process but metal arc welding may be used on copper-nickel-iron alloy pipes.

11.5.4 Mild steel flanges may be attached by argon arc welding to copper-nickel-iron pipes and give satisfactory service, provided that no part of the steel is exposed to the sea-water.

11.5.5 Where silver brazing is used, strength should be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet braze at the back of the flange or at the face is undesirable. The alloy used for silver brazing should contain not less than 49 per cent silver.

11.5.6 The use of a copper-zinc brazing alloy is not permitted.

11.6 Water velocity

11.6.1 Water velocities should be carefully assessed at the design stage and the materials of pipes, valves, etc., selected to suit the conditions.

11.6.2 The water velocity in copper pipes should not exceed 1 m/s.

11.6.3 The water velocity in the pipes of the materials below should normally be not less than about 1 m/s in order to avoid fouling and subsequent pitting, but should not be greater than the following:

- Galvanised steel 3,0 m/s
- Aluminium brass 3,0 m/s
- 90/10 copper-nickel-iron 3,5 m/s
- 70/30 copper-nickel 5,0 m/s

11.7 Fabrication and installation

11.7.1 Attention should be given to ensuring streamlined flow and reducing entrained air in the system to a minimum. Abrupt changes in the direction of flow, protrusions into the bores of pipes and other restrictions of flow should be avoided. Branches in continuous flow lines should be set at a shallow angle to the main pipe, and the junction should be smooth.

11.7.2 Pipe bores should be smooth and clean.

11.7.3 Jointing should be flush with the bore surfaces of pipes and misalignment of adjacent flange faces should be reduced to a minimum.

11.7.4 Pipe bends should be of as large a radius as possible, and the bore surfaces should be smooth and free from puckering at these positions. Any carbonaceous films or deposits formed on the bore surfaces during the bending processes should be carefully removed. Organic substances are not recommended for the filling of pipes for bending purposes.

11.7.5 The position of supports should be given special consideration in order to minimise vibration and ensure that excessive bending moments are not imposed on the pipes.

11.7.6 Systems should not be left idle for long periods, especially where the water is polluted.

11.7.7 Strainers should be provided at the inlet to sea-water systems.

11.8 Metal pipes for fresh water services

11.8.1 Mild steel or copper pipes are normally satisfactory for service in fresh water applications. Hot fresh water, however, may promote corrosion in mild steel pipes unless the hardness and pH of the water are controlled.

11.8.2 Water with a slight salt content should not be left stagnant for long periods in mild steel pipes. Low salinity and the limited supply of oxygen in such conditions promote the formation of black iron oxide, and this may give rise to severe pitting. Where stagnant conditions are unavoidable, steel pipes should be galvanised, or pipes of suitable non-ferrous material used.

11.8.3 Copper alloy pipes should be treated to remove any carbonaceous films or deposits before the tubes are put into service.

11.8.4 Brass fittings and flanges in contact with water should be made of an alpha-brass effectively inhibited against dezincification by suitable additions to the composition.

11.8.5 Aluminium brass has been widely used as material for heat exchanger and condenser tubes, but its use in ‘once through’ systems is not recommended since, under certain conditions, it is prone to pitting and cracking.

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter apply to piping systems on all types of ship except where otherwise stated.

1.1.2 Whilst the requirements satisfy the relevant regulations of the *International Convention for the Safety of Life at Sea, 1974*, and applicable amendments, attention should be given to any relevant regulations of the International Convention for the Prevention of Pollution from Ships, 1973, and applicable amendments, where these impact the design or construction of piping systems. Attention should also be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

1.1.3 Consideration will be given to special cases or to arrangements which are equivalent to those required by these Rules. Consideration will also be given to the pumping arrangements of small ships and ships to be assigned class notations for restricted or special services.

1.1.4 Piping design is to comply with Chapter 12 as applicable.

1.2 Prevention of progressive flooding in damage condition

1.2.1 For ships to which subdivision and damage stability requirements apply, precautions are to be taken to prevent progressive flooding between compartments resulting from damage to piping systems. For this purpose, piping systems are to be located inboard of the assumed extent of damage applicable to the ship type.

1.2.2 Where it is not practicable to locate piping systems as required by 1.2.1, the following precautions are to be taken:
(a) Bilge suction pipes are to be provided with non-return valves of approved type.
(b) Other piping systems are to be provided with shut-off valves capable of being operated from positions accessible in the damage condition, or from above the bulkhead deck where required by the Rules.

These valves are to be located in the compartment containing the open end or in a suitable position such that the compartment may be isolated in the event of damage to the piping system.

1.2.3 Where subdivision and damage stability requirements apply and where penetration of watertight divisions by pipes, ducts, trunks or other penetrations is necessary, arrangements are to be made to maintain the watertight integrity.

1.3 Plans and particulars

1.3.1 The following plans (in diagrammatic form) and particulars are to be submitted for approval. Additional plans should not be submitted unless the arrangements are of a novel or special character affecting classification:
(a) Arrangements of air pipes and closing devices for all tanks and enclosed spaces.
(b) Sounding arrangements for all tanks, enclosed spaces and cargo holds.
(c) Arrangements of level alarms fitted in tanks, cargo holds, machinery spaces, pump rooms and any other spaces.
(d) Arrangements of any cross flooding or heeling tank systems.
(e) Bilge drainage arrangements for all compartments which are to include details of location, number and capacity of pumping units on bilge service. In the case of passenger ships, the bilge pump numeral, as defined in the *International Convention for the Safety of Life at Sea, 1974*, and applicable amendments are to be stated, together with the number of flooded compartments which the ship is required to withstand under damage conditions.
(f) Ballast filling and drainage arrangements: a schematic piping drawing showing connection of the ballast water treatment system to the ballast filling and drainage arrangement is to be submitted.
(g) Oil fuel filling, transfer, relief and spill/drainage arrangements.
(h) Tank overflow arrangements.
(j) Blanking arrangements for bilge and ballast piping systems for bulk carriers having floodable holds.
(k) Isolation arrangements for bilge systems where cargo holds are intended for the carriage of dangerous goods.

(l) Details verifying compliance with the sizing of air pipes required by 12.8.
(m) Arrangements of oil fuel piping in connection with oil burning installations and oil fired galleys.
(n) Arrangements of oil fuel burning units for boilers and thermal fluid heaters.
(o) Arrangement of boiler feed system.
(p) Arrangements of thermal fluid circulation systems.
(q) Arrangement of compressed air systems for main and auxiliary services.
(r) Arrangements of lubricating oil systems.
(s) Arrangements of flammable liquids used for control and heating systems.
(t) Arrangements of power transmission systems for services essential for safety or for the operation of the ship at sea.
(u) Arrangements of cooling water systems for main and auxiliary services.
(v) Oil fuel settling service and other oil fuel tanks not forming part of the ship's structure and lubricating and hydraulic oil tanks with a capacity of 500 litres or more, not forming part of the ship's structure.
(w) Arrangements and dimensions of all steam pipes where the design pressure or temperature exceeds 16,0 bar (16,3 kgf/cm^2) or 300°C, respectively, and the outside diameter exceeds 76,1 mm, with details of flanges, bolts and weld attachments, and particulars of the material of pipes, flanges, bolts and electrodes.
(x) Details verifying compliance with the capacity of the oil fuel treatment plant required by Ch 14,3.9.1.
(y) Details verifying compliance of demands on low pressure air systems by supplying essential services as required by Ch 14,10.1.3.
(z) For water ingress detection arrangements, *see* Section 14, plans and information in accordance with Pt 6, Ch 1,1.2 and, additionally, general arrangement plans showing the spaces provided with water ingress detectors, installed equipment locations and cable routes. Details of National Administration approvals are to be included.

■ *Section 2* Construction and installation

2.1 Materials

2.1.1 Except where otherwise stated in this Chapter, pipes, valves and fittings are to be made of steel, cast iron, copper, copper alloy, or other approved material suitable for the intended service.

2.1.2 Where applicable, the materials are to comply with the relevant requirements of Chapter 12.

2.1.3 Materials sensitive to heat, such as aluminium, lead or plastics, are not to be used in systems essential to the safe operation of the ship, or for containing combustible liquids or sea-water where leakage or failure could result in fire or in the flooding of watertight compartments, *see* Chapter 12 for plastics pipes.

2.1.4 Aluminium alloy pipes are not acceptable for fire extinguishing pipes unless they are suitably protected against the effect of heat. The proposed use of aluminium alloy with appropriate insulation will be considered when it has been demonstrated that the arrangements provide equivalent structural and integrity properties compared to steel. In open and exposed locations where the insulation material is likely to suffer from mechanical damage suitable protection is to be provided.

2.2 Pipe wall thickness

2.2.1 The minimum nominal wall thickness of steel, copper and copper alloy pipes are to be in accordance with Chapter 12.

2.2.2 Special consideration will be given to the wall thickness of pipes made of materials other than steel, copper and copper alloy.

2.3 Valves – Installation and control

2.3.1 Valves and cocks are to be fitted in places where they are at all times readily accessible, unless otherwise specifically mentioned in the Rules. Valves in cargo oil and ballast systems may be fitted inside tanks, subject to 2.3.2.

2.3.2 All valves which are provided with remote control are to be arranged for local manual operation, independent of the remote operating mechanism. For shipside valves and valves on the collision bulkhead, the means for local manual operation are to be permanently attached. For submerged valves in cargo oil and ballast systems, as permitted by 2.3.1, local manual operation may be by extended spindle or a portable hand pump. Where manual operation is by hand pump, the control lines to each submerged valve are to incorporate quick coupling connections, as close to the valve actuator as practicable, to allow easy connection of the hand pump. Not less than two hand pumps are to be provided.

2.3.3 In case of valves which are required by the Rules to be provided with remote control, opening and/or closing of the valves by local manual means are not to render the remote control system inoperable.

2.4 Attachment of valves to watertight plating

2.4.1 Valve chests, cocks, pipes or other fittings attached direct to the plating of tanks, and to bulkheads, flats or tunnels which are required to be of watertight construction, are to be secured by means of studs screwed through the plating or by tap bolts, and not by bolts passing through clearance holes. Alternatively, the studs or the bulkhead piece may be welded to the plating.

2.4.2 For requirements relating to valves on the collision bulkhead, *see* 3.5.4.

2.5 Ship-side valves and fittings (other than those on scuppers and sanitary discharges)

2.5.1 All sea inlet and overboard discharge pipes are to be fitted with valves or cocks secured direct to the shell plating, or to the plating of fabricated steel water boxes attached to the shell plating. These fittings are to be secured by bolts tapped into the plating and fitted with countersunk heads, or by studs screwed into heavy steel pads fitted to the plating. The stud holes are not to penetrate the plating.

2.5.2 Valves for ship-side applications are to be installed such that the section of piping immediately inboard of the valve can be removed without affecting the watertight integrity of the hull.

2.5.3 Distance pieces of short, rigid construction, and made of approved material, may be fitted between the valves and shell plating. Distance pieces of steel may be welded to the shell plating. Details of the welded connections and of fabricated steel water boxes are to be submitted.

2.5.4 Gratings are to be fitted at all openings in the ship's side for sea inlet valves and inlet water boxes. The net area through the gratings is to be not less than twice that of the valves connected to the sea inlets, and provision is to be made for clearing the gratings by use of low pressure steam or compressed air, *see* 2.5.9.

2.5.5 All suction and discharge valves and cocks secured direct to the shell plating of the ship are to be fitted with spigots passing through the plating, but the spigots on the valves or cocks may be omitted if these fittings are attached to pads or distance pieces which themselves form spigots in way of the shell plating. Blow-down valves or cocks are also to be fitted with a protection ring through which the spigot is to pass, the ring being on the outside of the shell plating. Where alternative forms of attachment are proposed, details are to be submitted for consideration.

2.5.6 Blow-down valves or cocks on the ship's side are to be fitted in accessible positions above the level of the working platform, and are to be provided with indicators showing whether they are open or shut. Cock handles are not to be capable of being removed unless the cocks are shut, and, if valves are fitted, the hand wheels are to be suitably retained on the spindle.

2.5.7 Sea inlet and overboard discharge valves and cocks are in all cases to be fitted in easily accessible positions and, so far as practicable, are to be readily visible. Indicators are to be provided local to the valves and cocks, showing whether they are open or shut. Provision is to be made for preventing any discharge of water into lifeboats. The valve spindles are to extend above the lower platform, and the hand wheels of the main cooling water sea inlet and emergency bilge suction valves are to be situated not less than 460 mm above this platform.

2.5.8 Ship-side valves and fittings, if made of steel or other approved material with low corrosion resistance, are to be suitably protected against wastage.

2.5.9 The scantlings of valves and valve stools fitted with steam or compressed air clearing connections are to be suitable for the maximum pressure to which the valves and stools may be subjected.

2.5.10 Valves, cocks and distance pieces, intended for installation on the ship's side below the load waterline, are to be tested by hydraulic pressure to not less than 5 bar.

2.5.11 For sea connections for ships having notation for ice navigation, *see* Pt 8, Ch 2,3.3, Pt 8, Ch 2,3.5 and Pt 8, Ch 2,11.21.

2.6 Piping systems – Installation

2.6.1 Bilge, ballast and cooling water suction and discharge pipes are to be permanent pipes made in readily removable lengths with flanged joints, except as mentioned in 7.10, and are to be efficiently secured in position to prevent chafing or lateral movement. For joints in oil fuel piping systems, *see* Ch 14,4.5 and 4.6.

2.6.2 Where lack of space prevents the use of normal circular flanges, details of the alternative methods of joining the pipes are to be submitted.

2.6.3 Long or heavy lengths of pipes are to be supported by bearers so that no undue load is carried by the flanged connections of the pumps or fittings to which they are attached.

2.7 Provision for expansion

2.7.1 Suitable provision for expansion is to be made, where necessary, in each range of pipes.

2.7.2 Where expansion pieces are fitted, they are to be of an approved type and are to be protected against over extension and compression. The adjoining pipes are to be suitably aligned, supported, guided and anchored. Where necessary, expansion pieces of the bellows type are to be protected against mechanical damage.

2.7.3 Expansion pieces of an approved type incorporating special quality oil resistant rubber or other suitable synthetic material may be used in cooling water lines in machinery spaces. Where fitted in sea- water lines, they are to be provided with guards which will effectively enclose, but not interfere with, the action of the expansion pieces and will reduce to the minimum practicable any flow of water into the machinery spaces in the event of failure of the flexible elements. Proposals to use such fittings in water lines for other services, including:

- ballast lines in machinery spaces, in duct keels and inside double bottom water ballast tanks, and
- bilge lines inside duct keels only,

will be specially considered when plans of the pumping systems are submitted for approval.

2.7.4 For requirements relating to flexible hoses, *see* Chapter 12.

2.8 Piping in way of refrigerated chambers

2.8.1 All pipes, including scupper pipes, air pipes and sounding pipes which pass through chambers intended for the carriage or storage of refrigerated produce are to be well insulated.

2.8.2 Where the pipes referred to in 2.8.1 pass through chambers intended for temperatures of 0°C or below, they are also to be insulated from the steel structure, except in positions where the temperature of the structure is mainly controlled by the external temperature and will normally be above freezing point. Pipes passing through a deckplate within the ship side insulation, where the deck is fully insulated below and has an insulation ribband on top, are to be attached to the deck plating. In the case of pipes adjacent to the shell plating, metallic contact between the pipes and the shell plating or frames is to be arranged so far as practicable.

2.8.3 The air refreshing pipes to and from refrigerated compartments need not, however, be insulated from the steel work.

2.9 Miscellaneous requirements

2.9.1 All pipes situated in cargo spaces, fish holds, chain lockers or other positions where they are liable to mechanical damage are to be efficiently protected.

2.9.2 Wash deck pipes and discharge pipes from the pumps to domestic water tanks are not to be led through cargo holds. Any proposed departure from this requirement is to be submitted for consideration.

2.9.3 So far as practicable, pipelines, including exhaust pipes from oil engines, are not to be led in the vicinity of switchboards or other electrical appliances in positions where the drip or escape of liquid, gas or steam from joints or fittings could cause damage to the electrical installation. Where it is not practicable to comply with these requirements, drip trays or shields are to be provided as found necessary. Short sounding pipes to tanks are not to terminate near electrical appliances, *see* 12.13.2.

2.10 Testing after installation

2.10.1 After installation on board, all steam, hydraulic, compressed air and other piping systems covered by 1.3.1, together with associated fittings which are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

■ *Cross-reference*

For guidance on metal pipes for water services, *see* Ch 12,11.

■ *Section 3*
Drainage of compartments, other than machinery spaces

3.1 General

3.1.1 All ships are to be provided with efficient pumping plant having the suctions and means for drainage so arranged that any water within any compartment of the ship, or any watertight section of any compartment, can be pumped out through at least one suction when the ship is on an even keel and is either upright or has a list of not more than 5°. For this purpose, wing suctions will generally be necessary, except in short, narrow compartments where one suction can provide effective drainage under the above conditions.

3.1.2 In passenger ships, the pumping plant is to be capable of draining any watertight compartment under all practicable conditions after a casualty, whether the ship is upright or listed.

3.1.3 In the case of dry compartments, the suctions required by 3.1.1 are, except where otherwise stated, to be branch bilge suctions, i.e., suctions connected to a main bilge line.

3.1.4 For drainage arrangements of non-self-propelled ships, *see* Section 10.

3.1.5 For additional drainage arrangements on ferries and Roll on-Roll off ships, *see* Pt 4, Ch 2,9.9.

3.1.6 For a normally inaccessible small void compartment such as an echo sounding compartment, which is accessed from within a normally inaccessible space such as a forepeak tank, alternative drainage arrangements to those required by 3.1.1 may be considered. For such arrangements, a warning notice is to be located in a prominent position specifying the precautions to be taken prior to opening the manhole of the small void compartment. Means are to be provided to indicate flooding of the compartment without opening, such as fitting indicator plugs to the manhole. Drainage arrangements are to be submitted to LR for approval.

3.2 Cargo holds

3.2.1 In ships having only one hold, and this over 30 m in length, bilge suctions are to be fitted in suitable positions in the fore and after sections of the hold.

3.2.2 Where close ceiling or continuous gusset plates are fitted over the bilges, arrangements are to be made whereby water in a hold compartment may find its way to the suction pipes.

3.2.3 Where the inner bottom plating extends to the ship's side, the bilge suctions are to be led to wells placed at the wings. If the tank top plating has inverse camber, a well is also to be fitted at the centreline, but in the case of trawlers and fishing vessels, a single well fitted at the centre may be accepted. For capacity and construction of bilge wells, *see* 7.6.

3.2.4 For drainage arrangements from refrigerated cargo spaces, *see* Pt 6, Ch 3,4.19.

3.2.5 For cargo holds having non-weathertight hatch covers or where hatch covers have been omitted, drainage arrangements are to take into account the effects of additional water ingress into the hold(s). High level bilge alarms are to be provided in cargo holds having non-weathertight hatch covers or where hatch covers have been omitted, *see also* Pt 4, Ch 8,11.

3.2.6 Drainage arrangements of cargo holds intended for the carriage of flammable or toxic liquids are to be designed to prevent inadvertent drainage of such products through machinery space piping systems.

3.3 Holds and deep tanks for alternative carriage of liquid or dry cargo

3.3.1 Where holds and deep tanks are intended for the alternative carriage of liquid or dry cargo, the drainage arrangements are to be in accordance with the following:

(a) For dry cargoes, 3.1 and 3.2.
(b) For water ballast, oil fuel or cargo oil having a flash point of 60°C or above, 3.4.
(c) For cargo oil having a flash point below 60°C, Chapter 15.

3.3.2 For blanking arrangements of filling and suction pipes, *see* 7.12.

3.4 Tanks and cofferdams

3.4.1 All tanks (including double bottom tanks), whether used for water ballast, oil fuel or liquid cargoes, are to be provided with suction pipes, led to suitable power pumps, from the after end of each tank.

3.4.2 In general, the drainage arrangements are to be in accordance with 3.1. However, where the tanks are divided by longitudinal watertight bulkheads or girders into two or more tanks, a single suction pipe, led to the after end of each tank, will normally be acceptable.

3.4.3 Similar drainage arrangements are to be provided for cofferdams, except that the suctions may be led to the main bilge line.

3.4.4 The pumping arrangements for tanks that are intended to carry cargo oil having a flash point of 60°C or above, are also to comply with the requirements of Chapter 14, Sections 2, 3 and 4, as far as they are applicable.

3.5 Fore and after peaks

3.5.1 Fuel oil, lubrication oil and other flammable liquids are not to be carried in forepeak tanks.

3.5.2 Where the peaks are used as tanks, a power pump suction is to be led to each tank, except in the case of small tanks used for the carriage of domestic fresh water, where hand pumps may be used.

3.5.3 Where the peaks are not used as tanks, and main bilge line suctions are not fitted, drainage of both peaks may be effected by hand pump suctions, provided that the suction lift is well within the capacity of the pumps and in no case exceeds 7,3 m. In the case of trawlers and fishing vessels, drainage of the after peak may be effected by means of a self-closing cock fitted in a well lighted and readily accessible position.

3.5.4 Except as permitted by 3.5.5, the collision bulkhead is not to be pierced below the bulkhead deck by more than one pipe for dealing with the contents of the fore peak. The pipe is to be provided with a screw-down valve capable of being operated from an accessible position above the bulkhead deck, the chest being secured to the bulkhead inside the fore peak. An indicator is to be provided to show whether the valve is open or closed. The valves may be fitted on the after side of the collision bulkhead, provided that the valve is readily accessible under all service conditions and the space in which it is located is not a cargo space.

3.5.5 Where the fore peak is divided into two compartments, the collision bulkhead may be pierced below the bulkhead deck by two pipes (i.e., one for each compartment) provided there is no practical alternative to the fitting of a second pipe. Each pipe is to be provided with a screw-down valve, fitted and controlled as in 3.5.4.

3.6 Spaces above fore peaks, after peaks and machinery spaces

3.6.1 Provision is to be made for the drainage of the chain locker and watertight compartments above the fore peak tank by hand or power pump suctions.

3.6.2 Steering gear compartments or other small enclosed spaces situated above the after peak tank are to be provided with suitable means of drainage, either by hand or power pump bilge suctions.

3.6.3 Subject to special approval of any applicable subdivision requirements, compartments referred to in 3.6.2 that are adequately isolated from the adjacent 'tween decks, may be drained by scuppers of not less than 38 mm bore, discharging to the tunnel (or machinery space in the case of ships with machinery aft) and fitted with self-closing cocks situated in well lighted and visible positions.

3.6.4 In case of trawlers and fishing vessels, accommodation spaces which overhang the machinery space, may also be drained as in 3.6.3.

3.6.5 For drainage of the fore and after peaks, *see* 3.5.

3.7 Maintenance of integrity of bulkheads

3.7.1 The intactness of the machinery space bulkheads, and of tunnel plating required to be of watertight construction, is not to be impaired by the fitting of scuppers discharging to machinery space or tunnels from adjacent compartments which are situated below the bulkhead deck. These scuppers may, however, be led into a strongly constructed scupper drain tank situated in the machinery space or tunnel, but closed to these spaces and drained by means of a suction of appropriate size led from the main bilge line through a screw-down non-return valve.

3.7.2 The scupper tank air pipe is to be led to above the bulkhead deck, and provision is to be made for ascertaining the level of water in the tank.

3.7.3 Where one tank is used for the drainage of several watertight compartments, the scupper pipes are to be provided with screw-down non-return valves.

3.7.4 No drain valve or cock is to be fitted to the collision bulkhead. Drain valves or cocks are not to be fitted to other watertight bulkheads if alternative means of drainage are practicable.

3.7.5 Where drain valves or cocks are fitted to bulkheads other than the collision bulkhead, as permitted by 3.7.4, the drain valves or cocks are to be at all times readily accessible and are to be capable of being shut off from positions above the bulkhead deck. Indicators are to be provided to show whether the drains are open or shut. These arrangements are not permissible in passenger ships.

3.7.6 Bilge drain valves or cocks may be used for draining accommodation spaces and the after dry peak of trawlers and fishing vessels as stated in 3.6.4 and 3.5.3.

3.7.7 For drainage of stern compartment, *see* 3.6.

■ *Section 4* Bilge drainage of machinery spaces

4.1 General

4.1.1 The bilge drainage arrangements in the machinery space are to comply with 3.1, except that the arrangements are to be such that any water which may enter this compartment can be pumped out through at least two bilge suctions when the ship is on an even keel, and is either upright or has a list of not more than 5°. One of these suctions is to be a branch bilge suction, i.e., a suction connected to the main bilge line, and the other is to be a direct bilge suction, i.e., a suction led direct to an independent power pump. Examples of the necessary arrangements are detailed in 4.2 and 4.3.

4.1.2 In passenger ships, the drainage arrangements are to be such that machinery spaces can be pumped out under all practical conditions after a casualty, whether the ship is upright or listed.

4.2 Machinery space with double bottom

4.2.1 Where the double bottom extends the full length of the machinery space and forms bilges at the wings, it will be necessary to provide one branch and one direct bilge suction at each side.

4.2.2 Where the double bottom plating extends the full length and breadth of the compartment, one branch bilge suction and one direct bilge suction are to be led to each of two bilge wells, situated one at each side.

4.2.3 For capacity and construction of bilge wells, *see* 7.6.

4.3 Machinery space without double bottom

4.3.1 Where there is no double bottom and the rise of floor is not less than 5°, one branch and one direct bilge suction are to be led to accessible positions as near the centreline as practicable.

4.3.2 In ships where the rise of floor is less than 5°, and in all passenger ships, additional bilge suctions are to be provided at the wings.

4.4 Additional bilge suctions

4.4.1 Additional bilge suctions may be required for the drainage of depressions in the tank top formed by crankpits, or other recesses, by tank tops having inverse camber or by discontinuity of the double bottom.

4.4.2 In ships in which the propelling machinery is situated at the after end of the ship, it will generally be necessary for bilge suctions to be fitted in the forward wings as well as in the after end of the machinery space, but each case will be dealt with according to the size and structural arrangements of the compartment.

4.4.3 In ships propelled by electrical machinery, special means are to be provided to prevent the accumulation of bilge water under the main propulsion generators and motors.

4.5 Separate machinery spaces

4.5.1 Where the machinery space is divided by watertight bulkheads to separate the boiler room(s), or auxiliary engine room(s) from the main engine room, the number and position of the branch bilge suctions in the boiler room(s) or auxiliary engine room(s) are to be the same as for cargo holds.

4.5.2 In addition to the branch bilge suctions, required by 4.5.1, at least one independent power pump direct bilge suction is to be fitted in each compartment. Similar provision is to be made in separate motor rooms of electrically propelled ships.

4.5.3 In passenger ships, each independent bilge pump is to have a direct bilge suction from the space in which it is situated, but not more than two such suctions are required in any one space. Where two or more such suctions are provided, there is to be at least one suction on each side of the space.

4.6 Machinery space – Emergency bilge drainage

4.6.1 In addition to the bilge suctions detailed in 4.1 to 4.5, an emergency bilge suction is to be provided in each main machinery space. This suction is to be led to the main cooling water pump from a suitable low level in the machinery space and is to be fitted with a screw-down non-return valve having the spindle so extended that the hand wheel is not less than 460 mm above the bottom platform.

4.6.2 Where two or more cooling water pumps are provided, each capable of supplying cooling water for normal power, only one pump need be fitted with an emergency bilge suction.

4.6.3 In ships with steam propelling machinery, the suction is to have a diameter of at least two-thirds that of the pump suction. In other ships, the suction is to be the same size as the suction branch of the pump.

4.6.4 Where main cooling water pumps are not suitable for bilge pumping duties, the emergency bilge suction is to be led to the largest available power pump, which is not a bilge pump detailed in 6.1 and 6.2. This pump is to have a capacity not less than that required for a bilge pump and the bilge suction is to be the same size as that of the pump suction branch.

4.6.5 Where the pump to which the emergency bilge suction is connected is of the self-priming type, the direct bilge suction on the same side of the ship as the emergency suction may be omitted, except in passenger ships.

4.6.6 Emergency bilge suction valve nameplates are to be marked ‘For emergency use only’.

4.6.7 Where **UMS** (Unattended Machinery Space) notation is to be assigned, the requirements of Pt 6, Ch 1,4.6.2 are not applicable for valves serving an emergency bilge system, provided that:

(a) the emergency bilge valve is normally maintained in a closed position;
(b) a non-return device is installed in the emergency bilge piping; and
(c) the emergency bilge suction piping is located inboard of a shell valve that is fitted with the control arrangements complying with Pt 6, Ch 1,4.6.2.

4.7 Tunnel drainage

4.7.1 The tunnel well is to be drained by a suction from the main bilge line. In all ships, including passenger ships, this well may extend to the outer bottom.

4.7.2 Where the tank top in the tunnel slopes down from aft to forward, a bilge suction is to be provided at the forward end of the tunnel, in addition to the tunnel well suction required by 4.7.1.

■ *Section 5*
Sizes of bilge suction pipes

5.1 Main bilge line

5.1.1 The diameter, d_m, of the main bilge line is to be not less than required by the following formula, to the nearest 5 mm, but in no case is the diameter to be less than that required for any branch bilge suction:

$$d_m = 1{,}68\sqrt{L(B+D)} + 25 \text{ mm}$$

where

d_m = internal diameter of main bilge line, in mm
B = greatest moulded breadth of ship or maximum breadth of cargo hold for ore carriers, in metres
D = moulded depth to bulkhead deck, in metres
L = Rule length of ship as defined in Pt 3, Ch 1,6.1, in metres, for ships other than passenger ships
= length between perpendiculars at the extremities of the deepest subdivision load line, in metres, for passenger ships.

5.2 Branch bilge suctions to cargo and machinery spaces

5.2.1 The diameter, d_b, of branch bilge suction pipes to cargo and machinery spaces is to be not less than required by the following formula, to the nearest 5 mm, but in no case is the diameter of any suction to be less than 50 mm:

$$d_b = 2{,}15\sqrt{C(B+D)} + 25 \text{ mm}$$

where

d_b = internal diameter of branch bilge suction, in mm
C = length of compartment, in metres, and
B and D are as defined in 5.1.1.

5.3 Direct bilge suctions, other than emergency suctions

5.3.1 The direct bilge suctions in the main engine room, and the direct bilge suctions in large separate boiler rooms, motor rooms of electrically propelled ships and auxiliary engine rooms are not to be of a diameter less than that required for the main bilge line.

5.3.2 Where the separate machinery spaces are of small dimensions, the sizes of the direct bilge suctions to these spaces will be specially considered.

5.3.3 For sizes of emergency bilge suctions, *see* 4.6.

5.4 Main bilge line – Tankers and similar ships

5.4.1 In oil tankers and similar ships, where the engine room pumps do not deal with bilge drainage outside the machinery space, the diameter of the main bilge line may be less than that required by the formula in 5.1.1, provided that the cross-sectional area is not less than twice that required for the branch bilge suctions in the machinery space.

5.5 Distribution chest branch pipes

5.5.1 The area of each branch pipe connecting the bilge main to a distribution chest is to be not less than the sum of the areas required by the Rules for the two largest branch bilge suction pipes connected to that chest, but need not be greater than that required for the main bilge line.

5.6 Tunnel suction

5.6.1 The bilge suction pipe to the tunnel well is to be not less than 65 mm bore, except in ships not exceeding 60 m in length, in which case it may be 50 mm bore.

■ *Section 6* Pumps on bilge service and their connections

6.1 Number of pumps

6.1.1 For ships other than passenger ships, at least two power bilge pumping units are to be provided in the machinery space. In ships of 90 m in length and under, one of these units may be worked from the main engines and the other is to be independently driven. In larger ships both units are to be independently driven.

6.1.2 Each unit may consist of one or more pumps connected to the main bilge line, provided that their combined capacity is adequate.

6.1.3 In ships other than passenger ships, a bilge ejector in combination with a high pressure sea-water pump may be accepted as a substitute for an independent bilge pump as required by 6.1.1.

6.1.4 Special consideration will be given to the number of pumps for small ships and, in general, if there is a class notation restricting a small ship to harbour or river service, a hand pump may be accepted in lieu of one of the bilge pumping units.

6.1.5 For passenger ships, at least three power bilge pumps are to be provided, one of which may be operated from the main engines. Where the bilge pump numeral as derived from Regulation 35-1 of Chapter II-1 of the *International Convention for the Safety of Life at Sea, 1974*, and applicable amendments, is 30 or more, one additional independent power pump is to be provided.

6.1.6 For location of pumps on passenger ships, *see* 8.1.

6.2 General service pumps

6.2.1 The bilge pumping units, or pumps, required by 6.1 may also be used for ballast, fire or general service duties of an intermittent nature, but they are to be immediately available for bilge duty when required, *see also* SOLAS 1974 as amended Reg. II-2/C,10, as applicable.

6.3 Capacity of pumps

6.3.1 Each bilge pumping unit, or bilge pump in the case of passenger ships, is to be connected to the main bilge line and is to be capable of giving a speed of water through the Rule size of main bilge pipe of not less than 122 m/min.

6.3.2 The capacity of each bilge pumping unit or bilge pump is to be not less than required by the following formula:

$$Q = \frac{5,75}{10^3} d_m^2$$

where

d_m = Rule internal diameter of main bilge line, in mm
Q = capacity, in m^3/hour.

6.3.3 In ships other than passenger ships, where one bilge pumping unit is of slightly less than Rule capacity, the deficiency may be made good by an excess capacity of the other unit. In general, the deficiency is to be limited to 30 per cent.

6.4 Self-priming pumps

6.4.1 All power pumps which are essential for bilge services are to be of the self-priming type, unless an approved central priming system is provided for these pumps. Details of this system are to be submitted.

6.4.2 Cooling water pumps having emergency bilge suctions need not be of the self-priming type.

6.4.3 For requirements regarding emergency bilge suctions, *see* 4.6.

6.5 Pump connections

6.5.1 The connections at the bilge pumps are to be such that one unit may continue in operation when the other unit is being opened up for overhaul.

6.5.2 Pumps required for essential services are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any pumps so connected is unaffected by the other pumps being in operation at the same time.

6.6 Direct bilge suctions

6.6.1 The direct bilge suctions in the machinery space(s) are to be led to independent power pump(s), and the arrangements are to be such that these direct suctions can be used independently of the main bilge line suctions.

■ *Section 7* Piping systems and their fittings

7.1 Main bilge line suctions

7.1.1 Suctions from the main bilge line, i.e., branch bilge suctions, are to be arranged to draw water from any hold, compartment, watertight section or machinery compartment of the ship, excepting small spaces such as those mentioned in 3.1.6, 3.5 and 3.6, where manual pump suctions are accepted, and are not to be of smaller diameter than that required by the formula in 5.2.1, *see also* 7.4.1 and 7.5.1. For special arrangements for oil tankers, *see* Chapter 15.

7.1.2 Where passenger or cargo ships are of a design having enclosed car decks or cargo spaces located on the bulkhead deck or on the freeboard deck, special consideration will be given to the drainage arrangements where any fixed pressure water spray system is fitted, *see also* Pt 3, Ch 12,4.1 and 9.1.

7.2 Prevention of communication between compartments

7.2.1 The arrangement of valves, cocks and their connections is to be such as to prevent the possibility of one watertight compartment being placed in communication with another, or of dry cargo spaces, machinery spaces or other dry compartments being placed in communication with the sea or with tanks. For this purpose, screw-down non-return valves are to be provided in the following fittings:

- Bilge valve distribution chests.
- Bilge suction hose connections, whether fitted direct to the pump or on the main bilge line.
- Direct bilge suctions and bilge pump connections to main bilge line.

7.3 Isolation of bilge system

7.3.1 Bilge pipes which are required for draining cargo or machinery spaces are to be entirely distinct from sea inlet pipes or from pipes which may be used for filling or emptying spaces where water or oil is carried. This does not, however, exclude a bilge ejection connection, a connecting pipe from a pump to its suction valve chest, or a deep tank suction pipe suitably connected through a changeover device to a bilge, ballast or oil line.

7.4 Machinery space suctions – Mud boxes

7.4.1 Suctions for bilge drainage in machinery spaces and tunnels, other than emergency suctions, are to be led from easily accessible mud boxes fitted with straight tail pipes to the bilges and having covers secured in such a manner as to permit their being expeditiously opened or closed. Strum boxes are not to be fitted to the lower ends of these tail pipes or to the emergency bilge suctions.

7.5 Hold and other compartment suctions – Strum boxes

7.5.1 The open ends of bilge suctions in holds and other compartments outside machinery spaces and tunnels such as cofferdams and tanks other than those permanently arranged for the carriage of fresh water, water ballast, oil fuel or liquid cargo and for which other efficient means of pumping are provided, are to be enclosed in strum boxes having perforations of not more than 10 mm diameter, whose combined area is not less than twice that required for the suction pipe. The boxes are to be so constructed that they can be cleared without breaking any joint of the suction pipe.

7.6 Bilge wells

7.6.1 Bilge wells required by 3.2.3 and 4.2.2 are to be formed of steel plates and are to be not less than 0,15 m^3 capacity. In small compartments, steel bilge hats of reasonable capacity may be fitted.

7.6.2 In passenger ships, the depth of bilge wells in double bottom tanks will be specially considered.

7.6.3 Where access manholes to bilge wells are necessary, they are to be fitted as near to the suction strums as practicable.

7.7 Tail pipes

7.7.1 The distance between the foot of all bilge tail pipes and the bottom of the bilge well is to be adequate to allow a full flow of water and to facilitate cleaning.

7.8 Location of fittings

7.8.1 Bilge valves, cocks and mud boxes are to be fitted at, or above, the machinery space and tunnel platforms. Where it is not practicable to avoid the fittings being situated at the starting platform or in passageways, they may be situated just below the platform, provided readily removable traps or covers are fitted and nameplates indicate the presence of these fittings.

7.8.2 Where relief valves are fitted to pumps having sea connections, these valves are to be fitted in readily visible positions above the platform. The arrangements are to be such that any discharge from the relief valves will also be readily visible.

7.9 Bilge pipes in way of double bottom tanks

7.9.1 Bilge suction pipes are not to be led through double bottom tanks if it is possible to avoid doing so.

7.9.2 Bilge pipes which have to pass through these tanks are to have a wall thickness in accordance with Table 12.2.4 in Chapter 12. (The thickness of pipes made from material other than steel will be specially considered).

7.9.3 Expansion bends, not glands, are to be fitted to these pipes within the tanks, and the pipes are to be tested, after installation, to the same pressure as the tanks through which they pass.

7.10 Bilge pipes in way of deep tanks

7.10.1 In way of deep tanks, bilge pipes should preferably be led through pipe tunnels but, where this is not done, the pipes are to be of steel, having a wall thickness in accordance with Table 12.2.4 in Chapter 12, with welded joints or heavy flanged joints. The number of joints is to be kept to a minimum.

7.10.2 Expansion bends, not glands, are to be fitted to these pipes within the tanks, and the open ends of the bilge suction pipes in the holds are to be fitted with non-return valves of the special type approved for use in holds, *see* 7.11.1.

7.10.3 The pipes are to be tested, after installation, to a pressure not less than the maximum head to which the tanks can be subjected in service.

7.11 Hold bilge non-return valves

7.11.1 Where non-return valves are fitted to the open ends of bilge suction pipes in cargo holds in order to decrease the risk of flooding, they are to be of an approved type which does not offer undue obstruction to the flow of water.

7.12 Blanking arrangements

7.12.1 In case of deep tanks and cargo holds which may be used for either water ballast or dry cargo, provision is to be made for blank flanging the water ballast filling and suction pipes when the tank or hold is being used for the carriage of dry cargo, and for blank flanging the bilge suction pipes when the tank or hold is being used for the carriage of water ballast. Change-over devices may be used for this purpose.

7.12.2 For arrangements when oil fuel or cargo oil (having a flash point of 60°C or above) is carried in deep tanks, *see* Ch 14,4.14.

7.12.3 Where a ship is designed for the alternative carriage of dry cargo or oil having a flash point below 60°C, the blanking arrangements will be specially considered.

■ *Section 8*
Additional requirements for bilge drainage and cross-flooding arrangements for passenger ships

8.1 Location of bilge pumps and bilge main

8.1.1 In passenger ships, the power bilge pumps required by 6.1.5 are to be placed, if practicable, in separate watertight compartments which will not readily be flooded by the same damage. If the engines and boilers are in two or more watertight compartments, the bilge pumps are to be distributed throughout these compartments so far as is possible.

8.1.2 In passenger ships of 91,5 m or more in length, or having a bilge pump numeral of 30 or more (*see* 6.1.5), the arrangements are to be such that at least one power pump will be available for use in all ordinary circumstances in which the ship may be flooded at sea. This requirement will be satisfied if:

- one of the pumps is an emergency pump of a submersible type having a source of power situated above the bulkhead deck, or
- the pumps and their sources of power are so disposed throughout the length of the ship that, under any conditions of flooding which the ship is required by statutory regulation to withstand, at least one pump in an undamaged compartment will be available.

8.1.3 The bilge main is to be so arranged that no part is situated nearer the side of the ship than $\frac{B}{5}$, measured at right angles to the centreline at the level of the deepest subdivision load line, where B is the breadth of the ship.

8.1.4 Where any bilge pump or its pipe connection to the bilge main is situated outboard of the $\frac{B}{5}$ line, then a non-return valve is to be provided in the pipe connection at the junction with the bilge main. The emergency bilge pump and its connections to the bilge main are to be so arranged that they are situated inboard of the $\frac{B}{5}$ line.

8.2 Prevention of communication between compartments in the event of damage

8.2.1 Provision is to be made to prevent the compartment served by any bilge suction pipe being flooded, in the event of the pipe being severed, or otherwise damaged by collision or grounding in any other compartment. For this purpose, where the pipe is at any part situated nearer the side of the ship than $\frac{B}{5}$ or in a duct keel, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

8.3 Arrangement and control of bilge valves

8.3.1 All the distribution boxes, valves and cocks in connection with the bilge pumping arrangements are to be so arranged that, in the event of flooding, one of the bilge pumps may be operative on any compartment. If there is only one system of pipes common to all pumps, the necessary valves or cocks for controlling the bilge suctions must be capable of being operated from the bulkhead deck. Where, in addition to the main bilge pumping system, an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of operating on any compartment under flooding conditions; in this case, only the valves and cocks necessary for the operation of the emergency system need be capable of being operated from above the bulkhead deck.

8.3.2 All valves and cocks mentioned in 8.3.1 which can be operated from above the bulkhead deck are to have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

8.4 Cross-flooding arrangements

8.4.1 Where divided deep tanks or side tanks are provided with cross-flooding arrangements to limit the angle of heel after side damage, the arrangements are to be self-acting where practicable. In any case, where controls to cross-flooding fittings are provided, they are to be operable from above the bulkhead deck.

■ *Section 9* Additional requirements relating to fixed pressure water spray fire-extinguishing systems

9.1 Bilge drainage requirements

9.1.1 Where arrangements for cooling cargo, Ro-Ro or special category spaces below the bulk-head or freeboard deck, or fire-fighting by means of fixed spraying nozzles or by flooding of these spaces with water are provided, the following provisions are to apply, *see also* IMO guidelines (MSC.1/Circ.1320):

(a) The drainage system is to be sized to remove no less than 125 per cent of the combined capacity of both the water spraying system pumps and the required number of fire hose nozzles.
(b) The drainage system valves are to be operable from outside the protected space at a position in the vicinity of the extinguishing system controls.
(c) Adequately sized bilge wells are to be located at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment, the bilge wells should be uniformly distributed fore and aft, *see also* Pt 3, Ch 12, 4.1.4 and Pt 4, Ch 2,11.2. For cargo ships only, if this is not possible, the free surface effect on the ship's stability is to be determined and submitted to the Flag Administration for appraisal.

9.1.2 If drainage of vehicle or cargo spaces is by gravity, the drainage is to be led directly overboard or to a closed drain tank. If led overboard the scuppers are to comply with Pt 3, Ch 12,4.1.3. If led to a closed drain tank, this tank is to be located outside the machinery spaces and provided with a vent pipe leading to a safe location on the open deck. *See also* Pt 4, Ch 2,11.2.

9.1.3 Drainage from a cargo space into bilge wells in a lower space is only permitted if that space satisfies the same requirements as the cargo space above.

9.1.4 On ships with closed vehicle spaces, ro-ro spaces and special category spaces, means are to be provided to prevent the blockage of drainage systems from these spaces.

■ *Section 10* Drainage arrangements for ships not fitted with propelling machinery

10.1 Hand pumps

10.1.1 Where auxiliary power is not provided, hand pumps are to be fitted, in number and position, as may be required for the efficient drainage of the ship.

10.1.2 In general, one hand pump is to be provided for each compartment. Alternatively, two pumps connected to a bilge main, having at least one branch to each compartment, are to be provided.

10.1.3 The pumps are to be capable of being worked from the upper deck or from positions above the load waterline which are at all times readily accessible. The suction lift is not to exceed 7,3 m and is to be well within the capacity of the pump.

10.1.4 The sizes of the hand pumps are to be not less than those given in Table 13.10.1. Where the ship is closely subdivided into small watertight compartments, 50 mm bore suctions will be accepted.

Table 13.10.1 Sizes of hand pumps

Tonnage under upper deck	Diameter of barrel of bucket pump mm	Bore of suction pipe of bucket pumps and semi-rotary pumps mm
Not exceeding 500 tons	100	50
Above 500 tons but not exceeding 1000 tons	115	57
Above 1000 tons but not exceeding 2000 tons	125	65
Above 2000 tons	140	70

10.2 Ships with auxiliary power

10.2.1 In ships in which auxiliary power is available on board, power pump suctions are to be provided for dealing with the drainage of tanks and of the bilges of the principal compartments.

10.2.2 The pumping arrangements are to be as required for self-propelled ships, so far as these requirements are applicable, duly modified to suit the size and service of the ship.

10.2.3 Details of the pumping arrangements are to be submitted for special consideration.

■ *Section 11* Ballast system

11.1 Stand-by arrangements for ballast pumping

11.1.1 Where ballasting/de-ballasting is required for ship operation or trading purposes stand-by ballast pumping arrangements are to be provided, *see also* 6.2.1 and Ch 15,2.4.4.

11.2 Integrated cargo and ballast systems

11.2.1 Where ballast and cargo systems share power supplies and/or control engineering systems, the additional requirements of this sub-Section apply.

11.2.2 A failure is not to prevent operation of the ballast system by other means.

11.2.3 Controls to stop the cargo system, including normal controls and emergency stop and safety shut-downs, are not to prevent operation of the ballast system.

11.3 Ballast water treatment system installations

11.3.1 Failure of a ballast water treatment system is not to impair or restrict ballasting or de-ballasting operations.

11.3.2 Failure of a ballast water treatment system shall not impair or restrict any other essential system as defined by Pt 6, Ch 2,1.5.

11.3.3 Ballast water treatment systems are to be installed on a by-pass arrangement, designed to ensure that the treatment system can be efficiently isolated from the ballast water system without impairing ballast water flow.

11.3.4 Pipe work associated with ballast water treatment systems units is to meet the requirements of Table 12.5.3 in Chapter 12.

11.3.5 Valves are to comply with the requirements of Ch 12,6.

11.3.6 All electrical equipment forming part of ballast water treatment units is to meet the applicable requirements of Pt 6, Ch 2. Hazardous areas associated with ballast water treatment system installations are to be determined in accordance with the requirements of Pt 6, Ch 2,14.

11.3.7 Any deck and bulkhead penetrations are to meet the requirements of Section 1.

11.3.8 Arrangements for transferring ballast water from non-hazardous to hazardous areas is only permitted where:
- There is no ballast water supply from hazardous areas to non-hazardous areas.
- Ballast water from the non-hazardous area is discharged to a hazardous area with the piping provided with two non-return valves installed in series.
- All pipe penetrations from the non-hazardous area to the hazardous area are led above main deck level.
- Engine room and pump-room bulkheads are not to be penetrated.

■ *Section 12* Air, overflow and sounding pipes

12.1 Definitions

12.1.1 Reference to cargo oil in this Section is to be taken to mean cargo oil which has a flash point 60°C or above (closed cup test).

12.2 Materials

12.2.1 Air, overflow and sounding pipes are to be made of steel or other approved material. For use of plastics pipes of approved type, *see* Chapter 12.

12.2.2 The portions of air, overflow and sounding pipes fitted above the weather deck are to be of steel or equivalent material.

12.3 Nameplates

12.3.1 Nameplates are to be affixed to the upper ends of all air and sounding pipes.

12.4 Air pipes

12.4.1 Air pipes are to be fitted to all tanks, cofferdams, tunnels and other compartments which are not fitted with alternative ventilation arrangements.

12.4.2 The air pipes are to be fitted at the opposite end of the tank to that which the filling pipes are placed and/or at the highest part of the tank. Where the tank top is of unusual or irregular profile, special consideration will be given to the number and position of the air pipes.

12.4.3 For a normally inaccessible small void compartment such as an echo sounding compartment, which is accessed from within a normally inaccessible space such as a forepeak tank, alternative air pipe arrangements to those required by 12.4.1 may be considered. For such arrangements, a warning notice is to be located in a prominent position specifying the precautions to be taken prior opening the manhole and entering the small void compartment. Ventilation arrangements are to be submitted to LR for approval.

12.5 Termination of air pipes

12.5.1 Air pipes to double bottom tanks, deep tanks extending to the shell plating, or tanks which can be run up from the sea are to be led to above the bulkhead deck. Air pipes to oil fuel and cargo oil tanks, cofferdams and all tanks which can be pumped up are to be led to the open. For height of air pipes above deck, *see* Pt 3, Ch 12,3.

12.5.2 Air pipes from storage tanks containing lubricating or hydraulic oil may terminate in the machinery space, provided that the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces. Air pipes from heated lubricating oil tanks are to be led to the open.

12.5.3 The open ends of air pipes to oil fuel and cargo oil tanks are to be situated where no danger will be incurred from issuing oil vapour when the tank is being filled.

12.5.4 The location and arrangement of air pipes for oil fuel service, settling and lubricating oil tanks are to be such that in the event of a broken vent pipe, this does not directly lead to the risk of ingress of sea-water or rainwater.

12.5.5 For special requirements for the termination of air pipes on ferries, *see* Pt 3, Ch 12,3 and Pt 4, Ch 2,11.

12.6 Gauze diaphragms

12.6.1 The open ends of air pipes to oil fuel and cargo oil tanks are to be furnished with a wire gauze diaphragm of incorrodible material which can be readily removed for cleaning or renewal.

12.6.2 Where wire gauze diaphragms are fitted at air pipe openings, the area of the opening through the gauze is to be not less than the cross-sectional area required for the pipe, *see* 12.8.

12.7 Air pipe closing appliances

12.7.1 The closing appliances fitted to tank air pipes in accordance with Pt 3, Ch 12,3 are to be of an automatic opening type which will allow the free passage of air or liquid to prevent the tanks being subjected to a pressure or vacuum greater than that for which they are designed, and prevent the free entry of water into the tanks.

12.7.2 Air pipe closing devices are to be of a type acceptable to Lloyd's Register (hereinafter referred to as 'LR') and are to be tested in accordance with a National or International Standard recognised by LR. The flow characteristic of the closing device is to be determined using water, *see* 12.8.1 and 12.8.2.

12.7.3 Wood plugs and other devices which can be secured closed are not to be fitted at the outlets.

12.7.4 Air pipe automatic closing devices shall be so designed that they will withstand both ambient conditions as indicated in Pt 5, Ch 1,3.5 and 3.6 and designed working conditions, and be suitable for use at inclinations up to and including ±40°.

12.7.5 Air pipe automatic closing devices shall be constructed to allow inspection of the closure and the inside of the casing as well as changing the seals.

12.7.6 Efficient ball or float seating arrangements are to be provided for the closures. Bars, cages or other devices are to be provided to prevent the ball or float from contacting the inner chamber in its normal state, and made in such a way that the ball or float is not damaged when subjected to liquid impact due to a tank being overfilled.

12.7.7 Air pipe automatic closing devices are to be self-draining.

12.7.8 The clear area through an air pipe closing device in the open position shall be at least equal to the area of the inlet.

12.7.9 In the case of air pipe closing devices of the float type, suitable guides are to be provided to ensure unobstructed operation under all working conditions of heel and trim as specified in 12.7.4.

12.7.10 The maximum allowable tolerances for wall thickness of floats shall not exceed ±10 per cent of thickness.

12.7.11 The inner and the outer chambers of an automatic air pipe head are to be of a minimum thickness of 6 mm.

12.7.12 Casings of air pipe closing devices are to be of approved metallic materials, adequately protected against corrosion.

12.7.13 For galvanised steel air pipe heads, the zinc coating is to be applied by the hot method and the thickness is to be 70 to 100 microns.

12.7.14 For areas of the head susceptible to erosion (e.g., those parts directly subjected to ballast water impact when the tank is being pressed up, such as the inner chamber area above the air pipe plus an overlap of 10° or more either side) an additional harder coating should be applied. This is to be an aluminium-bearing epoxy, or other equivalent coating, applied over the zinc.

12.7.15 Closures and seats made of non-metallic materials are to be compatible with the media intended to be carried in the tank and to sea-water, and suitable for operating at ambient temperatures between –25°C and 85°C.

12.8 Size of air pipes

12.8.1 For every tank which can be filled by the ship's pumps, the total cross-sectional area of the air pipes and the design of the air pipe closing devices are to be such that when the tank is overflowing at the maximum pumping capacity available for the tank, it will not be subjected to a pressure greater than that for which it is designed.

12.8.2 In all cases, whether a tank is filled by ship's pumps or other means, the total cross-sectional area of the air pipes is to be not less than 25 per cent greater than the effective area of the respective filling pipe.

12.8.3 Where tanks are fitted with cross flooding connections, the air pipes are to be of adequate area for these connections.

12.8.4 Air pipes are to be not less than 50 mm bore.

12.9 Overflow pipes

12.9.1 For all tanks which can be filled by the ship's pumps or by shore pumps, overflow pipes are to be fitted where:

(a) The total cross-sectional area of the air pipe is less than that required by 12.8.
(b) The pressure head corresponding to the height of the air pipe is greater than that for which the tank is designed.

12.9.2 In the case of oil fuel and lubricating oil tanks, the overflow pipe is to be led to an overflow tank of adequate capacity or to a storage tank having a space reserved for overflow purposes. Suitable means are to be provided to indicate when overflow is occurring, or when the contents reach a predetermined level in the tanks.

12.9.3 Overflow pipes are to be self draining under normal conditions of trim.

12.9.4 Where overflow sight glasses are provided, they are to be in a vertically dropping line and designed such that the oil does not impinge on the glass. The glass is to be of heat resisting quality, adequately protected from mechanical damage and well lit.

12.10 Air and overflow systems

12.10.1 Where a combined air or overflow system is fitted, the arrangement is to be such that in the event of any one of the tanks being bilged, tanks situated in other watertight compartments of the ship cannot be flooded from the sea through combined air pipes or the overflow main. For this purpose, it will normally be necessary to lead the overflow pipe to a point close to the bulkhead deck.

12.10.2 In the case of trawlers and fishing vessels, the arrangement is to be such that in the event of any one of the tanks being bilged, the other tanks cannot be flooded from the sea through the combined air pipes or the overflow main.

12.10.3 Where overflow from tanks which are used for the alternative carriage of oil and water ballast is connected to an overflow system, arrangements are to be made to prevent water ballast overflowing into tanks containing oil, *see also* Ch 14,4.14.

12.10.4 Where a common overflow main is provided, the main is to be sized to allow any two tanks connected to that main to overflow simultaneously.

12.11 Sounding arrangements

12.11.1 Provision is to be made for sounding all tanks and the bilges of those compartments which are not at all times readily accessible. The soundings are to be taken as near the suction pipes as practicable.

12.11.2 Bilges of compartments which are not at all times readily accessible are to be provided with sounding pipes.

12.11.3 Where fitted, sounding pipes are to be as straight as practicable, and if curved to suit the structure of the ship, the curvature must be sufficiently easy to permit the ready passage of the sounding rod or chain.

12.11.4 Sounding devices of approved type may be used in lieu of sounding pipes for sounding tanks. These devices are to be tested, after fitting on board, to the satisfaction of the Surveyors.

12.11.5 Where gauge glasses are used for indicating the level of liquid in tanks containing lubricating oil, oil fuel or other flammable liquid, the glasses are to be of the flat type of heat-resisting quality, adequately protected from mechanical damage, and fitted with self-closing valves at the lower ends and at the top ends if these are connected to the tanks below the maximum liquid level.

12.11.6 If means of sounding, other than a sounding pipe, is fitted in any ship for indicating the level of liquid in tanks containing oil fuel, lubricating oil or other flammable liquid, failure of such means or over filling of the tank should not result in the release of tank contents.

12.11.7 In passenger ships, sounding devices for oil fuel tanks, lubricating oil tanks and other tanks which may contain flammable liquids are to be of a type which does not require penetration below the top of the tank.

12.11.8 For a normally inaccessible small void compartment such as an echo sounding compartment, which is accessed from within a normally inaccessible space such as a forepeak tank, alternative sounding arrangements to those required by 12.11.1 may be considered. For such arrangements, a warning notice is to be located in a prominent position specifying precautions to be taken prior opening the manhole of the small void compartment. Means are to be provided to indicate flooding of the compartment without

opening, such as fitting indicator plugs to the manhole. Sounding arrangements are to be submitted to LR for approval.

12.12 Termination of sounding pipes

12.12.1 Sounding pipes are to be led to positions above the bulkhead deck which are at all times accessible and, in the case of oil fuel tanks, cargo oil tanks, lubricating oil tanks and tanks containing other flammable oils, the sounding pipes are to be led to safe positions on the open deck.

12.12.2 For closing requirements, *see also* Pt 3, Ch 12,3.

12.13 Short sounding pipes

12.13.1 In machinery spaces and tunnels, in circumstances where it is not practicable to extend the sounding pipes as mentioned in 12.12, short sounding pipes extending to well lighted readily accessible positions above the platform may be fitted to double bottom tanks. Where such pipes serve tanks containing oil fuel or other flammable liquid, an additional sounding device of approved type is to be fitted. An additional sounding device is not required for lubricating oil tanks. Any proposal to terminate in the machinery space, sounding pipes to tanks, other than double bottom tanks, will be the subject of special consideration.

12.13.2 Short sounding pipes to oil fuel, cargo oil (flash point not less than 60°C), lubricating oil tanks and other flammable oil tanks (flash point not less than 60ºC) are to be fitted with cocks having parallel plugs with permanently attached handles, so loaded that, on being released, they automatically close the cocks. In addition, a small diameter self-closing test cock is to be fitted below the cock mentioned above in order to ensure that the sounding pipe is not under a pressure of oil before opening-up the sounding cock. Provision is to be made to ensure that discharge of oil through this test cock does not present an ignition hazard. An additional small diameter self-closing test cock is not required for lubricating oil tanks.

12.13.3 As a further precaution against fire, such sounding pipes are to be located in positions as far removed as possible from any heated surface or electrical equipment and, where necessary, effective shielding is to be provided in way of such surfaces and/or equipment.

12.13.4 In ships that are required to be provided with a double bottom, short sounding pipes, where fitted to double bottom tanks, are in all cases to be provided with self-closing cocks as described in 12.13.2.

12.13.5 Where a double bottom is not required to be fitted, short sounding pipes to tanks other than oil tanks are to be fitted with shut-off cocks or with screw caps attached to the pipes by chains.

12.13.6 In passenger ships, short sounding pipes are permissible only for sounding cofferdams and double bottom tanks situated in a machinery space, and are in all cases to be fitted with self-closing cocks as described in 12.13.2.

12.14 Elbow sounding pipes

12.14.1 Elbow sounding pipes are not to be used for deep tanks unless the elbows and pipes are situated within closed cofferdams or within tanks containing similar liquids. They may, however, be fitted to other tanks and may be used for sounding bilges, provided that it is not practicable to lead them direct to the tanks or compartments, and subject to any subdivision and damage stability requirements that may apply, *see* 1.2.1.

12.14.2 The elbows are to be of heavy construction and adequately supported.

12.14.3 In passenger ships, elbow sounding pipes are not permissible.

12.15 Striking plates

12.15.1 Striking plates of adequate thickness and size are to be fitted under open-ended sounding pipes.

12.15.2 Where slotted sounding pipes having closed ends are employed, the closing plugs are to be of substantial construction.

12.16 Sizes of sounding pipes

12.16.1 Sounding pipes are to be not less than 32 mm bore.

12.16.2 All sounding pipes, whether for compartments or tanks, which pass through refrigerated spaces or the insulation thereof, in which the temperatures contemplated are 0°C or below, are to be not less than 65 mm bore, *see also* 2.8.1 for insulation.

■ *Cross-references*

For ‘Ice Class’ requirements, *see* Part 8.

For venting and gauging equipment for cargo tanks in oil tankers, *see* Ch 15,4 and Ch 15,5.

For control engineering equipment, *see* Pt 6, Ch 1.

For requirements relating to scuppers and sanitary discharges, *see* Pt 3, Ch 12.

Section 13
Additional requirements for drainage and pumping arrangements for bulk carriers

13.1 General requirements

13.1.1 Arrangements for drainage and pumping are to be in accordance with the requirements of SOLAS 1974 as amended, Chapter XII, Regulation 13.

13.1.2 On bulk carriers, the means for draining and pumping ballast tanks forward of the collision bulkhead and bilges of dry spaces any part of which extends forward of the foremost cargo hold are to be capable of being brought into operation from a readily accessible enclosed space, the location of which is accessible from the navigation bridge or propulsion machinery control positions without traversing exposed freeboard or superstructure decks. Where pipes serving such tanks or bilges pierce the collision bulkhead, valve operation by means of remotely operated actuators may be accepted, as an alternative to the valve control specified in 3.5.4, provided that the location of such valve controls complies with this requirement.

13.2 Dewatering capability

13.2.1 The dewatering system for ballast tanks located forward of the collision bulkhead, and for bilges of dry spaces any part of which extends forward of the foremost cargo hold, is to be designed to remove water from the forward spaces at a rate of not less than 320A m^3/h, where A is the cross-sectional area in m^2 of the largest air pipe or ventilator pipe connected from the exposed deck to a closed forward space that is required to be dewatered by these arrangements.

Section 14
Water ingress detection arrangements

14.1 General requirements

14.1.1 Equipment for detecting the ingress of water in bulk carriers is to be fitted in accordance with the requirements of SOLAS 1974 as amended, Chapter XII, Regulation 12.

14.1.2 Equipment for detecting the ingress of water in single hold cargo ships is to be fitted in accordance with the requirements of SOLAS 1974 as amended, Chapter II-1, Regulation 25.

14.1.3 Flooding detection systems in passenger ships carrying 36 persons or more are to be fitted in accordance with the requirements of SOLAS 1974 as amended, Chapter II-1, Regulation 22-1.

14.1.4 Alarm and indicators specified in 14.2 to 14.4 are to be provided on the navigation bridge and, for passenger ships, additionally in the safety centre if located in a separate space from the navigation bridge.

14.1.5 Equipment required by 14.1.2 to 14.1.4 is to satisfy the applicable requirements of Pt 6, Ch 1.

14.1.6 Pt 6, Ch 1,1.3.1 details applicable requirements for Survey at the manufacturer's works. At the initial installation and during each subsequent Complete Survey of Machinery alarm systems or Special Survey, the operation of the ingress detection arrangements is to be demonstrated to the satisfaction of the LR Surveyor.

14.1.7 Where alternative arrangements to those required by 14.1.2 to 14.1.4 are proposed, evidence is to be submitted for consideration by LR that demonstrates:

- water ingress will be detected in all areas considered necessary to reliably detect flooding of watertight spaces;
- responsible personnel will be effectively notified in the event of water ingress to allow for planned response; and
- acceptance by the National Administration with which the ship is registered.

14.2 Water ingress detection arrangements in bulk carriers

14.2.1 Bulk carriers are to be fitted with water level detectors:

(a) in each cargo hold, giving audible and visual alarms, one when the water level above the inner bottom in any hold reaches a height of 0,5 m and another at a height not less than 15 per cent of the depth of the cargo hold but not more than 2 m. The water level detectors are to be fitted in the aft end of each cargo hold. For cargo holds which are used for water ballast, an alarm overriding device may be installed. The visual alarms are to clearly discriminate between the two different water levels detected in each hold;

(b) in any ballast tank forward of the collision bulkhead required by Pt 3, Ch 3,4, giving an audible and visual alarm when the liquid in the tank reaches a level not exceeding 10 per cent of the tank capacity. An alarm overriding device may be installed to be activated when the tank is in use; and

(c) in any dry or void space other than a chain cable locker, any part of which extends forward of the foremost cargo hold, giving an audible and visual alarm at a water level of 0,1 m above the deck. Such alarms need not be provided in enclosed spaces the volume of which does not exceed 0,1 per cent of the ship's maximum displacement volume.

14.3 Water ingress detection arrangements in single hold cargo ships

14.3.1 Ships having a length, *L*, of less than 80 m and a single cargo hold below the freeboard deck or cargo holds below the freeboard deck which are not separated by at least one bulkhead made watertight up to that deck, are to be fitted in such space or spaces with water level detectors.

14.3.2 The water level detectors required by 14.3.1 are to:

(a) give an audible and visual alarm when the water level above the inner bottom in the cargo hold reaches a height of not less than 0,3 m, and another when such level reaches not more than 15 per cent of the mean depth of the cargo hold; and

(b) be fitted at the aft end of the hold, or above its lowest part where the inner bottom is not parallel to the designed waterline. Where webs or partial watertight bulkheads are fitted above the inner bottom, the installation of additional detectors is to be considered.

14.3.3 The water level detectors required by 14.3.1 need not be fitted in ships complying with 14.2, or in ships having watertight side compartments each side of the cargo hold length which extend vertically at least from inner bottom to freeboard deck.

14.4 Flooding detection systems in passenger ships

14.4.1 Passenger ships for 36 persons or more are to be provided with a flooding detection system for watertight spaces below the bulkhead deck.

14.4.2 The flooding detection system required by 14.4.1 is to be fitted in all watertight spaces below the bulkhead deck that:

(a) have a volume, in cubic metres, that is more than the ship's moulded displacement per centimetre immersion at deepest subdivision draught; or

(b) have a volume more than 30 cubic metres, whichever is the greater.

14.4.3 Any watertight spaces that are individually equipped with a liquid level monitoring system (such as fresh water, ballast water, fuel, etc.), including an indicator panel or other means of monitoring at the navigation bridge, and the safety centre if located in a separate space from the navigation bridge, are excluded from the requirements of this sub-Section.

14.4.4 The number and location of flooding detection sensors is to be sufficient to ensure that any substantial water ingress into a watertight space requiring a flooding detection system is detected under reasonable angles of trim and heel. To accomplish this, flooding detection sensors are to be installed as indicated below:

(a) **Vertical location** – sensors are to be installed as low as practical in the watertight space;

(b) **Longitudinal location** – in watertight spaces located forward of the mid-length sensors are generally to be installed at the forward end of the space; and in watertight spaces located aft of the mid-length, sensors are generally to be installed at the aft end of the space. For watertight spaces located in the vicinity of the mid-length, consideration is to be given to the appropriate longitudinal location of the sensor. In addition, any watertight space of length more than 20 per cent of the ship's subdivision length or with arrangements that would seriously restrict the longitudinal flow of water is to be provided with sensors at both the forward and aft ends; and

(c) **Transverse location** – sensors are generally to be installed at the centreline of the space (or alternatively at both the port and starboard sides). In addition, any watertight space that extends the full breadth of the ship or with arrangements that would seriously restrict the transverse flow of water is to be provided with sensors at both the port and starboard sides.

14.4.5 Where a watertight space extends in height over more than one deck, there is to be at least one flooding detection sensor at each deck level. This provision is not applicable in cases where a continuous flood level monitoring system is installed.

14.4.6 Consideration may be given to the number and location of flooding detection sensors in watertight spaces with unusual arrangements or in other cases where these requirements would not achieve the intended purpose, *see* 14.1.7.

Section

■ *Section 1* General requirements

1.1 General

1.1.1 In addition to the requirements detailed in this Chapter, the requirements of Ch 13,1 and 2 are to be complied with, where applicable.

1.1.2 The requirements of Ch 13,3 are also to be complied with, so far as they are applicable, for the drainage of tanks, oily bilges and cofferdams, etc.

1.1.3 The requirements of Sections 2 and 4 are to be complied with, as far as they are applicable, for all flammable liquids.

■ *Section 2* Oil fuel – General requirements

2.1 Flash point

2.1.1 The flash point (closed-cup test) of oil fuel for use in ships classed for unrestricted service is, in general, to be not less than 60°C. For emergency generator engines a flash point of not less than 43°C is permissible.

2.1.2 The use of oil fuel having a flash point of less than 60° but not less than 43° may be permitted for emergency generators, emergency fire pumps, engines and auxiliary machines which are not located in machinery spaces subject to the requirements of 4.19.

2.1.3 The use of fuel having a lower flash point than specified in 2.1.1 or 2.1.2 may be permitted in cargo ships provided that such fuel is not stored in any machinery space and the arrangements for the complete installation are specially approved.

2.1.4 Oil fuel in storage tanks is not to be heated to a temperature exceeding 10°C below its flash point. Higher temperatures will be considered for oil fuel stored in settling and service tanks where:

(a) The tanks are vented to a safe position outside the engine room and, as in the case of all oil fuel tanks, the ends of the ventilation pipes are fitted with gauze diaphragms.
(b) Openings in the drainage systems of tanks containing heated oil fuel are located in spaces where no accumulation of oil vapours at temperatures close to the flash point can occur.
(c) The length of vent pipes from such tanks and/or a cooling device is sufficient for cooling oil vapours to below 60°C, or the outlet of the vent pipes is located at least 3 m from sources of ignition.
(d) There is no source of ignition in the vicinity of openings in the drainage systems.
(e) There are no openings from the vapour space of the fuel tanks into machinery spaces other than bolted manhole covers.
(f) Enclosed spaces are not located directly over such fuel tanks, except for vented cofferdams.
(g) Electrical equipment is not fitted in the vapour space of tanks unless it meets the requirements of Pt 6, Ch 2,14.2.4 for electrical equipment in zone 0 explosive atmospheres.

2.1.5 The temperature of any heating medium is not to exceed 220°C.

2.2 Special fuels

2.2.1 When it is desired to carry a quantity of fuel having a flash point below 43°C for special services, e.g. aviation spirit for use in helicopters, full particulars of the proposed arrangements are to be submitted for special consideration. For helicopter refuelling, as a minimum, the requirements of SOLAS 1974 as amended II-2/G, 18-7 will apply.

2.2.2 For the burning of methane gas in methane tankers, *see* the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk* (hereinafter referred to as the Rules for Ships for Liquefied Gases).

2.2.3 Where it is proposed to use gaseous fuels for main or auxiliary engines in ships other than LNG carriers, the relevant requirements of the *Rules for the Classification of Natural Gas Fuelled Ships* are to be complied with. Full particulars of the proposed arrangements are to be submitted for special consideration. Attention is to be given to any relevant statutory requirements of the National Authority of the country in which the ships are to be registered.

2.3 Oil fuel sampling

2.3.1 Sampling points are to be provided at locations within the oil fuel system that enable samples of oil fuel to be taken in a safe manner.

2.3.2 The position of a sampling point is to be such that the sample of the oil fuel is representative of the oil fuel quality at that location within the system.
NOTE:
Samples taken from sounding pipes are not considered to be representative of the tank's contents.

2.3.3 The sampling arrangements within the machinery space are to be capable of safely providing samples when machinery is running and are to be provided with isolating valves and cocks of the self-closing type. The sampling points are to be located in positions as far removed as possible from any heated surface or electrical equipment so as to preclude impingement of oil fuel onto such surfaces on equipment under all operating conditions, *see* Ch 1,3.7.

2.4 Ventilation

2.4.1 The spaces in which the oil fuel burning appliances and the oil fuel settling and service tanks are fitted are to be well ventilated and easy of access.

2.5 Boiler insulation and air circulation in boiler room

2.5.1 The boilers are to be suitably lagged. The clearance spaces between the boilers and tops of the double bottom tanks, and between the boilers and the sides of the storage tanks in which oil fuel and cargo oil is carried, are to be adequate for the free circulation of the air necessary to keep the temperature of the stored oil sufficiently below its flash point.

2.5.2 Where water tube boilers are installed, there is to be a space of at least 760 mm between the tank top and the underside of the pans forming the bottom of the combustion spaces.

2.5.3 Smoke-box doors are to be shielded and well fitting, and the uptake joints made gastight. Where the surface temperature of the uptakes may exceed 220°C, they are to be efficiently lagged to minimise the risk of fire and to prevent damage by heat. Where lagging covering the uptakes, including flanges, is oil-absorbing or may permit penetration of oil, the lagging is to be encased in sheet metal or equivalent. In locations where the Surveyor is satisfied that oil impingement could not occur, the lagging need not be encased.

2.6 Funnel dampers

2.6.1 Dampers which are capable of completely closing the gas passages are not to be fitted to inner funnels of ships equipped for burning oil fuel only. In ships burning oil or coal alternatively, dampers may be retained, if they are provided with a suitable device whereby they may be securely locked in the fully open position.

2.7 Heating arrangements

2.7.1 Where steam is used for heating oil fuel, cargo oil or lubricating oil, in bunkers, tanks, heaters or separators, the exhaust drains are to discharge the condensate into an observation tank in a well lighted and accessible position where it can be readily seen whether or not it is free from oil, *see* Ch 15,6.4.

2.7.2 Where hot water is used for heating, means are to be provided for detecting the presence of oil in the return lines from the heating coils.

2.7.3 Where it is proposed to use any heating medium other than steam or hot water, full particulars of the proposed arrangements are to be submitted for special consideration.

2.7.4 The heating pipes in contact with oil are to be of iron, steel, approved aluminium alloy or approved copper alloy, and, after being fitted on board, are to be tested by hydraulic pressure in accordance with the requirements of Ch 12,8.1.

2.7.5 Where electric heating elements are fitted means are to be provided to ensure that all elements are submerged at all times when electric current is flowing and that their surface temperature cannot exceed 220°C.

2.8 Temperature indication

2.8.1 Tanks and heaters in which oil is heated are to be provided with suitable means for ascertaining the temperature of the oil. Where thermometers or temperature sensing devices are not fitted in blind pockets, a warning notice, in raised letters, is to be affixed adjacent to the fittings stating 'Do not remove unless tank/heater is drained'.

2.8.2 Controls are to be fitted to limit oil temperatures in oil storage and service tanks in accordance with 2.1.4 and in oil heaters to the maximum approved operating temperature, *see* Pt 6, Ch 1.

2.9 Precautions against fire

2.9.1 Oil fuel tanks and oil fuel filters are not to be situated immediately above boilers or other highly heated surfaces, *see also* Ch 1,4.5.

2.9.2 Oil fuel pipes are not to be installed above or near high temperature equipment. Oil fuel pipes should also be installed and screened or otherwise suitably protected to avoid oil spray or oil leakages onto hot surfaces, into machinery air intakes, or other sources of ignition such as electrical equipment. Pipe joints are to be kept to a minimum, and where provided are to be of a type acceptable to LR. Pipes are to be led in well lit and readily visible positions, *see also* Ch 2,8.

2.9.3 Pumps, filters and heaters are to be located to avoid oil spray or oil leakages onto hot surfaces or other sources of ignition, or onto rotating machinery parts. Where necessary, shielding is to be provided and the arrangements are to allow easy access for routine maintenance. The design of filter and strainer arrangements is to be such as to avoid the possibility of them being opened inadvertently when under pressure. This may be achieved by either mechanically preventing the pressurised filter from being opened or by providing pressure gauges which clearly indicate which filter is under pressure. In either case, suitable means for pressure release are to be provided, with drain pipes led to a safe location.

2.9.4 The arrangement and location of short sounding pipes to oil tanks are to be in accordance with Ch 13,12.13. For alternative sounding arrangements, *see* Ch 13,12.11.

2.9.5 Water service pipes and hoses are to be fitted in order that the floor plates and tank top or shell plating in way of boilers, oil fuel apparatus or deep storage tanks in the engine and boiler spaces can at any time be flushed with sea-water.

2.9.6 So far as is practicable, the use of wood is to be avoided in the engine rooms, boiler rooms and tunnels of ships burning oil fuel.

2.9.7 Drip trays are to be fitted at the furnace mouths to intercept oil escaping from the burners, and under all other oil fuel appliances which are required to be opened up frequently for cleaning or adjustment.

2.9.8 Oil-tight drip trays of ample size having suitable drainage arrangements are to be provided at pipes, pumps, valves and other fittings where there is a possibility of leakage. Valves should be located in well lighted and readily visible positions. Drip trays will not be required where pumps, valves and other fittings are placed in special compartments either inside or outside the machinery space with approved overall drainage arrangements or for valves which are so positioned that any leakage will drain directly into the bilges *see* 2.9.2.

2.9.9 Where drainage arrangements are provided from collected leakages, they are to be led to a suitable oil drain tank not forming part of an overflow system.

2.9.10 Separate oil fuel tanks are to be placed in an oil-tight spill tray of ample size having drainage arrangements leading to a drain tank of suitable size, *see* 4.17.

2.9.11 Where level switches are used below the tank top, they are to be contained in a steel enclosure or other enclosures which provide equivalent protection against fire.

2.10 Oil fuel contamination

2.10.1 The materials and/or their surface treatment used for the storage and distribution of oil fuel are to be selected such that they do not introduce contamination or modify the properties of the fuel. The use of copper or zinc compounds in oil fuel distribution and utilisation piping is not permitted except for small diameter pipes in low pressure systems, *see* 4.6.1.

2.10.2 For prevention of ingress of water into oil fuel tanks via air pipes, *see* Ch 13,10.5.4.

2.10.3 The piping arrangements for oil fuel are to be separate and distinct from those intended for lubricating oil systems to prevent contamination of fuel oil by lubricating oil.

2.10.4 Piping arrangements or alternative means are to be provided to ensure that distillates (i.e. gas oils/diesel grades) are to be kept separate and distinct from residual grades, up to the service tanks required by 4.18, in order to prevent cross-contamination. Cross-connection is permitted between separate arrangements in the event of failure of a designated item of equipment.

2.11 Tanks and cofferdams

2.11.1 Tanks containing oil fuel are to be separated from passenger, crew and baggage compartments by a gastight and watertight boundary or a cofferdam which is suitably ventilated and drained.

■ *Cross-reference*

For requirements regarding refrigerated cargo spaces in way of oil storage tanks, *see* Pt 6, Ch 3,4.

■ *Section 3*
Oil fuel burning arrangements

3.1 Oil burning units

3.1.1 All oil burning equipment is to be capable of operating at defined power/rating levels where specified by the Owner/Operator. Confirmation by the manufacturer of this capability is to be provided to LR including the specified power/rating parameters, and operating and maintenance regimes. *See also* Pt 5, Ch 1,3.1.2.

3.1.2 Where steam is required for the main propelling engines, or where steam or thermal oil is required for auxiliary machinery for essential services, or for heating of heavy oil fuel and is generated by burning oil fuel under pressure, there are to be not less than two oil burning units. For auxiliary boilers, a single oil burning unit may be accepted, provided that alternative means, such as an exhaust gas boiler or composite boiler, are available for supply of essential services. Where the oil burning unit is not of the monobloc type (i.e., separate register and oil supply unit), each oil burning unit is to comprise a pressure pump, suction filter, discharge filter and, when required, a heater.

3.1.3 In installations consisting of two or more oil burning units, the number, arrangement and capacity of such units is to be capable of supplying sufficient fuel to allow the steam to be generated or thermal oil heated, as applicable to provide essential services with any one unit out of action.

3.1.4 Unit pressure pumps are to be entirely separate from the feed, bilge or ballast systems.

3.1.5 In dual oil fuel burning systems for boilers which are primarily designed for operation with residual fuel oil grades, arrangements are to be such that atomising steam cannot be used in combination with distillate fuel oil grades where the burner arrangements have not been designed for such use.

3.1.6 In all dual oil fuel burning systems for boilers, the manufacturer of the combustion equipment is to ensure that the full system, including control and monitoring systems, is capable of continuous operation in all conditions for each fuel grade.

3.1.7 Whenever the oil fuel burning units are stopped, shut-off arrangements for oil fuel to the units are to be provided as follows:

(a) If the supply oil fuel is under pressure during shut-off to oil burning units, duplicated shut-off valves in series are to be fitted. Arrangements are to be such to allow manual testing for leakage from each of the valves in the installed condition, the test arrangement is to be such to prevent inadvertent operation, and any discharges are to be led to a safe position to ensure that discharge of leakage oil does not present an ignition hazard.
(b) If arrangements are such that oil fuel pressure is released through drainage during oil fuel shut-off to oil burning units, a single shut-off device may be accepted subject to approval by LR.

3.1.8 When combined air and fuel/steam/air combustion systems are used for multiple boiler installations, they are to be such that single boiler operation will not be adversely affected by the operation of another boiler system at any time.

3.1.9 Arrangements are to be such that furnace pre-purging is completed prior to any burner ignition sequence. The purge time is to be based on a minimum of 4 air changes of the combustion chamber, furnace and uptake spaces. The purge timing is to take account of the air flow rate and the sequence is not to commence until all air registers and dampers, as applicable, are fully open and the forced draft fans are operating.

3.1.10 The effect of multiple light-off failures is to be assessed and the need to lock out further ignition sequences established. The manufacturer's recommended procedures are to be followed before further attempts to ignite the boiler are made. These procedures are to be displayed at the ignition control positions and included in the warning notice required by 3.1.11.

3.1.11 Means are to be provided so that, in the event of flame failure, the oil fuel supply to the burner(s) is shut-off automatically, and an alarm is given, *see* Pt 5, Ch 10,18.3, Ch 14,12.2 and Ch14,12.3, as applicable.

3.1.12 It is to be demonstrated to the Surveyor's satisfaction during trials that burner shut-off times due to flame failure comply with the following requirements, and details of the procedures and means used to set this time interval are to be submitted for consideration:

(a) The time interval at burner start up between the burner oil fuel valve(s) being opened and then closed in the event of flame failure is to be long enough to allow a stable flame to be established and detected under normal operational circumstances, but is to be set to minimise the quantity of oil fuel delivered to the furnace and the possibility of subsequent damage as a result of unintended ignition.
(b) The time interval between flame failure detection and closing of burner oil fuel valve(s) is to be long enough to prevent shutdown due to incorrect detection of a flame failure under normal operational circumstances, but is to be set to minimise the quantity of unburned oil fuel delivered to the furnace and the possibility of subsequent damage as a result of unintended ignition.

3.1.13 A warning notice is to be fitted in a prominent position at every oil burning unit local manual control station which specifies that burners operated with manual or local overrides in use are only to be ignited after sufficient purging of the furnace and of any additional precautions required when operating in this condition.

3.2 Gravity feed

3.2.1 In systems where oil is fed to the burners by gravity, duplex filters are to be fitted in the supply pipeline to the burners and so arranged that one filter can be opened up when the other is in use.

3.3 Starting-up unit

3.3.1 A starting-up oil fuel unit, including an auxiliary heater and hand pump, or other suitable starting-up device, which does not require power from shore, is to be provided.

3.3.2 Alternatively, where auxiliary machinery requiring compressed air or electric power is used to bring the boiler plant into operation, the arrangements for starting such machinery are to comply with Ch 2,9.1.

3.4 Steam connections to burners

3.4.1 Where burners are provided with steam purging and/or atomising connections, the arrangements are to be such that oil fuel cannot find its way into the steam system in the event of valve leakage.

3.5 Burner arrangements

3.5.1 The burner arrangements are to be such that a burner cannot be withdrawn unless the oil fuel supply to that burner is shut off, and that the oil cannot be turned on unless the burner has been correctly coupled to the supply line.

3.6 Quick-closing valve

3.6.1 A quick-closing master valve is to be fitted to the oil supply to each boiler manifold, suitably located so that the valve can be readily operated in an emergency, either directly or by means of remote control, having regard to the machinery arrangements and location of controls.

3.7 Spill arrangements

3.7.1 Provision is to be made, by suitable non-return arrangements, to prevent oil from spill systems being returned to the burners when the oil supply to these burners has been shut off.

3.8 Alternately-fired furnaces

3.8.1 For alternately-fired furnaces of boilers using exhaust gases and oil fuel, the exhaust gas inlet pipe is to be provided with an isolating device and interlocking arrangements whereby oil fuel can only be supplied to the burners when the isolating device is closed to the boiler.

3.9 Oil fuel treatment for supply to main and auxiliary oil engines and gas turbines

3.9.1 A suitable fuel treatment plant that may include filtration, centrifuging and/or coalescing is to be provided to reduce the level of water and particulate contamination of the oil fuel to within the engine or gas turbine manufacturer's limits for inlet to the combustion system. The capacity and arrangements of the treatment plant is to be suitable for ensuring availability of treated oil fuel for the maximum continuous demand of the propulsion and electrical generating plant.

3.9.2 Two or more treatment systems are to be provided as part of the fuel treatment plant such that failure of one system will not render the other system(s) inoperative. Arrangements are to ensure that the failure of a treatment system will not interrupt the supply of clean oil fuel to oil engines or gas turbines used for propulsion and electrical generating purposes where treatment plant is installed between oil fuel service tanks and the inlet to the combustion system. Any treatment equipment in the system is to be capable of being cleaned without interrupting the flow of treated fuel to supply the combustion system.

3.9.3 Centrifuges used for oil fuel treatment are to be type tested for their intended usage when installed on board a ship in accordance with a standard acceptable to LR.

3.9.4 Where heating of the oil fuel is required for the efficient functioning of the oil fuel treatment plant, a minimum of two heating units are to be provided. Each heating unit is to be of sufficient capacity to raise and maintain the required temperature of the oil fuel for the required delivery flow rate.

3.9.5 Heating units may be in circuit with separate treatment systems or provided with connections such that any heating unit can be connected to any treatment system.

3.9.6 Where heating of the oil fuel is required for combustion, not less than two pre-heaters are to be provided, each with sufficient capacity to raise the temperature of the fuel to provide a viscosity suitable for combustion.

3.9.7 Filters and/or coalescers are to be fitted in the oil fuel supply lines to each oil engine and gas turbine to ensure that only suitably filtered oil is fed to the combustion system. The arrangements are to be such that any unit can be cleaned without interrupting the supply of filtered oil to the combustion system.

3.10 Booster pumps

3.10.1 Where an oil fuel booster pump is fitted, which is essential to the operation of the main engine, a standby pump is to be provided.

3.10.2 The standby pump is to be connected ready for immediate use but where two or more main engines are fitted, each with its own pump, a complete spare pump may be accepted provided that it is readily accessible and can easily be installed.

3.11 Booster pumps when operating in emissions control areas

3.11.1 Ships intending to use Heavy Fuel Oil (HFO) or Marine Diesel Oil (MDO) when operating outside emissions control areas and marine fuels with a sulphur content not exceeding 0,1 per cent m/m and minimum viscosity of 2 cSt when operating inside emission control areas are to meet the requirements of 3.11.2. or 3.11.3.

3.11.2 The booster pumps which are fitted in compliance with 3.10 are acceptable for use in emissions control areas where these pumps are each suitable for marine fuels with a sulphur content not exceeding 0,1 per cent m/m and minimum viscosity of 2 cSt operation at the required capacity for normal operation of propulsion machinery.

3.11.3 When the booster pumps which are fitted in compliance with 3.10 are suitable to operate on marine fuels with a sulphur content not exceeding 0,1 per cent m/m and minimum viscosity of 2 cSt, but one pump alone is not capable of delivering marine fuels with a sulphur content not exceeding 0,1 per cent m/m and minimum viscosity of 2 cSt at the required capacity, two booster pumps may operate in parallel to achieve the required capacity for normal operation of propulsion machinery. In this case, one additional fuel oil pump is to be provided. The additional booster pump shall, when operating in parallel with one of the booster pumps in 3.10, be suitable for and capable of delivering marine fuels with a sulphur content not exceeding 0,1 per cent m/m and minimum viscosity of 2 cSt at the required capacity for normal operation of the propulsion machinery.

3.12 Fuel valve cooling pumps

3.12.1 Where pumps are provided for fuel valve cooling, the arrangements are to be in accordance with 3.10.

3.13 Oil-fired galleys

3.13.1 The oil fuel tank is to be located outside the galley and is to be fitted with approved means of filling and venting.

3.13.2 The fuel supply to the burners is to be controlled from a position which will always be accessible in the event of a fire occurring in the galley.

3.13.3 The galley is to be well ventilated.

3.13.4 When liquefied petroleum gas is used, bottles are to be stored on the open deck or in a well ventilated space which only opens to the open deck.

■ *Section 4*
Oil fuel pumps, pipes, fittings, tanks, etc.

4.1 Transfer pumps

4.1.1 Where a power driven pump is necessary for transferring oil fuel, a standby pump is to be provided and connected ready for use, or, alternatively, emergency connections may be made to one of the unit pumps or to another suitable power driven pump.

4.2 Control of pumps

4.2.1 The power supply to all independently driven oil fuel transfer and pressure pumps is to be capable of being stopped from a position outside the space which will always be accessible in the event of fire occurring in the compartment in which they are situated, as well as from the compartment itself.

4.3 Relief valves on pumps

4.3.1 All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be in closed circuit, i.e. arranged to discharge back to the suction side of the pump and to effectively limit the pump discharge pressure to the design pressure of the system.

4.4 Pump connections

4.4.1 Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, in order that any pump may be shut off for opening up and overhauling.

4.5 Pipes conveying oil

4.5.1 Pipes conveying oil under pressure are to be of seamless steel or other approved material having flanged or welded joints, and are to be placed in sight above the platform in well lighted and readily accessible parts of the machinery spaces. The number of flanged joints is to be kept to a minimum.

4.5.2 Where pipes convey heated oil under pressure the flanges are to be machined, and the jointing material, which is to be impervious to oil heated to 150°C, is to be the thinnest possible, so that flanges are practically metal to metal. The scantlings of the pipes and their flanges are to be suitable for a pressure of at least 13,7 bar (14 kgf/cm^2) or for the design pressure, whichever is the greater.

4.5.3 The short joining lengths of pipes to the burners from the control valves at the boiler may have cone unions, provided these are of specially robust construction.

4.5.4 Flexible hoses of approved material and design may be used for the burner pipes, provided that spare lengths, complete with couplings, are carried on board.

4.5.5 For requirements relating to flexible hoses, *see* Ch 12.7.

4.6 Low pressure pipes

4.6.1 Transfer, suction and other low pressure oil pipes and all pipes passing through oil storage tanks are to be made of cast iron or steel, having flanged joints suitable for a working pressure of not less than 6,9 bar (7 kgf/cm^2). The flanges are to be machined and the jointing material is to be impervious to oil. Where the pipes are 25 mm bore or less, they may be of seamless copper or copper alloy, except those which pass through oil storage tanks. Oil pipes within the engine and boiler spaces are to be fitted where they can be readily inspected and repaired.

4.6.2 For requirements regarding bilge pipes in way of double bottom tanks and deep tanks, *see* Ch 13,7.9 and 7.10.

4.7 Valves and cocks

4.7.1 Valves, cocks and their pipe connections are to be so arranged that oil cannot be admitted into tanks which are not structurally suitable for the carriage of oil or into tanks which can be used for the carriage of fresh water.

4.7.2 All valves and cocks forming part of the oil fuel installation are to be capable of being controlled from readily accessible positions which, in the engine and boiler spaces, are to be above the working platform, *see also* Ch 13,2.3.

4.7.3 Every oil fuel suction pipe from a double bottom tank is to be fitted with a valve or cock.

4.8 Valves on deep tanks and their control arrangements

4.8.1 Every oil fuel suction pipe from a storage, settling and daily service tank situated above the double bottom, and every oil fuel levelling pipe within the boiler room or engine room, is to be fitted with a valve or cock secured to the tank.

4.8.2 The valves and cocks mentioned in 4.8.1 are to be capable of being closed locally and from positions outside the space in which the tank is located. The remote controls are to be accessible in the event of fire occurring in the deep tank's space. Instructions for closing the valves or cocks are to be indicated at the valves and cocks and at the remote control positions.

4.8.3 The control for remote operation of the valve on the emergency generator fuel tank is to be in a separate location from the controls for the remote operation of other valves for tanks located in machinery spaces.

4.8.4 In the case of tanks of less than 500 litres capacity, consideration will be given to the omission of remote controls.

4.8.5 Every oil fuel suction pipe which is led into the engine and boiler spaces, from a tank situated above the double bottom outside these spaces, is to be fitted in the machinery space with a valve controlled as in 4.8.2, except where the valve on the tank is already capable of being closed from an accessible position above the bulkhead deck.

4.8.6 Where the filling pipes to deep oil tanks are not connected to the tanks near the top, they are to be provided with non-return valves at the tanks or with valves or cocks fitted and controlled as in 4.8.2.

4.9 Water drainage from settling tanks

4.9.1 Settling tanks are to be provided with means for draining water from the bottom of the tanks.

4.9.2 If settling tanks are not provided, the oil fuel bunkers or daily service tanks are to be fitted with water drains.

4.9.3 Open drains for removing the water from oil tanks are to be fitted with valves or cocks of self-closing type, and suitable provision is to be made for collecting the oily discharge.

4.10 Relief valves on oil heaters

4.10.1 Relief valves are to be fitted on the oil side of heaters and are to be adjusted to operate at a pressure of 3,4 bar (3,5 kgf/cm^2) above that of the supply pump relief valve, *see* 4.3. The discharge from the relief valves is to be led to a safe position.

4.11 Filling arrangements

4.11.1 Filling stations are to be isolated from other spaces and are to be efficiently drained and ventilated.

4.11.2 Provision is to be made against over-pressure in the filling pipelines, and any relief valve fitted for this purpose is to discharge to an overflow tank or other safe position.

4.12 Transfer arrangements – Passenger ships

4.12.1 In passenger ships, provision is to be made for the transfer of oil fuel from any oil fuel storage or settling tank to any other oil fuel storage or settling tank in the event of fire or damage.

4.13 Alternative carriage of oil fuel and water ballast

4.13.1 Where it is intended to carry oil fuel and water ballast in the same compartments alternatively, the valves or cocks connecting the suction pipes of these compartments with the ballast pump and those connecting them with the oil fuel transfer pump are to be so arranged that the oil may be pumped from any one compartment by the oil fuel pump at the same time as the ballast pump is being used on any other compartment. In passenger ships the arrangement will require to be specially approved.

4.13.2 Where settling or service tanks are fitted, each having a capacity sufficient to permit 12 hours normal service without replenishment, the above requirement may be dispensed with.

4.13.3 Attention is drawn to the statutory regulations issued by National Authorities in connection with the *International Convention for the Prevention of Pollution of the Sea by Oil, 1973/78*.

4.14 Deep tanks for the alternative carriage of oil, water ballast or dry cargo

4.14.1 In the case of deep tanks which can be used for the carriage of oil fuel, cargo oil, water ballast or dry cargo, provision is to be made for blank flanging the oil and water ballast filling and suction pipes, also the steam heating coils if retained in place, when the tank is used for dry cargo, and for blank flanging the bilge suction pipes when the tanks are used for oil or water ballast.

4.14.2 If the deep tanks are connected to an overflow system, the arrangements are to be such that liquid or vapour from other tanks cannot enter the deep tanks when dry cargo is carried in them.

4.15 Separation of cargo oils from oil fuel

4.15.1 Pipes conveying vegetable oils or similar cargo oils are not to be led through oil fuel tanks, nor are oil fuel pipes to be led through tanks containing these cargo oils. For requirements regarding provision of cofferdams between oil and water tanks, *see* Pt 3, Ch 3,4.7.

4.16 Fresh water piping

4.16.1 Pipes in connection with compartments used for storing fresh water are to be separate and distinct from any pipes which may be used for oil or oily water, and are not to be led through tanks which contain oil, nor are oil pipes to be led through fresh water tanks.

4.17 Separate oil fuel tanks

4.17.1 Where separate oil fuel tanks are permitted, their construction is to be in accordance with the requirements of 4.17.2 to 4.17.6, *see also* SOLAS 1974 as amended Reg.II-2/B4.2.2.3.2.

4.17.2 In general, the minimum thickness of the plating of service, settling and other oil tanks, where they do not form part of the structure of the ship, is to be 5 mm, but in the case of very small tanks, the minimum thickness may be 3 mm.

4.17.3 For rectangular steel tanks of welded construction, the plate thicknesses are to be not less than those indicated in Table 14.4.1. The stiffeners are to be of approved dimensions.

4.17.4 The dimension given in Table 14.4.1 for the breadth of the panel is the maximum distance allowable between continuous lines of support, which may be stiffeners, wash-plates or the boundary of the tank.

Table 14.4.1 Plate thickness of separate oil fuel tanks

Thickness of plate, mm	Head from bottom of tank to top of overflow pipe, metres				
	2,5	3,0	3,7	4,3	4,9
	Breadth of panel, mm				
5	585	525	–	–	–
6	725	645	590	–	–
7	860	770	700	650	–
8	1000	900	820	750	700
10	1280	1140	1040	960	900

4.17.5 Where necessary, stiffeners are to be provided, and if the length of the stiffener exceeds twice the breadth of the panel, transverse stiffeners are also to be fitted, or, alternatively, tie bars are to be provided between stiffeners on opposite sides of the tank.

4.17.6 On completion, the tanks are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

4.18 Oil fuel service tanks

4.18.1 An oil fuel service tank is an oil fuel tank which contains only the required quality of fuel ready for immediate use.

4.18.2 Two oil fuel service tanks, for each type of fuel used on board, necessary for propulsion and generator systems, are to be provided. Each tank is to have a capacity for at least eight hours' operation, at sea, at maximum continuous rating of the propulsion plant and/or generating plant associated with that tank.

4.18.3 The arrangement of oil fuel service tanks is to be such that one tank can continue to supply oil fuel when the other is being cleaned or opened up for repair.

4.18.4 For ships of less than 500 gross tonnage, the capacity of each oil fuel service tank required by 4.18.2 may be less than for eight hours operation, where the class notation includes a service restriction.

4.19 Arrangements for fuels with a flash point between 43° and 60°

4.19.1 Fuel oil tanks other than those in double bottom compartments shall be located outside 'Category A' machinery spaces, *see also* Pt 3, Ch 3,4.7.

4.19.2 Provisions are to be made for the measurement of oil fuel temperature at the pump suction pipe.

4.19.3 Stop valves are to be provided at the inlet and outlet side of oil fuel strainers.

4.19.4 Pipe joints shall be either welded or spherical type union joints.

Section 5 Steam piping systems

5.1 Provision for expansion

5.1.1 In all steam piping systems, provision is to be made for expansion and contraction to take place without unduly straining the pipes.

5.1.2 Where expansion pieces are used, particulars are to be submitted.

5.1.3 For installation requirements regarding expansion pieces, *see* Ch 13,2.7.

5.2 Drainage

5.2.1 The slope of the pipes and the number and position of the drain valves or cocks are to be such that water can be efficiently drained from any portion of the steam piping system when the ship is in normal trim and is either upright or has a list of up to 5°.

5.2.2 Arrangements are to be made for ready access to the drain valves or cocks.

5.2.3 For the drainage of boiler and exhaust gas economiser safety valves, *see* Ch 10,15.2.8.

5.3 Soot cleaning drains

5.3.1 The capacity of the drains from exhaust gas economisers/boilers is to be sufficient to remove all wash water or condensate generated by installed washing systems and arrangements are to be such that engines and turbo-chargers are protected from wash water or condensate drainage from the washing system.

5.3.2 Adequate arrangements are to be made for the collection and disposal of the waste water generated during periodic water washing of the exhaust gas economiser/boiler. Details are to be submitted for approval.

5.4 Pipes in way of holds

5.4.1 In general, steam pipes are not to be led through spaces which may be used for cargo, but where it is impracticable to avoid this arrangement, plans are to be submitted for consideration. The pipes are to be efficiently secured and insulated, and well protected from mechanical damage. Pipe joints are to be as few as practicable and preferably butt welded.

5.4.2 If these pipes are led through shaft tunnels, pipe tunnels in way of cargo holds or through duct keels, they are to be efficiently secured and insulated.

5.5 Reduced pressure lines

5.5.1 Pipelines which are situated on the low pressure side of reducing valves, and which are not designed to withstand the full pressure at the source of supply, are to be fitted with pressure gauges and with relief valves having sufficient discharge capacity to protect the piping against excessive pressure.

5.6 Steam for fire-extinguishing in cargo holds

5.6.1 Where steam is used for fire-extinguishing in cargo holds provision is to be made to prevent damage to cargo by leakage of steam or by drip.

5.6.2 Details of the proposed precautionary measures are to be submitted.

Cross-reference

For steam heating arrangements for oil fuel, cargo oil or lubricating oil, *see* 2.7.

Section 6 Boiler feed water, condensate and thermal fluid circulation systems

6.1 Feed water piping

6.1.1 Two separate means of feed are to be provided for all main and auxiliary boilers which are required for essential services. In the case of steam/steam generators, one means of feed will be accepted provided steam for essential services is available simultaneously from another source.

6.2 Feed and circulation pumps

6.2.1 Two or more feed pumps are to provided of sufficient capacity to supply the boilers under full load conditions with any one pump out of action.

6.2.2 Feed pumps may be worked from the main engines or may be independently driven, but at least one of the pumps required in 6.2.1 is to be independently driven.

6.2.3 In twin screw ships in which there is only one independent feed pump, each main engine is to be fitted with a feed pump. Where all the feed pumps are independently driven, the pumps are to be connected to deal with the condensate from both engines or from either engine.

6.2.4 Independent feed pumps required for feeding the main boilers are to be fitted with automatic regulators for controlling their output.

6.2.5 The arrangement of forced water/thermal fluid circulation pumps for exhaust gas economisers/boilers/thermal heaters is to be such that where required, the flow through the exhaust gas economiser/boiler/thermal heater is to be established prior to engine start up. Where applicable, provision is to be made to allow for operation in the dry condition.

6.2.6 The forced circulation flow required by 6.2.5 is to be maintained on completion of engine shutdown for a sufficient duration in accordance with the exhaust gas economiser/boiler/thermal heater manufacturer's instructions. Details of arrangements are to be submitted for approval.

6.2.7 Where arrangements are such that exhaust gas economisers/boilers/thermal heaters require forced water/thermal fluid circulation, standby pumps are to be fitted, *see* Pt 5, Ch 4,8.8.3.

6.3 Harbour feed pumps

6.3.1 Where main-engine driven feed pumps are fitted and there is only one independent feed pump, a harbour feed pump or an injector is to be fitted to provide the second means of feed to the boilers which are in use when the main engines are not working. This requirement need not be complied with in the case of trawlers and fishing vessels.

6.3.2 The harbour feed pump required by 6.3.1 may be used for general service, provided that it is not connected to tanks containing oil, or to tanks, cofferdams and bilges which may contain oily water.

6.3.3 The valves on the suction pipes from the hotwell or condenser and the feed drain tank or filter are to be of the non-return type.

6.4 Condensate pumps

6.4.1 Two or more extraction pumps are to be provided for dealing with the condensate from the main and auxiliary condensers, at least one of which is to be independently driven. Where one of the independent feed pumps is fitted with direct suctions from the condensers and a discharge to the feed tank, it may be accepted for this purpose.

6.5 Valves and cocks

6.5.1 Feed and condensate pumps are to be provided with valves or cocks, interposed between the pumps and the suction and the discharge pipes, so that any pump may be opened up for overhaul while the others continue in operation.

6.6 Reserve feed water

6.6.1 All ships fitted with boilers are to be provided with storage space for reserve feed water, the structural and piping arrangements being such that this water cannot be contaminated by oil or oily water, *see* Pt 3, Ch 3,4.7 for structural arrangements.

6.6.2 For main boilers, one or more evaporators, of adequate capacity, are also to be provided.

■ *Cross-reference*

For feed water level regulators for water tube boilers, *see* Ch 10,16.8.

■ *Section 7* Engine cooling water systems

7.1 Main supply

7.1.1 Provision is to be made for an adequate supply of cooling water to the main propelling machinery and essential auxiliary engines, also to the lubricating oil and fresh water coolers and air coolers for electric propelling machinery, where these coolers are fitted. The cooling water pump(s) may be worked from the engines or be driven independently.

7.1.2 In the case of main steam turbine installations, a sea inlet scoop arrangement may replace the main sea-water circulating pump, subject to the conditions stated in 7.2.2(c).

7.2 Standby supply

7.2.1 Provision is also to be made for a separate supply of cooling water from a suitable independent pump of adequate capacity.

7.2.2 The following arrangements are acceptable depending on the purpose for which the cooling water is intended:

(a) Where only one main engine is fitted, the standby pump is to be connected ready for immediate use.
(b) Where more than one main engine is fitted, each with its own pump, a complete spare pump of each type may be accepted.
(c) Where a sea inlet scoop arrangement is fitted, and there is only one independent condenser circulating pump, a further pump, or a connection to the largest available pump suitable for circulation duties, is to be fitted to provide the second means of circulation when the ship is manoeuvring. The pump is to be connected ready for immediate use.
(d) Where fresh water cooling is employed for main and/or auxiliary engines, a standby fresh water pump need not be fitted if there are suitable emergency connections from a salt water system.

(e) Where each auxiliary is fitted with a cooling water pump, standby means of cooling need not be provided. Where, however, a group of auxiliaries is supplied with cooling water from a common system, a standby cooling water pump is to be provided for this system. This pump is to be connected ready for immediate use and may be a suitable general service pump.

7.3 Selection of standby pumps

7.3.1 When selecting a pump for standby purposes, consideration is to be given to the maximum pressure which it can develop if the overboard discharge valve is partly or fully closed and, when necessary, condenser doors, water boxes, etc., are to be protected by an approved device against inadvertent over-pressure. *See* Ch 3,7.3 for the hydraulic test pressure which condensers are required to withstand.

7.4 Relief valves on main cooling water pumps

7.4.1 Where cooling water pumps can develop a pressure head greater than the design pressure of the system, they are to be provided with relief valves on the pump discharge to effectively limit the pump discharge pressure to the design pressure of the system. For location of relief valves, *see* Ch 13,7.8.

7.5 Sea inlets

7.5.1 Not less than two sea inlets are to be provided for the pumps supplying the sea-water cooling system, one for the main pump and one for the standby pump. Alternatively, the sea inlets may be connected to a suction line available to main and standby pumps.

7.5.2 Where standby pumps are not connected ready for immediate use, *see* 7.2.2(b), the main pump is to be connected to both sea inlets.

7.5.3 Cooling water pump sea inlets are to be low inlets and one of them may be the ballast pump or general service pump sea inlet.

7.5.4 The auxiliary cooling water sea inlets are preferably to be located one on each side of the ship.

7.6 Strainers

7.6.1 Where sea-water is used for the direct cooling of the main engines and essential auxiliary engines, the cooling water suction pipes are to be provided with strainers which can be cleaned without interruption to the cooling water supply.

■ *Cross-reference*

For guidance on metal pipes for water services, *see* Ch 12,11.

■ *Section 8* Lubricating oil systems

8.1 General requirements

8.1.1 The arrangements for storage, distribution and utilisation of lubricating oils are to comply with the requirements of this Section.

8.2 Pumps

8.2.1 Where lubricating oil for the main engine(s) is circulated under pressure, a standby lubricating oil pump is to be provided where the following conditions apply:

(a) The lubricating oil pump is independently driven and the total output of the main engine(s) exceeds 370 kW (500 shp).
(b) One main engine with its own pump is fitted and the output of the engine exceeds 370 kW (500 shp).
(c) More than one main engine each with its own lubricating oil pump is fitted and the output of each engine exceeds 370 kW (500 shp).

8.2.2 The standby pump is to be of sufficient capacity to maintain the supply of oil for normal conditions with any one pump out of action. The pump is to be fitted and connected ready for immediate use, except that where the conditions referred to in 8.2.1(c) apply a complete spare pump may be accepted. In all cases satisfactory lubrication of the engines is to be ensured while starting and manoeuvring.

8.2.3 Similar provisions to those of 8.2.1 and 8.2.2 are to be made where separate lubricating oil systems are employed for piston cooling, reduction gears, oil operated couplings and controllable pitch propellers, unless approved alternative arrangements are provided.

8.2.4 Independently driven pumps of rotary type are to be fitted with a non-return valve on the discharge side of the pump.

8.3 Control of pumps

8.3.1 The power supply to all independently driven lubricating oil transfer and pressure pumps is to be capable of being stopped from a position outside the space, which will always be accessible in the event of fire occurring in the compartment in which they are situated, as well as from the compartment itself.

8.4 Relief valves on pumps

8.4.1 All lubricating oil pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves or equivalent. Each relief valve is to be in closed circuit, i.e., arranged to discharge back to the suction side of the pump, thereby limiting the pump discharge pressure to the design pressure of the system.

8.4.2 Where centrifugal type lubricating oil pumps are fitted, pressure relief valves will not be required, provided that pipes, valves and fittings are suitable for the greater of the design pressure or pump non-delivery pressure.

8.5 Emergency supply for propulsion turbines and propulsion turbo-generators

8.5.1 A suitable emergency supply of lubricating oil is to be arranged to come automatically into use in the event of a failure of the supply from the pump.

8.5.2 The emergency supply may be obtained from a gravity tank containing sufficient oil to maintain adequate lubrication for not less than six minutes, and, in the case of propulsion turbo-generators, until the unloaded turbine comes to rest from its maximum rated running speed.

8.5.3 Alternatively, the supply may be provided by the standby pump or by an emergency pump. These pumps are to be so arranged that their availability is not affected by a failure in the power supply.

8.5.4 For automatic shutdown arrangements of main turbines in the event of failure of the lubrication system, *see* Ch 3,5.1 and Ch 4,8.

8.6 Maintenance of bearing lubrication

8.6.1 The arrangements for lubricating bearings and for draining crankcase and other oil sumps of main and auxiliary engines, gearcases, electric generators, motors, and other running machinery are to be so designed that lubrication will remain efficient with the ship inclined under the conditions as shown in Ch 1,3.7.

8.6.2 For details of the requirements relating to the lubrication of bearings of electric generators and motors, *see* Pt 6, Ch 2,1.10 and Section 8.

8.7 Filters

8.7.1 Where the lubricating oil for main propelling engines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the engine or reducing the supply of filtered oil to the engine. Proposals for an automatic by-pass for emergency purposes in high speed engines are to be submitted for special consideration.

8.7.2 In the case of propulsion turbines and their gears, arrangements are to be made for the lubricating oil to pass through magnetic strainers and fine filters. Generally, the openings in the filter elements are to be not coarser than required by the manufacturer of the turbines, especially for the supply to turbine thrust bearings.

8.7.3 Centrifuges used for lubricating oil treatment are to be type tested for a ship in accordance with a national or international standard acceptable to LR.

8.8 Filling arrangements

8.8.1 Filling stations are to be isolated from other spaces and are to be efficiently drained and ventilated.

8.8.2 Provision is to be made against over-pressure in the filling pipelines, and any relief valve fitted for this purpose is to discharge to an overflow tank or other safe position, or an equivalent arrangement is to be provided, except filling by means of loose hose.

8.9 Cleanliness of pipes and fittings

8.9.1 Extreme care is to be taken to ensure that lubricating oil pipes and fittings, before installation, are free from scale, sand, metal particles and other foreign matter.

8.10 Pipes conveying oil

8.10.1 Pipes conveying lubricating oil under pressure are to be of seamless steel or other approved material having flanged or welded joints, and are to be placed in sight above the platform in well lit and readily accessible parts of the machinery spaces. The number of flanged joints is to be kept to a minimum.

8.10.2 For requirements relating to flexible hoses, *see* Ch 12,7.

8.11 Lubricating oil drain tank

8.11.1 Where an engine lubricating oil drain tank extends to the bottom shell plating in ships that are required to be provided with a double bottom, a shut-off valve is to be fitted in the drainpipe between the engine casing and the double bottom tank. This valve is to be capable of being closed from an accessible position above the level of the lower platform.

8.12 Lubricating oil contamination

8.12.1 The materials used in the storage and distribution of lubricating oil are to be selected such that they do not introduce contaminants or modify the properties of the oil. The use of cadmium or zinc in lubricating oil systems where they may normally come into contact with the oil is not permitted.

8.12.2 Arrangements are to be made for each forced lubrication system, renovation system, ready to use tank(s) and their associated rundown lines to drain tanks to be flushed after system installation and prior to running of machinery. The flushing arrangements are to be in accordance with the equipment manufacturer's procedures and recommendations.

8.12.3 For prevention of ingress of water into lubricating oil tanks via air pipes, *see* Ch 13,12.5.4.

8.12.4 The design and construction of engine and gear box piping arrangements are to prevent contamination of engine lubricating oil systems by leakage of cooling water or from bilge water where engines or gearboxes are partly installed below the lower platform. Where flexibility is required to accommodate movement between the engine and sump tank, any flexible joint assembly is to be of an approved type suitable for its intended application.

8.12.5 Where there is a permanently attached oil filling pipe and cap provided for an engine or other item of machinery, provision is to be made for the topping up oil to safely pass through a suitable strainer to prevent unwanted matter getting into the lubricating oil system. The caps are to be capable of being secured in the closed position.

8.12.6 Sampling points are to be provided that enable samples of lubricating oil to be taken in a safe manner. The sampling arrangements are to have the capability to provide samples when machinery is running and are to be provided with valves and cocks of the self-closing type and located in positions as far removed as possible from any heated surface or electrical equipment.

8.13 Deep tank valves and their control arrangements

8.13.1 The requirements for remote operation of valves on deep tank suction pipes may be waived where the valves are closed during normal operation.

8.13.2 Remotely operated valves on lubricating oil deep tank suctions should not be of the quick-closing type where inadvertent use would endanger the safe operation of the main propulsion and essential auxiliary machinery.

8.13.3 Every lubricating oil suction pipe from a storage, settling and service tank situated above the double bottom, and every oil levelling pipe within the engine room, is to be fitted with a valve or cock secured to the tank.

8.13.4 Valves and cocks are to be capable of being closed locally and from positions outside the space in which the tank is located. The remote controls are to be accessible in the event of fire occurring in the deep tank's space. Instructions for closing the valves or cocks are to be indicated at the valves and cocks and at the remote control positions.

8.13.5 In the case of tanks of less than 500 litres, capacity, consideration will be given to the omission of remote controls.

8.13.6 Every lubricating oil suction pipe which is led into the engine space from a tank situated above the double bottom outside this space is to be fitted in the machinery space with a valve controlled as in 8.13.4, except where the valve on the tank is already capable of being closed from an accessible position above the bulkhead deck.

8.13.7 Where the filling pipes to deep lubricating oil tanks are not connected to the tanks near the top, they are to be provided with non-return valves at the tanks or with valves or cocks, fitted and controlled as in 8.13.4.

8.14 Separate oil tanks

8.14.1 On completion, the tanks are to be tested by a head of water equal to the maximum to which the tanks may be subjected.

8.15 Precautions against fire

8.15.1 Lubricating oil tanks and filters are not to be situated immediately above boilers or other highly heated surfaces.

8.15.2 Lubricating oil pipes are not to be installed above or near high-temperature equipment. Lubricating oil pipes should also be installed and screened or otherwise suitably protected, to avoid oil spray or oil leakages on to hot surfaces, into machinery air intakes, or other sources of ignition such as electrical equipment. Pipe joints are to be kept to a minimum and where provided are to be of a type acceptable to LR. Pipes are to be led in well lit and readily visible positions.

8.15.3 Pumps, filters and heaters are to be located to avoid lubricating oil spray or leakage on to hot surfaces or other sources of ignition, or on to rotating machinery parts. Where necessary, shielding is to be provided and the arrangements are to allow easy access for routine maintenance. The design of filter and strainer arrangements is to be such as to avoid the possibility of them being opened inadvertently when under pressure. This may be achieved either by mechanically preventing the pressurised filter from being opened or by providing pressure gauges which clearly indicate which filter is under pressure. In either case, suitable means for pressure release are to be provided, with drain pipes led to a safe location.

■ *Cross-references*

For air, sounding pipes and gauge glasses, *see* Ch 13,12. For separation of lubricating oil tanks from fuel tanks, *see* Pt 3, Ch 3,4.7.

■ *Section 9* Hydraulic systems

9.1 General

9.1.1 The requirements of this Section are applicable to flammable oils employed under pressure in power transmission, control, actuating and heating systems, and hydraulic media in systems which are providing essential services.

9.1.2 The arrangements for storage, distribution and utilisation of hydraulic and flammable oils employed in the systems defined in 9.1.1 are to comply with the requirements of this Section.

9.2 System arrangements

9.2.1 Hydraulic fluids are to be suitable for the intended purpose under all operating service conditions.

9.2.2 Materials used for all parts of hydraulic seals are to be compatible with the working fluid at the appropriate working temperature and pressure.

9.2.3 Provision is to be made for hand operation of the systems in an emergency, unless an acceptable alternative is available.

9.2.4 Where hydraulic securing arrangements are applied, the system is to be capable of being locked in the closed position so that in the event of hydraulic system failure the securing arrangements will remain locked.

9.2.5 Where pilot operated non-return valves are fitted to hydraulic cylinders for locking purposes, the valves are to be connected directly to the actuating cylinder(s) without intermediate pipes or hoses.

9.2.6 Hydraulic circuits for securing and locking of bow, inner, stern or shell doors are to be arranged such that they are isolated from other hydraulic circuits when securing and locking devices are in the closed position. For requirements relating to hydraulic steering gear arrangements *see* Ch 19,3.

9.2.7 Suitable oil collecting arrangements for leaks shall be fitted below hydraulic valves and cylinders.

9.3 Relief valves on pumps

9.3.1 All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be in closed circuit, i.e., arranged to discharge back to the suction side of the pump and effectively to limit the pump discharge pressure to the design pressure of the system.

9.4 Pipes conveying oil

9.4.1 Pipes conveying hydraulic oil under pressure are to be of seamless steel or other approved material having flanged or welded joints, and are to be placed in sight above the platform in well lit and readily accessible parts of the machinery spaces. The number of flanged joints is to be kept to a minimum.

9.4.2 For requirements relating to flexible hoses, *see* Ch 12,7.

9.5 Filling arrangements

9.5.1 Filling stations are to be isolated from other spaces and are to be efficiently drained and ventilated.

9.5.2 Provision is to be made against over-pressure in the filling pipelines, and any relief valve fitted for this purpose is to discharge to an overflow tank or other safe position, or an equivalent arrangement is to be provided, except filling by means of a loose hose.

9.6 Separate oil tanks

9.6.1 On completion, the tanks are to be tested by a head of water equal to the maximum to which the tanks may be subjected.

9.7 Precaution against fire

9.7.1 Hydraulic oil tanks and filters are not to be situated immediately above boilers or other highly heated surfaces.

9.7.2 Hydraulic oil pipes are not to be installed above or near high-temperature equipment. Hydraulic oil pipes should also be installed and screened or otherwise suitably protected, to avoid oil spray or oil leakages on to hot surfaces, into machinery air intakes, or other sources of ignition such as electrical equipment. Pipe joints are to be kept to a minimum and where provided are to be of a type acceptable to LR. Pipes are to be led in well lit and readily visible positions.

9.7.3 Pumps, filters and heaters are to be located to avoid hydraulic oil spray or leakage on to hot surfaces or other sources of ignition or on to rotating machinery parts. Where necessary, shielding is to be provided and the arrangements are to allow easy access for routine maintenance. The design of filter and strainer arrangements is to be such as to avoid the possibility of them being opened inadvertently when under pressure. This may be achieved either by mechanically preventing the pressurised filter from being opened or by providing pressure gauges which clearly indicate which filter is under pressure. In either case, suitable means for pressure release are to be provided, with drain pipes led to a safe location.

■ *Section 10*
Low pressure compressed air systems

10.1 General

10.1.1 The requirements of this Section are applicable to low pressure (LP) compressed air systems intended for essential pneumatic control and instrumentation purposes. The documentation required by Ch 13,1.3.1 is to provide information to demonstrate compliance with 10.1.2 to 10.1.5.

10.1.2 Low pressure compressed air systems are to produce and distribute cooled compressed air throughout the ship to supply all pneumatic control and instrumentation systems where the air pressure requirements are typically 3 to 10 bar. LP compressed air systems may include air compressors, oil/water separators, filters, dryers, distribution lines and air receivers.

10.1.3 The design of LP compressed air systems is to be capable of providing a continuous flow of air to meet the demands of all essential services under all ambient conditions. This demand may include the use of intermittently used equipment that is part of the ship's equipment, such as power tools for machinery maintenance, testing equipment and line cleaning. Compressed air systems used for diesel engine or gas turbine starting are to comply with the requirements of Ch 2,16 and Ch 4,6 as applicable.

10.1.4 User equipment requirements for the quality of compressed air in terms of dewpoint (dryness), oil content and solid particle count are to be recognised in the selection and configuration of compressors, equipment, filters and dryers which are included in the system.

10.1.5 Configuration arrangements of LP compressed air systems may consist of:

(a) Dedicated LP air compressors and LP air receivers with a distribution system for LP users; or
(b) Supply from the starting air system to dedicated air pressure reducing valves/cross-over stations feeding into a distribution system for LP users.

10.2 Compressors and reducing valves/stations

10.2.1 Where LP air is not derived from the starting air system, at least two LP air compressors are to be provided. The output of any one compressor is to match the total demand of all essential users. The system is to be arranged for auto-start of the compressors and means are to be provided to indicate if any compressor is operating longer and more frequently than the manufacturer's recommended operating periods.

10.2.2 If only one LP air compressor is to be provided, a cross connection to the starting air system is to be made via a reducing valve/cross-connection station.

10.2.3 Where LP air is derived only from the starting air system, at least two means of supplying air to the LP air system are to be provided. Each of the two means of supplying air is to have sufficient capability of supplying the total demand on the LP air system with one of the means out of action.

10.2.4 Where the starting air system is fitted with an auxiliary compressor it is to be capable of continuous running and to be capable of maintaining the stored capacity of starting compressed air in the air receivers as required by Ch 2,16 and Ch 4,6 whilst also supplying essential LP services.

10.2.5 Where the starting air system is designed to maintain sufficient compressed air for LP services and engine starting arrangements, an additional auxiliary compressor will not be required.

10.3 Air receivers

10.3.1 The LP air system and any associated air receivers are to be configured to provide sufficient stored energy to supply LP compressed air without the pressure in the system falling below a level that is insufficient for the operation of all essential users. *See also* Pt 6, Ch 1,2.5.7.

10.3.2 All air receivers are to comply with the requirements of Chapter 11 as applicable.

10.3.3 Stop valves on air receivers are to permit slow opening to avoid sudden pressure rises in the piping system.

10.4 Distribution system

10.4.1 Drain pots with drain valves are to be provided throughout the distribution system at all low points.

10.4.2 Pipelines that are situated on the low pressure side of reducing valves/stations and that are not designed to withstand the full pressure of the source supply, are to be provided with pressure gauges and with relief valves having sufficient capacity to protect the piping against excessive pressure.

10.4.3 In-line filters capable of being cleaned/changed without interrupting the flow of filtered air are to be fitted in the system.

10.5 Pneumatic remote control valves

10.5.1 Where valves, which are required by the Rules to be capable of being closed from outside a machinery space, have pneumatic closing arrangements, a dedicated air receiver is to be fitted to supply compressed air to the valves. This air receiver is to be located outside the machinery space.

10.5.2 The air receiver is to be maintained fully charged from the main LP air system via a non-return valve located at the air receiver inlet which is to be locked in the open position.

10.5.3 In the case of passenger ships, a permanently attached hand-operated air compressor capable of charging the air receiver is to be provided in the space in which the air receiver is located.

10.5.4 The capacity of the air receiver is to be sufficient to operate all valves and any other essential supplies such as ventilation flaps without replenishment.

10.6 Control arrangements

10.6.1 The control, alarm and monitoring systems are to comply with Pt 6, Ch 1.

Section 11
Multi-engined ships

11.1 General

11.1.1 This Section is applicable to ships of less than 500 gross tons and which are not required to comply with the *International Convention for the Safety of Life at Sea, 1974*, as amended (SOLAS 74), and that have multi-engine installations for propulsion purposes.

11.1.2 For vessels in which the propulsion systems are independent and the propulsion system prime movers are also fully independent of each other such that in the event of the failure of one of the sources of propulsion power the vessels will retain the capability of safely manoeuvring under all conditions of service, the following may not be required:
(a) Spare fuel oil booster pump stipulated in 3.10.2.
(b) Spare lubricating oil pump stipulated in 8.2.1(c), 8.2.2 and 8.2.3.
(c) Spare cooling water pump stipulated in 7.2.2(b).

Section 12
Control, alarm and safety systems of machinery

12.1 General

12.1.1 Where machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, it is to be provided with the alarms and safety arrangements required by 12.2 to 12.5, as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

12.1.2 Where machinery is arranged to start automatically or from a remote control station, interlocks are to be provided to prevent start-up under conditions which could hazard the machinery.

12.1.3 Where machinery specified in this Section is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

12.1.4 Where a first stage alarm together with a second stage alarm and automatic shut-down of machinery are required in the relevant Tables of this Section, the sensors and circuits utilised for the second stage alarm and automatic shut-down are to be independent of those required for the first stage alarm.

12.2 Thermal fluid heaters

12.2.1 Alarms and safeguards are indicated in 12.2.2 to 12.2.8 and Table 14.12.1.

12.2.2 The standby pumps for oil fuel and thermal fluid circulation are to start automatically when the discharge pressure from the working pump falls below a predetermined value. The standby pumps for thermal fluid circulation are to start before shut-off due to low thermal fluid pressure, *see* Table 14.12.1, is activated.

12.2.3 The following heater services are to be fitted with automatic controls so as to maintain steady state conditions throughout the operating range of the heater:
(a) Combustion system.
(b) Oil fuel supply temperature or viscosity (heavy oil only).
(c) Thermal fluid temperature.

12.2.4 Burner controls are to be arranged such that light-off is only possible at the minimum firing rate compatible with flame establishment. If ignition is set to occur at a fuel rich condition then the burner is to revert to the correct operating air/fuel ratio on establishment of a stable flame.

12.2.5 Arrangements are to be such that burner oil fuel valve(s) do not open:
(a) prior to completion of required warm up times for residual fuel oil; or
(b) when the power supply to the igniter has failed, as applicable; or
(c) until a pilot flame is established, as applicable; or
(d) prior to the completion of furnace purging, *see* 3.1.7.

12.2.6 Arrangements for flame failure detection are to be provided with self-monitoring capabilities which ensure that the flame detector is not erroneously indicating the presence of a flame. In the event of failure being detected by these self-monitoring capabilities:
- an alarm is to be activated;
- In the event of loss of flame detection capability for a burner;
- oil fuel to the burner is to be shut off automatically; and
- an alarm is to be activated.

12.2.7 Where established as necessary by 3.1.8, means are to be provided to prevent starting of the ignition sequence following multiple flame failures until completion of the identified lock-out period.

12.2.8 Following burner shut-down, the furnace is to be purged automatically for at least the required pre-purging time. In event of shut-down due to activation of a required safeguard, this purging is to be manually initiated.

12.3 Incinerators

12.3.1 Alarms and safeguards are indicated in 12.3.2, 12.3.3 and Table 14.12.2.

12.3.2 Where arrangements are provided to introduce solid waste into the furnace, these are to be such that there is no risk of a fire hazard.

12.3.3 The combustion temperature is to be controlled to ensure that all liquid and solid waste is efficiently burned without exceeding predetermined temperature limits.

Table 14.12.1 Thermal fluid heaters: Alarms and safeguards

Item	Alarm	Note
Expansion tank level*	Low	Oil fuel burners to be shut off automatically
Thermal fluid flow	Low	Oil fuel burners to be shut off automatically, *see* Note 5
Thermal fluid pressure	Low	Oil fuel burners to be shut off automatically
Thermal fluid outlet temperature*	1st stage high 2nd stage high	— Oil fuel burners to be shut off automatically, *see* 12.1.4
Combustion air pressure*	Low	Oil fuel burners to be shut off automatically in operation or not released during start-up, *see* Note 3. Purge sequence to be inhibited *see* 3.1.9
Oil fuel pressure*	Low	—
Oil fuel temperature or viscosity*	High and low	Heavy oil only
Oil fuel atomising steam/air pressure	Low	—
Burner flame*	Failure	Each burner to be monitored. Oil fuel to burner to be shut off automatically, *see* 3.1.11 to 3.1.12, and Note 3
Flame monitoring device(s)*	Failure	*See* 12.2.6 and Note 3
Igniter power supply*	Failure	Each igniter to be checked before oil fuel is supplied to burner(s), *see* 12.2.5 and Note 3
Forced draft fan*	Power failure	Oil fuel burners to be shut off automatically in operation or not released during start-up, *see* Note 3
Air register and dampers (including those in the uptake)*	Not fully open	Purge sequence to be inhibited, *see* 3.1.9
Control system*	Power failure	Oil fuel burners to be shut off automatically. Control using alternative arrangement is to remain available, *see* Pt 6, Ch 1,2.5.7
Uptake temperature	High	To monitor for soot fires. Oil fuel to the burner is to be shut off, *see* Notes 4 and 6

NOTES
1. Special consideration may be given to the requirements for oil-fired hot water heaters.
2. For heaters not supplying thermal oil for services essential for the safety or the operation of the ship at sea, only the items marked* are required.
3. These safeguards are to remain operative during automatic, manual and emergency operation.
4. Alarm and oil fuel shut-off is only required where exhaust gas economisers/boilers are fitted.
5. For exhaust gas economisers/boilers requiring thermal fluid forced circulation, the low flow alarm is to be fitted with provision to override the alarm if the exhaust gas economiser/boiler is to be operated in the dry condition. *See also* 6.2.5.
6. Alternatively, details of an appropriate fire detection system are to be submitted for consideration.

Table 14.12.2 Incinerators: Alarms and safeguards

Item	Alarm	Note
Oil fuel temperature or viscosity	High and low	Heavy oil and sludge
Oil fuel pressure	Low	—
Combustion air pressure	Low	Oil fuel and/or sludge to burners to be shut off automatically
Burner flame and ignition	Failure	Oil fuel and/or sludge to burners to be shut off automatically, *see* Note
Furnace temperature	High	Oil fuel and/or sludge to burners to be shut off automatically
Furnace temperature	Low	If applicable
Exhaust temperature	High	—

NOTE
Combustion spaces are to be purged automatically before re-ignition takes place in the event of a flame-out on all burners.

12.4 Miscellaneous machinery

12.4.1 Alarms and safeguards are indicated in 12.4.2 to 12.4.6 and Table 14.12.3.

12.4.2 **Dual fuel systems**. Oil and gas dual-fired systems for boilers and engines are to be provided with indication to show which fuel is in use.

12.4.3 **Lifts**. For details of alarms and safeguards for lifts classed by LR, reference is to be made to LR's *Code for Lifting Appliances in a Marine Environment*.

12.4.4 **Oil heaters**. Oil fuel or lubricating oil heaters are to be fitted with a high temperature alarm which may be incorporated in the temperature control system. In addition to the temperature control system, an independent sensor with manual reset is to be fitted, which will automatically cut off the heating supply in the event of excessively high temperatures or loss of flow, except where the maximum temperature of the heating medium remains limited to a value below 220°C.

12.4.5 **Oil tank electric heating**. Oil fuel and lubricating oil tanks that are provided with electric heating elements are to be fitted with a high temperature alarm, which may be incorporated in the temperature control system, a low level alarm and an additional low level sensor to cut off the power supply at a level above that at which the heating element would be exposed.

12.4.6 **Oil fuel tanks**. Means are to be provided to eliminate the possibility of overflow from oil fuel service tanks into the machinery space and to safeguard against overflow of oil from oil fuel service tanks through the air pipe. *See* Chapter 13 regarding the termination of air pipes.

Table 14.12.3 Miscellaneous machinery: Alarms and safeguards

Item	Alarm	Note
Sterntube lubricating oil tank level	Low	—
Sterntube bearing temperature (oil lubricated)	High	—
Coolant tanks level	Low	—
Oil fuel service tanks level	High and low	Where a common overflow tank is fitted, a high level alarm in the common overflow tank may be accepted
Oil fuel service tanks temperature	High	Where heating arrangements are fitted
Oil fuel settling tanks temperature	High	Where heating arrangements are fitted
Sludge tanks level	High	—
Feed water tanks level	Low	Service tank only
Purifier water seal broken	Fault	—
Purifier oil inlet temperature	High	—
Air compressor lubricating oil	Failure	Automatic shut-down
Air compressor discharge air temperature	High	—
Hydraulic control system pressure	Low	—
Pneumatic control system pressure	Low	—
Oil heater temperature	High	—
Control environmental conditions	Abnormal	*See also* Pt 6, Ch 1,1.3.3

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter are additional to those of Chapter 13 and are applicable to ships which are intended for the carriage of oil in bulk.

1.1.2 The requirements are based on the assumption that the ships are of normal tanker type having the main propelling machinery aft. Departures from this arrangement will require special consideration.

1.1.3 The requirements are primarily intended for ships which are to carry flammable liquids having a flash point not exceeding 60°C (closed-cup test).

1.1.4 Where ships are intended to carry specific cargoes which are non-flammable or which have a flash point exceeding 60°C, the requirements will be modified, where necessary, to take account of the lesser hazards associated with the cargoes.

1.1.5 For a list of cargoes which can be carried in oil tankers, *see* Table 9.1.2 in Pt 4, Ch 9.

1.2 Plans and particulars

1.2.1 In addition to the plans and particulars required in Chapter 13, the following plans (in a diagrammatic form) are to be submitted for consideration:

- Pumping arrangement at the fore and aft ends and drainage of cofferdams and pump-rooms.
- General arrangement of cargo piping in tanks and on deck.
- General arrangement of cargo tank vents. The plan is to indicate the type and position of the vent outlets from any superstructure, erection, air intake, etc.
- Arrangement of inert gas piping system together with details of inert gas generating plant including all control and monitoring devices.
- Piping arrangements for cargo oil (F.P. 60°C or above, closed-cup test).
- Ventilation arrangements of cargo and/or ballast pump-rooms and other enclosed spaces which contain cargo handling equipment.
- Arrangements for venting, purging and gas measurement for double hull and double bottom spaces.
- Details of alarms and safety arrangements required by 1.6, *see also* Pt 6, Ch 1,2.

1.3 Materials

1.3.1 All materials used in the cargo pumping and piping systems are to be suitable for use with the intended cargoes and, where applicable, they are to comply with the requirements of Chapter 12.

1.3.2 The requirements of 1.3.1 are also applicable to other piping systems which may come into contact with cargo.

1.4 Design

1.4.1 All piping, valves and fittings are to be suitable for the maximum pressure to which the system can be subjected.

1.4.2 Piping subject to pressure is to be of seamless or other approved type, and is to comply with the requirements of Chapter 12.

1.5 Hazardous zones and spaces

1.5.1 Oil engines, or any other equipment which could constitute a possible source of ignition, are not to be situated within cargo tanks, pump-rooms, cofferdams or other spaces liable to contain petroleum or other explosive vapours, or in spaces or zones immediately adjacent to cargo oil or slop tanks. The temperature of steam, or other fluid, in pipes (or heating coils) in these spaces is not to exceed 220°C. On gas tankers and chemical tankers, the maximum temperature is not to exceed that of the required temperature class of electrical equipment in the cargo area.

1.5.2 For definition of hazardous zones and spaces and requirements for electrical equipment within such spaces, *see* Pt 6, Ch 2,14.5.

1.5.3 For the requirements for earthing and bonding of pipework for the control of static electricity, *see* Pt 6, Ch 2,1.13.

1.6 Cargo pump-room

1.6.1 Control engineering systems are to be in accordance with the requirements of Pt 6, Ch 1.

1.6.2 Cargo pump-rooms are to be totally enclosed and are to have no direct communication with machinery spaces. For bilge drainage arrangements in pump-room, *see* 2.2.

1.6.3 Pump-rooms are to be situated within, or adjacent to the cargo tank area and are to be provided with ready means of access from the open deck, *see also* Pt 4, Ch 9,13.

1.6.4 In cargo pump-rooms any drain pipes from steam or exhaust pipes from the steam cylinders of the pumps are to terminate well above the level of the bilges.

1.6.5 Alarms and safety arrangements are to be provided as indicated in 1.6.6 and Table 15.1.1. These requirements are applicable to pump-rooms where pumps for cargo, such as cargo pumps, stripping pumps, pumps for slop tanks, pumps for COW or similar pumps are provided and not for pump-rooms intended solely for ballast transfer. *See also* 1.6.7.

Table 15.1.1 Alarms and safety arrangements

Item	Alarm	Note
Temperature sensing of bulkhead shaft glands, bearings and pump casings	High *see* Note 1	Cargo, ballast and stripping pumps
Bilge level	High	—
Hydrocarbon concentration	High *see* Note 2	> 10% LEL

NOTES
1. The alarm signals shall trigger continuous visual and audible alarms in the cargo control room or the pump control station.
2. This alarm signal shall trigger a continuous audible and visual alarm in the pump-room, cargo control room, engine control room and bridge.

1.6.6 A system for continuously monitoring the concentrations of hydrocarbon gases within the cargo pump-room is to be fitted. Monitoring points are to be located in positions where potentially dangerous concentrations may be readily detected. Gas analysing units with non-safe-type measuring equipment may be located outside cargo areas (e.g. in cargo control room, navigation bridge or engine room when mounted on the forward bulkhead) provided that:

(a) sampling lines do not pass through gas safe spaces, except where permitted by (e);

(b) the gas sampling pipes are fitted with flame arresters. Sample gas is to be led to the atmosphere with outlets arranged in a safe location, in the open atmosphere;

(c) bulkhead penetrations of sample pipes between safe and dangerous areas are of an approved type. A manual isolating valve is to be fitted in each of the sampling lines at the bulkhead in the safe area;

(d) the gas detection equipment including sampling piping, sampling pumps, solenoid valves and analysing units, are located in a fully enclosed steel cabinet, with a gasketed door, monitored by its own sampling point. At gas concentrations above 30 per cent LEL inside the steel cabinet, the entire gas-analysing unit is to be automatically shut down; and

(e) where the cabinet cannot be arranged on the bulkhead, sample pipes are to be of steel or other equivalent material and without detachable connections, except for the connection points for isolating valves at the bulkhead and analysing units. The sample pipes are to be led by their shortest route.

Sequential sampling is acceptable as long as it is dedicated for the pump-room only, including exhaust ducts, and the detection equipment is capable of monitoring from each sampling head location at intervals not exceeding 30 minutes.

1.6.7 Where items of equipment other than described in Table 15.1.1 are located in the pump-room and are driven by shafts passing through bulkheads, the potential risk of ignition of hydrocarbon gas is to be assessed and proposals for mitigation submitted to LR for consideration.

1.7 Arrangements for fixed hydrocarbon gas detection systems in double hull and double bottom spaces of oil tankers

1.7.1 In accordance with SOLAS 1974, as amended, Ch II-2/B, Reg. 4.5.7, double hull and double bottom spaces of oil tankers with a deadweight of 20 000 tonnes and above that are not provided with a constant operative inerting system are to be provided with a fixed hydrocarbon gas detection system.

1.7.2 Where a fixed hydrocarbon gas detection system is required by 1.7.1, it is to be of an approved type and it is to meet the requirements of Chapter 16 of the *International Code for Fire Safety Systems (FSS Code)*.

1.8 Cargo pump-room ventilation

1.8.1 Cargo pump-rooms and other closed spaces which contain cargo handling equipment, and to which regular access is required during cargo handling operations, are to be provided with permanent ventilation systems of the mechanical extraction type.

1.8.2 The ventilation system is to be capable of being operated from outside the compartment being ventilated and a notice to be fixed near the entrance stating that no person is to enter the space until the ventilation system has been in operation for at least 15 minutes.

1.8.3 The ventilation systems are to be capable of 20 air changes per hour, based on the gross volume of the pump-room or space.

1.8.4 The ventilation ducting is to be arranged to permit extraction from the vicinity of the pump-room bilges, immediately above the transverse floor plates or bottom longitudinals. An emergency intake is also to be arranged in the ducting at a height of 2 m above the pump-room lower platform and is to be provided with a damper capable of being opened or closed from the weather deck and lower platform level. An arrangement involving a specific ratio of areas of upper emergency and lower main ventilation openings, which can be shown to result in at least the required number of air changes through the lower inlets, can

be accepted without the use of dampers. When the lower inlets are sealed off, owing to flooding of the bilges, then at least 75 per cent of the required number of air changes is to be obtainable through the upper inlets. Means are to be provided to ensure the free flow of gases through the lower platform to the duct intakes.

1.8.5 Protection screens of not more than 13 mm square mesh are to be fitted in outside openings of ventilation ducts, and ventilation intakes are to be so arranged as to minimise the possibility of re-cycling hazardous vapours from any ventilation discharge opening. Vent exits are to be arranged to discharge to a safe place on the open deck and comply with the requirements of 1.8.6.

1.8.6 The vent exits from pump-rooms are to discharge at least 3 m above deck, and from the nearest air intakes or openings to accommodation and enclosed working spaces, and from possible sources of ignition.

1.8.7 The ventilation is to be interlocked to the lighting system (except emergency lighting) such that the cargo pump-room lighting may only come on when the ventilation is in operation. Failure of the ventilation system shall not cause the lighting to go out.

1.9 Non-sparking fans for hazardous areas

1.9.1 The air gap between impeller and housing of the fan is to be not less than 0,1 of the impeller shaft bearing diameter or 2 mm whichever is the larger, subject also to compliance with 1.9.2(e). Generally, however, the air gap need be no more than 13 mm.

1.9.2 The following combinations of materials are permissible for the impeller and the housing in way of the impeller:

(a) impellers and/or housings of non-metallic material, due regard being paid to the elimination of static electricity,
(b) impellers and housings of non-ferrous metals,
(c) impellers and housings of austenitic stainless steel,
(d) impellers of aluminium alloys or magnesium alloys and a ferrous housing provided that a ring of suitable thickness of non-ferrous material is fitted in way of the impeller,
(e) any combination of ferrous impellers and housings with not less than 13 mm tip clearance,
(f) any combination of materials for the impeller and housing which are demonstrated as being spark proof by appropriate rubbing tests.

1.9.3 The following combinations of materials for impellers and housing are not considered spark proof and are not permitted:

(a) impellers of an aluminium alloy or magnesium alloy and a ferrous housing, irrespective of tip clearance,
(b) impellers of a ferrous material and housings made of an aluminium alloy, irrespective of tip clearance,
(c) any combination of ferrous impeller and housing with less than 13 mm tip clearance, other than permitted by 1.9.2(c).

1.9.4 Electrostatic charges both in the rotating body and the casing are to be prevented by the use of antistatic materials (i.e. materials having an electrical resistance between 5 x 10^4 ohms and 10^8 ohms), or special means are to be provided to avoid dangerous electrical charges on the surface of the material.

1.9.5 Type tests on the complete fan are to be carried out to the Surveyor's satisfaction.

1.9.6 Protection screens of not more than 13 mm square mesh are to be fitted in the inlet and outlet of ventilation ducts to prevent the entry of objects into the fan housing.

1.9.7 The installation of the ventilation units on board is to be such as to ensure the safe bonding to the hull of the units themselves.

1.10 Slop tanks

1.10.1 The requirements in 1.10.2 to 1.10.7 are applicable to ships intended for the carriage of ore or oil when oil residues are to be retained in the slop tanks and the ship is otherwise gas free, *see also* Pt 4, Ch 9,11.3.

1.10.2 Slop tanks are to be provided with an approved independent venting system, *see* Section 4.

1.10.3 At least two portable instruments are to be available on board for gas detection.

1.10.4 Means are to be provided for isolating the piping connecting the pump-room with the slop tanks. The means of isolation is to consist of a valve followed by a spectacle flange or a spool piece with appropriate blank flanges. This arrangement is to be located adjacent to the slop tanks, but where this is unreasonable or impracticable it may be located within the pump-room directly after the piping penetrates the bulkhead. A separate permanently installed pumping and piping arrangement is to be provided for discharging the contents of the slop tanks directly to the open deck for transfer to shore reception facilities when the ship is in the dry cargo mode. When this transfer system is used for slop transfer in dry cargo mode, it shall have no connection to other systems. Separation by means of removal of spool pieces may be accepted.

1.10.5 Adequate ventilation is to be provided for spaces surrounding slop tanks, *see also* Pt 4, Ch 9,11.3.

1.10.6 Warning notices are to be erected at suitable points detailing precautions to be observed prior to the ship loading or unloading, or when the ship is carrying dry cargo with liquid in the slop tanks.

1.10.7 In order to satisfy the requirements of certain National and/or Terminal Authorities, it may be necessary to provide an inert gas system for blanketing the slop tank contents.

1.11 Steam connections to cargo tanks

1.11.1 Where steaming out and/or fire-extinguishing connections are provided for cargo tanks or cargo pipe lines, they are to be fitted with valves of the screw-down non-return type. The main supply to these connections is to be fitted with a master valve placed in a readily accessible position clear of the cargo tanks.

■ *Cross-reference*

See Pt 6, Ch 1,3 for alarm system requirements.

■ *Section 2*
Piping systems for bilge, ballast, oil fuel, etc.

2.1 Pumping arrangements at ends of ship outside hazardous zones and spaces

2.1.1 The pumping arrangements in the machinery space and at the forward end of the ship are to comply with the requirements for general cargo ships, in so far as they are applicable, and with the special requirements detailed in this Section.

2.1.2 Bilge, ballast and oil fuel lines, etc., which are connected to pumps, tanks or compartments at the ends of the ship outside hazardous zones and spaces, are not to pass through cargo tanks or have any connections to cargo tanks, or cargo piping. No objection will be made to these lines being led through ballast tanks or void spaces within the range of the cargo tanks.

2.1.3 The oil fuel bunkering system is to be entirely separate from the cargo handling system.

2.1.4 Where non-permanent connections are required in piping systems between non-hazardous and hazardous spaces, two means of isolation are to be provided. One of these means is to provide positive separation by means of a removable spool piece or flexible hose, and blank flanges are to be fitted. The other is to be a non-return valve, or similar, in accordance with an acceptable National or International Standard that is appropriate for the design conditions of the piping system. The non-return valve and removable piece are to be located within the existing hazardous spaces. A notice is also to be provided located in a prominent position adjacent to the means of isolation, clearly indicating that the spool piece or flexible hose is to be removed, and blanking flanges are to be fitted, when the piping is not in use. The removable spool piece is to be clearly identified (labelled/painted in a distinctive colour) and stowed close to its working position.

2.2 Cargo pump-room drainage

2.2.1 Provision is to be made for the bilge drainage of the cargo pump-rooms by pump or bilge ejector suctions. The cargo pumps or cargo stripping pumps may be used for this purpose, provided that the bilge suctions are fitted with screw-down non-return valves and, in addition, an isolating valve or cock is fitted on the pump connection to the bilge chest. The pump-room bilges of small tankers may be drained by means of a hand pump having a 50 mm bore suction. Pump-room suctions are not to enter machinery spaces.

2.3 Deep cofferdam drainage

2.3.1 Cofferdams, which are required to be provided at the fore and aft ends of the cargo spaces in accordance with Pt 4, Ch 9,1.2 are to be provided with suitable drainage arrangements. Examples of acceptable arrangements are detailed in 2.3.2 and 2.3.3.

2.3.2 Where deep cofferdams can be filled with water ballast, a ballast pump in the main engine room may be used for emptying the after cofferdam. Where fitted, a ballast pump in a forward pump-room may be used for emptying the forward cofferdam. In each case, the suctions are to be led direct to the pump and not to a pipe system.

2.3.3 Where intended to be dry compartments, after cofferdams adjacent to the pump-room may be drained by a cargo pump, provided that isolating arrangements are fitted in the bilge system as required by 2.2.1; forward cofferdams may be drained by a bilge and ballast pump in a forward pump-room. Alternatively, cofferdams may be drained by bilge ejectors or, in the case of small ships, by hand pumps.

2.3.4 Cofferdams are not to have any direct connections to the cargo tanks or cargo lines.

2.4 Drainage of ballast tanks and void spaces within the range of the cargo tanks

2.4.1 Ballast tanks and void spaces within the range of the cargo tanks are not to be connected to cargo pumps, or have any connections to the cargo system. A separate ballast/bilge pump is to be provided for dealing with the contents of these spaces. This pump is to be located in the cargo pump-room or other suitable space within the range of the cargo tanks.

2.4.2 Ballast pumps shall be provided with suitable arrangements to ensure efficient suction from ballast tanks.

2.4.3 Where submerged water ballast pumps are fitted, they are to be located in separate compartments on opposite sides of the ship such that, in the event of hull damage due to grounding or collision, the risk of total loss of ballast pumping capability is minimised.

2.4.4 Ballast piping is not to pass through cargo tanks and is not to be connected to cargo oil piping. Provision may, however, be made for emergency discharge of water ballast by means of a portable spool connection to a cargo oil pump and where this is arranged, a non-return valve is to be fitted in the ballast suction to the cargo oil pump.

2.4.5 Consideration will be given to connecting double bottom and/or wing tanks, which are in the range of the cargo tanks, to pumps in the machinery space where the tanks are completely separated from the cargo tanks by cofferdams, heating ducts or containment spaces, etc.

2.5 Air and sounding pipes

2.5.1 Deep cofferdams at the fore and aft ends of the cargo spaces and other tanks or cofferdams within the range of the cargo tanks, which are not intended for cargo, are to be provided with air and sounding pipes led to the open deck. The air pipes are to be fitted with gauze diaphragms at their outlets.

2.5.2 The air and sounding pipes required by 2.5.1 are not to pass through cargo tanks.

2.5.3 On oil tankers of less than 5000 tonnes deadweight, where wing ballast tanks or spaces are not required, the sounding and air pipes to double bottom spaces below cargo tanks may pass through the cargo tanks. However, the pipes are to be of heavy gauge steel, and are to be in continuous lengths or with welded joints.

2.6 Ballast piping in pump-room double bottoms

2.6.1 Ballast piping is permitted to be located within the cargo pump-room double bottom provided any damage to that piping does not render the ship's ballast and cargo pumps, located in the cargo pump-room, ineffective.

2.7 Fore peak ballast tank

2.7.1 The fore peak tank can be ballasted with the system serving other ballast tanks within the cargo area, provided that:

(a) the fore peak tank is considered as a hazardous area;
(b) the vent pipe openings are located on open deck at an appropriate distance from sources of ignition. In this respect, the hazardous zones distances are to be defined in accordance with Pt 6, Ch 2,14.5;
(c) means are provided, on the open deck, to allow measurement of flammable gas concentrations within the fore peak tank by a suitable portable instrument;
(d) the sounding arrangement to the fore peak tank is direct from open deck; and
(e) the access to the fore peak tank is direct from open deck; alternatively, indirect access from the open deck to the fore peak tank through an enclosed space may be accepted, provided that:
    (i) in case the enclosed space is separated from the cargo tanks by cofferdams, the access is through a gas-tight bolted manhole located in the enclosed space and a warning sign is to be provided at the manhole, stating that the fore peak tank may only be opened after it has been proven to be gas free, or any electrical equipment which is not certified safe in the enclosed space is isolated.
    (ii) where the enclosed space has a common boundary with the cargo tanks and is therefore a hazardous area, the enclosed space is to be well ventilated.

■ *Section 3* Cargo handling system

3.1 General

3.1.1 A complete system of piping and pumps is to be fitted for dealing with the cargo.

3.1.2 Standby means for pumping out each cargo tank are to be provided.

3.1.3 Where cargo tanks are provided with single deep well pumps, or submerged pumps, it will be necessary to provide alternative means for emptying the tanks in the event of the failure of a pump. Portable submersible pumps may be provided on board for this purpose, but the arrangements are to be such that a portable pump could be safely introduced into a full or part-full tank. Details of the arrangements are to be submitted.

3.1.4 Provision is to be made for the gas freeing of the cargo oil tanks when the cargo has been discharged, and for the ventilation and gas freeing of all compartments adjacent to cargo oil tanks. It is recommended that arrangements be provided to enable double bottom tanks situated below cargo tanks to be filled with water ballast to assist in the gas freeing of these tanks, *see also* 7.6.2.

3.1.5 At least two portable instruments are to be available on board for gas detection.

3.1.6 Cargo tank access hatches and all other openings to cargo tanks, such as ullage and tank cleaning openings and restricted sounding devices, *see* 5.2, are to be located on the weather deck.

3.2 Cargo pumps

3.2.1 Pumps for the purpose of filling or emptying the cargo oil tanks are to be used exclusively for this purpose, except as provided in 2.2.1. They are not to have any connections to compartments outside the range of cargo oil tanks.

3.2.2 Means are to be provided for stopping the cargo oil pumps from a position outside the pump-rooms, as well as at the pumps.

3.2.3 The pumps are to be provided with effective relief valves which are to be in closed circuit, i.e. discharging to the suction side of the pumps. Alternative proposals to safeguard against over-pressure on the discharge side of the pump will be specially considered.

3.2.4 Where cargo pumps are driven by shafting which passes through a pump-room bulkhead or deck, gastight glands are to be fitted to the shaft at the pump-room plating. The glands are to be efficiently lubricated from outside the pump-room. The seal parts of the glands are to be of materials that will not initiate sparks. The glands are to be of an approved type and are to be attached to the bulkhead in accordance with Ch 13,2.4. Where a bellows piece is incorporated in the design, it is to be hydraulically tested to 3,4 bar (3,5 kgf/cm^2) before fitting.

3.2.5 Where cargo pumps are driven by hydraulic motors which are located inside cargo tanks, the design is to be such that contamination of the operating medium with cargo liquid cannot take place under normal operating conditions. The arrangements are to comply with 3.7.7 and 3.7.8, in so far as they are applicable.

3.3 Cargo piping system

3.3.1 Cargo piping and similar piping to cargo tanks are not to pass through ballast tanks.

3.3.2 Cargo pipes are not to pass through tanks or compartments which are outside the cargo tank area.

3.3.3 Means are to be provided to enable the contents of the cargo lines pumps to be drained to a cargo tank or other suitable tank. Where drain tanks are fitted in pump-rooms, they are to be of the closed type with air and sounding pipes led to the open deck.

3.3.4 Expansion joints of approved type or bends are to be provided, where necessary, in the cargo pipe lines.

3.3.5 Expansion pieces of an approved type, incorporating oil resistant rubber or other suitable material, may be accepted in cargo piping, *see also* Ch 13,2.7.2.

3.3.6 In combination carriers where cargo wing tanks are provided, cargo oil lines below deck are to be installed inside these tanks. However, Lloyd's Register (hereinafter referred to as 'LR') may permit cargo oil lines to be placed in special ducts which are to be capable of being adequately cleaned and ventilated to the satisfaction of LR's Surveyors. Where cargo wing tanks are not provided cargo oil lines below deck are to be placed in special ducts.

3.3.7 Means are to be provided for keeping deck spills away from accommodation and service areas. This may be accomplished by means of a 300 mm coaming extending from side to side. Special consideration shall be given to the arrangements associated with stern loading.

3.4 Terminal fittings at cargo loading stations

3.4.1 Terminal pipes, valves and other fittings in the cargo loading and discharging lines to which shore installation hoses are directly connected, are to be of steel or approved ductile material. They are to be of robust construction and strongly supported, *see also* 1.3 and 1.4.

3.4.2 A manually operated shut-off valve is to be fitted to each shore loading/discharging connection.

3.4.3 Drip pans for collecting cargo residues in cargo lines and hoses are to be provided beneath pipe and hose connections in the manifold area.

3.5 Bow or stern loading and discharge arrangements

3.5.1 Where a ship is arranged for bow and/or stern loading and discharge of cargo outside the cargo tank area, the pipe lines and related piping and equipment forward and/or aft of the cargo area are to have only welded joints and are to be provided with spectacle flanges or removable spool pieces, where branched off from the main line, and a blank flange at the bow and/or stern end connections, irrespective of the number and type of valves in the line.

3.5.2 The spaces within 4,5 m of flanged connections to, or valves or drip trays associated with, discharge manifolds discharge manifolds are to be considered as hazardous spaces with regard to electrical or incendive equipment, *see also* Pt 6, Ch 2,14.10.

3.6 Connections to cargo tanks

3.6.1 Where cargo tanks are provided with direct filling connections, the loading pipes are to be led to as low a level as practicable inside the tank.

3.6.2 Where cargo suction and/or filling lines are led through cargo tanks, or through other spaces situated below the weather deck, the connection to each tank is to be provided with a valve situated inside the tank, and capable of being operated from the deck. In the case of cargo tanks which are located adjacent to below-deck pump-rooms, or pipe tunnels, the deck operated valves may be located in these spaces at the bulkhead. In any case, not less than two isolating shut-off valves are to provided in the pipe lines between the tanks and the cargo pumps.

3.7 Remote control valves

3.7.1 Valves on deck and in pump-rooms which are provided with remote control, are, in general, to be arranged for local manual operation independent of the remote operating mechanism, *see also* Ch 13,2.3.2 and 2.3.3.

3.7.2 Where the valves and their actuators are located inside the cargo tanks, two separate suctions are to be provided in each tank, or alternative means of emptying the tank, in the event of a defective actuator, are to be provided.

3.7.3 All actuators are to be of a type which will prevent the valves from opening inadvertently in the event of the loss of pressure in the operating medium. Indication is to be provided at the remote control station showing whether the valve is open or shut.

3.7.4 Materials of construction of the actuators and piping inside the cargo tanks are to be suitable for use with the intended cargo.

3.7.5 Compressed air is not to be used for operating actuators inside cargo tanks.

3.7.6 The actuator operating medium in hydraulic systems is to have a flash point of 60°C or above (closed-cup test) and is to be compatible with the intended cargoes.

3.7.7 The design of the actuators is to be such that contamination of the operating medium with cargo liquid cannot take place under normal operating conditions.

3.7.8 Where the operating medium is oil, or other fluid, the supply tank is to be located as high as practicable above the level of the top of the cargo tanks, and all actuator supply lines are to enter the cargo tanks through the highest part of the tanks. Furthermore, the supply tank is to be of the closed type with an air pipe led to a safe space on the open deck and fitted with a flameproof wire gauze diaphragm at its open end. This tank is also to be fitted with a high and low level audible and visual alarm. The requirements of this paragraph need not be complied with if the actuators and piping are located external to the cargo tanks.

3.7.9 It is recommended that for remote control valves not arranged for manual operation, emergency means be provided for operating the valve actuators in the event of damage to the main hydraulic circuits on deck. In the case of valves located inside cargo tanks, this could be achieved by ensuring that the supply lines to the actuators are led vertically inside the tanks from deck, and that connections, with necessary isolating valves, are provided on deck for coupling to a portable pump carried on board.

3.8 Cargo handling controls

3.8.1 Electrical measuring, monitoring control and communication circuits located in hazardous spaces are to be in accordance with Pt 6, Ch 2,14.2, appropriate to the defined hazardous zone.

3.8.2 The handling controls and instruments are to be arranged for safe and easy operation. They may be grouped at a number of control stations or at one main control station.

3.8.3 A satisfactory means of communication is to be provided between cargo handling stations, open deck, the bridge and the machinery space.

3.8.4 The cargo handling controls and instrumentation are, so far as possible, to be separate from the propulsion and auxiliary machinery controls and instrumentation.

■ *Section 4* Cargo tank venting, purging and gas-freeing

4.1 Cargo tank venting

4.1.1 The venting systems of cargo tanks are to be entirely distinct from the air pipes of the other compartments of the ship. The arrangements and position of openings in the cargo tank deck from which emission of flammable vapours can occur are to be such as to minimise the possibility of flammable vapours being admitted to enclosed spaces containing a source of ignition, or collecting in the vicinity of deck machinery and equipment which may constitute an ignition hazard.

4.1.2 The venting arrangements are to be so designed and operated as to ensure that neither pressure nor vacuum in cargo tanks exceeds design parameters and are to be such as to provide for:

(a) the flow of the small volumes of vapour, air or inert gas mixtures caused by thermal variations in a cargo tank in all cases through pressure/vacuum valves: and
(b) the passage of large volumes of vapour, air or inert gas mixtures during cargo loading and ballasting, or during discharging.
(c) a secondary means of allowing full flow relief of vapour, air or inert gas mixtures to prevent overpressure or underpressure in the event of failure of the arrangements in 4.1.2(b). Alternatively, pressure sensors may be fitted to monitor the pressure in each tank protected by the arrangement required in 4.1.2(b), with a monitoring system in the ship's cargo control room or the position from which cargo operations are normally carried out. Such monitoring equipment is also to provide an alarm facility which is activated by detection of over-pressure or under-pressure conditions within a tank.

4.1.3 The venting arrangements in each cargo tank may be independent or combined with other cargo tanks and may be incorporated into the inert gas piping.

4.1.4 Where the arrangements are combined with other cargo tanks either stop valves or other acceptable means are to be provided to isolate each cargo tank. Where stop valves are fitted, they are to be provided with locking arrangements which are to be under the control of the responsible ship's officer.

4.1.5 There is to be a clear visual indication of the operational status of the valves, or other acceptable means. Where tanks have been isolated, it is to be ensured that the relevant isolating valves are opened before cargo loading or ballasting or discharging of those tanks is commenced. Any isolation is to continue to permit the flow caused by thermal variations in a cargo tank in accordance with 4.1.2(a).

4.1.6 If cargo loading and ballasting or discharging of a cargo tank or cargo tank group, which is isolated from a common venting system is intended, that cargo tank or cargo tank group is to be fitted with a means for over-pressure or under-pressure protection as required in 4.1.2(c).

4.1.7 The venting arrangements are to be connected to the top of each cargo tank and are to be self-draining to the cargo tanks under all normal conditions of trim and list of the ship. Where it may not be possible to provide self-draining lines permanent arrangements are to be provided to drain the vent lines to a cargo tank.

4.1.8 The venting system is to be provided with devices to prevent the passage of flame into the cargo tanks. The design, testing and locating of these devices are to comply with recognised International Standards.

4.1.9 Ullage openings are not to be used for pressure equalisation and they should be fitted with self-closing tightly sealing covers. Flame arrestors and screens are not permitted in these openings.

4.1.10 Provision is to be made to guard against liquid rising in the venting system to a height which would exceed the design head of cargo tanks. This is to be accomplished by overflow control systems, or other equivalent means, e.g., overfill alarms, together with gauging devices and cargo tank filling procedures but not spill valves which are not considered equivalent to an overflow system. The system for guarding against liquid rising to a height which would exceed the design head of cargo tanks is to be independent of the gauging devices.

4.1.11 Openings for pressure release required by 4.1.2(a) are to:

(a) have as great a height as is practicable above the cargo tank deck to obtain maximum dispersal of flammable vapours but in no case less than 2 m above the cargo tank deck, and
(b) be arranged at the furthest distance practicable but not less than 5 m from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery, chain locker openings and equipment which may constitute an ignition hazard.

4.1.12 Pressure/vacuum valves required by 4.1.2(a) may be provided with a by-pass arrangement when they are located in a vent main or masthead riser. Where such an arrangement is provided there are to be suitable indicators to show whether the by-pass is open or closed.

4.1.13 Vent outlets for cargo loading, discharging and ballasting required by 4.1.2(b) are to:

(a) permit the free flow of vapour mixtures or alternatively, permit the throttling of the discharge of the vapour mixtures to achieve a velocity of not less than 30 m/sec;
(b) be so arranged that the vapour mixture is discharged vertically upwards;
(c) where the method is by free flow of vapour mixtures, be such that the outlet is not less than 6 m above the cargo tank deck or fore and aft gangway if situated within 4 m of the gangway and located not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery, chain locker openings and equipment which may constitute an ignition hazard;
(d) where the method is by high velocity discharge, be located at a height not less than 2 m above the cargo tank deck and not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery, chain locker openings and equipment which may constitute an ignition hazard. These outlets are to be provided with high velocity devices of an approved type; and
(e) be designed on the basis of the maximum designed loading rate multiplied by a factor of at least 1,25 to take account of gas evolution, in order to prevent the pressure in any cargo tank from exceeding the design pressure. The master is to be provided with information regarding the maximum permissible loading rate for each cargo tank and in the case of combined venting systems, for each group of cargo tanks.

4.1.14 Pressure/vacuum valves are to be set at a positive pressure of not more than 0,2 bar (0,2 kgf/cm^2) above atmospheric and a negative pressure of not more than 0,07 bar (0,07 kgf/cm^2) below atmospheric. Higher positive pressures not exceeding 0,7 bar (0,7 kgf/cm^2) gauge may be permitted in specially designed integral tanks.

4.1.15 In combination carriers the arrangements to isolate slop tanks containing oil or residues from other cargo tanks are to consist of blank flanges which will remain in position at all times when cargoes other than liquid cargoes referred to in 7.5.16 are carried.

4.2 Cargo tank purging and/or gas-freeing

4.2.1 Arrangements for purging and/or gas-freeing are to be such as to minimise the hazards due to the dispersal of flammable vapours in the atmosphere and to flammable mixtures in cargo tank, thus the requirements of 4.2.2 to 4.2.4 are to be complied with, as applicable.

4.2.2 When the ship is provided with an inert gas system the cargo tanks are first to be purged in accordance with the provisions of 7.6.2 until the concentration of hydrocarbon vapours in the cargo tanks has been reduced to less than two per cent by volume. Thereafter gas freeing may take place at the cargo tank deck level.

4.2.3 When the ship is not provided with an inert gas system, the operation is to be such that the flammable vapour is initially discharged either:

(a) through the vent outlets as specified in 4.1.13, or
(b) through outlets at least 2 m above the cargo tank deck level with a vertical efflux velocity of at least 30 m/sec. maintained during gas freeing operation, or
(c) through outlets at least 2 m above the cargo tank deck level with a vertical efflux velocity of at least 20 m/sec. and which are protected by suitable devices to prevent the passage of flame.

4.2.4 When the flammable vapour concentration at the outlet has been reduced to 30 per cent of the lower flammable limit, gas-freeing may thereafter be continued at the cargo tank deck level.

4.3 Venting, purging and gas measurement of double hull and double bottom spaces

4.3.1 Double hull and double bottom spaces are to be fitted with suitable connections for the supply of air.

4.3.2 On tankers required to be fitted with inert gas systems:

(a) double hull spaces are to be fitted with suitable connections for the supply of inert gas;
(b) where such spaces are connected to a permanently fitted inert gas distribution system means are to be provided to prevent hydrocarbon gases from the cargo tanks entering the double hull spaces through the system;
(c) where such spaces are not permanently connected to an inert gas distribution system, appropriate means are to be provided to allow connection to the inert gas main.

4.3.3 When selecting portable instruments for measuring oxygen and flammable vapour, due attention is to be given to their use in combination with the fixed gas sampling line systems referred to in 4.3.4.

4.3.4 Where the atmosphere in double hull spaces cannot be reliably measured using flexible gas sampling hoses, such spaces are to be fitted with permanent gas sampling lines. The configuration of such line systems is to be adapted to the design of such spaces.

4.3.5 The materials of construction and the dimensions of gas sampling lines are to be such as to prevent restriction. Where plastics materials are used, they are to be electrically conductive.

4.4 Gas measurement

4.4.1 All tankers are to be equipped with at least two portable instruments for measuring per cent LEL of hydrocarbon concentrations in air.

4.4.2 All tankers are to be equipped with at least two portable oxygen analysers.

4.4.3 For tankers fitted with an inert gas system two portable gas detectors capable of measuring flammable vapour concentrations in inerted atmospheres are to be provided, *see* 7.8.7.

4.4.4 Suitable means are to be provided for the calibration of gas measurement instruments.

■ *Section 5* Cargo tank level gauging equipment

5.1 General

5.1.1 Each cargo tank is to be fitted with suitable means for ascertaining the liquid level in the tank in accordance with the requirements of 5.2 and 5.3.

5.2 Restricted sounding device

5.2.1 Sounding pipes or other approved devices, which may permit a limited amount of vapour to escape to atmosphere when being used, would be accepted for those tanks which are not required to be fitted with closed sounding devices, *see* 5.3. The devices are to be so designed as to minimise the sudden release of vapour or liquid under pressure and the possibility of liquid spillage on deck. Means are also to be provided for relieving tank pressure before the device is operated.

5.2.2 Separate ullage openings may be fitted as a reserve means for sounding cargo tanks.

5.2.3 Arrangements which permit the escape of vapour to the atmosphere are not to be fitted in enclosed spaces.

5.3 Closed sounding devices

5.3.1 In all tankers fitted with a fixed inert gas system, the cargo tanks are to be fitted with closed sounding devices of an approved type, which do not permit the escape of cargo to the atmosphere when being used.

5.3.2 Proposals to use indirect sounding or measuring devices which do not penetrate the tank plating will be specially considered.

■ *Section 6* Cargo heating arrangements

6.1 General

6.1.1 Where heating systems are provided for the cargo tanks, the arrangements are to comply with the requirements of 6.2 to 6.5.

6.2 Blanking arrangements

6.2.1 Spectacle flanges of spool pieces are to be provided in the heating medium supply and return pipes to the cargo heating system, at a suitable position within the cargo area, so that lines can be blanked off in circumstances where the cargo does not require to be heated or where the heating coils have been removed from the tanks. Alternatively, blanking arrangements may be provided for each tank heating circuit.

6.3 Heating medium

6.3.1 Where a combustible liquid is used as the heating medium it is to have a flash point of 60°C or above (closed-cup test).

6.3.2 In general, the temperature of the heating medium is not to exceed 220°C, *see* 1.5.

6.4 Heating circuits

6.4.1 The heating medium supply and return lines are not to penetrate the cargo tank plating, other than at the top of the tank, and the main supply lines are to be run above the weather deck.

6.4.2 Isolating shut-off valves or cocks are to be provided at the inlet and outlet connections to the heating circuit(s) of each tank, and means are to be provided for regulating the flow.

6.4.3 Where steam or water is employed in the heating circuits, the returns are to be led to an observation tank which is to be in a well ventilated and well lighted part of the machinery space remote from the boilers.

6.4.4 Where a thermal oil is employed in the heating circuits, the arrangements will be specially considered but, in any case, they are to be such that contamination of the thermal oil with cargo liquid cannot take place under normal operating conditions. In general, the arrangements are, at least, to comply with 3.7.8, in so far as they are applicable.

6.4.5 In any heating system, a higher pressure is to be maintained within the heating circuit than the maximum pressure head which can be exerted by the contents of the cargo tank on the circuit. Alternatively, when the heating circuit is not in use, it may be drained and blanked.

6.5 Temperature indication

6.5.1 Means are to be provided for measuring the cargo temperature. Where overheating could result in a dangerous condition, an alarm system which monitors the cargo temperature is to be provided.

■ *Section 7* Inert gas systems

7.1 General

7.1.1 The following requirements apply where an inert gas system, based on flue gas, is fitted on board ships intended for the carriage of oil in bulk having a flash point not exceeding 60°C (closed-cup test). For inert gas systems utilising nitrogen, additional requirements contained in 7.10 are to be applied.

7.1.2 Ships complying with these requirements will be eligible for the additional notation **IGS** in the *Register Book*, *see* Pt 1, Ch 2.

7.1.3 Throughout this Section the term ‘cargo tank’ includes also ‘slop tanks’. For definition of Machinery spaces of Category ‘A’, *see* SOLAS Reg. II-2/A.

7.1.4 The inert gas system is to comply with the requirements of Chapter 15 of the FSS Code, insofar as they are applicable, to new ships only. For the purposes of classification any use of the word ‘Administration’ in the Regulation is to be taken as meaning LR.

7.1.5 Those parts of scrubbers, blowers, non-return devices, scrubber effluent and other drain pipes which may be subjected to corrosive action by the gases and/or liquids, are to be either constructed of corrosion resistant material or lined with rubber, glass fibre epoxy resin or other equivalent coating material.

7.1.6 The compartment in which any oil fired inert gas generator is situated is to be treated as a machinery space of Category A with respect to fire protection, *see also* Ch 1,4.8.

7.1.7 Arrangements are to be made to vent the inert gas from oil fired inert gas generators to the atmosphere when predetermined limits are reached, *see* 7.8.9(a) to (d), e.g., during start-up or in the event of equipment failure.

7.1.8 Automatic shut-down of the oil fuel supply to inert gas generators is to be arranged on predetermined limits being reached with respect to low water pressure or low water flow rate to the cooling and scrubbing arrangement and with respect to high gas temperature.

7.1.9 Automatic shut-down of the gas regulating valve is to be arranged with respect to failure of the power supply to the oil fired inert gas generators.

7.2 Gas supply

7.2.1 The inert gas may be treated flue gas from the main or auxiliary boiler(s), gas turbine(s), or from a separate inert gas generator. In all cases, automatic combustion control, capable of producing suitable inert gas under all service conditions, is to be fitted.

7.2.2 Two oil fuel pumps are to be fitted to the inert gas generator. One fuel pump only may be accepted provided sufficient spares for the oil fuel pump and its prime mover are carried on board to enable any failure of the oil fuel pump and its prime mover to be rectified by the ship’s crew.

7.2.3 The inert gas system is to be capable of:

(a) inerting empty cargo tanks by reducing the oxygen content of the atmosphere in each tank to a level at which combustion cannot be supported;

(b) maintaining the atmosphere in any part of any cargo tank with an oxygen content not exceeding eight per cent by volume and at a positive pressure at all times in port and at sea except when it is necessary for such a tank to be gas free;

(c) eliminating the need for air to enter a tank during normal operations except when it is necessary for such a tank to be gas free;
(d) purging empty cargo tanks of hydrocarbon gas, so that subsequent gas freeing operations will at no time create a flammable atmosphere within the tank.

7.2.4 The system is to be capable of delivering inert gas to the cargo tanks at a rate of at least 125 per cent of the maximum rate of discharge capacity of the ship expressed as a volume to time rate.

7.2.5 The system is to be capable of delivering inert gas with an oxygen content of not more than five per cent by volume in the inert gas supply main to the cargo tanks at any required rate of flow.

7.2.6 Flue gas isolating valves are to be fitted in the inert gas supply mains between the boiler uptakes and the flue gas scrubber. These valves are to be provided with indicators to show whether they are open or shut, and precautions are to be taken to maintain them gastight and keep the seatings clear of soot. Arrangements are to be made to ensure that boiler soot blowers cannot be operated when the corresponding flue gas valve is open.

7.3 Gas scrubber

7.3.1 A flue gas scrubber is to be fitted which will effectively cool the volume of gas specified in 7.2.4 and remove solids and sulphur combustion products. The cooling water arrangements are to be such that an adequate supply of water will always be available without interfering with any essential services on the ship. Provision is also to be made for alternative supply of cooling water.

7.3.2 Filters or equivalent devices are to be fitted to minimise the amount of water carried over to the inert gas blowers.

7.3.3 The scrubber is to be located aft of all cargo tanks, cargo pump-rooms and cofferdams separating these spaces from machinery spaces of Category A.

7.4 Gas blowers

7.4.1 At least two blowers are to be fitted which together are capable of delivering to the cargo tanks at least the volume of gas required by 7.2.4. In no case is one of these blowers to have a capacity less than one-third of the total capacity required. In a system with gas generators one blower only may be accepted if that system is capable of delivering the total volume of gas required by 7.2.4 to the protected cargo tanks, provided that sufficient spares for the blower and its prime mover are carried on board to enable any failure of the blower and its prime mover to be rectified by the ship's crew.

7.4.2 The inert gas system is to be so designed that the maximum pressure which it can exert on any cargo tank will not exceed the test pressure of any cargo tank. Suitable shut-off arrangements are to be provided on the suction and discharge connections of each blower. Arrangements are to be provided to enable the functioning of the inert gas plant to be stabilised before commencing cargo discharge. If the blowers are to be used for gas freeing, their air inlets are to be provided with blanking arrangements.

7.4.3 The blowers are to be located aft of all cargo tanks, cargo pump-rooms and cofferdams separating these spaces from machinery spaces of Category A.

7.5 Gas distribution lines

7.5.1 Special consideration is to be given to the design and location of scrubber and blowers with relevant piping and fittings in order to prevent flue gas leakages into enclosed spaces.

7.5.2 To permit safe maintenance, an additional water seal or other effective means of preventing flue gas leakage is to be fitted between the flue gas isolating valves and scrubber or incorporated in the gas entry to the scrubber.

7.5.3 A gas regulating valve is to be fitted in the inert gas supply main. This valve is to be automatically controlled to close as required in 7.8.11 and 7.8.12. It is also to be capable of automatically regulating the flow of inert gas to the cargo tanks unless means are provided to automatically control the speed of the inert gas blowers required in 7.4.1.

7.5.4 The valve referred to in 7.5.3 is to be located at the forward bulkhead of the forwardmost gas safe space through which the inert gas supply main passes.

7.5.5 At least two non-return devices, one of which is to be a water seal, are to be fitted in the inert gas supply main, in order to prevent the return of hydrocarbon vapour to the machinery space uptakes or to any gas safe spaces under all normal conditions of trim, list and motion of the ship. They are to be located between the automatic valve required by 7.5.3 and the aftermost connection to any cargo tank or cargo pipeline.

7.5.6 The devices referred to in 7.5.5 are to be located in the cargo area on deck.

7.5.7 The water seal referred to in 7.5.5 is to be capable of being supplied by two separate pumps, each of which is to be capable of maintaining an adequate supply at all times.

7.5.8 The arrangement of the seal and its associated fittings is to be such that it will prevent backflow of hydrocarbon vapours and will ensure the proper functioning of the seal under operating conditions.

7.5.9 Provision is to be made to ensure that the water seal is protected against freezing in such a way that the integrity of seal is not impaired by overheating.

7.5.10 A water loop or other approved arrangement is also to be fitted to each associated water supply and drain pipe and each venting or pressure-sensing pipe leading to gas safe spaces. Means are to be provided to prevent such loops from being emptied by vacuum.

7.5.11 The deck water seal and all loop arrangements are to be capable of preventing return of hydrocarbon vapours at a pressure equal to the test pressure of the cargo tanks.

7.5.12 The second non-return device is to be a non-return valve or equivalent capable of preventing the return of vapours or liquids and fitted forward of the deck water seal required in 7.5.5. It is to be provided with positive means of closure. As an alternative to positive means of closure, an additional valve having such means of closure may be provided forward of the non-return valve to isolate the deck water seal from the inert gas main to the cargo tanks.

7.5.13 As an additional safeguard against the possible leakage of hydrocarbon liquids or vapours back from the deck main, means are to be provided to permit this section of the line between the valve having positive means of closure referred to in 7.5.12 and the valve referred to in 7.5.3 to be vented in a safe manner when the first of these valves is closed.

7.5.14 The inert gas main may be divided into two or more branches forward of the non-return devices required by 7.5.5.

7.5.15 The inert gas supply mains are to be fitted with branch piping leading to each cargo tank. Branch piping for inert gas is to be fitted with either stop valves or equivalent means of control for isolating each tank. Where stop valves are fitted, they are to be provided with locking arrangements, which are to be under the control of a responsible ship's officer. The method of control is to provide positive indication of the operational status of such valves.

7.5.16 In combination carriers, the arrangement to isolate the slop tanks containing oil or oil residues from other tanks is to consist of blank flanges which will remain in position at all times other than when cargoes other than oil are being carried except as provided for in 1.9.

7.5.17 Means are to be provided to protect cargo tanks against the effect of over-pressure or vacuum caused by thermal variations when the cargo tanks are isolated from the inert gas mains.

7.5.18 Piping systems are to be so designed as to prevent the accumulation of cargo or water in the pipelines under all normal conditions.

7.5.19 Arrangements are to be provided to enable the inert gas main to be connected to an external supply of inert gas. The arrangement is to consist of a 250 mm nominal size pipe bolted flange connection, isolated from the inert gas main by a valve and connected to the system forward of the non-return valve referred to in 7.5.12.

7.6 Venting arrangements

7.6.1 The arrangements for the venting of all vapours displaced from the cargo tanks during loading and ballasting are to comply with Section 4 and are to consist of either one or more mast risers, or a number of high velocity vents. The inert gas supply mains may be used for such venting.

7.6.2 The arrangements for inerting, purging or gas freeing of empty tanks as required in 7.2.3 are to be such that the accumulation of hydrocarbon vapours in pockets formed by the internal structural members in a tank is minimised and that:

(a) on individual cargo tanks the gas outlet pipe, if fitted, is to be positioned as far as practicable from the inert gas/air inlet and in accordance with Section 4. The inlet of such outlet pipes may be located either at deck level or at not more than 1 m above the bottom of the tank;

(b) the cross sectional area of such gas outlet pipes referred to in (a) is to be such that an exit velocity of at least 20 m/s can be maintained when any three tanks are being simultaneously supplied with inert gas. Their outlets are to extend not less than 2 m above deck level;

(c) each gas outlet referred to in (b) is to be fitted with suitable blanking arrangements;

(d) if a connection is fitted between the inert gas supply mains and the cargo piping system, arrangements are to be made to ensure an effective isolation having regard to the large pressure difference which may exist between the systems. This is to consist of two shut-off valves with an arrangement to vent the space between the valves in a safe manner or an arrangement consisting of a spool-piece with associated blanks. The valve separating the inert gas supply main from the cargo main and which is on the cargo main side is to be a non-return valve with a positive means of closure.

7.6.3 One or more pressure-vacuum breaking devices are to be provided to prevent the cargo tanks from being subject to:

(a) a positive pressure in excess of the test pressure of the cargo tank if the cargo were to be loaded at the maximum rated capacity and all other outlets were left shut; and

(b) a negative pressure in excess of 700 mm water gauge if cargo were to be discharged at the maximum rated capacity of the cargo pumps and the inert gas blowers were to fail.

Such devices shall be installed on the inert gas main unless they are installed in the venting system required by Section 4 or on individual cargo tanks.

7.6.4 The location and design of the devices referred to in 7.6.3 are to be in accordance with Section 4.

7.7 Unattended machinery

7.7.1 Where inert gas generators are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by 7.7.2, 7.7.3, 7.8 and 7.10, as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

7.7.2 Where machinery is arranged to start automatically or from a remote control station, interlocks are to be provided to prevent start-up under conditions which could hazard the machinery.

7.7.3 Where machinery specified in 7.7.1 and 7.7.2 is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

7.8 Instrumentation and alarms

7.8.1 Alarms and safeguards are indicated in 7.8.2 to 7.8.17 and Table 15.7.1.

7.8.2 Inert gas generators are to be fitted with an automatic combustion control system so as to maintain steady state conditions throughout the operating range of the generator.

7.8.3 Means are to be provided for continuously indicating the temperature and pressure of the inert gas at the discharge side of the gas blowers, whenever the gas blowers are operating.

7.8.4 Instrumentation is to be fitted for continuously indicating and permanently recording, when the inert gas is being supplied:

(a) the pressure of the inert gas supply mains forward of the non-return devices required by 7.5.5; and

(b) the oxygen content of the inert gas in the inert gas supply mains on the discharge side of the gas blowers.

7.8.5 The devices referred to in 7.8.4 are to be placed in the cargo control room where provided. But where no cargo control room is provided, they are to be placed in a position easily accessible to the officer in charge of cargo operations.

7.8.6 In addition to 7.8.4, meters are to be fitted:

(a) in the navigating bridge to indicate at all times the pressure referred to in 7.8.4(a) and the pressure in the slop tanks of combination carriers, whenever those tanks are isolated from the inert gas supply main; and

(b) in the machinery control room or in the machinery space to indicate the oxygen content referred to in 7.8.4(b).

7.8.7 Portable instruments for measuring oxygen and flammable vapour concentration are to be provided. In addition, suitable arrangement is to be made on each cargo tank such that the condition of the tank atmosphere can be determined using these portable instruments.

Table 15.7.1 Inert gas systems – Alarms and safeguards

Item	Alarm	Note
Water pressure or water flow to flue gas scrubber	Low	1, 2, 3
Water level in flue gas scrubber	High	1, 2, 3
Inert gas temperature from inert gas blowers	High	1, 2, 3
Inert gas blower operation	Failure	4
Oxygen content of gas in excess of 5%	High	5, 6
Power supply to automatic control system for inert gas regulating valve and indicating devices	Failure	5
Water level in inert gas system water seal	Low	7
Inert gas pressure discharge from inert gas blowers less than 100 mm water gauge	Low	5, 8
Inert gas pressure	High	8
Combustion air pressure to oil burner	Low	3
Oil fuel pressure	Low	—
Oil fuel temperature or viscosity	High and Low	9
Burner flame and ignition	Failure	3
Cooling water temperature	High	—
Oil fuel supply	Insufficient	—
Power supply to inert gas generator	Failure	4
Automatic control system power supply	Failure	—

NOTES
1. Combustion spaces are to be purged automatically before re-ignition takes place in the event of a flame out on all burners.
2. Inert gas blowers to be shut down automatically and inert gas regulating valve is to be closed automatically.
3. Oil fuel to burner to be shut off automatically.
4. Inert gas regulating valve to be closed automatically.
5. To be fitted in the machinery space and cargo control room, where provided, *see* 7.8.14.
6. Operator is required to submit operational procedures for the suspension of cargo operations until inert gas quality is improved for review, *see* 7.8.17.
7. For dry and semi-dry water seals, *see* 7.8.15.
8. *See* 7.8.4(a).
9. Heavy oil only.
10. The Table contains the minimum list of alerts and shutdowns for an inert gas generator; additional alerts and shutdowns may be necessary as determined through risk-mitigating activities in response to the completed Risk-Based Analysis (e.g., FMECA) for the inert gas generator.

7.8.8 Suitable means are to be provided for the zero and span calibration of both fixed and portable gas concentration measurement instruments, referred to in 7.8.4, 7.8.6 and 7.8.7.

7.8.9 For inert gas systems of both flue gas type and the inert gas generator type audible and visual alarms are to be provided to indicate:

(a) low water pressure or low water flow rate to the flue gas scrubber as referred to in 7.3.1;
(b) high water level in the flue gas scrubber as referred to in 7.3.1;
(c) high gas temperature as referred to in 7.8.3;
(d) failure of the inert gas blowers referred to in 7.4;
(e) oxygen content in excess of eight per cent by volume as referred to in 7.8.4(b);
(f) failure of the power supply to the automatic control system for the gas regulating valve and to the indicating devices as referred to in 7.5.3 and 7.8.4;
(g) low water level in the water seal as referred to in 7.5.5;
(h) gas pressure less than 100 mm water gauge as referred to in 7.8.4(a). The alarm arrangements is to be such as to ensure that pressure in slop tanks in combination carriers can be monitored at all times; and
(j) high gas pressure as referred to in 7.8.4(a).

7.8.10 For inert gas systems of the inert gas generator type, additional audible and visual alarms are to be provided to indicate:

(a) insufficient oil fuel supply,
(b) failure of the power supply to the generator,
(c) failure of the power supply to the automatic control system for the generator.

See also Pt 6, Ch 1 for requirements for control, alarm and safety systems.

7.8.11 Automatic shutdown of the inert gas blowers and gas regulating valve is to be arranged on predetermined limits being reached in respect of (a), (b) and (c) of 7.8.9.

7.8.12 Automatic shut-down of the gas regulating valve is to be arranged in respect of 7.8.9(d).

7.8.13 In respect of 7.8.9(e), when the oxygen content of the inert gas exceeds eight per cent by volume, immediate action is to be taken to improve the gas quality. Unless the quality of the gas improves, all cargo tank operations are to be suspended so as to avoid air being drawn into the tanks and the isolation valve referred to in 7.5.12 is to be closed.

7.8.14 The alarms required in (e), (f) and (h) of 7.8.9 are to be fitted in the machinery space and cargo control room, where provided, but in each case in such a position that they are immediately received by responsible members of the crew.

7.8.15 In respect of 7.8.9(g), where a semi-dry or dry water seal is fitted, the arrangements are to be such that the maintenance of an adequate reserve of water will be ensured at all times and that the water seal will be automatically formed when the gas flow ceases. The audible and visual alarm on the low level of water in the water seal is to operate when the inert gas is not being supplied.

7.8.16 An audible alarm system independent of that required in 7.8.9(h) or automatic shut-down of cargo pumps is to be provided to operate on predetermined limits of low pressure in the inert gas mains being reached.

7.8.17 Detailed instruction manuals are to be provided on board, covering the operations, safety and maintenance requirements and occupational health hazards relevant to the inert gas system and its application to the cargo tank system. The manuals are to include guidance on procedures to be followed in the event of a fault or failure of the inert gas system.

7.9 Installation and tests

7.9.1 The inert gas system, including alarms and safety devices, is to be installed on board and tested under working conditions to the satisfaction of the Surveyors.

7.10 Nitrogen generator systems

7.10.1 The following requirements are specific only to the gas generator system and apply where inert gas is produced by separating air into its component gases by passing compressed air through a bundle of hollow fibres, semi-permeable membranes or adsorber materials.

7.10.2 Alarms and safeguards are indicated in 7.10.3 to 7.10.19 and Table 15.7.2.

7.10.3 Where nitrogen generator systems are provided in place of boiler flue gas or oil fired inert gas generators referred to in 7.1, the following requirements of Chapter 15 of the FSS Code remain applicable for the piping arrangements, alarms and instrumentation downstream of the gas generator: 2.3.1.3.1, 2.3.1.3.2, 2.3.1.5, 2.3.2, 2.4.2, 2.4.3.1.6, 2.4.3.1.8, 2.4.3.1.9, 2.4.3.3, 2.4.3.4, 2.4.4, as well as SOLAS Reg.II-2/4.5.3.4.2, 4.5.6.3 and 11.6.3.4.

7.10.4 A nitrogen generator consisting of a feed air treatment system and any number of membrane or adsorber modules in parallel is to be capable of delivering nitrogen to the cargo tanks at a rate of at least 125 per cent of the maximum discharge capacity of the ship expressed as a volume to time rate.

7.10.5 The air compressor and the nitrogen generator may be installed in the engine room or in a separate compartment, which may be treated as an 'other machinery space' with respect to fire protection.

7.10.6 Where a separate compartment is provided, it is to be positioned outside the cargo area and is to be fitted with an independent mechanical extraction ventilation system providing at least 6 air changes per hour. The compartment is to have no direct access to accommodation spaces, service spaces and control stations, and is to be provided with oxygen level detection equipment with a low oxygen level alarm.

Table 15.7.2 Nitrogen generator systems – Alarms and safeguards

Item	Alarm	Note
Feed air pressure from air compressor	Low	1, 4
Air compressor discharge temperature	High	1, 4
Water level in condensate drain separator	High	1, 4
Electric heater (where fitted)	Failure	1, 4
Oxygen content	High	1, 2, 4
Power supply to oxygen content monitoring instrumentation downstream of Nitrogen generator	Failure	1, 3

NOTES
1. To be fitted in the machinery space and cargo control room, where provided, *see* 7.8.14.
2. Oxygen content not to exceed 5% with automatic discharge to atmosphere where this is exceeded, *see* 7.10.7.
3. *See* 7.10.15.
4. Automatic shutdown of inert gas generating system.
5. The Table contains the minimum list of alerts and shutdowns for an inert gas generator; additional alerts and shutdowns may be necessary as determined through risk-mitigating activities in response to the completed Risk-Based Analysis (e.g., FMECA) for the inert gas generator.

7.10.7 The nitrogen generator is to be capable of delivering high purity nitrogen with oxygen content not exceeding 5 per cent by volume. The system is to be fitted with automatic means to discharge gas to the atmosphere during start-up and abnormal operation when predetermined limits are reached, *see* 7.10.17(a) to (e).

7.10.8 The system is to be provided with two air compressors. The total required capacity of the system is preferably to be divided equally between the two compressors, and in no case is one compressor to have a capacity less than 1/3 of the total capacity required. A system with one air compressor only may be accepted provided that sufficient spares for the air compressor and its prime mover are carried on board to enable their failure to be rectified by the ship's crew.

7.10.9 A feed air treatment system is to be fitted to remove free water, particles and traces of oil from the compressed air, and to maintain the specification temperature.

7.10.10 Where a nitrogen receiver/buffer tank is required to be fitted it may be installed in a dedicated compartment or in the separate compartment containing the air compressor and the generator or may be located in the cargo area. Where the nitrogen receiver/buffer tank is installed in an enclosed space, the access is to be arranged from the open deck only and the access door is to open outwards. Permanent ventilation and alarm arrangements are to be fitted as required by 7.10.6.

7.10.11 The oxygen-enriched air from the nitrogen generator and the nitrogen-product enriched gas from the protective devices of the nitrogen receiver are to be arranged to discharge to a safe location on the open deck. This safe location needs to address the two types of discharges separately.
For oxygen-enriched air from the nitrogen generator, safe locations on the open deck are:
- outside of hazardous areas as defined by Pt 6, Ch 2,13.5;
- not within 3 m of areas traversed by personnel;
- not within 6 m of air intakes for machinery and all ventilation inlets.

For nitrogen-product enriched gas from the protective devices of the nitrogen receiver, safe locations on the open deck are:
- not within 3 m of areas traversed by personnel;
- not within 6 m of air intakes for machinery and all ventilation inlets/outlets.

7.10.12 In order to permit maintenance, means of isolation are to be fitted between the generator and the receiver.

7.10.13 At least two non-return devices are to be fitted in the inert gas supply main, one of which is to be of the double block and bleed arrangement. The second non-return device is to be equipped with positive means of closure.

7.10.14 Instrumentation is to be provided for continuously indicating the temperature and pressure of air:
(a) at the discharge of the compressor,
(b) at the inlet to the nitrogen generator.

7.10.15 Instrumentation is to be fitted for continuously indicating and permanently recording the oxygen content of the inert gas downstream of the nitrogen generator when inert gas is being supplied.

7.10.16 The instrumentation referred to in 7.10.15 is to be placed in the cargo control room where provided. Where no cargo control room is provided, the instrumentation is to be placed in a position easily accessible to the officer in charge of cargo operations.

7.10.17 Audible and visual alarms are to be provided to indicate:
(a) low feed-air pressure from compressor as referred to in 7.10.14(a),
(b) high air temperature as referred to in 7.10.14(a),
(c) high condensate level at automatic drain of water separator as referred to in 7.10.9,
(d) failure of electrical heater, if fitted,
(e) oxygen content in excess of that required in 7.10.7,
(f) failure of power supply to the instrumentation as referred to in 7.10.15.

7.10.18 Automatic shut-down of the system is to be arranged upon alarm conditions as required by 7.10.17(a) to (e).

7.10.19 The alarms required by 7.10.17(a) to (f) are to be fitted in the machinery space and cargo control room, where provided, but in each case in such a position that they are immediately received by responsible members of the crew.

7.11 Nitrogen/inert gas systems fitted for purposes other than inerting required by SOLAS Reg. II-2/4.5.5.1.1

7.11.1 This section applies to systems fitted on oil tankers of less than 20000 DWT.

7.11.2 The requirements of 7.10 apply except paragraphs 7.10.1, 7.10.3, 7.10.4 and 7.10.8.

7.11.3 Where the connections to the cargo tanks, to the hold spaces or to cargo piping are not permanent, the non-return devices required by 7.10.13 may be substituted by two non-return valves.

■ *Cross-reference*

For vapour detection, *see also* Ch 13,2 of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquid Chemicals in Bulk.*

■ *Section 1* Scope

1.1 General

1.1.1 For the purposes of these Rules, a water jet propulsion unit is described as a machine which takes in water, by means of a suitable inlet and conduit and accelerates the mass of water using an impeller and nozzle to form a jet propulsion system. The water jet system comprises the unit and its associated actuation and control devices. The detail of the prime mover is excluded but not its effect on the water jet system.

1.1.2 This Chapter defines the requirements for the design and service life of marine water jet propulsion systems and is to be read in conjunction with the General Requirements for the Design and Construction of Machinery in Chapter 1.

1.1.3 The requirements for a fixed or steerable water jet propulsion system rated at 500 kW and above, which is integral with the ship's hull structure and forms a means of main propulsion, are detailed in this Chapter. This includes support arrangements, controls and the systems necessary to maintain operation and functionality of the water jet unit.

1.1.4 These requirements relate to water jets driven by axial or mixed flow pumps. Where units driven by radial flow pumps or inducers are proposed, details are to be submitted for consideration.

■ *Section 2* General requirements

2.1 Water jet arrangement

2.1.1 In general, for a ship to be assigned an unrestricted service notation, a minimum of two water jet systems are to be provided where these form the sole means of propulsion. For ships where a single water jet system is the sole means of propulsion or steering, a detailed engineering and safety justification is to be evaluated by LR, *see* 2.3.22. This evaluation process will include a risk assessment analysis using a recognised technique to verify that sufficient levels of redundancy and monitoring are incorporated in the water jet unit's essential support systems and operating equipment.

2.1.2 Water jet propulsion units are to be capable of continuous operation between their maximum and minimum output power rating at specified operating conditions, *see* Ch 1,3 and within the operational service profiles defined by 2.3.11 and 2.3.12.

2.1.3 It is the Shipbuilder's responsibility to ensure that all of the installed equipment is suitable for operation in the location and under the environmental conditions defined in Chapter 1. Where anticipated environmental conditions are outside these limits or where additional conditions are to be considered, such as vibration and impulsive accelerations, requirements and details of compliance are to be submitted to LR.

2.2 Plans to be submitted

2.2.1 Plans, in triplicate, and information as detailed below and in 2.3 and 2.4, are to be submitted for consideration.

2.2.2 General arrangement plans showing details of the following:
(a) Shafting assembly indicating bearing positions.
(b) Steering assembly.
(c) Reversing assembly.
(d) Shaft sealing arrangement assembly.
(e) Longitudinal section of the complete water jet unit.

2.2.3 Detailed and dimensioned plans indicating scantlings, materials of construction and where applicable surface finish of the following:
(a) Arrangement of the system, including the intended method of attachment to the hull and building-in, tunnel geometry, shell openings, method of stiffening, reinforcement, etc.
(b) All torque transmitting components, including the shafting system, impeller and stator if fitted.
(c) Steering components, together with a description and line diagram of the control circuit. This is to include steerable exit water jet nozzles where fitted.
(d) Components of the retractable buckets where these are used for providing astern thrust.
(e) The bearing or bearings absorbing the thrust and supporting the impeller, together with the method of lubrication.
(f) Details of any shafting support or guide vanes used in the water jet system.

2.2.4 Schematic plans of the lubrication and hydraulics required for steering/reversing systems, together with pipe material, relief valves and the working pressures required.

2.3 Calculations and information

2.3.1 Strength calculations based on fatigue considerations incorporating the maximum continuous torque rating and the most 'onerous' operating condition, *see* 2.3.12, including any short-term high power operation, and including the effects of mean and fluctuating loads, transitory loadings, residual stress allowances, and stress raisers, for the following components:

(a) Impeller, stator and any bolting arrangements supporting propulsion or steering loads.
(b) Shaft supports and coupling arrangements.
(c) Inlet guide vanes, if fitted.
(d) Steering components, including the lugs of steerable nozzles where fitted.
(e) Retractable buckets and associated mechanisms which are used to provide astern thrust. A calculation of the hydrodynamic transient loads is to be made for each design and is to include the full ahead to full astern condition. The calculation procedure used is to be supported, where possible, with full scale or model test data, or satisfactory service experience, to validate the design method.

2.3.2 Calculations supporting the connection method of the impeller to the shaft, including details of the fit, push-up, securing, bolting arrangements, etc. In addition, where lengths of shafts are joined using couplings of the shrunk element type, full particulars of the method of achieving the grip force.

2.3.3 Calculations relating to the design of the shaftline as evidence of compliance with Chapter 6.

2.3.4 Torsional vibration calculations of the complete dynamic system in accordance with the relevant requirements included in Chapter 8.

2.3.5 Shaft lateral vibration calculations where required by Chapter 8.

2.3.6 Calculations of the tunnel strength and supporting structure.

2.3.7 A calculation to determine the stresses within the impeller blade.

2.3.8 A calculation of the blade natural frequency for the impeller blades.

2.3.9 A calculation of the relative blade passing frequency between the rotor and stator blades.

2.3.10 The value of the fluctuating stresses during one revolution of the impeller and from transient loadings.

2.3.11 Details of the power/speed range of operation, indicating the maximum continuous torque rating, together with the associated thrusts; this information may be presented in the form of a characteristic curve for the water jet.

2.3.12 The water jet thrust for the assessment of the strength condition being considered is to be as follows:

(a) For ships which are intended to operate predominantly in a free-running condition and at steady service conditions, the water jet thrust is to correspond to the absorption of the maximum continuous shaft power and corresponding revolutions per minute, giving the maximum torque for which the shaft system is approved.
(b) For ships which are designed for several operating conditions, the maximum thrust associated with these conditions and the absorption of the corresponding power, in addition to the maximum continuous powering condition, are to be used in the calculation.
(c) The justification for the thrust selected is to be submitted for consideration in the approval process and this is to include the ship type and the ship speed at the conditions considered.

2.3.13 A justification that the water jet system will meet the self-priming criteria, *see* 3.1.6.

2.3.14 Specifications of materials and NDE procedures for components essential for propulsion and steering operation and, in the case of the impeller and stator, the yield strength and the fatigue characteristics of the material intended for their manufacture.

2.3.15 A detailed weld specification where an impeller has welded blades.

2.3.16 Full details of the means of corrosion protection in the case of carbon or carbon manganese steel shafts. Alternatively, where it is proposed to use composite shafts, details of the connections at flanges, materials, resin, lay-up procedures, quality control procedures and documentary evidence of fatigue endurance strength is to be provided.

2.3.17 Dry impeller mass and polar moment of inertia.

2.3.18 The prime mover type and designation.

2.3.19 Details of the control engineering aspects of the system design in accordance with Pt 6, Ch 1.

2.3.20 The tolerance specification, agreed between the manufacturer and the Shipbuilder or Owner, to which the components of the unit are to be manufactured is to be defined, together with a justification.

2.3.21 Details of the water jet's loading reactions together with the positions of application within the hull and is to include the maximum applied thrust, tunnel pressures, moments and forces imposed on the ship.

2.3.22 The water jet unit's rated flow and head.

2.3.23 Where an engineering and safety justification report is required, the following supporting information is to be submitted:

- A Failure Mode and Effects Analysis report (FMEA), *see* 2.4.
- Design standards and assumptions.
- Limiting operating parameters.
- A statement and evidence in respect of the anticipated reliability of any non-duplicated components.

2.3.24 Recommended installation, inspection, maintenance and component replacement procedures. This is to include any in-water engineering procedures where recommended by the water jet manufacturer.

2.3.25 All transient loads which the steering unit is likely to experience from manoeuvring, accelerating, decelerating and the sea conditions.

2.4 Failure Mode and Effects Analysis (FMEA)

2.4.1 An FMEA is to be carried out where a single water jet system is the ship's sole means of propulsion, *see* 2.2.3. The FMEA is to identify components where a single failure could cause the loss of all propulsion and/or steering capability, and the proposed arrangements for preventing and mitigating the effects of such a failure.

2.4.2 The FMEA is to be carried out using the format presented in Table 22.2.1 in Chapter 22 or an equivalent format that addresses the same reliability issues. Analyses in accordance with IEC 60812 *Analysis for System Reliability – Procedure for Failure Mode and Effects Analysis*, or the IMO Code of Safety for High Speed Craft, 2000, Annex 4 – *Procedures for Failure Mode and Effects Analysis*, would be acceptable.

2.4.3 The FMEA is to be organised in terms of equipment and function. The effects of item failures at a stated level and at higher levels are to be analysed to determine these effects on the system as a whole. Actions for mitigation of the effects of failure are to be determined, *see* 2.4.1.

2.4.4 The FMEA is to:

(a) identify the equipment or sub-system and mode of operation;
(b) identify potential failure modes and their causes;
(c) evaluate the effects on the system of each failure mode;
(d) identify measures for reducing the risks associated with each failure mode;
(e) identify measures for preventing failure; and
(f) identify trials and testing necessary to prove conclusions.

2.4.5 At sub-system level it is acceptable, for the purpose of these Rules, to consider failure of equipment items and their functions. It is not required that the failure of components within that equipment item be analysed, *see* Ch 22,2.1.5.

2.4.6 Where a FMEA is used for consideration of systems that depend on software-based functions for control or co-ordination, the analysis is to investigate failure of the functions rather than a specific analysis of the software code itself.

■ *Section 3* Design requirements

3.1 General

3.1.1 The arrangement of water jet units is to be such that the ship can be satisfactorily manoeuvred to a declared performance capability. The operating conditions covered are to include the following:

(a) Maximum continuous shaft power/speed to the impeller in the ahead condition at the declared steering angles and conditions.
(b) Manoeuvring speeds of the impeller shaft and/or reversing mechanism in the ahead and astern direction at the declared steering angles and sea conditions.
(c) The stopping manoeuvre described in Ch 1,5.2.2(b).
(d) Astern running conditions for the ship.

3.1.2 The mean loadings are those loadings induced by the water jet absorbing the mean torque supplied by the prime mover.

3.1.3 Fluctuating loads are defined as those loads which occur during one revolution of the impeller due to cyclic variations. For example, the spatial flow variations and torsional vibration at nominally steady state operating conditions.

3.1.4 Transient loads are defined as those loadings resulting from acceleration and deceleration of the ship, manoeuvring, seaway conditions and other similar forms of loading. This also includes any significant back-pressure effects developed from the operation of the reversing bucket, if fitted.

3.1.5 To ensure self-priming of the water jet unit, the shaft centreline of the unit is to be lower than the light draught static waterline of the ship. In cases where this is either impracticable or undesirable, the distance of the impeller shaft centreline above the ship's light draught waterline is to be less than or equal to 10 per cent of the pump inlet diameter.

3.1.6 Provision is to be made to allow for the in-service visual inspection of the complete blade surfaces of both the impeller and stator blades using either a direct visual or borescope inspection technique.

3.2 Shaftline

3.2.1 The diameter of the shaftline components are to comply with Chapter 6. For calculation purposes the shaft carrying the impeller is to be taken as equivalent to a screwshaft.

3.2.2 Where it is proposed to use carbon or carbon manganese steel shafts which may be in contact with sea-water, these are to be protected.

3.2.3 The diameter of unprotected screwshafts of corrosion-resistant material is not to be less than that given in Vol 7, Pt 11, Ch 2,4.4.7 of the *Rules and Regulations for the Classification of Special Service Craft*.

3.2.4 The use of composite shafts is permitted, *see* 2.3.16.

3.2.5 Where lengths of shafts are joined using couplings of the shrunk element type, a factor of safety, based upon the mean plus the vibratory and transient torques, against slippage of 2,0 is to be achieved for couplings which are located inboard and 2,5 for couplings which are located outboard.

3.2.6 Where shaftline components are bolted together, a factor of safety of 1,5 is to be achieved for the design of the bolted connection when considered in the context of the mean, fluctuating and transitory loadings.

3.2.7 If a keyed fitting of the impeller to the shaft is contemplated, then the requirements of Ch 6,3.10 are to be satisfied.

3.2.8 Where it is proposed to fit a keyless impeller, the fitting is to comply with the requirements of Ch 7,3.2, as applicable, excluding the requirements for Ice Class. Use of the words 'propeller' and 'screwshaft' are to be taken as meaning 'impeller' and 'impellershaft' respectively.

3.3 Shaft support system and guide vanes

3.3.1 In cases where the shaft requires support from the tunnel walls ahead of the impeller or, alternatively, where guide vanes are required to assist the flow around a bend in the ducting system, the supports or guide vanes are to be suitably aligned to the flow and have suitably rounded leading and trailing edges or be of an aerofoil section.

3.3.2 In general, the fillet radius should be greater than or equal to the maximum thickness of the vane or support at that location. Smaller radii may be considered for which the results of an approved measurement programme or calculation procedure are to be submitted. In all cases, a factor of safety of at least 1,5 is to be demonstrated for the maximum designed operating conditions.

3.3.3 A facility for the inspection of the supports or guide vanes is to be provided which will allow either direct visual or borescope inspection of these components and their transition to other members.

3.4 Impeller

3.4.1 A calculation to determine the stresses within the impeller blades is to be carried out, which takes into account the mean blade loading, fluctuating loadings, transient loads and centrifugal force. The computations may be accomplished by either classical methods or numerical analysis. Designs of water jet systems which have been based on a combination of computational fluid dynamics and finite element methods will be considered. However, it will be necessary to demonstrate to the satisfaction of LR that the formulation of the methods used has been correlated with previous full scale measurement or other calculation experience.

3.4.2 For the purposes of the calculation required by this sub-Section, the fluctuating stresses during one revolution of the impeller is to be taken as 20 per cent of the maximum mean stress, and the stresses from transient loadings are to be taken as 15 per cent of the hydrodynamic mean stress, unless otherwise specified by the designer.

3.4.3 The fatigue assessment of the impeller blades is to be based on the stress in the root sections, excluding the influence of the blade root fillets. This assessment is to include the following components:

- the maximum stresses derived from the mean loading, including both the hydrodynamic and centrifugal components;
- the amplitude of the fluctuating stresses during one revolution of the impeller;
- the stresses derived from transient loading and an allowance for any residual stresses in the material.

It is permissible to combine the variable components of stress in a linear fatigue damage accumulation assessment procedure. A factor of safety of at least 1,5 against fatigue failure is to be demonstrated for the maximum continuous rating condition or any other more onerous condition, *see* 3.1.1.

3.4.4 In general, the fillet radius is to be greater than the maximum thickness of the impeller blade at that location. Composite radiused fillets or elliptical fillets which provide an improved stress concentration factor are preferred.

3.4.5 Where an impeller has bolted-on blades, consideration is to be given to the distribution of stress in the palms of the blade and in the boss and bolting arrangements.

3.4.6 Where an impeller has welded blades the welds are to be of the full penetration type or of equivalent strength. Where laser welding is to be used, details are to be submitted for consideration.

3.4.7 The blades are to be provided with hydrodynamically faired leading and trailing edges which may be either of simple radius or of a more complex aerofoil edge form. The tip clearance, whilst being kept to a minimum for hydrodynamic purposes, is to be sufficient to allow for any transient vibrational behaviour, axial shaft movement or differential thermal expansion.

3.4.8 A calculation of the blade natural frequency for the impeller blades is to be undertaken. The fundamental natural frequency in water of the blade is to be shown to lie outside any expected excitation frequencies within a speed range of the water jet unit and up to 10 per cent above the maximum impeller speed.

3.5 Stator

3.5.1 The stator blades, where fitted, are to be designed to be capable of withstanding the combined hydrodynamic mean, fluctuating, transient and mechanical loads, including any loads transmitted via shaft bearings, developed by the unit and reacted through the blades when the impeller is absorbing full power. Consideration is to be given to situations when the vessel is either free running or in a condition specified by 3.1.1 or undergoing stopping, accelerating or decelerating manoeuvres. A factor of safety against mechanical failure by yielding of the blades of 1,5 is to be demonstrated.

3.5.2 In general, the fillet radius is to be greater than the maximum thickness of the blade at that location. Composite radiused fillets or elliptical fillets which provide improved stress concentration factors are preferred.

3.5.3 If the stator ring comprises a segmented assembly, then consideration is also to be given to the distribution of stress in the various adjacent members of the overall assembly.

3.5.4 A calculation of the relative blade passing frequency between the rotor and stator blades is to demonstrate that this does not coincide with the natural frequency of the stator blades over the speed range of the water jet unit and up to 10 per cent above maximum impeller speed.

3.5.5 The stator blades are to be provided with hydrodynamically faired leading edges which may have either a simple radius or a more complex aerofoil edge form.

3.5.6 Where the stator blading assembly forms part of the nozzle, the requirements of 3.7 are to be considered in association with those for the stator assembly.

3.6 Tunnel and securing arrangements

3.6.1 The tunnel is to be adequately supported, framed and fully integrated into the hull structure. The critical locations and integrity of the supports and framing are to be as specified in the FMEA and agreed by the Shipbuilder and LR.

3.6.2 The tunnel and supporting structure scantlings are to be not less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnel(s) is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

3.6.3 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of this guard, if fitted, are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and the susceptibility to clog with weed and other flow-restricting matter.

3.6.4 The inlet profile of the tunnel is to be designed so as to provide a smooth uptake of the water over the range of vessel operating trims and avoid significant separation and/or cavitation of the flow which may then pass downstream into the rotating machinery.

3.6.5 Design consideration is to take account of pressures which could develop as a result of a duct blockage as well as in relation to the axial location of rotating parts.

3.6.6 The strength of the tunnel and supporting structure are to be examined by direct calculation procedures.

3.7 Nozzle/steering arrangements

3.7.1 In general, the steering systems and components are to comply with the requirements of Chapter 19.

3.7.2 For vessels with more than one steerable water jet, the requirement for auxiliary steering arrangements in Ch 19,2 is to be achieved by equipping each of the steerable water jets with its own dedicated and independent steering gear control system and power actuating system. Consideration will be given to alternative arrangements providing equivalence can be demonstrated.

3.7.3 The main steering arrangements are to be operated by power and capable of changing the direction of the ship's directional control system from one side to the other at declared steering angle limits at an average rotational speed of not less than 0,4 rev/min, with the ship running ahead at maximum ahead service speed.

3.7.4 The auxiliary steering arrangements are to be:

(a) Capable of changing the direction of the ship's directional control system from one side to the other at declared steering angle limits at an average rotational speed of not less than 0,083 rev/min, with the ship running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater.

(b) For all ships, operated by power where necessary to meet the requirements of (a) and in any ship having power more than 2,500 kW propulsion power per thruster unit.

3.7.5 Nozzles can be either of a fixed or steerable form. The design of the nozzle is to take into account fully the change in pressure distribution along its inner surface together with the other mechanical loads (e.g. stator assembly loads) and transient loads caused by the flow-directing attachments which may be reacted through the body of the nozzle. In this analysis the changes to the pressure distribution caused by transient manoeuvres are to be considered.

3.7.6 In addition to the requirements of Chapter 19, the steering mechanism and bucket are to be capable of maintaining the manoeuvrability of the ship in terms of turning circle, zig-zag and stopping requirements within the limits defined by IMO Resolution MSC.137(76), *Standards for Ship Manoeuvrability*.

3.7.7 Consideration is to be given to all transient loads which the steering unit is likely to experience from manoeuvring, accelerating, decelerating and the sea conditions.

3.7.8 The nozzle/bucket is to be given mechanical protection by the Shipbuilder from other impact damage such as collision.

3.8 Bolts

3.8.1 Detailed consideration and analysis is to be given to essential bolting arrangements in critical locations as specified in the FMEA and where indicated by the manufacturer or Shipbuilder and agreed by LR. These are to include; bolts used in the securing of blades or guide vanes, assembly of the unit in the ship and any conduit components.

■ *Section 4* Piping systems

4.1 General

4.1.1 The piping systems for a water jet unit are to comply with the general requirements of Chapter 12.

4.1.2 Lubricating and hydraulic oil systems and standby arrangements are to comply with the requirements of Chapter 14; in addition, steering hydraulic systems are to comply with the applicable requirements of Chapter 19.

■ *Section 5* Control and monitoring

5.1 General

5.1.1 In addition to this Section, the control engineering systems are to comply with Pt 6, Ch 1.

5.1.2 For water jets used as the only means of propulsion and steering, a standby or alternative power source for the actuating device that controls the angular position and/or the reversing angle is to be provided. Automatic start of the standby pump supplying hydraulic power for steering and reversing is to be provided.

5.1.3 Means are to be provided at each control station to stop each water jet.

5.2 Monitoring and alarms

5.2.1 In addition to the requirements of Chapter 19, alarms and monitoring requirements are indicated in 5.2.2 to 5.2.4 and Table 16.5.1.

Table 16.5.1 Alarms

Item	Alarm	Note
Hydraulic system pressure	Low	—
Hydraulic oil supply tank level	Low	—
Hydraulic oil temperature	High	Where an oil cooler is fitted
Lubricating oil temperature	High	—
Lubricating oil pressure	Low	In forced lubrication systems
Lubricating oil tank level	Low	Where a tank is provided
Ratio of jet rpm/vessel speed	High	Only if installed power per jet >4 MW
Control system failure	Fault	Includes follow-up failure of steering or reversing system
Control system power supply	Failure	—

5.2.2 An indication of the angular position of the nozzle is to be provided at each station from which it is possible to control the direction of thrust from the units.

5.2.3 An indication of both the required and actual reversing bucket position is to be provided at each station from which it is possible to control the reversal of thrust.

5.2.4 All alarms associated with water jet unit faults are to be indicated individually at the control stations and in accordance with the alarm system specified by Pt 6, Ch 1.

■ *Section 6* Electrical systems

6.1 Installation and distribution arrangements

6.1.1 The electrical installation is to comply with the relevant sections of Pt 6, Ch 2.

6.1.2 Water jet auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as practicable and without the use of common feeders, transformers, converters, protective devices or control circuits.

■ *Section 7*
Inspection, testing and fitting of water jets

7.1 General

7.1.1 The finished impeller is to be statically balanced on completion of the manufacturing process and meet the requirements of ISO 1940 or an alternative standard acceptable to LR. In the case where the blade tip speed is greater than 60 m/s, dynamic balancing is required unless otherwise agreed by the manufacturer and LR.

7.1.2 The following tests, markings and inspections are to be carried out in the presence of the Surveyor:
(a) The balancing of the impeller or the blades.
(b) Non-destructive examination of the impeller blades and the principal component parts of the propulsion system; *see* Ch 4,8 for austenitic stainless steels and Ch 8,3 for aluminium alloys of the Rules for Materials.
(c) The quality of the fit of the impeller boss on the shaft taper.
(d) The fitting of the impeller to the shaft and its subsequent functional testing.
(e) The finished surfaces of the impeller boss, conical bores, fillets, cones and blade surfaces are to be shown to conform to the tolerances specified on the impeller drawing.

7.1.3 Bolts and nuts in critical locations, as specified in the FMEA and where indicated by the manufacturer or Shipbuilder and agreed by LR, are to be equipped with adequate securing arrangements to the satisfaction of the LR Surveyor.

7.2 Shop tests and installation of water jet systems

7.2.1 The completed water jet unit is to undergo a tightness test in which an internal hydrostatic pressure of 1,5 bar above the maximum working pressure of the unit is to be applied.

7.2.2 In cases where the impeller is fitted to the shaft using an interference fit, the bedding of the impeller with the shaft is to be demonstrated in the shop to the satisfaction of the LR Surveyor. Sufficient time is to be allowed for the temperature of the components to equalise before bedding. A contact marking between the bore of the impeller boss and the shaft surface of better than 80 per cent is to be demonstrated when the contact marking ink is spread thinly on the surface of the shaft. Alternative means for demonstrating the bedding of the impeller will be considered.

7.2.3 Means are to be provided to indicate the relative axial position of the impeller boss on the shaft. Permanent reference marks are to be made on the impeller boss, shaft and any nut to indicate angular and axial positioning of the impeller. Care is to be taken in marking the inboard end of the shaft taper to minimise stress-raising effects.

7.2.4 A copy of the fitting curve relative to temperature and means for determining any subsequent movement are to be placed on board.

7.2.5 The impeller running clearances are to be checked following the installation of the unit in the ship.

7.2.6 The thrust bearing clearances in the water jet system are to be verified against the required design values. This is to be done following the installation of the unit in the ship.

7.2.7 The piping systems are to be adequately flushed in accordance with the manufacturer's recommendations and the final levels of contamination recorded. Similarly, pressure testing of the piping systems is to comply with Chapter 12.

7.3 Sea trial requirement

7.3.1 The following requirements are to be complied with:
- Ch 1,5.2 for sea trials.
- Ch 19,7.2 for steering trials.

In addition, the general design capability specified in 3.1.1 is to be demonstrated to the Surveyor's satisfaction.

7.3.2 The control systems relating to the correct functioning of the water jet are to be the subject of harbour and then sea trials. Demonstration of the requirements of Pt 6, Ch 1 is required and the design combinations of control functions are to be undertaken during the trials programme.

7.3.3 On sea trials and under free running conditions the relationship between ship speed and impeller rotational speed is to be verified against the water jet's design basis.

7.3.4 Any trials and testing identified from the FMEA report, *see* 2.4.4, are to be carried out.

■ *Section 8*
Installation, maintenance and replacement

8.1 General

8.1.1 All water jet system propulsion units are to be provided with a copy of the manufacturer's installation and maintenance manual that is pertinent to the actual equipment. *See* 2.3.24.

8.1.2 The manual required by 8.1.1 is to be placed on board and is to contain the following information:

(a) Description of the water jet propulsion system with details of function and design operating limits. This is also to include details of support systems such as lubrication, cooling and condition monitoring arrangements.

(b) Identification of all components together with details of any that have a defined maximum operating life.

(c) Instructions for installation of the system on board ship with details of any required specialised equipment.

(d) Instructions for commissioning at initial installation and following maintenance.

(e) Maintenance and service instructions to include inspection/renewal of bearings and sealing arrangements. This is also to include component fitting procedures, clearance measurements and lubricating oil treatment where applicable.

(f) Actions required in the event of fault/failure conditions being detected.

(g) Precautions to be taken by personnel working during installation and maintenance.

Requirements for Fusion Welding of Pressure Vessels and Piping

Section

■ *Section 1* General

1.1 Scope

1.1.1 The requirements of this Chapter apply to the welding of pressure vessels and process equipment, heating and steam raising boilers and pressure pipes. The allocation of Class is determined from the design criteria referenced in Chapters 10, 11 and 12.

1.1.2 Fusion welded pressure vessels will be accepted only if manufactured by firms equipped and competent to undertake the quality of welding required for the Class of vessel proposed. For Class 1, 2/1 and 2/2 pressure vessels, the manufacturer's works are to be approved in accordance with the requirements specified in *Materials and Qualification Procedures for Ships*, Book A Procedure MQPS 0-4.

1.1.3 For pressure vessels which only have circumferential seams, *see* Ch 10,1.5.4 and Ch 11,1.5.5.

1.2 General requirements for welding plant and welding quality

1.2.1 In the first instance, and before work is commenced, the Surveyors are to be satisfied that the required quality of welding is attainable with the proposed welding plant, equipment and procedures in accordance with the guidelines specified in *Materials and Qualification Procedures for Ships Book A, Procedure 0-4*.

1.2.2 All welding is to be in accordance with the requirements specified in Chapter 13 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.3 Manufacture and workmanship of fusion welded pressure vessels

1.3.1 Pressure vessels are to be constructed and examined in accordance with the requirements specified in Chapter 13 of the Rules for Materials, unless more stringent requirements are specified.

■ *Section 2* Manufacture and workmanship of fusion welded pressure vessels

2.1 General requirements

2.1.1 Prior to commencing construction, the design of the vessel is to be approved where required by Ch 10,1.6 and Ch 11,1.6.

2.1.2 Pressure vessels will be accepted only if manufactured by firms that have been assessed and approved in accordance with MQPS 0-4.

2.2 Materials of construction

2.2.1 Where the construction requires post weld heat treatment, consideration should be given to certifying the material after subjecting the test pieces to a simulated heat treatment.

2.3 Tolerances for cylindrical shells

2.3.1 Measurements are to be made to the surface of the parent plate and not to a weld, fitting or other raised part.

2.3.2 In assessing the out-of-roundness of pressure vessels, the difference between the maximum and minimum internal diameters measured at one cross-section is not to exceed the amount given in Table 17.2.1.

Table 17.2.1 Tolerances for cylindrical shells

Nominal internal diameter of vessel in mm	Difference between maximum and minimum diameters	Maximum departure from designed form
≤ 300 > 300 ≤ 460 > 460 ≤ 600 > 600 ≤ 900 > 900 ≤ 1220 > 1220 ≤ 1520 > 1520 ≤ 1900	1,0 per cent of internal diameter	1,2 mm 1,6 mm 2,4 mm 3,2 mm 4,0 mm 4,8 mm 5,6 mm
> 1900 ≤ 2300 > 2300 ≤ 2670 > 2670 ≤ 3950	19 mm	6,4 mm 7,2 mm 8,0 mm
> 3950 ≤ 4650 > 4650	19 mm 0,4 per cent of internal diameter	0,2 per cent of internal diameter

2.3.3 The profile measured on the inside or outside of the shell, by means of a gauge of the designed form of the shell, and having a chord length equal to one-quarter of the internal diameter of the vessel, is not to depart from the designed form by more than the amount given in Table 17.2.1. This amount corresponds to *x* in Fig. 17.2.1.

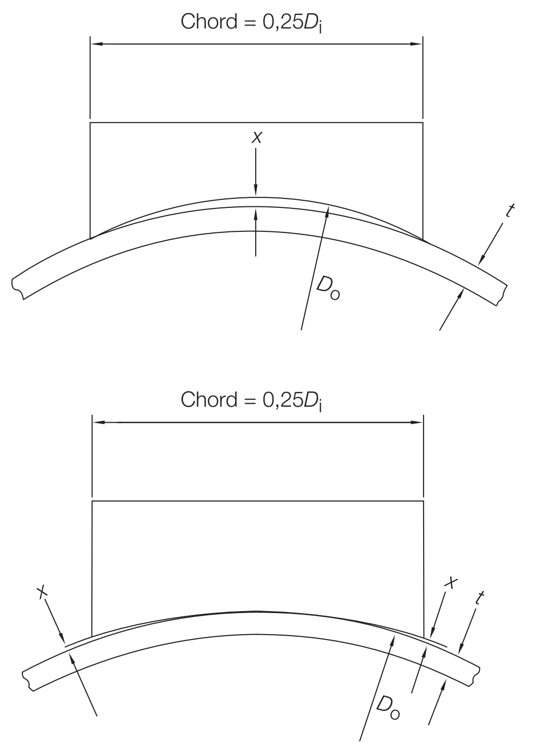


Fig. 17.2.1 Tolerances for cylindrical shells

2.3.4 Shell sections are to be measured for out-of-roundness, either when laid flat on their sides or when set up on end. When the shell sections are checked while lying on their sides, each measurement for diameter is to be repeated after turning the shell through 90° about its longitudinal axis. The two measurements for each diameter are to be averaged, and the amount of out-of-roundness calculated from the average values so determined.

2.3.5 Where there is any local departure from circularity due to the presence of flats or peaks at welded seams, the departure from designed form shall not exceed that of Table 17.2.1.

2.3.6 The external circumference of the completed shell is not to depart from the calculated circumference (based upon nominal inside diameter and the actual plate thickness) by more than the amounts given in Table 17.2.2.

Table 17.2.2 Circumferential tolerances

Outside diameter (nominal inside diameter plus twice actual plate thickness), in mm	Circumferential tolerance
300 to 600 inclusive	±5 mm
Greater than 600	±0,25 per cent

Section 3
Repairs to welds on fusion welded pressure vessels

3.1 General

3.1.1 Repairs to welds on fusion welded pressure vessels are to be in accordance with the requirements of Chapter 13 of the Rules for Materials.

Section 4
Post-weld heat treatment of pressure vessels

4.1 General

4.1.1 Post-weld heat treatment of fusion welded pressure vessels are to be in accordance with the requirements of Chapter 13 of the Rules for Materials.

Section 5
Welded pressure pipes

5.1 General

5.1.1 Fabrication of pipework is to be carried out in accordance with the requirements of Ch 13,5 of the Rules for Materials.

5.2 Welding workmanship

5.2.1 Preheating is to be effected by a method which ensures uniformity of temperature at the joint. The method of heating and the means adopted for temperature control are to be to the satisfaction of the Surveyors.

5.2.2 All welding is to be performed in accordance with the approved welding procedures in this Section by welders who are qualified for the materials, joint types and welding processes employed.

5.2.3 Welding without filler metal is generally not permitted for welding of duplex stainless steel materials.

5.2.4 All welds in high pressure and high temperature pipelines are to have a smooth surface finish and even contour; if necessary, they are to be made smooth by grinding.

5.2.5 Check tests of the quality of the welding are to be carried out periodically at the discretion of the Surveyors.

■ *Section 6*
Non-Destructive Examination

6.1 General

6.1.1 Non-Destructive Examination (NDE) of pressure vessels and piping is to be performed in accordance with the requirements of Ch 13,4 and 5 of the Rules for Materials.

Section

Section 1 General requirements

1.1 General

1.1.1 This Chapter applies to both cargo ships and passenger ships and is in addition to other relevant Chapters of the Rules.

1.1.2 The Rules contained in this Chapter cover machinery arrangements and control systems necessary for operating essential machinery from a (centralised) control station on the bridge under normal sea-going and manoeuvring conditions, but do not signify that the machinery space may be operated unattended.

1.1.3 In general, ships complying with the requirements of this Chapter will be eligible for the machinery class notation **IP**, *see* Pt 1, Ch 2,2.4.

1.1.4 The details of control systems will vary with the type of machinery being controlled, and special consideration will be given to each case.

1.2 Plans

1.2.1 **Control systems**. Where control systems are applied to essential machinery or equipment the following plans are to be submitted in triplicate:

- Details of operating medium, i.e. pneumatic, hydraulic or electric including standby sources of power.
- Description of operation with explanatory diagrams.
- Line diagrams of control circuits.
- List of monitored points.
- List of control points.
- List of alarm points.
- Test schedule including test facilities provided.

1.2.2 Plans for the control systems of the following machinery are to be submitted:

- Main propelling machinery, including all auxiliaries essential for propulsion.
- Controllable pitch propellers.
- Electric generating plant.
- Evaporating and distilling systems for use with main steam machinery.
- Steam raising plant for essential services.

1.2.3 **Alarm systems**. Details of the overall alarm system linking the machinery space control station with the bridge control station are to be submitted.

1.2.4 **Control stations**. Details of bridge and machinery space control stations are to be submitted, e.g. control panels and consoles.

1.2.5 **Machinery configurations**. Plans showing the general arrangement of the machinery space, together with the layout and configuration of the main propulsion and essential machinery, are to be submitted.

Section 2 Machinery arrangements

2.1 Main propulsion machinery

2.1.1 The main propulsion machinery may be oil engines, turbines or electric motors but the configuration of the propulsion system and its relationship with other essential equipment is to comply with the remaining requirements of this Section.

2.1.2 The main propulsion machinery is to drive one of the generators required by 2.2.2. This generator is to be capable of supplying the essential electrical load under all normal sea-going and manoeuvring conditions.

2.1.3 Standby machinery is to be provided capable of being readily connected to the main propulsion system so as to provide emergency propulsion. This standby machinery is to be capable of connection so as to provide an alternative drive to the generator required in 2.1.2. It need not provide power to both systems simultaneously, *see also* 2.2.2.

2.2 Supply of electric power and essential services

2.2.1 Continuity of electrical power supply and essential services are to be ensured under all normal sea-going and manoeuvring conditions without manual intervention in the machinery space. Methods by which this may be achieved include automatic start-up of generating sets and essential pumps or manual start-up of these services from the bridge.

2.2.2 Generating sets and converting sets are to be sufficient to ensure the operation of services essential for the propulsion and safety of the ship even when one generating set or converting set is out of service.

2.3 Controllable pitch propellers

2.3.1 For propulsion systems with controllable pitch propellers a standby or alternative power source for the actuating medium for controlling the pitch of the propeller blades is to be provided.

Section 3
Control arrangements

3.1 Bridge control

3.1.1 Means are to be provided to ensure satisfactory control of propulsion from the bridge in both the ahead and astern directions when operating on either the main or standby engine(s).

3.1.2 Instrumentation to indicate the following is to be fitted on the bridge and at any other station from which the propulsion machinery may be controlled:
(a) Propeller speed.
(b) Direction of rotation of the propeller for a fixed pitch propeller.
(c) Pitch position for a controllable pitch propeller.
(d) Direction and magnitude of thrust.
(e) Clutch position, where applicable.

3.1.3 An alarm is to operate in the event of a failure of the power supply to the bridge control system.

3.1.4 Emergency Stop Functions, independent of the bridge control system, are to be provided on the bridge to enable the watchkeeping officer to stop the main propulsion machinery in an emergency.

3.2 Alarm system

3.2.1 An alarm system is to be provided to indicate faults in essential machinery and control systems in accordance with this Chapter.

3.2.2 Machinery faults are to be indicated at the control stations on the bridge and in the machinery space.

3.2.3 In the event of a machinery fault occurring, the alarm system is to be such that the watchkeeping officer on the bridge is made aware of the following:
(a) A machinery fault has occurred.
(b) The machinery fault is being attended to, and
(c) The machinery fault has been rectified. (Alternative means of communication between the bridge control station and the machinery control station may be used for this function.)

3.2.4 The alarm system should be designed with self-monitoring properties. As far as practicable, any fault in the alarm system should cause it to fail to the alarm condition.

3.2.5 The alarm system should be capable of being tested during normal machinery operation.

3.2.6 Failure of the power supply to the alarm system is to be indicated as a separate fault alarm.

3.2.7 Alarm indication is to be both audible and visual. If arrangements are made to silence audible alarms they are not to extinguish visual alarms.

3.2.8 The acceptance of an alarm on the bridge is not to silence the audible alarm in the machinery space.

3.2.9 Machinery alarms should be distinguishable from other audible alarms, e.g. fire, carbon dioxide.

3.2.10 Acknowledgement of visual alarms is to be clearly shown.

3.2.11 If the audible alarm has been silenced and a second fault occurs before the first has been rectified, the audible alarm is again to operate. To assist in the detection of transient faults which are subsequently self-correcting, fleeting alarms should lock-in until accepted.

3.3 Communication

3.3.1 Two means of communication are to be provided between the bridge and the control station in the machinery space. One of these means may be the bridge control system; the other is to be independent of the main electrical power supply.

3.3.2 The bridge, machinery space control station and any other control position from which the propulsion machinery can be controlled are to be fitted with means to indicate which station is in command.

3.3.3 Change-over between control stations is to be possible under all normal sea-going and manoeuvring conditions without affecting the speed or direction of propulsion. This changeover may be effected only with the acceptance of the station taking control.

3.4 Engine starting safeguards

3.4.1 Where it is possible to start a main propulsion or auxiliary oil engine from the bridge, an indication that sufficient starting air pressure is available is to be provided on the bridge.

3.4.2 The number of automatic consecutive attempts which fail to produce a start is to be limited to safeguard sufficient starting air pressure, or, in the case of electric starting, a sufficient charge level in the batteries.

3.4.3 An alarm is to be provided for low starting air pressure, set at a limit which will still permit engine starting operations.

3.4.4 Where propulsion or auxiliary engines are started from the bridge, interlocks are to be provided to prevent starting of the engine under conditions which could hazard the machinery. These are to include ‘turning gear engaged’, ‘low lubricating oil pressure’ and ‘shaft brake engaged’.

3.5 Operational safeguards

3.5.1 Means are to be provided to prevent the machinery and shafting being subjected to excessive torque or other detrimental mechanical and thermal overloads.

3.5.2 Prolonged running in a restricted speed range is to be prevented automatically or, alternatively, an indication of restricted speed ranges is to be provided at each control station.

3.5.3 For ships propelled by steam turbines the risk of thermal distortion of the turbines is to be prevented by automatic steam spinning when the shaft is stopped in the manoeuvring mode. An audible and visual alarm is to operate on the bridge and in the machinery space when the shaft has been stopped for two minutes.

3.5.4 In the case of lubricating oil systems for main propulsion and standby engine(s), the engine(s) is to be stopped automatically on failure of the lubricating oil supply. The circuit and sensor employed for this automatic shutdown are to be additional to the alarm circuit and sensor required by Ch 14,8. Where means are provided to over-ride the automatic shutdown required by this paragraph, the arrangements are to be such as to preclude inadvertent operation. Visual indication of operation of the over-ride is to be fitted.

3.5.5 In the case of oil engines, oil mist monitoring is to be provided for crankcase protection where arrangements are fitted to over-ride the automatic stop for failure of the lubricating oil supply.

3.5.6 Boilers with automatic controls which under normal operating conditions do not require any manual intervention by the operators are to be provided with safety arrangements which automatically shut-off the oil fuel to all the burners in the event of either low water level or combustion air failure. Oil fuel is to be shut-off automatically to any burner in the event of flame failure.

3.5.7 Arrangements are to be provided to automatically stop propulsion gas turbines for the following fault conditions:
(a) Overspeed, *see* Ch 4,4.
(b) High exhaust temperature, *see* Ch 4,3.
(c) Flame failure, or
(d) Excessive vibration.

3.5.8 Where standby pumps are arranged to start automatically in the event of low discharge pressure from the working pump an alarm is to be given to indicate when the standby pump has started.

3.6 Automatic control of essential services

3.6.1 All control systems for essential services are to be stable throughout the operating range of the main propulsion machinery.

3.6.2 The temperature of the following is to be automatically controlled within normal operating limits:
Oil engines:
(a) Lubricating oil to the main engine and/or auxiliary engines.
(b) Oil fuel – temperature or viscosity.
(c) Piston coolant, where applicable.
(d) Cylinder coolant main and auxiliary engines, where applicable.
(e) Fuel valve coolant, where applicable.
Steam plant:
(a) Lubricating oil to main engine and/or auxiliary engines.
(b) Oil fuel to burners – temperature or viscosity.
(c) Superheated steam.
(d) External de-superheated steam.
Gas turbines:
(a) Lubricating oil to main engine and auxiliary engines.
(b) Oil fuel – temperature or viscosity.
(c) Exhaust gas.

3.6.3 The pressure of the following is to be automatically controlled within normal operating limits:
Steam plant:
(a) Superheated steam.
(b) Oil fuel.
(c) External de-superheated steam system(s).
(d) Gland steam.
(e) Reduced steam ranges.

3.6.4 The level of the following is to be automatically controlled within normal operating limits:
Steam plant:
(a) Boiler drum level.
(b) De-aerator level.
(c) Condenser level.

3.6.5 Boilers essential for the propulsion of the vessel are to be provided with an automatic combustion control system.

3.7 Local control

3.7.1 The arrangements are to be such that essential machinery can be operated with the system of bridge control or any automatic controls out of action. Alternatively, the control systems should have sufficient redundancy so that failure of the control equipment in use does not render essential machinery inoperative.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to the design and construction of steering gear.

1.1.2 Whilst the requirements satisfy the relevant regulations of the *International Convention for the Safety of Life at Sea 1974* as amended, and the IMO Protocol of 1978, attention should be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

1.1.3 Consideration will be given to other cases, or to arrangements which are equivalent to those required by the Rules.

1.2 Definitions

1.2.1 **Steering gear control system** means the equipment by which orders are transmitted from the navigating bridge to the steering gear power units. Steering gear control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

1.2.2 **Main steering gear** means the machinery, rudder actuator(s), the steering gear power units, if any, and ancillary equipment and the means of applying torque to the rudder stock (e.g., tiller or quadrant) necessary for effecting movement of the rudder for the purpose of steering the ship under normal service conditions.

1.2.3 **Steering gear power unit** means:

(a) in the case of electric steering gear, an electric motor and its associated electrical equipment;

(b) in the case of electrohydraulic steering gear, an electric motor and its associated electrical equipment and connected pump;

(c) in the case of other hydraulic steering gear, a driving engine and connected pump.

1.2.4 **Auxiliary steering gear** means the equipment other than any part of the main steering gear necessary to steer the ship in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose.

1.2.5 **Power actuating system** means the hydraulic equipment provided for supplying power to turn the rudder stock, comprising a steering gear power unit or units, together with the associated pipes and fittings, and a rudder actuator. The power actuating systems may share common mechanical components, i.e., tiller quadrant and rudder stock, or components serving the same purpose.

1.2.6 **Maximum ahead service speed** means the maximum service speed which the ship is designed to maintain, at the summer load waterline at maximum propeller RPM and corresponding engine MCR.

1.2.7 **Rudder actuator** means the components which converts directly hydraulic pressure into mechanical action to move the rudder.

1.2.8 **Maximum working pressure** means the maximum expected pressure in the system when the steering gear is operated to comply with 2.1.2(b).

1.2.9 **Steering arrangements** means the complete system of components for providing ship directional control.

1.2.10 **Directional control system** means the equipment used to effect changes in ship direction e.g., the rudder, podded propulsion unit, azimuth thrusters or water jet nozzle. Note that for podded propulsion systems, azimuth thrusters, water jet systems, or other similar systems for effecting changes in ship direction, it is to be assumed that the units must provide thrust in addition to rotation and hence the directional control system must include the propulsion system.

1.3 General

1.3.1 The steering gear is to be secured to the seating by fitted bolts, and suitable chocking arrangements are to be provided. The seating is to be of substantial construction.

1.3.2 The steering gear compartment is to be:

(a) readily accessible and, as far as practicable, separated from machinery spaces; and

(b) Provided with suitable arrangements to ensure working access to steering gear machinery and controls. These arrangements are to include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

1.4 Plans

1.4.1 Before starting construction, the steering gear machinery plans, specifications and calculations are to be submitted. The plans are to give:

(a) Details of scantlings and materials of all load bearing and torque transmitting components and hydraulic pressure retaining parts together with proposed rated torque and all relief valve settings.
(b) Schematic of the hydraulic system(s), together with pipe material, relief valves and working pressures.
(c) Details of control and electrical aspects.

1.5 Materials

1.5.1 All components used in steering arrangements for ship directional control are to be of sound reliable construction to the Surveyor's satisfaction.

1.5.2 All components transmitting mechanical forces to the rudder stock are to be tested according to the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.5.3 Ram cylinders; pressure housings of rotary vane type actuators, hydraulic power piping, valves, flanges and fittings; and all steering gear components transmitting mechanical forces to the rudder stock (such as tillers, quadrants, or similar components) are to be of steel or other approved ductile material, duly tested in accordance with the requirements of the Rules for Materials. In general, such material is to have an elongation of not less than 12 per cent nor a tensile strength in excess of 650 N/mm^2. Special consideration will be given to the acceptance of grey cast iron for valve bodies and redundant parts with low stress levels.

1.5.4 Where appropriate, consideration will be given to the acceptance of non-ferrous material.

1.6 Rudder, rudder stock, tiller and quadrant

1.6.1 For the requirements of rudder and rudder stock, *see* Pt 3, Ch 13,2.

1.6.2 For the requirements of tillers and quadrants including the tiller to stock connection, *see* Table 19.1.1.

1.6.3 In bow rudders having a vertical locking pin operated from the deck above, positive means are to be provided to ensure that the pin can be lowered only when the rudder is exactly central. In addition, an indicator is to be fitted at the deck to show when the rudder is exactly central.

1.6.4 The factor of safety against slippage, S (i.e., for torque transmission by friction) is generally based on

$$S = \frac{\text{the torque transmissible by friction}}{M}$$

where

M is the maximum torque at the relief valve pressure which is generally equal to the design torque as specified by the steering gear manufacturer.

1.6.5 For conical sections, S is based on the following equation:

$$S = \frac{\mu\, A\, \sigma_r}{\sqrt{(W + A\, \sigma_r\, \theta)^2 + Q^2}}$$

where

A = interfacial surface area, in mm^2
W = weight of rudder and stock, if applicable, when tending to separate the fit, in N
Q = shear force = $\dfrac{2M}{d_m}$ in N

where

d_m in mm is the mean contact diameter of tiller/stock interface and M in Nmm is defined in 1.6.4
θ = cone taper half angle in radians (e.g., for cone taper 1:10, θ = 0,05)
μ = coefficient of friction
σ_r = radial interfacial pressure or grip stress, in N/mm^2.

Table 19.1.1 Connection of tiller to stock

Item	Requirements
(1) Dry fit – tiller to stock, *see also* 1.6.4 and 1.6.5	(a) For keyed connection, factor of safety against slippage, S = 1,0 The maximum stress in the fillet radius of the tiller keyway should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:10 (b) For keyless connection, factor of safety against slippage, S = 2,0 The maximum equivalent von Mises stress should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:15 (c) Coefficient of friction (maximum) = 0,17 (d) Grip stress not to be less than 20 N/mm^2
(2) Hydraulic fit – tiller to stock, *see also* 1.6.4 and 1.6.5	(a) For keyed connection, factor of safety against slippage, S = 1,0 The maximum stress in the fillet radius of the tiller keyway should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:10 (b) For keyless connection, factor of safety against slippage, S = 2,0 The maximum equivalent von Mises stress should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:15 (c) Coefficient of friction (maximum) = 0,14 (d) Grip stress not to be less than 20 N/mm^2
(3) Ring locking assemblies fit – tiller to stock, *see also* 1.6.3	(a) Factor of safety against slippage, S = 2,0 The maximum equivalent von Mises stress should not exceed the yield stress (b) Coefficient of friction = 0,12 (c) Grip stress not to be less than 20 N/mm^2
(4) Bolted tiller and quadrant (this arrangement could be accepted provided the proposed rudder stock diameter in way of tiller does not exceed 350 mm diameter), *see* symbols	Shim to be fitted between two halves before machining to take rudder stock, then removed prior to fitting Minimum thickness of shim, For 4 connecting bolts: $t_s = 0{,}0014\,\delta_t$ mm For 6 connecting bolts: $t_s = 0{,}0012\,\delta_t$ mm Key(s) to be fitted Diameter of bolts, $\delta_{tb} = \dfrac{0{,}60\,\delta_{su}}{\sqrt{n_{tb}}}$ mm A predetermined setting-up load equivalent to a stress of approximately 0,7 of the yield strength of the bolt material should be applied to each bolt on assembly. A lower stress may be accepted provided that two keys, complying with item (5), are fitted. Distance from centre of stock to centre of bolts should generally be equal to $\delta_t\left(1{,}0 + \dfrac{0{,}30}{\sqrt{n_{tb}}}\right)$ mm Thickness of flange on each half of the bolted tiller ≥ $\dfrac{0{,}66\,\delta_t}{\sqrt{n_{tb}}}$ mm
(5) Key/keyway, *see* symbols	Effective sectional area of key in shear ≥ $0{,}25\,\delta_t^2$ mm^2 Key thickness ≥ $0{,}17\,\delta_t$ mm Keyway is to extend over full depth of tiller and is to have a rounded end. Keyway root fillets are to be provided with suitable radii to avoid high local stress
(6) Section modulus – tiller arm (at any point within its length about vertical axis), *see* symbols	To be not less than the greater of: (a) $Z_{TA} = \dfrac{0{,}15\,\delta_t^3\,(b_T - b_s)}{1000\,b_T}$ cm^3 (b) $Z_{TA} = \dfrac{0{,}06\,\delta_t^3\,(b_T - 0{,}9\,\delta_t)}{1000\,b_T}$ cm^3 If more than one arm fitted, combined modulus is to be not less than the greater of (a) or (b) For solid tillers, the breadth to depth ratio is not to exceed 2
(7) Boss, *see* symbols	Depth of boss ≥ δ_t Thickness of boss in way of tiller ≥ $0{,}4\,\delta_t$

Symbols

b_s = distance between the section of the tiller arm under consideration and the centre of the rudder stock, in mm
NOTE: b_T and b_s are to be measured with zero rudder angle

b_T = distance from the point of application of the load on the tiller to the centre of the rudder stock, in mm

n_{tb} = number of bolts in the connection flanges, but generally not to be taken greater than six

t_s = thickness of shim for machining bolted tillers and quadrants, in mm

Z_{TA} = section modulus of tiller arm, in cm^3

δ_t = Rule rudderstock diameter in way of tiller, *see* Pt 3, Ch 13

δ_{tb} = diameter of bolts securing bolted tillers and quadrants, in mm

Section 2
Performance

2.1 General

2.1.1 Unless the main steering arrangements for ship directional control comprise two or more identical power units, in accordance with 2.1.4 or 8.1.1, every ship is to be provided with main steering arrangements and auxiliary steering arrangements in accordance with the requirements of the Rules. The main steering arrangements and the auxiliary steering arrangements are to be so arranged that the failure of one of them will not render the other one inoperative.

2.1.2 The main steering arrangements for ship directional control are to be:
(a) Of adequate strength and capable of steering the ship at maximum ahead service speed which shall be demonstrated in accordance with 7.2;
(b) Capable of putting the rudder over from 35° on one side to 35° on the other side with the ship at its deepest sea-going draught and running ahead at maximum ahead service speed and under the same conditions, from 35° on either side to 30° on the other side in not more than 28 seconds.
(c) Operated by power where necessary to meet the requirements of (b) and in any case when the Rules excluding strengthening for navigation in ice, require a rudder stock over 120 mm diameter in way of the tiller; and
(d) So designed that they will not be damaged at maximum astern speed; however, this design requirement need not be proved by trials at maximum astern speed and maximum rudder angle.

2.1.3 The auxiliary steering arrangements for ship directional control are to be:
(a) Of adequate strength and capable of steering the ship at navigable speed and of being brought speedily into action in an emergency;
(b) Capable of putting the rudder over from 15° on one side to 15° on the other side in not more than 60 seconds with the ship at its deepest sea-going draught and running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater; and
(c) Operated by power where necessary to meet the requirements of (b) and in any case when the Rules, excluding strengthening for navigation in ice, require a rudder stock over 230 mm diameter in way of the tiller.

2.1.4 Where the main steering arrangements for ship directional control comprise two or more identical power units, auxiliary steering arrangements need not be fitted, provided that:
(a) In a passenger ship, the main steering arrangements are capable of operating the ship's directional control system as required by 2.1.2(b) while any one of the power units is out of operation;
(b) In a cargo ship, the main steering arrangements are capable of operating the ship's directional control system as required by 2.1.2(b) while operating with all power units;
(c) The main steering arrangements are arranged so that after a single failure in its piping system or in one of the power units the defect can be isolated so that steering capability can be maintained or speedily regained.

2.1.5 Main and auxiliary steering gear power units are to be:
(a) Arranged to re-start automatically when power is restored after power failure;
(b) Capable of being brought into operation from a position on the navigating bridge. In the event of a power failure to any one of the steering gear power units, an audible and visual alarm is to be given on the navigating bridge;
(c) Arranged so that transfer between units can be readily effected.

2.1.6 Where the steering gear is so arranged that more than one power or control system can be simultaneously operated, the risk of hydraulic locking caused by a single failure is to be considered.

2.1.7 A means of communication is to be provided between the navigating bridge and the steering gear compartment.

2.1.8 Steering gear, other than of the hydraulic type, will be accepted provided the standards are considered equivalent to the requirements of this Section.

2.1.9 Manually operated gears are only acceptable when the operation does not require an effort exceeding 16 kg under normal conditions.

2.2 Rudder angle limiters

2.2.1 Power-operated steering gears are to be provided with positive arrangements, such as limit switches, for stopping the gear before the rudder stops are reached. These arrangements are to be synchronised with the gear itself and not with the steering gear control.

Section 3
Construction and design

3.1 General

3.1.1 Rudder actuators other than those covered by 8.3 and the 'Guidelines' are to be designed in accordance with the relevant requirements of Chapter 11 for Class I pressure vessels (notwithstanding any exemptions for hydraulic cylinders).

3.1.2 Accumulators, if fitted, are to comply with the relevant requirements of Chapter 11.

3.1.3 The welding details and welding procedures are to be approved. All welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads are to be of full penetration type or of equivalent strength.

3.1.4 The construction is to be such as to minimise local concentrations of stress.

3.1.5 The design pressure for calculations to determine the scantlings of piping and other steering gear components subjected to internal hydraulic pressure shall be at least 1,25 times the maximum working pressure to be expected under the operational conditions specified in 2.1.2(b) taking into account any pressure which may exist in the low pressure side of the system. Fatigue criteria may be applied for the design of piping and components, taking into account pulsating pressures due to dynamic loads, *see* Section 9.

3.1.6 For the rudder actuator, the permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{\sigma_B}{A} \text{ or } \frac{\sigma_y}{B}$$

where

σ_B = specified minimum tensile strength of material at ambient temperature

σ_y = specified minimum yield stress or 0,2 per cent proof stress of the material, at ambient temperature

A and *B* are given by the following Table:

	Wrought steel	*Cast steel*	*Nodular cast iron*
A	3,5	4	5
B	1,7	2	3

3.2 Components

3.2.1 Special consideration is to be given to the suitability of any essential component which is not duplicated. Any such essential component shall, where appropriate, utilise anti-friction bearings such as ball bearings, roller bearings or sleeve bearings which shall be permanently lubricated or provided with lubrication fittings.

3.2.2 All steering gear components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength at least equivalent to that of the rudder stock in way of the tiller.

3.2.3 Actuator oil seals between non-moving parts, forming part of the external pressure boundary, are to be of the metal upon metal type or of an equivalent type.

3.2.4 Actuator oil seals between moving parts, forming part of the external pressure boundary, are to be duplicated, so that the failure of one seal does not render the actuator inoperative. Alternative arrangements providing equivalent protection against leakage may be accepted.

3.2.5 Piping, joints, valves, flanges and other fittings are to comply within the requirements of Chapter 12 for Class I piping systems components. The design pressure is to be in accordance with 3.1.5.

3.2.6 Hydraulic power operated steering gear are to be provided with the following:

(a) Arrangements to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system;

(b) A fixed storage tank having sufficient capacity to recharge at least one power actuating system including the reservoir, where the main steering gear is required to be power operated. The storage tank is to be permanently connected by piping in such a manner that the hydraulic systems can be readily recharged from a position within the steering gear compartment and provided with a contents gauge.

3.3 Valve and relief valve arrangements

3.3.1 For vessels with non-duplicated actuators, isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly fitted on the actuator.

3.3.2 Arrangements for bleeding air from the hydraulic system are to be provided, where necessary.

3.3.3 Relief valves are to be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. The settings of the relief valves is not to exceed the design pressure. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure.

3.3.4 Relief valves for protecting any part of the hydraulic system which can be isolated, as required by 3.3.3 are to comply with the following:

(a) The setting pressure is not to be less than 1,25 times the maximum working pressure.

(b) the minimum discharge capacity of the relief valve(s) is not to be less than 110 per cent of the total capacity of the pumps which can deliver through it (them).
Under such conditions the rise in pressure is not to exceed 10 per cent of the setting pressure. In this regard, due consideration is to be given to extreme foreseen ambient conditions in respect of oil viscosity.

3.4 Flexible hoses

3.4.1 Hose assemblies approved by Lloyd's Register (hereinafter referred to as 'LR') may be installed between two points where flexibility is required but are not to be subjected to torsional deflection (twisting) under normal operating conditions. In general, the hose should be limited to the length necessary to provide for flexibility and for proper operation of machinery, *see also* Ch 12,7.

3.4.2 Hoses should be high pressure hydraulic hoses according to recognised Standards and suitable for the fluids, pressures, temperatures and ambient conditions in question.

3.4.3 Burst pressure of hoses is to be not less than four times the design pressure.

Section 4
Steering control systems

4.1 General

4.1.1 Steering gear control is to be provided:

(a) For the main steering gear, both on the navigating bridge and in the steering gear compartment;
(b) Where the main steering gear is arranged according to 2.1.4, by two independent control systems, both operable from the navigating bridge. This does not require duplication of the steering wheel or steering lever. Where the control system consists of a hydraulic telemotor, a second independent system need not be fitted, except in a tanker, chemical tanker or gas carrier of 10 000 gross tonnage and upwards;
(c) For the auxiliary steering gear, in the steering gear compartment and, if power operated, it shall also be operable from the navigating bridge and is to be independent of the control system for the main steering gear.
(d) Where the steering gear is so arranged that more than one control system can be simultaneously operated, the risk of hydraulic locking caused by single failure is to be considered.

4.1.2 Any main and auxiliary steering gear control system operable from the navigating bridge is to comply with the following:

(a) Means are to be provided in the steering gear compartment for disconnecting any control system operable from the navigating bridge from the steering gear it serves;
(b) The system is to be capable of being brought into operation from a position on the navigating bridge.

4.1.3 The angular position of the rudder shall:

(a) If the main steering gear is power-operated, be indicated on the navigating bridge. The rudder angle indication is to be independent of the steering gear control system;
(b) Be recognisable in the steering gear compartment.

4.1.4 Appropriate operating instructions with a block diagram showing the changeover procedures for steering gear control systems and steering gear actuating systems are to be permanently displayed in the wheelhouse and in the steering gear compartment.

4.1.5 Where the system failure alarms for hydraulic lock, *see* Table 19.5.1, are provided, appropriate instructions shall be placed on the navigating bridge to shut down the system at fault.

Section 5
Electric power circuits, electric control circuits, monitoring and alarms

5.1 Electric power circuits

5.1.1 Short-circuit protection, an overload alarm and, in the case of polyphase circuits, an alarm to indicate single phasing is to be provided for each main and auxiliary motor circuit. Protective devices are to operate at not less than twice the full load current of the motor or circuit protected and are to allow excess current to pass during the normal accelerating period of the motors.

5.1.2 Where steering gear motor circuits are supplied by converters, consideration will be given to arrangements that provide an equivalent level of safety, reliability, availability and indication to those specified in 5.1.1 provided that technical justification is submitted.

5.1.3 The alarms required by 5.1.1 are to be provided on the bridge and in the main machinery space or control room from which the main machinery is normally controlled.

5.1.4 Indicators for running indication of each main and auxiliary motor are to be installed on the navigating bridge and at a suitable main machinery control position.

5.1.5 A low-level alarm is to be provided for each power actuating system hydraulic fluid reservoir to give the earliest practicable indication of hydraulic fluid leakage. Alarms are to be given on the navigation bridge and in the machinery space where they can be readily observed.

5.1.6 Two exclusive circuits are to be provided for each electric or electrohydraulic steering gear arrangement consisting of one or more electric motors.

5.1.7 Each of these circuits is to be fed from the main switchboard. One of these circuits may pass through the emergency switchboard.

5.1.8 One of these circuits may be connected to the motor of an associated auxiliary electric or electrohydraulic power unit.

5.1.9 Each of these circuits is to have adequate capacity to supply all the motors which can be connected to it and which can operate simultaneously.

5.1.10 These circuits are to be separated throughout their length as widely as is practicable.

5.1.11 In ships of less than 1600 gross tonnage, if an auxiliary steering gear is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering gear may be fed by one circuit from the main switchboard. Consideration would be given to other protective arrangements than described in 5.1.1, for such a motor primarily intended for other services.

5.2 Electric control circuits

5.2.1 Electric control systems are to be independent and separated as far as is practicable throughout their length.

5.2.2 Each main and auxiliary electric control system which is to be operated from the navigating bridge is to comply with the following:

(a) It is to be served with electric power by a separate circuit supplied from the associated steering gear power circuit, from a point within the steering gear compartment, or directly from the same section of switchboard busbars, main or emergency, to which the associated steering gear power circuit is connected.

(b) Each separate circuit is to be provided with short-circuit protection only.

5.3 Monitoring and alarms

5.3.1 Alarms and monitoring requirements are indicated in 5.3.2 and Table 19.5.1.

Table 19.5.1 Alarm requirements

Item	Alarm	Note
Rudder position	— Failure	Indication, *see* 4.1.3 *See* 5.3.3
Steering gear power units, power	Failure	—
Steering gear motors	Overload, Single phase	For alarm and running indication locations, *see* 5.1.3 and 5.1.4
Control system	Failure	*See* 5.3.3
Control system power	Failure	—
Steering gear hydraulic oil level	Low	Each reservoir to be monitored. For alarm locations, *see* 5.1.5
Auto pilot	Failure	Running indication
Hydraulic oil temperature	High	Where oil cooler is fitted
Hydraulic lock	Fault	Where more than one system (either power or control) can be operated simultaneously each system is to be monitored, *see* Note
Hydraulic oil filter differential pressure	High	When oil filters are fitted

NOTE
This alarm is to identify the system at fault and to be activated when (for example):

- position of the variable displacement pump control system does not correspond with given order; or
- incorrect position of 3-way full flow valve or similar in constant delivery pump system is detected.

5.3.2 The alarms described in Table 19.5.1 are to be indicated on the navigating bridge and the additional locations described and are to be in accordance with the alarm system specified by Pt 6, Ch 1,2.3.

5.3.3 Steering control systems are to be monitored and an audible and visual alarm is to be initiated on the navigation bridge in the event of:

- failure of the control system, including command and feedback circuits; or
- unacceptable deviation between the rudder order and actual rudder position and/or unacceptable delay in response to changes in the rudder order.

■ *Section 6* Emergency power

6.1 General

6.1.1 Where the rudder stock is required to be over 230 mm diameter in way of the tiller, excluding strengthening for navigation in ice, or for ships fitted with podded propulsion units or water jet systems where the power per propulsion unit exceeds 2,500 kW, an alternative power supply, sufficient at least to supply the steering arrangements which comply with the requirements of 2.1.3 and also its associated control system and the steering angle indicator, shall be provided automatically, within 45 seconds, either from the emergency source of electrical power or from an independent source of power located in the steering gear compartment. This independent source of power shall be used only for this purpose.

6.1.2 In every ship of 10 000 gross tonnage and upwards, the alternative power supply shall have a capacity for at least 30 minutes of continuous operation and in any other ship for at least 10 minutes.

6.1.3 Where the alternative power source is a generator, or an engine driven pump, starting arrangements are to comply with the requirements relating to the starting arrangements of emergency generators.

■ *Section 7* Testing and trials

7.1 Testing

7.1.1 The requirements of the Rules relating to the testing of Class 1 pressure vessels, piping, and related fittings including hydraulic testing apply.

7.1.2 After installation on board the vessel the steering gear is to be subjected to the required hydrostatic and running tests.

7.1.3 Each type of power unit pump is to be subjected to a type test. The type test shall be for a duration of not less than 100 hours, the test arrangements are to be such that the pump may run in idling conditions, and at maximum delivery capacity at maximum working pressure. During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another should occur at least as quickly as on board. During the whole test no abnormal heating, excessive vibration or other irregularities are permitted. After the test, the pump is to be opened out and inspected. Type tests may be waived for a power unit which has been proven to be reliable in marine service.

7.2 Trials

7.2.1 The steering gear is to be tried out on the trial trip in order to demonstrate to the Surveyor's satisfaction that the requirements of the Rules have been met. The trial is to include the operation of the following:

(a) The steering gear, including demonstration of the performances required by 2.1.2(b) and 2.1.3(b):
   - For the main steering gear trial, the propeller pitch of controllable pitch propellers is to be at the maximum design pitch approved for the maximum continuous ahead RPM;
   - If the ship cannot be tested at the deepest draught then the loading condition can be accepted on the conditions that either the rudder is fully submerged (at zero speed waterline) and the vessel is in an acceptable trim condition, or the rudder load and torque at the trial loading condition have been reliably predicted and extrapolated to the full load condition, to the satisfaction of the Administration. In any case, for the main steering gear trial, the speed of the ship corresponding to the maximum continuous revolutions of main engine and maximum design pitch applies;

(b) The steering gear power units, including transfer between steering gear power units;
(c) The isolation of one power actuating system, checking the time for regaining steering capability;
(d) The hydraulic fluid recharging system;
(e) The emergency power supply required by 6.1.1;
(f) The steering gear controls, including transfer of control and local control;
(g) The means of communication between the steering gear compartment and the wheelhouse, also the engine room, if applicable;
(h) The alarms and indicators;
(j) Where the steering gear is designed to avoid hydraulic locking this feature shall be demonstrated.

Test items (d), (g), (h) and (j) may be effected at the dockside.

7.2.2 The ability of the machinery to reverse the direction of thrust in sufficient time and bring the ship to rest within a reasonable distance from maximum ahead service speed is to be demonstrated and recorded.

7.2.3 The stopping times, ship headings and distances recorded on trials, together with the results of trials to determine the ability of ships having multiple propulsion/steering arrangements to navigate and manoeuvre with one or more of these devices inoperative, shall be available on board for the use of the Master or designated personnel.

■ *Section 8*
Additional requirements

8.1 For tankers, chemical tankers or gas carriers of 10 000 tons gross and upwards and every other ship of 70 000 tons gross and upwards

8.1.1 The main steering gear is to comprise two or more identical power units complying with provisions of 2.1.4.

8.2 For tankers, chemical tankers or gas carriers of 10 000 tons gross and upwards

8.2.1 Subject to 8.3 the following are to be complied with:

(a) The main steering gear is to be so arranged that in the event of loss of steering capability due to a single failure in any part of one of the power actuating systems of the main steering gear, excluding the tiller, quadrant or components serving the same purpose, or seizure of the rudder actuators, steering capability is to be regained in not more than 45 seconds after the loss of one power actuating system.
(b) The main steering gear is to comprise either:
   (i) two independent and separate power actuating systems, each capable of meeting the requirements of 2.1.2(b); or
   (ii) at least two identical power actuating systems which, acting simultaneously in normal operation, are capable of meeting the requirements of 2.1.2(b). Where necessary to comply with these requirements, inter-connection of hydraulic power actuating systems is to be provided. Loss of hydraulic fluid from one system is to be capable of being detected and the defective system automatically isolated so that the other actuating system or systems remain fully operational.
(c) Steering gears other than of the hydraulic type are to achieve equivalent Standards.

8.3 For tankers, chemical tankers or gas carriers of 10 000 tons gross and upwards but of less than 100 000 tons deadweight

8.3.1 Solutions other than those set out in 8.2.1 which need not apply the single failure criterion to the rudder actuator or actuators, may be permitted provided that an equivalent safety Standard is achieved and that:

(a) Following loss of steering capability due to a single failure of any part of the piping system or in one of the power units, steering capability is regained within 45 seconds; and
(b) Where the steering gear includes only a single rudder actuator special consideration is given to stress analysis for the design including fatigue analysis and fracture mechanics analysis, as appropriate, the material used, the installation of sealing arrangements and the testing and inspection and provision of effective maintenance. In consideration of the foregoing, regard will be given to the 'Guidelines' in Section 9.

8.3.2 Manufacturers of steering gear who intend their product to comply with the requirements of the 'Guidelines' are to submit full details when plans are forwarded for approval.

■ *Section 9*
'Guidelines' for the acceptance of non-duplicated rudder actuators for tankers, chemical tankers and gas carriers of 10 000 tons gross and upwards but of less than 100 000 tons deadweight

9.1 Materials

9.1.1 Parts subject to internal hydraulic pressure or transmitting mechanical forces to the rudder-stock are to be made of duly tested ductile materials complying with recognised Standards. Materials for pressure retaining components are to be in accordance with recognised pressure vessel Standards. These materials are not to have an elongation less than 12 per cent nor a tensile strength in excess of 650 N/mm^2.

9.2 Design

9.2.1 **Design pressure**. The design pressure should be assumed to be at least equal to the greater of the following:
(a) 1,25 times the maximum working pressure to be expected under the operating conditions required in 2.1.2(b).
(b) The relief valve(s) setting.

9.2.2 **Analysis.** In order to analyse the design the following are required:
(a) The manufacturers of rudder actuators should submit detailed calculations showing the suitability of the design for the intended service.
(b) A detailed stress analysis of pressure retaining parts of the actuator should be carried out to determine the stresses at the design pressure.
(c) Where considered necessary because of the design complexity or manufacturing procedures, a fatigue analysis and fracture mechanics analysis may be required. In connection with these analyses, all foreseen dynamic loads should be taken into account. Experimental stress analysis may be required in addition to, or in lieu of, theoretical calculations depending upon the complexity of the design.

9.2.3 **Dynamic loads for fatigue and fracture mechanics analysis.** The assumption for dynamic loading for fatigue and fracture mechanics analysis where required by 3.1.5, 8.3 and 9.2.2 are to be submitted for appraisal. Both the case of high cycle and cumulative fatigue are to be considered.

9.2.4 **Allowable stresses.** For the purpose of determining the general scantlings of parts of rudder actuators subject to internal hydraulic pressure the allowable stresses should not exceed:

$$\sigma_m \le f$$
$$\sigma_1 \le 1{,}5f$$
$$\sigma_b \le 1{,}5f$$
$$\sigma_1 + \sigma_b \le 1{,}5f$$
$$\sigma_m + \sigma_b \le 1{,}5f$$

where

f = the lesser of $\dfrac{\sigma_B}{A}$ or $\dfrac{\sigma_y}{B}$

σ_b = equivalent primary bending stress
σ_m = equivalent primary general membrane stress
σ_y = specified minimum yield stress or 0,2 per cent proof stress of material at ambient temperature
σ_B = specified minimum tensile strength of material at ambient temperature
σ_1 = equivalent primary local membrane stress

A and B are as follows:

	Wrought steel	*Cast steel*	*Nodular cast iron*
A	4	4,6	5,8
B	2	2,3	3,5

9.2.5 **Burst test.** Pressure retaining parts not requiring fatigue analysis and fracture mechanics analysis may be accepted on the basis of a certified burst test and the detailed stress analysis required by 9.2.2 need not be provided.
The minimum bursting pressure should be calculated as follows:

$$P_b = P A \frac{\sigma_{Ba}}{\sigma_B}$$

where
A = as from table in 9.2.4
P = design pressure as defined in 9.2.1
P_b = minimum bursting pressure
σ_B = tensile strength as defined in 9.2.4
σ_{Ba} = actual tensile strength.

9.3 Construction details

9.3.1 **General.** The construction should be such as to minimise local concentrations of stress.

9.3.2 **Welds.**

(a) The welding details and welding procedures should be approved.

(b) All welded joints within the pressure boundary of a rudder actuator or connection parts transmitting mechanical loads should be full penetration type or of equivalent strength.

9.3.3 **Oil seals.** Oil seals forming part of the external pressure boundary are to comply with 3.2.3 and 3.2.4.

9.3.4 **Isolating valves** are to be fitted at the connection of pipes to the actuator, and should be directly mounted on the actuator.

9.3.5 **Relief valves** for protecting the rudder actuator against over-pressure as required in 3.3.3 are to comply with the following:

(a) The setting pressure is not to be less than 1,25 times the maximum working pressure expected under operating conditions required by 2.1.2(b).

(b) The minimum discharge capacity of the relief valve(s) is to be not less than 110 per cent of the total capacity of all pumps which provided power for the actuator. Under such conditions the rise in pressure should not exceed 10 per cent of the setting pressure. In this regard due consideration should be given to extreme foreseen ambient conditions in respect of oil viscosity.

9.4 Non-destructive testing

9.4.1 The rudder actuator should be subjected to suitable and complete non-destructive testing to detect both surface flaws and volumetric flaws. The procedure and acceptance criteria for non-destructive testing should be in accordance with requirements of recognised Standards. If found necessary, fracture mechanics analysis may be used for determining maximum allowable flaw size.

9.5 Testing

9.5.1 Tests, including hydrostatic tests, of all pressure parts at 1,5 times the design pressure should be carried out subject to any limitations imposed by valves and other components. Where additional testing of systems or sub-systems following final assembly is required, the test pressure may be subject to any limitations imposed by valves and other components.

9.5.2 When installed on board the ship, the rudder actuator should be subjected to a hydrostatic test at the pressure defined in 9.5.1 and a running test.

9.6 Additional requirements for steering gear fitted to ships with Ice Class notations

9.6.1 *See* Pt 3, Ch 9.

Section 1 General requirements

1.1 Application

1.1.1 This Chapter applies to azimuth or rotatable thruster units, for propulsion or D.P. duty which transmit a power greater than 220 kW used as the sole means of steering and are in addition to the relevant requirements of Chapter 19.

1.1.2 In general, for a vessel to be assigned an unrestricted service notation a minimum of two azimuth thruster units are to be provided where these form the sole means of propulsion. Where a single thruster installation is proposed, it will be subject to special consideration.

1.2 Plans

1.2.1 The following additional plans are to be submitted for consideration together with particulars of materials and the maximum shaft power and revolutions per minute:

- Sectional assembly including nozzle ring structure, nozzle support struts, etc.
- Shafts, gears and couplings.
- Steering mechanisms with details of ratings.
- Bearing specifications.
- Schematic piping systems.

Section 2 Performance

2.1 General

2.1.1 The arrangement of thrusters is to be such that the ship can be satisfactorily manoeuvred.

2.1.2 For vessels with multiple azimuthing thrusters, the requirement for auxiliary steering arrangements in Ch 19,2 is to be achieved by equipping each of the azimuthing thrusters with its own dedicated and independent steering gear control system and power actuating system. Consideration will be given to alternative arrangements providing equivalence can be demonstrated.

2.1.3 In addition to the requirements of Chapter 19, the azimuthing mechanism is to be capable of a rotational speed of not less than 1,5 rev/min.

2.1.4 The main steering arrangements are to be capable of changing the direction of the ship's directional control system from one side to the other at declared steering angle limits at an average rotational speed of not less than 0,4 rev/min, with the ship running ahead at maximum ahead service speed.

2.1.5 The auxiliary steering arrangements are to be:

(a) Capable of changing the direction of the ship's directional control system from one side to the other at declared steering angle limits at an average rotational speed of not less than 0,083 rev/min, with the ship running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater.

(b) For all ships, operated by power where necessary to meet the requirements of (a) and in any ship having power more than 2,500 kW propulsion power per thruster unit.

Section 3 Construction and design

3.1 Materials

3.1.1 Specification for materials of gears, shafts, couplings and propeller, giving chemical composition, heat treatment and mechanical properties are to be submitted for approval.

3.1.2 Specification for materials for the stock, struts, etc., are to be submitted for approval.

3.1.3 Where an ice class notation is included in the class of a ship, additional requirements are applicable as detailed in Part 8 and Pt 3, Ch 9.

3.2 Design

3.2.1 The requirements detailed in Chapters 1, 5, 6, 7, 8, 9, 14 and 19 are to be complied with where applicable.

3.2.2 For steerable thrusters with a nozzle, the equivalent rudder stock diameter in way of tiller, used in Table 19.1.1 in Chapter 19, is to be determined as follows:

$$\delta_t = 26{,}03 \sqrt[3]{(V + 3)^2 A_N x_P} \quad \text{mm}$$

where

V = maximum service speed, in knots, which the ship is designed to maintain under thruster operation

A_N = projected nozzle area, in m^2, and is equal to the length of the nozzle multiplied by the mean external vertical height of the nozzle

and

x_P = horizontal distance from the centreline of the steering tube to the centre of pressure, in metres. The position of the centre of pressure is determined for both ahead and astern cases from Pt 3, Ch 13, 2.3.1.

The corresponding maximum turning moment, M_T, is to be determined as follows:

M_T = turning moment for conical couplings and is to be taken as the greatest of M_F, M_A or M_W

M_F = $P_L\, x_P$ x 10^6 N mm (kgf mm) in the ahead condition

M_A = $P_L\, x_P$ x 10^6 N mm (kgf mm) in the astern condition

M_W = the torque generated by the steering gear at the maximum working pressure supplied by the manufacturer, in N mm (kgf mm). M_W is not to exceed the greater of $3{,}0M_F$ or $3{,}0M_A$

P_L = lateral force on rudder acting at centre of pressure, as defined in Pt 3, Ch 13,2.2.1 (where A_R equals $2A_N$), in kN (tonne-f).

3.2.3 The nozzle structure is to be in accordance with Pt 3, Ch 13,3.

3.2.4 In addition to the requirements of Table 13.3.1, in Pt 3, Ch 13, the scantlings of the nozzle stock or steering tube are to be such that the section modulus against transverse bending at any section xx is not less than:

$$Z = 1{,}73 \sqrt{\left(V + 3^4\right) A_N^2\, x_P^2 + \frac{a^2}{4}\, T_M^2\, 10^4} \quad \text{cm}^3$$

where

a = dimension, in metres, as shown in Fig. 20.3.1

T_M = maximum thrust of the thruster unit in tonnes.

3.2.5 The scantlings of nozzle connections or struts will be specially considered. In the case of certain high powered ships, direct calculation may be required.

3.2.6 For steerable thrusters without a nozzle the scantlings in way of the tiller will be specially considered.

3.3 Steering gear elements

3.3.1 These gears are to be considered for the following conditions:

- a design maximum dynamic duty steering torque;
- a static duty ($\leq 10^3$ load cycles) steering torque, and the static duty steering torque should be not less than M_T.

Values for the above should be submitted together with the plans.

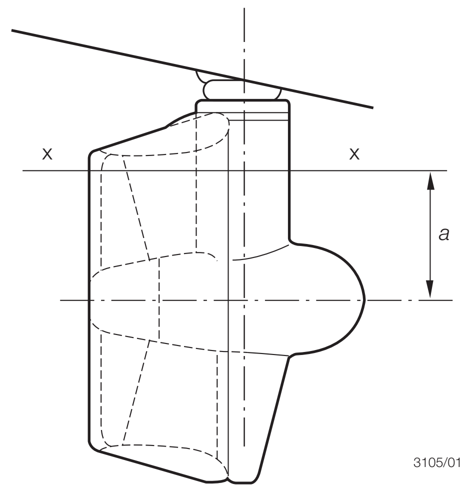


Fig. 20.3.1 Steerable thruster

3.4 Components

3.4.1 The hydraulic power operating systems for each azimuth thruster are to be provided with the following:

(a) arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system;

(b) a fixed storage tank having sufficient capacity to recharge at least one azimuth power actuating system including the reservoir. The piping from the storage tank is to be permanent and arranged in such a manner as to allow recharging from within the thruster space.

■ *Section 4* Control engineering arrangements

4.1 General

4.1.1 Except where indicated in this Section the control engineering systems are to be in accordance with Pt 6, Ch 1.

4.1.2 Steering control is to be provided for the azimuth thrusters from the navigating bridge, the main machinery control station and locally.

4.1.3 An indication of the angular position of the thruster(s) and the magnitude of the thrust are to be provided at each station from which it is possible to control the direction of thrust.

4.1.4 Means are to be provided at the remote control station(s) to stop each thrust unit.

4.2 Monitoring and alarms

4.2.1 Alarms and monitoring requirements are indicated in 4.2.2 and Table 20.4.1.

Table 20.4.1 Alarms for control systems

Item	Alarm	Note
Thruster azimuth	–	Indicator, *see* 4.1.3
Steering motor	Power failure, single phase	Also running indication on bridge and at machinery control station
Propulsion motor	Overload, power failure	Also running indication on bridge and at machinery control station
Control system power	Failure	
Hydraulic oil supply tank level	Low	
Hydraulic oil system pressure	Low	
Hydraulic oil system temperature	High	Where oil cooler is fitted
Hydraulic oil filters differential pressure	High	Where oil filters are fitted
Lubricating oil supply	Low	If separate forced lubrication

4.2.2 The alarms described in Table 20.4.1 are to be indicated individually on the navigating bridge and in accordance with the alarm system specified by Pt 6, Ch 1,2.3.

Section 5
Electrical equipment

5.1 General

5.1.1 The electrical installation is to be designed, constructed and installed in accordance with the requirements of 5.2 to 5.4.

5.1.2 Where the thruster units are electrically driven the relevant requirements, including surveys, of Pt 6, Ch 2 are to be complied with.

5.2 Generating arrangements

5.2.1 Where a central power generation system is employed, the requirements of Pt 6, Ch 2,16.3.5 are to be complied with.

5.2.2 The generating and distribution system is to be so arranged that after any single failure, steering capability can be maintained or regained within a period not exceeding 45 seconds, and the effectiveness of the steering after such a fault will not be reduced by more than 50 per cent. This may be achieved by the parallel operation of two or more generating sets, or alternatively when the electrical requirements may be met by one generating set in operation, on loss of power, the automatic starting and connection to the switchboard of a standby set, provided that this set can restart and run a thruster with its auxiliaries.

5.2.3 The failure of one thruster unit or its control system is not to render any other thruster inoperative.

5.3 Distribution arrangements

5.3.1 Thruster auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as is practicable and without the use of common feeders, transformers, converters, protective devices or control circuits.

5.4 Auxiliary supplies

5.4.1 Where the auxiliary services and thruster units are supplied from a common source, the following requirements are to be complied with:
(a) the voltage regulation and current sharing requirements defined in Pt 6, Ch 2,9.4.2 and 9.4.7 are to be maintained over the full range of power factors that may occur in service,
(b) auxiliary equipment and services are to operate with any waveform distortion introduced by converters without deleterious effect. (This may be achieved by the provision of suitably filtered/converted supplies).

Section 6
Testing and trials

6.1 General

6.1.1 The requirements detailed in Chapters 1, 5 and 19 are to be complied with and, in addition, the performance specified in 2.1.2 is to be demonstrated to the Surveyor's satisfaction.

6.1.2 The actual values of steering torque should be verified during sea trials to confirm that the design maximum dynamic duty torque has not been exceeded.

Section 1
Requirements for Condition Monitoring Systems and Machinery Condition-Based Maintenance Systems

1.1 Scope

1.1.1 The requirements of this Chapter are applicable to condition monitoring systems and machinery condition-based maintenance systems which:

(a) provide control, alarm or safety functions for essential machinery and equipment (*see* Pt 6, Ch 1,2.1.1) in accordance with manufacturers recommendations; or
(b) provide machinery condition related information as part of a machinery planned maintenance scheme for use as an alternative to machinery and equipment surveys required by the Regulations (*see* Pt 1, Ch 3) in accordance with LR's ShipRight procedures.

1.1.2 Condition monitoring systems which deviate from the requirements of this Section but provide an equivalent level of performance may be submitted to LR for consideration.

1.1.3 The requirements of this Section are to be applied to condition monitoring systems where the assignment of the **MCM** descriptive note is requested.

1.1.4 The requirements of this Section are to be applied to machinery condition-based maintenance systems where the assignment of the **MCBM** Descriptive Note is requested in addition to the **MCM** Descriptive Note.

1.2 Plans and particulars

1.2.1 The information and plans required to be submitted are as specified in the relevant Chapters of Parts 5 and 6 applicable to the particular machinery and where specified in this Chapter.

1.2.2 In addition to information required by 1.2.1, the documents listed in the *ShipRight Procedures for Machinery Planned Maintenance and Condition Monitoring* are to be submitted to LR for consideration.

1.2.3 In addition to information required by 1.2.1, the documents listed in the *ShipRight Procedures for Machinery Planned Maintenance and Condition Monitoring* are to be submitted to LR for consideration where the **MCBM** Descriptive Note is requested.

1.2.4 Equipment type approval reports providing evidence of compliance with 1.3.1 and 1.3.2 are to be submitted.

1.2.5 Additional information and plans providing evidence of compliance with the requirements of 1.3.3, 1.4.1 and 1.5.4 are to be submitted.

1.3 General requirements for condition monitoring systems

1.3.1 Condition monitoring equipment is to be capable of providing the service for which it is intended and is to satisfy the relevant requirements for condition monitoring equipment in LR's Type Approval System, *Product Assessment and Test Specification* (*TACM*).

1.3.2 Condition monitoring equipment is to be suitable for the environment in which it is intended to operate and is to satisfy the relevant requirements for environmental testing in LR's Type Approval System, *Test specification No.1*.

1.3.3 The installation of condition monitoring equipment in spaces and locations in which flammable mixtures are liable to collect, e.g., areas containing flammable gas or vapour and/or combustible dust, is to be minimised as far as is practicable and is to satisfy the relevant requirements for the use of electrical equipment in flammable atmospheres in Pt 6, Ch 2,14.

1.3.4 Where permanently installed condition monitoring systems are used, the cables are to comply with the relevant Sections of Pt 6, Ch 2,11 and the piping systems are to comply with relevant Sections of Chapters 12 and 13.

1.3.5 Where the system is based on programmable electronic systems, the requirements of Pt 6, Ch 1,3.6.3 are to be complied with.

1.3.6 Portable condition monitoring equipment is to be maintained and calibrated in accordance with a recognised National or International Standard to ensure the accuracy of the readings obtained. The standard is to include the issue of calibration certificates by a recognised test house in accordance with a recognised National or International Standard for instrument calibration. Copies of calibration certificates are to be retained on board and referenced on all condition monitoring reports submitted as part of the onboard condition monitoring program. Portable equipment used in hazardous areas is to be of a safe type suitable for use in the appropriate hazardous zone.

1.3.7 Measuring points are to be clearly identified in the submission and proposals to ensure repeatability of measurements are to be included.

1.3.8 The condition monitoring equipment is, as far as is practicable, to be located and installed such that it is accessible for maintenance and survey.

1.3.9 The condition monitoring equipment is to be installed in accordance with the manufacturer's instructions, *see* the *Product Assessment and Test Specification (PACM)*, or by an approved technical organisation as defined in the LR *ShipRight Procedures for Machinery Planned Maintenance and Condition Monitoring*, and to the satisfaction of the LR Surveyor.

1.4 Requirements for systems providing control, alarm and safety functions

1.4.1 In addition to the requirements of 1.3, condition monitoring equipment which provides control, alarm or safety functions for essential machinery and equipment is also to satisfy the relevant requirements for control, alarm and safety systems in Pt 6, Ch 1 and the installation of electrical equipment in Pt 6, Ch 2.

1.5 Requirements for systems providing machinery condition related information as part of machinery condition-based maintenance systems

1.5.1 In addition to the requirements of 1.3, condition monitoring equipment which provides machinery condition related information as part of a machinery planned maintenance scheme for use as an alternative to machinery and equipment surveys required by the Regulations is also to satisfy the relevant requirements of LR's *ShipRight Procedures for Machinery Planned Maintenance and Condition Monitoring*.

1.5.2 Where condition monitoring data is used as part of a machinery condition-based maintenance system, persons interpreting data and making diagnostic decisions are to be suitably competent, in accordance with ISO 18436 or an equivalent recognised National Standard. Evidence of competence, including training certificates of those providing analysis and data interpretation, are to be submitted and held on board. These certificates are to be made available to LR on request for audit and survey purposes.

1.5.3 The condition monitoring equipment is, as far as is practicable, to be located and installed such that it is accessible for maintenance and survey.

1.5.4 The condition monitoring equipment is to be installed in accordance with the manufacturer's instructions, *see* the *Product Assessment and Test Specification* (*TACM*) or by an approved technical organisation as defined in the *ShipRight Procedures for Machinery Planned Maintenance and Condition Monitoring*, and to the satisfaction of the LR Surveyor.

1.6 Requirements for machinery condition-based maintenance systems

1.6.1 Any vessel applying to operate a machinery condition-based maintenance system with the **MCBM** Descriptive Note is also to have an approved planned maintenance system in place with the **MPMS** Descriptive Note assigned.

1.6.2 Where a **MCBM** Descriptive Notation is requested and a vessel operates both an approved continuous machinery (CSM) survey cycle and has an approved machinery condition monitoring system in place which meets the requirements of the **MCM** Descriptive Notation, the **MCBM** Descriptive Notation is to be taken to mean that the vessel complies with the requirements of the **MCM** notation; however, the **MCM** Descriptive Notation will not be assigned.

1.6.3 Proposals for machinery condition-based maintenance systems are to be submitted for approval and are to meet the requirements of LR's *ShipRight Procedures for Machinery Planned Maintenance and Condition Monitoring*, and be to the satisfaction of the LR Surveyor. This plan is to include proposals for returning the vessel to a conventional maintenance and survey regime, and withdrawal of the **MCBM** Descriptive Notation, if the Owner decides for any reason to withdraw from condition-based maintenance or if the vessel should change ownership and the new Owners do not wish to retain the **MCBM** Descriptive Note.

1.6.4 Machinery condition-based maintenance systems are to be developed in accordance with the methodology given in ISO 17359 or an equivalent recognised National Standard.

1.6.5 Proposals are to identify those items of machinery and equipment which are to be maintained according to their condition and those which are to be maintained in accordance with manufacturer's time-based and running hours-based service and maintenance requirements. To assess which items are to be maintained according to their condition, a criticality assessment is to be carried out.

1.6.6 The criticality assessment is to include a FMEA/ FMECA assessment and is to take account of:

- machinery and equipment redundancy;
- failure rate and mean time to repair;
- local effects of failure on the safe operation of the machinery and equipment; and
- wider effects of failure on the ship's essential services and the safe operation of the ship, including environmental impact.

The criticality assessment is included in the submission for approval in accordance with LR's *ShipRight Procedures for Machinery Planned Maintenance and Condition Monitoring*, as stated in 1.6.3, and is to be to the satisfaction of the LR Surveyor.

1.6.7 Boilers and pressure vessels are not eligible for condition-based monitoring.

1.6.8 For all machinery and equipment which is proposed for maintenance based on condition monitoring data, in addition to the criticality assessment in 1.6.5, evidence is to be submitted which demonstrates that the condition of the machinery and equipment can be measured accurately and that the measured parameters are clearly defined in the condition monitoring plan.

1.6.9 Machinery condition monitoring is to meet the requirements of 1.3 and 1.5; in addition, the machinery condition-based maintenance plan is to include guidance on parameter limit values, trend analysis and fault diagnosis. This requirement for guidance information does not remove the requirement for those persons with responsibility for analysing condition monitoring data to be suitably trained and competent, in accordance with 1.5.2.

1.6.10 As part of the criticality assessment, it is to be demonstrated that any machinery included in the list of items for condition-based maintenance shall have measurable performance parameters which will give adequate warning of machinery deterioration that may result in failure, to allow maintenance to be scheduled in advance of such failure.

1.6.11 The condition-based maintenance plan is to maintain records of all data included in the plan approval document. The plan shall include proposals for:

- essential data describing the machine;
- essential data describing operating conditions;
- the measurement position;
- the measured quantity units and processing; and
- date and time information.

These records are to be available on request to any LR Surveyor or representative.

1.6.12 Proposals to ensure repeatability of results are to be submitted for approval.

1.6.13 Those items of machinery and equipment which are subject to a mandatory five-year survey are still required to be surveyed by a LR Surveyor at intervals not exceeding five years. A list of these items is to be found in LR's *ShipRight Procedures for Machinery Planned Maintenance and Condition Monitoring*.

1.6.14 For items which are not suitable for condition-based maintenance, *see* 1.6.7, the required maintenance will, as a minimum, comply with the equipment manufacturer's maintenance requirements.

1.6.15 The **MCBM** records, including diagnostic analysis and condition assessment reports, for items of machinery and equipment being maintained on the basis of condition monitoring data, are to be surveyed over a five-year continuous survey cycle, with 20 per cent of the records being subject to survey each year such that all records are surveyed over a five-year period.

Section 1 General requirements

1.1 General

1.1.1 This Chapter states the requirements for ships having machinery redundancy, and are in addition to the relevant requirements in other relevant Sections of these Rules.

1.1.2 The requirements, which are optional, cover machinery arrangements and control systems necessary for ships which have propulsion and steering systems configured such that, in the event of a single failure of a system or item of active equipment, *see* 1.1.3, the ship will retain the ability to use available installed prime mover capacity and installed propulsion systems that are unaffected by the failure. The ship is also to retain steering capability at a service speed of not less than seven knots. The requirements also cover machinery arrangements where the propulsion and steering systems are installed in separate compartments such that, in the event of a loss of one compartment, the ship will retain availability of propulsion power and manoeuvring capability.

1.1.3 For the purpose of this Chapter, items of active equipment are those which have a defined function for operation of a propulsion or steering system, such as but not limited to:

- Prime movers, i.e. diesel engines, electric motors, steam turbines and gas turbines;
- Generators and their excitation equipment;
- Transformers and converters;
- Gearing and shafting systems;
- Propulsion devices, i.e. propellers, water jets and thrusters;
- Pumps;
- Valves (where power actuated);
- Fuel treatment plant;
- Coolers/heaters;
- Filters;

Piping and electrical cables connecting items of active equipment are not considered to be active.

1.1.4 Requirements additional to these Rules may be imposed by the Flag State with whom the ship is registered and/or by the Administration within whose territorial jurisdiction the ship is intended to operate.

1.1.5 Sections 2, 3 and 4 state the applicable requirements for arrangements necessary to maintain availability of propulsion and manoeuvring capability, in the event of a single failure in equipment. Ships complying with the applicable requirements of Sections 2 to 4 will be eligible for the machinery class notation **PMR** or **PMRL** (Propulsion Machinery Redundancy), **SMR** or **SMRL** (Steering Machinery Redundancy) or **PSMR** or **PSMRL** (Propulsion and Steering Machinery Redundancy), which will be recorded in the *Register Book*.

NOTE
The additional **L** character to **PMR**, **SMR** and **PSMR** notations indicates a limited capability.

1.1.6 Section 5 states the additional requirements necessary to maintain availability of propulsion and manoeuvring capability where machinery is installed in separate compartments and the loss of any one compartment due to fire or flooding has been addressed. Ships complying with the applicable requirements of Sections 2 to 5 of this Chapter will be eligible for the machinery class notation **PMR★** or **PMRL★** (Propulsion Machinery Redundancy in separate machinery spaces), **SMR★** or **SMRL★** (Steering Machinery Redundancy in separate machinery spaces) or **PSMR★** or **PSMRL★** (Propulsion and Steering Machinery Redundancy in separate machinery spaces) which will be recorded in the *Register Book*.

1.1.7 For assignment of **PSMR** or **PSMR★** machinery class notations, the ship is to retain the ability to use not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems and retain steering capability at a service speed of not less than seven knots in the event of a single failure of a system or item of equipment.

1.1.8 Where the ship does not comply with 1.1.7 but can retain a service speed of not less than seven knots using available installed prime mover capacity and propulsion systems (which may be less than 50 per cent) following a failure of a system or item of equipment, machinery class notations **PSMRL** or **PSMRL★** may be assigned. The available installed prime mover capacity and installed propulsion systems are to be identified and included in 1.2.7.

1.2 Plans and information

1.2.1 In addition to the plans and information required by Parts 5 and 6, the information detailed in 1.2.2 to 1.2.6 is also to be submitted.

1.2.2 **Machinery spaces**. Plans showing the general arrangement of the machinery spaces, together with a description of the propulsion system, main and emergency electrical power supply systems and steering arrangements are to be submitted. The plans are to indicate segregation and access arrangements for machinery spaces and associated control rooms/stations.

1.2.3 **Failure Mode and Effects Analysis (FMEA)**. For the propulsion systems, electrical power supplies, essential services, control systems and steering arrangements, a FMEA report is to be submitted and is to address the requirements identified in Sections 2 and 5.

1.2.4 **Manoeuvring capability**. An assessment of the ship's ahead and astern manoeuvring capability, under the following operating conditions, is to be submitted:

(a) Where only 50 per cent or less of the installed prime mover capacity and 50 per cent or less of the installed propulsion systems are available.

(b) Where the steering capability requirements described in 3.2.1 are available.

IMO Resolution MSC 137(76) – *Standards for Ship Manoeuvrability*, provides guidance, on standard manoeuvres required in an assessment of the manoeuvrability of ships.

1.2.5 **Testing and trials procedures**. A schedule of testing and trials to demonstrate that the ship is capable of being operated with machinery functioning as described in 4.2 is to be submitted. In addition, any testing programme that may be necessary to prove the conclusions of the FMEA is to be submitted.

1.2.6 **Operating Manuals**. Operating Manuals are to be submitted for information and provided on board. The manuals are to include the following information:

(a) Particulars of machinery and control systems.

(b) General description of systems for propulsion and steering.

(c) Operating instructions for all machinery and control systems used for propulsion and steering.

(d) Procedures for dealing with the situations identified in the FMEA report.

1.2.7 **Installed prime mover capacity and installed propulsion systems**. A schedule of the propulsion systems and their operating capacity and capability under normal and foreseeable failure conditions is to be submitted.

■ *Section 2*
Failure Mode and Effects Analysis (FMEA)

2.1 General

2.1.1 An FMEA is to be carried out in accordance with 2.1.2 to 2.1.7 for the propulsion systems, electrical power supply systems and steering systems to demonstrate that a single failure in active equipment or loss of an associated sub-system, *see* 1.1.3, will not cause loss of all propulsion and/or steering capability as required by a class notation. Typical sub-systems include associated control and monitoring arrangements, data communications, power supplies (electrical, hydraulic or pneumatic), fuel, lubricating, cooling, etc.

2.1.2 The FMEA is to be carried out using the format presented in Table 22.2.1 or an equivalent format that addresses the same safety issues. Analyses in accordance with IEC 60812, *Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)* or IMO MSC Resolution 36(63) Annex 4 – *Procedures for Failure Mode and Effects Analysis*, would be acceptable.

2.1.3 The FMEA is to be organised in terms of equipment and function. The effects of item failures at a stated level and at higher levels are to be analysed to determine the effects on the system as a whole. Actions for mitigation are to be determined.

2.1.4 The FMEA is to:

(a) identify the equipment or sub-system, mode of operation and the equipment;

(b) identify potential failure modes and their causes;

(c) evaluate the effects on the system of each failure mode;

(d) identify measures for reducing the risks associated with each failure mode; and

(e) identify trials and testing necessary to prove conclusions.

Table 22.2.1 Failure Mode and Effects Analysis

Project: **Failure Mode and Effects Analysis**												
System:				Element:								Sheet No:
Item No.	Component Description	Function	Mode of Operation	Failure Mode	Failure Cause	Failure Detection	Effect of Failure		Severity	Corrective Action		Remarks
							On Item	On System				
NOTE The 'severity category' is to be in accordance with the following: (a) Catastrophic; (b) Hazardous; (c) Major; or (d) Minor.												

2.1.5 At sub-system level it is acceptable, for the purpose of these Rules, to consider failure of equipment items and their functions, e.g. failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed. In addition, their failure need only be dealt with as a cause of failure of the pump.

2.1.6 Where FMEA is used for consideration of systems that depend on software-based functions for control or co-ordination, the analysis is to investigate failure of the functions rather than a specific analysis of the software code itself.

2.1.7 The FMEA is to establish that in the event of a single failure:

(a) for **PSMR** and **PSMR★** notations, that the ship will retain not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems and retain steering capability;
(b) for **PMR** and **PMR★** notations, that the ship will retain not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems;
(c) for **SMR** and **SMR★** notations, that the steering capability remains available;
(d) for **PSMRL★** notation, that the ship will retain the ability to use available installed prime mover capacity and installed propulsion systems that are not directly affected by the failure and retain steering capability at a service speed of not less than seven knots; and
(e) for **PMRL★** notation, that the ship will retain the ability to use available installed prime mover capacity and installed propulsion systems that are not directly affected by the failure.

■ *Section 3*
Machinery arrangements

3.1 Main propulsion machinery

3.1.1 For **PSMR**, **PSMR★**, **PMR** and **PMR★** notations, independent main propulsion systems are to be provided so that the ship will retain not less than 50 per cent of the prime mover capacity and not less than 50 per cent of the installed propulsion systems in the event of a single failure of a system or active item of equipment, *see* 1.1.3. In the event of a single failure in equipment, the remaining system(s) is to be capable of maintaining a service speed of not less than seven knots and, for **PSMR** and **PSMR★** notations, give adequate manoeuvring capability, *see* 1.2.4.

3.1.2 For **PMRL**, **PSMRL**, **PMRL★** and **PSMRL★** notations, independent main propulsion systems are to be provided so that there remains the ability to use the remaining available installed prime mover capacity and installed propulsion systems following a single failure of a system or item of equipment. In the event of a single failure in equipment, the remaining system(s) is to be capable of maintaining a manoeuvring speed and, for **PSMRL** and **PSMRL★** notations, give adequate manoeuvring capability, *see* 1.2.4.

3.2 Steering machinery

3.2.1 For **PSMR**, **PSMR★**, **SMR** and **SMR★** notations, independent steering systems for manoeuvring the ship are to be installed, such that steering capability will continue to be available in the event of any of the following:

(a) Single failure in the steering gear equipment.
(b) Loss of power supply or control system to any steering system.

3.3 Electrical power supply

3.3.1 The main busbars of the switchboard supplying the propulsion machinery and essential services are to be capable of being isolated by a multi-pole linked circuit breaker, disconnector, or switch-disconnector into at least two independent sections.

3.3.2 In the event of the loss of one section or failure of the power supply from one generator, there is to be continuity of sufficient electrical power to supply essential services such that the available installed prime mover capacity and installed propulsion systems will continue to have the ability of functioning at their operational capability where **PSMRL**, **PSMRL★**, **PMRL and PMRL★** notations are required. *See* 3.2.1 for steering machinery requirements.

3.3.3 In the event of the loss of one section or failure of the power supply from one generator, there is to be continuity of sufficient electrical power to supply essential services such that the ship will retain not less than 50 per cent of the prime mover capacity and not less than 50 per cent of the installed propulsion systems where **PSMR**, **PSMR★**, **PMR** and **PMR★** notations are required. *See* 3.2.1 for steering machinery requirements.

3.3.4 For ships capable of operating with one service generator connected to the switchboard, arrangements are to be such that a standby generator will automatically start and connect to the switchboard on loss of the service generator. Sequential starting of essential services is to be provided.

3.3.5 For ships operating with two or more generator sets in service connected to the switchboard, arrangements are to be such that, in the event of loss of one generator, the remaining set(s) is to be adequate for the continuity of essential services supplied from that switchboard. This may be achieved by preferential tripping of non-essential services. Alternatively, arrangements can be such that a standby generator will start automatically and connect to the switchboard on loss of one of the generator sets in service.

3.4 Essential services for machinery

3.4.1 Services essential for the operation of the propulsion machinery, steering and the supply of electrical power are to be arranged so to that the ship will retain not less than 50 per cent of the prime mover capacity and 50 per cent of the installed propulsion systems and retain steering capability in the event of a single failure in any of the services, where required by the respective class notations.

3.5 Oil fuel storage and transfer systems

3.5.1 The arrangements for the storage of oil fuel bunkers are to ensure that there is an adequate supply of existing oil fuel on board to allow sufficient time for a shore-based quality analysis of new bunkers, in accordance with ISO 8217 *Petroleum Products – Fuels (Class F) Specification of Marine Fuels* prior to use.

3.5.2 Provision is to be made to enable samples of oil fuel to be taken at the bunkering manifolds.

■ *Section 4*
Control arrangements

4.1 General

4.1.1 This Section states the requirements for the installation of control, alarm and safety systems but does not signify that machinery spaces may be operated unattended. For unattended machinery space operation, compliance with Pt 6, Ch 1,4 is also required.

4.1.2 The control, alarm and safety systems required in 4.2 are to comply with Pt 6, Ch 1,2.

4.2 Bridge control

4.2.1 The controls, alarms, instrumentation and safeguards required in 4.2.2 to 4.2.6 are to be provided on the bridge.

4.2.2 For **PSMR**, **PSMR★**, **PMR** and **PMR★** notations, means are to be provided to ensure satisfactory control of propulsion in both the ahead and astern directions when all main propulsion systems are functioning and when one propulsion system is not available.

4.2.3 For **PSMR**, **PSMR★**, **SMR** and **SMR★** notations, means are to be provided to ensure satisfactory control of steering when all steering systems are functioning and when any one steering system is not available.

4.2.4 Where required by 5.4.3, isolation of essential services is to be carried out either automatically or manually from the bridge. Indication of the status of isolation arrangements is to be provided.

4.2.5 Instrumentation to indicate the operational status of running and standby machinery is to be provided for the propulsion systems, the supply of electrical power, steering systems and other essential services.

4.2.6 Alarms are to be provided in the event of:

(a) A fire in any machinery compartment.

(b) A high bilge level in any machinery compartment. Irrespective of the assignment of the **UMS** notation, the bilge level detection system and arrangements for automatically pumping bilges, if applicable, are to comply with Pt 6, Ch 1,4.6.

■ *Section 5*
Separate machinery spaces ★ (star) Enhancement

5.1 General

5.1.1 This Section states the additional requirements where propulsion and steering machinery are installed in separate compartments such that, in the event of the loss of one compartment, the ship will retain availability of propulsion power and manoeuvring capability.

5.1.2 The machinery arrangements, control arrangements and FMEA required by Sections 2 to 4, together with testing and trials requirements in Section 6, are to be complied with in addition to 5.2 to 5.7.

5.2 Machinery arrangements

5.2.1 The main propulsion machinery is to be arranged in not less than two compartments such that, in the event of the loss of one compartment, propulsion power and/or manoeuvring capability will continue to be available, where required by the respective class notations.

5.2.2 The steering systems are to be arranged in not less than two separate compartments, such that steering capability will continue to be available in the event of the loss of one compartment, where required by the respective class notations.

5.3 Electrical power supply

5.3.1 The generating sets and converting sets required by Pt 6, Ch 2,2 are to be arranged so that they are located in at least two separate machinery compartments.

5.3.2 The independent sections of the switchboard required by 3.3.1 are to be arranged in not less than two separate compartments.

5.3.3 In the event of the loss of one compartment, there is to be continuity of sufficient electrical power to supply essential services, such that propulsion power and steering capability will continue to be available.

5.4 Essential services for machinery

5.4.1 Services essential for the operation of the propulsion machinery, steering and the supply of electrical power are to be arranged, so that propulsion power and steering capability are maintained in the event of the loss of one machinery compartment.

5.4.2 The design of systems which may have a common source, such as those used for supplying oil fuel, lubricating oil, fresh and sea-water cooling, ventilation of compartments and engine starting energy, is to ensure continuous availability of supply in the event of the loss of any one compartment. Where applicable, continuous availability of heating services, oil fuel and water treatments is also to be provided. *See* 3.5 and 5.6 for oil fuel storage and transfer systems.

5.4.3 Where essential services are arranged so that they may supply machinery in another compartment, means of isolation from that compartment is to be provided.

5.4.4 Where pumps for essential services are arranged to supply more than one compartment, standby pumps for the same supplies are to be provided in a different compartment. The standby pumps are to be arranged to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

5.5 Bilge drainage arrangements

5.5.1 The independent power pumps for bilge drainage are to be located in two separate watertight compartments. Each pump is to be capable of draining any compartment. Means of isolation from other compartments is to be provided.

5.5.2 In addition to the independent power pumps installed to comply with 5.5.1, an emergency bilge drainage arrangement is to be provided in each main propulsion machinery space.

5.5.3 Each separate machinery compartment is to be provided with at least one independent power pump direct bilge suction.

5.6 Oil fuel storage

5.6.1 The oil fuel service tanks required by Ch 14,4.18 are to be located in separate compartments.

5.6.2 Provision is to be made to ensure that oil fuel preparation and transfer arrangements to the oil fuel service tanks are continuously available in the event of the loss of any one compartment, *see also* 5.4.2.

5.7 FMEA

5.7.1 The FMEA required by 2.1.1 for the propulsion systems, electrical power supplies, essential services, control systems and steering arrangements is also to address the following:

(a) Fire in a machinery space or control room.
(b) Flooding of any watertight compartment which could affect propulsion or steering capability.
(c) Separation of machinery spaces.

■ *Section 6* Testing and trials

6.1 Sea trials

6.1.1 In addition to the requirements for sea trials in Ch 1,5.2, trials are to be carried out to demonstrate that when the ship is operating 50 per cent of the prime mover capacity and 50 per cent of the installed propulsion systems, a speed of not less than 7 knots can be maintained with adequate steering capability, where required by the respective class notations.

6.1.2 Trials are to be carried out to demonstrate the ship's steering capability in accordance with the assessment required by 1.2.4 with one steering system out of action.

6.1.3 Where the FMEA report has identified the need to prove the conclusions, testing and trials are to be carried out as necessary to investigate the following:

(a) The effect of a specific component failure.
(b) The effectiveness of automatic/manual isolation systems.
(c) The behaviour of any interlocks that may inhibit operation of essential systems.

6.1.4 During sea trials, the operational envelope(s) is to be determined under the conditions detailed in 3.1.1 and/or 3.2.1, as required for the class notation.

Section

■ *Section 1* General

1.1 Scope and application

1.1.1 The requirements of this Chapter are additional for passenger ships and are related to machinery and equipment providing services necessary to support safe return to port under the ship's own propulsion in the event of flooding or after a fire and to support orderly evacuation and abandonment in the event of a fire.

1.1.2 The requirements of this Chapter are restricted to machinery and equipment specifically addressed by relevant engineering systems Rules.

1.1.3 The requirements of this Chapter should be read in conjunction with LR's ShipRight Procedure SRtP. Where the requirements of this Chapter and ShipRight SRtP are complied with, the vessel will be assigned the Descriptive Note SRtP.

NOTE

Vessels without the descriptive note should also be appraised, using the ShipRight Procedure SRtP Appendix 1 and 2 unless otherwise advised.

1.1.4 The performance of machinery and equipment for services referred to in the relevant SOLAS Regulations that are not specifically addressed by relevant engineering systems Rules are not considered (e.g., basic services to safe areas, radiocommunications, navigation systems, etc.). However, these services are to be considered in terms of:

(a) the supply of electrical power in accordance with SOLAS 1974, as amended; and
(b) protection provided to machinery and equipment described in 1.1.2 (e.g., fire suppression measures in spaces containing propulsion machinery).

1.1.5 For passenger ships having a length of 120 m or more, or having three or more main vertical zones, the requirements of Sections 1 to 5 apply.

1.1.6 For other passenger ships not covered by 1.1.5, the requirements of Sections 2 and 4 are not applicable. The requirements of Section 3 shall be restricted to the qualitative failure analysis described in 3.2.2.

1.1.7 These requirements do not address operational decisions on the actual use of machinery and equipment in the event of flooding or fire (e.g., the use of propulsion and steering in a flooding damage condition).

1.2 Definitions

1.2.1 For the purposes of this Chapter, 'the relevant SOLAS Regulations' refers to SOLAS 1974, as amended:

(a) Chapter II-1/B-1, Regulation 8-1, *System capabilities after a flooding casualty on passenger ships*;
(b) Chapter II-2/G, Regulation 21, *Casualty threshold, safe return to port and safe areas*; and
(c) Chapter II-2/G, Regulation 22, *Design criteria for systems to remain operational after a fire casualty*.

(a) and (b) apply for Sections 2 and 3, (c) applies for Section 4.

1.2.2 For the purposes of this Chapter, 'relevant engineering systems Rules' refers to this Part (i.e., Part 5), Pt 6, Ch 1 and Pt 6, Ch 2.

1.2.3 The 'casualty threshold' in the context of a fire includes:

(a) loss of space of origin up to the nearest 'A' class boundaries, which may be a part of the space of origin, if the space of origin is protected by a fixed fire extinguishing system; or
(b) loss of the space of origin and adjacent spaces up to the nearest 'A' class boundaries, which are not part of the space of origin.

1.2.4 Ship lengths and main vertical zones considered are to be as defined by Pt 3, Ch 1,6.1.8 and SOLAS 1974, as amended Chapter II-2/A, Regulation 3.32, respectively.

1.2.5 'Safe areas' are those that will be available, during a ship's return to port under its own propulsion after a casualty that does not exceed the casualty threshold stipulated, to provide the basic services to ensure that the health of passengers and crew is maintained.

1.2.6 For the purposes of this Chapter, 'reversionary control stations' are those control stations provided for use during safe return to port and orderly evacuation and abandonment to satisfy the requirements of Sections 2 and 4 in the event of the normal control station being subject to fire damage or flooding.

1.2.7 A 'failure' is the termination of the ability of an item to perform a required function. For the purposes of Section 3:

(a) failures result from a fault in a component or system such that it cannot perform an intended or required function, including faults resulting from fire or flooding damage;
(b) 'common cause failures' are those failures which will cause more than one item to fail simultaneously, or within a sufficiently short period of time as to have the effect of simultaneous failures; and
(c) 'consequential failures' are secondary failures caused by the effects of a primary failure, i.e., where the occurrence of a failure leads directly to further failures.

1.3 General requirements and risk management

1.3.1 For passenger ships having a length of 120 m or more, or having 3 or more main vertical zones, it is the responsibility of the Shipbuilder to ensure that the arrangement of the ship's machinery and equipment as described in 1.1.2 are sufficient for the intended operating modes and to support the provision of the services that the National Administration has determined to be necessary for:

(a) the ship's safe return to port under its own propulsion, *see* Section 2:
  (i) after a casualty that does not exceed the casualty threshold; or
  (ii) when the ship is subject to flooding of any single watertight compartment; and/or
(b) supporting the orderly evacuation and abandonment of the ship if the casualty threshold is exceeded, *see* Section 4.

This necessitates activities, which will normally be risk based, to determine the machinery and equipment needed to remain operational for a period of time to satisfy the requirements of the relevant SOLAS Regulations to the satisfaction of the National Administration. These activities are to be carried out prior to the submission of plans in accordance with this Chapter.

1.3.2 The activities referred to in 1.3.1 may be conducted at the same time, or in conjunction with, activities to determine the criteria that the National Administration specify as necessary to achieve overall compliance with the relevant SOLAS Regulations. The ship's intended operational routes and/or service restrictions may be considered when establishing criteria.

1.3.3 It is the responsibility of the Shipbuilder to ensure that watertight and fire divisions, fire-fighting systems and bulkhead decks shown on the plans are those approved by the National Administration.

1.3.4 Where alternatives to the requirements of this Chapter are proposed, details demonstrating that the machinery and engineering systems comply with the relevant SOLAS Regulations are to be submitted for consideration.

1.4 Plans and information

1.4.1 In addition to the plans and information otherwise required by relevant engineering systems Rules, the plans and information detailed in 1.4.2 to 1.4.12 are to be submitted.

1.4.2 The analysis report described in 3.1.5(a) that includes the following information:

(a) identification of any applicable standards used for analysis of the design;
(b) description of the analysis team and their roles for information only;
(c) identification of the objectives of the analysis, including any National Administration acceptance criteria;
(d) identification of assumptions made in the analysis;
(e) description of intended system function under normal conditions and in the event of fire or flooding;
(f) identification of the equipment, system or sub-system and mode of operation, including the design plans and information considered;
(g) identification of casualty scenarios, probable failure modes and acceptable deviations from the intended or required function;
(h) evaluation of the local effects and the effects on the overall installation of each failure mode as applicable;
(j) identification of the worst case scenario in the event of a fire casualty or flooding, as described in 2.1.1, and an assessment of the ship's ahead and astern manoeuvring capability under these conditions (IMO Resolution MSC.137(76), *Standards for Ship Manoeuvrability*, provides standards to assess the manoeuvrability of ships); and
(k) trials, testing and other activities necessary to verify compliance with Section 3. The final report described in 3.1.5(b) is to be submitted once the proposed design is finalised.

1.4.3 Description of intended system function under normal conditions and in the event of fire or flooding for the services referred to in Sections 2 and 4.

1.4.4 Details of analyses conducted to assess the availability of services referred to in Sections 2 and 4 in the event of fire or flooding.

1.4.5 Details of National Administration criteria (*see also* 1.3.1), including:

(a) service speed, manoeuvring capability and time period of operation and ship range for ship return to port under its own propulsion;
(b) systems determined to be vital to damage control efforts;
(c) identification of required internal communications arrangements; and
(d) identification of navigation light circuits to be capable of operation during return to port.

1.4.6 General arrangement plans of the ship showing the location of machinery and equipment, piping systems, cables and controls stations to be employed for:

(a) each of the services described in 2.1.2, 2.1.3, and 4.1.2; and
(b) the provision of electrical power described in 2.1.4 and 4.1.3.

The plans are to identify:

(c) watertight compartments and the bulkhead deck; and
(d) for passenger ships having a length of 120 m or more or having three or more main vertical zones:
  (i) safe areas in the context of a casualty; and
  (ii) casualty threshold 'A' class structural fire protection boundaries.

The plans are to indicate segregation and fire/flooding protection measures and access arrangements for machinery spaces and associated control stations. These plans are also to be made available to the Surveyor on board.

1.4.7 A functional description of the system configurations and intended systems operation in the event of a fire or flooding casualty for the services referred to in Sections 2 to 4. This is to include reversionary control stations and required internal communications. A copy is to be provided on board.

1.4.8 Identification and details:
(a) equipment designed to operate in flooded spaces or under fire conditions; and/or
(b) other flooding or fire protection measures.

1.4.9 A schedule of normal and emergency operating loads on the electrical system for the different expected operating conditions and services described in Sections 2 and 4.

1.4.10 Details identifying the auxiliary systems required for the operation and control of machinery and equipment to provide the services described in Sections 2 and 4.

1.4.11 Details of time period of operation and ship range and service speed corresponding to fuel storage capacity available in the event of fire or flooding scenarios.

1.4.12 A schedule of activities, including testing and trials, to verify that the ship is capable of providing the services described in Sections 2 and 4.

■ *Section 2* Safe return to port

2.1 General

2.1.1 Consistent with the requirements of the relevant SOLAS Regulations, this Section provides design criteria for machinery and equipment described in 1.1.2 to remain operational for the ship's safe return to port under its own propulsion, in the event of:
(a) a fire casualty that does not exceed the casualty threshold; or
(b) flooding of any single watertight compartment.

2.1.2 When fire damage from a casualty does not exceed the casualty threshold or when the ship is subject to flooding of any single watertight compartment, machinery and equipment essential for the following services are to remain operational in the remaining part of the ship not affected by fire or flooding:
(a) **propulsion systems and their necessary auxiliaries and control systems**. Propulsion machinery and auxiliary machinery essential for the propulsion of the ship at a service speed and range/distance acceptable to the National Administration for return to port under its own propulsion, *see* Section 3;
(b) **steering systems and steering-control systems**. Steering systems and steering-control systems sufficient to provide manoeuvring capability acceptable to the National Administration for return to port under its own propulsion, *see* Section 3;
(c) **systems for transfer and service of oil fuel**. Systems for internal transfer and service of oil fuel capable of fuel supply to active propulsion and power generation equipment;
(d) **bilge and ballast system**. The bilge pumping systems, and all associated equipment essential for its operation, in all spaces not directly affected by the casualty, *see also* Chapter 13 and Pt 6, Ch 1,2.7;
(e) **flooding detection systems**. *See also* Ch 13,14;
(f) **internal communications**. The means of communication required by:
  (i) Ch 1,4.7, Pt 6, Ch 1,2.2.2 and/or 2.6.3 between the bridge and machinery main and subsidiary control stations and engineer's accommodation; and
  (ii) Ch 19,2.1.7 between the navigating bridge and the steering gear compartment;
necessary for operation of machinery and equipment, or otherwise identified by the National Administration to be required, during a ship's return to port under its own propulsion; and
(g) **navigation lights**. Electric circuit protection, controls and failure alarms for lights specified by the National Administration to be capable of operation, *see also* Pt 6, Ch 2,15.6.

2.1.3 In addition to the requirements of Pt 6, Ch 2,1.16 and 1.17, when fire damage from a casualty does not exceed the casualty threshold or when the ship is subject to flooding of any single watertight compartment, machinery and equipment essential for the following services are to remain operational in the remaining part of the ship not affected by fire or flooding:
(a) for **internal communication**:
  (i) general emergency alarm system. This is in addition to the requirements of Pt 6, Ch 2,18.2;
  (ii) public address system. This is in addition to the requirements of Pt 6, Ch 2,18.3; and
  (iii) from the safety centre as required by Pt 6, Ch 2,17.10.3;
where identified by the National Administration to be required to satisfy the relevant SOLAS Regulations for communication between the bridge, engineering spaces, safety centre, fire-fighting and damage control teams, and for passenger and crew notification and mustering;
(b) for **fire main systems** where supplied by electrically driven fire pumps, the pumps (and electrical equipment essential for their operation) are to be located and arranged such that operating capability will be available in the event of any main vertical zones being directly affected by the casualty. This is in addition to the requirements of Pt 6, Ch 2,17.4;
(c) for **fixed fire-extinguishing systems**:
  (i) for automatic sprinkler systems where supplied by electrically driven pumps, the pumps are to be located and arranged such that operating capability will be available in all spaces not directly affected by the casualty. This is in addition to the requirements of Pt 6, Ch 2,17.2;
  (ii) for electrically driven refrigeration units for carbon dioxide fire-extinguishing systems, the units are to be located and arranged such that operating capability will be available in all spaces not directly affected by the casualty. This is in addition to the requirements of Pt 6, Ch 2,17.5; and
  (iii) electrically operated fire-extinguishing media release alarms in spaces not directly affected by the casualty. This is in addition to the requirements of Pt 6, Ch 2,17.9.

(d) the fire detection and alarm system in all spaces not directly affected by the casualty. This is in addition to the requirements of Pt 6, Ch 1,2.8 and Pt 6, Ch 2,17.1;
(e) power-operated watertight doors in spaces not directly affected by the casualty. This is in addition to the requirements of Pt 6, Ch 2,19.1;
(f) lighting of safe areas and escape route or electrically powered low location lighting. This is in addition to the requirements of Pt 6, Ch 2, 3, 5.4, 5.7, 18.1 and 18.4; and
(g) other systems required by relevant engineering systems Rules that the National Administration has determined to be vital to damage control efforts.

2.1.4 When fire damage from a casualty does not exceed the casualty threshold or when the ship is subject to flooding of any single watertight compartment, electrical power, where required, is to be available and sustainable for the following services:
(a) those required by 2.1.2;
(b) navigational systems, including navigation lights, required by the National Administration to be capable of operation during return to port (*see also* Pt 7, Ch 9 for relevant classification notations);
(c) internal communication required during a ship's return to port under its own propulsion. Where applicable, charging power for portable means of communication is to be included;
(d) external communication (for communicating via the GMDSS or the VHF Marine and Air Band distress frequencies even if the main GMDSS equipment is lost);
(e) fire pumps for the fire main system not directly affected by the casualty;
(f) fixed fire-extinguishing systems (gaseous and water) designed to protect an entire space in all spaces not directly affected by the casualty;
(g) fire detection and alarm system in all spaces not directly affected by the casualty;
(h) power-operated watertight and semi-watertight doors;
(j) systems and equipment intended to support the provision of services to safe areas;
(k) other systems that the National Administration has determined to be vital to damage control efforts; and
(l) other fixed electrically powered loads intended to be operated during return to port.

The electrical power available is to be at least sufficient to supply the machinery and equipment specified by the National Administration as necessary and any additional loads identified in (l) during a ship's return to port under its own propulsion with due regard to such services as may be operated simultaneously.

2.1.5 Auxiliary and support systems (e.g., engine-room ventilation, lighting of spaces outside safe areas not affected by the casualty, etc.) required for the operation and control of machinery and equipment required to operate in accordance 2.1.2 and 2.1.3 and to provide electrical power in accordance with 2.1.4 are to remain operational.

2.1.6 Oil fuel stores, machinery and equipment are to have sufficient capacity to permit the services required by 2.1.2 to 2.1.5 to be provided for a time period of operation, ship range/distance and service speed acceptable to the National Administration for the ship's return to port under its own propulsion.

2.1.7 To satisfy 2.1.2 to 2.1.6, machinery and equipment is to be provided, constructed, segregated and arranged such that the services specified may be provided safely and effectively in the event of potential damage to machinery and equipment as a result of a fire that does not exceed the casualty threshold or flooding of any single watertight compartment, including control, safety, alarm and monitoring equipment and control stations.

2.1.8 A description of the intended system function in the event of fire or flooding for the services referred to in this Section are to be submitted for consideration, *see* 1.4.2 and 1.4.3. A risk based analysis is to be conducted in accordance with standards acceptable to LR to assess the availability of services required by this Section (for propulsion and steering, *see* Section 3; for other services, *see* 1.4.4 and 3.3.4).

■ *Section 3*
Qualitative failure analysis for propulsion, steering and essential services

3.1 General

3.1.1 A qualitative risk based failure analysis is to be conducted in accordance with this Section to assess compliance with the analysis objectives.

3.1.2 The analysis is to assess the magnitude and consequences of various types of potential hazards in the design that might lead to failure to fulfil the analysis objective(s) stated in 3.2. The following are to be considered during the analysis:
(a) analysis facilitation;
(b) these Rules;
(c) relevant statutory regulations and National Administration criteria;
(d) the ship design;
(e) the intended ship operation; and
(f) the relevant machinery, equipment and systems.

3.1.3 Those conducting the analysis and their roles are to be recorded in the analysis report.

3.1.4 Requirements specified by the National Administration to satisfy the relevant SOLAS Regulations for the ship's propulsion and steering during return to port, *see* 2.1.2, are to be identified in the analysis report, *see also* 1.3.1.

3.1.5 The analysis is to be documented, *see* 1.4.2, and two reports are to be submitted:

(a) a preliminary analysis, after the initial arrangements of different compartments and propulsion and steering arrangements are known, to permit an assessment of compliance with this Section. This is to include an assessment of propulsion and steering capability in the event of a failure, fire or flooding in any compartment casualty; and then

(b) a final report on the design, documenting compliance with this Section, that includes a detailed assessment of machinery and equipment required to provide propulsion and steering safely and effectively in accordance with the applicable requirements of 2.1.2.

3.2 Analysis objectives

3.2.1 For passenger ships having a length of 120 m or more, or having 3 or more main vertical zones, the analysis is to:

(a) assess, identify and record the effects of failure in propulsion and steering equipment and systems after a fire casualty or flooding as described in 2.1.1(a) and (b); and

(b) verify compliance with 2.1.2(a) and (b).

3.2.2 For other passenger ships, the analysis is to assess, identify and record the effects of failure in propulsion and steering equipment in any space.

3.3 Analysis scope

3.3.1 The analysis is to consider the propulsion and steering machinery, equipment and other associated systems and equipment which might impair the availability of propulsion and steering.

3.3.2 To consider the effects of fire or flooding, the analysis is to address the installed locations of relevant equipment and systems.

3.3.3 The analysis is to include assessment of potential common cause failures and consequential failures when analysing system redundancy intended to maintain propulsion and/or steering in the event of a failure.

3.3.4 Where the analysis scope is extended to additionally consider other services and verify additional compliance with the requirements of Sections 2 and/or 4, details may be submitted, *see* 1.4.3 and 1.4.4.

■ *Section 4*

Orderly evacuation and abandonment after a casualty

4.1 General

4.1.1 Consistent with the requirements of the relevant SOLAS Regulations, this Section provides design criteria for machinery and equipment described in 1.1.2 to remain operational, thereby supporting orderly evacuation and abandonment of the ship in the event of a fire that exceeds the casualty threshold.

4.1.2 In addition to the requirements of Pt 6, Ch 2,1.14, when fire damage from a casualty exceeds the casualty threshold, machinery and equipment essential for the provision of the following emergency services are to remain operational in the remaining part of the ship not affected by fire:

(a) for **fire main systems** where supplied by electrically driven fire pumps, the pumps (and electrical equipment essential for their operation) are to be located and arranged such that operating capability will be available in all main vertical zones not directly affected by the casualty. This is in addition to the requirements of Pt 6, Ch 2,17.4;

(b) for **internal communication**:
   - (i) general emergency alarm system. This is in addition to the requirements of Pt 6, Ch 2,18.2;
   - (ii) public address system. This is in addition to the requirements of Pt 6, Ch 2,18.3; and
   - (iii) from the safety centre as required by Pt 6, Ch 2,17.10.3;

   where identified by the National Administration to be required to satisfy SOLAS 1974 as amended, Chapter II-2/G, Regulation 22.3.1.2 for communication in support of fire-fighting and/or for passenger and crew notification and evacuation;

(c) for **bilge systems**, the bilge pumping systems, and all associated equipment essential for its operation, in all spaces not directly affected by the casualty to permit the removal of fire-fighting water. This is in addition to the requirements of Chapter 13 and Pt 6, Ch 1,2.7; and

(d) lighting of escape routes, assembly stations and at embarkation stations of life-saving appliances and electrically powered low location lighting. This is in addition to the requirements of Pt 6, Ch 2, 3, 5.4, 5.7, 18.1 and 18.4.

4.1.3 When fire damage from a casualty exceeds the casualty threshold, electrical power, where required, is to be available and sustainable for the following services:

(a) those required by 4.1.2;

(b) other required means of internal communications systems not addressed by 4.1.2(b);

(c) means of external communications provided to communicate via the GMDSS or the VHF Marine and Air Band distress frequencies even if the main GMDSS equipment is lost;

(d) guidance systems for evacuation not addressed by 4.1.2(d);

(e) life-saving appliances and arrangements;

(f) other systems that the National Administration has determined to be necessary to comply with SOLAS 1974 as amended, Chapter II-2/G, Regulation 22.3.1; and
(g) other fixed electrically powered loads intended to be operated during evacuation and abandonment.

The electrical power available is to be at least sufficient to supply the machinery and equipment specified by the National Administration as necessary to support orderly evacuation and abandonment with due regard to such services as may be operated simultaneously.

4.1.4 Machinery and equipment required to satisfy this sub-Section is to be capable of operation for at least 3 hours based on the assumption of no damage outside the unserviceable main vertical zone. System operation within the unserviceable main vertical zones is not required.

4.1.5 A description of the intended system function in the event of fire for the services referred to in this Section is to be submitted for consideration, *see* 1.4.3. A risk based analysis is to be conducted in accordance with standards acceptable to LR to assess the availability of services required by this Section, *see* 1.4.4 and 3.3.4.

■ *Section 5*
Verification, testing and trials

5.1 General

5.1.1 Activities, including testing and trials, are to be carried out to verify that the services described in Sections 2 and 4 may be provided in the event of fire or flooding to the satisfaction of LR, *see* 1.1.3 and 1.4.12. These activities are to include at least those in 5.1.2 and 5.1.3.

5.1.2 System Capability Testing is to be carried out to verify the ability of each essential system to provide capabilities in line with the design criteria. This testing is to be completed during harbour acceptance trials and sea trials, to the satisfaction of LR.

5.1.3 Scenario testing is to be carried out, verifying the ability of all the essential systems to provide the required capabilities under the identified fire and flooding casualties, taking full account of interaction and dependencies between the essential systems. Tests can be performed during harbour acceptance trials; however, certain scenarios will be required to be tested under sea-going conditions, where performance can only be properly verified during trials at sea (e.g., navigational systems, manoeuvrability, etc.). Testing of at least six scenarios is to be completed and is to include at least:
(a) loss of a Main Vertical Zone;
(b) casualty that results in the largest reduction in propulsion power;
(c) casualty that results in the largest reduction in steering capability;
(d) casualty that results in the most manual actions;
(e) casualty with the highest fire risk/load; and
(f) casualty affecting the greatest number of essential systems.

NOTE: It is acceptable that scenarios (b), (c), (d), (e) and (f) may be covered by the same test if applicable.

5.1.4 The above testing is to verify:
(a) The effect of a specific component failure.
(b) The effectiveness of automatic/manual isolation systems.
(c) The behaviour of any interlocks that may inhibit operation of essential systems.

5.2 Trials

5.2.1 In addition to the requirements for sea trials in Ch 1,5.2, trials are to be carried out to demonstrate that an acceptable service speed and steering capability for return to port can be achieved in the event of fire or flooding, *see* 2.1.2(a), (b) and 5.1.3. The operational envelope(s) under the failure conditions is(are) to be determined.

■ *Section 1* General

1.1 Scope

1.1.1 The requirements of this Chapter apply to machinery and equipment fitted to combustion machinery in order to reduce emissions produced by the combustion of fuel. Such machinery and equipment is hereinafter referred to as emissions abatement plant.

The requirements are intended to ensure that the emissions abatement plant is safe to operate and maintain and, additionally, where the combustion machinery provides power for essential services, that failure of the emissions abatement plant does not result in an unacceptable loss or degradation of those essential services.

The requirements are applicable to emissions abatement plant making use of both primary techniques, which reduce emissions by controlling the combustion process or removing pollutants prior to combustion, and to secondary emissions abatement techniques which reduce emissions from the exhaust gas after combustion.

It should be noted that these requirements do not provide for the reliability or redundancy necessary to ensure continued operation of the emissions abatement plant, and thereby compliance with relevant emissions requirements, following failure of any machinery, equipment or components associated with the emissions abatement plant.

■ *Section 2* Functional requirements

2.1 Functional requirements of emissions abatement plant

2.1.1 Emissions abatement plant is to be capable of operating at the maximum output power of the combustion machinery to which it is connected. Where the machinery installation is configured such that it is not intended to operate all the combustion machinery connected to the emissions abatement plant simultaneously in normal operating conditions, this will be subject to special consideration and supported by the submission required by 3.1.2. For engines, the maximum power is as stated on the Engine International Air Pollution Prevention Certificate (EIAPPC) or an equivalent certificated engine rating for vessels which are not subject to MARPOL Annex VI.

2.1.2 Operation and maintenance of the emissions abatement plant is not to present a hazard to the ship's occupants or to the environment.

2.1.3 Failure of the emissions abatement plant is not to present a hazard to the ship's occupants or any other hazard other than untreated emissions to the environment.

2.1.4 Where the emissions abatement plant is connected to combustion machinery providing power for essential services, failure of, or the inability to operate, the emissions abatement plant is not to prevent the combustion machinery from delivering sufficient power to those essential services so as to ensure the safe operation of the ship.

2.1.5 Any discharges to water from the emissions abatement plant are to be in accordance with the requirements of National and International Regulations, as applicable.

■ *Section 3* Information to be submitted

3.1 General

3.1.1 The information required by this Section, the information required by Pt 3, Ch 1,5 and Chapter IV of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquid Chemicals in Bulk*, as applicable (hereinafter referred to as the Rules for Ships for Liquid Chemicals).

3.1.2 A description of the emissions abatement plant and the abatement technique(s) used. This is to include details of the proposed combustion machinery operating configurations where using a common emissions abatement system for multiple exhaust gas inlet streams and any limitations on the operation of combustion machinery connected to the emissions abatement system.

3.1.3 Where emissions abatement plant makes use of more than one abatement technique, e.g., separate means for reducing NO_x and SO_x, details demonstrating their compatibility with the combustion machinery and with each other.

3.1.4 Diagram showing the process flows.

3.1.5 Details of the maximum and minimum ambient and sea-water temperatures within which the emissions abatement plant is to operate, and maximum and minimum ambient air temperature and humidity where applicable.

3.1.6 Details of the hazards associated with operation and maintenance and reasonably foreseeable failure of the emissions abatement plant and the means by which they are mitigated.

3.1.7 Details of any fuel treatments, fuel additives or fuel emulsification used as a primary means of emissions abatement from combustion machinery, together with a manufacturer's letter confirming the suitability of combustion machinery to operate with such treatments and additives. Details are to include evidence that materials, fuel filtration and arrangements for the control of viscosity and temperature have been suitably modified, along with evidence of the suitability of fuel pumps and fuel valves for the treated fuel, with particular attention to viscosity, lubricity and stability, as applicable.

3.2 Materials

3.2.1 Details of the materials proposed for all types of construction.

3.3 Chemical substances

3.3.1 Details of the flammability, toxicity, corrosivity and reactivity of any chemicals used, together with details of any exothermic and hazardous reactions, particularly with regard to sea-water.

3.3.2 General arrangement of spaces where toxic or flammable liquids, gases, dusts or vapours are stored or may accumulate, indicating the hatches and other access openings.

3.3.3 Details of arrangements for loading, storage, transfer and disposal of chemicals, by-products or waste products.

3.3.4 General arrangement showing spaces maintained at an over-pressure to prevent the ingress of gases, dusts or vapours.

3.3.5 Details and arrangements of blowdown and bleed-off systems, where applicable, including quantities of chemicals, substances and effluents and the capacity and working pressure of tanks and receivers installed for the reception of such substances and effluents.

3.3.6 Arrangements for purging, gas freeing, inerting or otherwise rendering safe of the emissions abatement plant and storage facilities for chemicals, effluent and by-products associated with the plant.

3.3.7 The flow and return flow of chemicals, substances, effluent or by-products, including:

(a) Substance supply and product discharge, with details of the arrangements showing the location of shut-off valves and of the control and indicating stations.
(b) The process plant parameters and analysis of conditions under which emergency shut-down will be initiated.
(c) Measures to eliminate risk of process fluid reverse flows which could present a risk to propulsion engines, auxiliary engines and essential services.
(d) The proposed emergency procedures for controlled shut-down of the plant, i.e., depressurising, isolating and the arrangements for the continued operation of the essential services necessary to allow for such controlled shut-down under the emergency conditions identified in 3.3.7(b), as applicable.

3.3.8 Proposals for the decontamination of the emissions abatement plant compartments for installations using chemicals, substances and/or producing effluent or by-products or where there is a possibility of generating hazardous substances during the operation of plant. These proposals are to include both normal operating requirements for decontamination (such as for carrying out maintenance) and post-incident decontamination.

3.3.9 Arrangement for the detection of liquids, gas and vapours where such substances could present a fire, explosion or health hazard.

3.4 Mechanical equipment

3.4.1 Details of mechanical equipment associated with the emissions abatement plant to be installed.

3.4.2 Details of any safety and pressure-relief devices and their discharge arrangements.

3.4.3 Plans showing the materials of construction, working pressures and temperatures, maximum and minimum exhaust gas flows, fuel quality parameters, maximum and minimum flow rates of any water, fluids, chemicals or substances required by the process, maximum effluent or by-product discharge rate resulting from the process.

3.4.4 Details of the arrangements for protecting the emissions abatement plant, its tanks and vessels against temperature, over-pressure and vacuum. Details are to include consideration of storage temperature requirements and, where applicable, tanks are to be maintained within the temperature limits of the chemicals and substances they contain so as to avoid risks of boiling, stress corrosion, freezing and other temperature-sensitive processes.

3.4.5 Details of the by-pass arrangements or, where considered unnecessary, evidence demonstrating that the emissions abatement plant is capable of continued operation with the expected gas flows. Evidence is to include conditions where the emissions abatement plant is in a shut-down condition, both as a result of emergency conditions and when shut down for normal operational reasons. This is to be supported by detailed proposals demonstrating material suitability and is to ensure that, where there is a risk of blockage, this can be monitored so as to ensure that remedial action can be taken before blockage presents a risk to both propulsion and auxiliary engine and emissions abatement plant operations.

3.5 Pressure vessels

3.5.1 Plans of any pressure vessels, including details of the support of the vessels. Diagrammatic plans for systems associated with emissions abatement process equipment as required by Chapter 10 and Chapter 11, as applicable.

3.5.2 Details of the safety and pressure-relief devices and their discharge arrangements.

3.5.3 Stress calculations taking into account the ship linear and angular accelerations, roll and pitch amplitudes, ship flexure and wind loads, appropriate to any condition which may normally arise at sea.

3.6 Pumping and piping

3.6.1 Plans of the emissions abatement plant piping systems, showing the materials of construction, scantlings, support and expansion arrangements, together with the calculations.

3.6.2 Diagrammatic plans for systems associated with emissions abatement process equipment, as required by Chapter 12, Chapter 13 and Chapter 14 and by the Rules for Ships for Liquid Chemicals, as applicable.

3.6.3 Plans showing the arrangement and dimensions of main exhaust pipes, with details of flanges, bolts and weld attachments and particulars of the materials of the pipes, flanges, bolts and welding consumables.

3.6.4 Details of the safety and pressure-relief devices and their discharge arrangements.

3.6.5 Details of air and sounding pipes to tanks containing chemicals, substances and effluent.

3.6.6 The arrangements for the storage on board the ship, and the disposal, of bilge and effluent from the emissions abatement plant spaces, giving particular consideration to the risk of flooding as a result of emissions abatement plant failure. Recognition is to be given to the requirements of the appropriate National Authority.

3.7 Electrical and control equipment

3.7.1 General arrangement plan of the process plant, showing the location of the major items of electrical equipment.

3.7.2 Line diagram of the installation(s), indicating the rating of the various items of rotating machinery, converters and transformers.

3.7.3 Arrangement plans and circuit diagrams of the switchboards.

3.7.4 General arrangement plan of the process plant, showing the location of electrical equipment in hazardous zones.

3.7.5 A schedule of safe-type electrical equipment located in hazardous zones, giving details of the type of equipment employed, the certifying authority and the certificate number.

3.7.6 Line diagrams of any control system(s) fitted.

3.7.7 General arrangement plan of the process plant, showing the locations of items of control equipment and the locations of hazardous zones.

3.7.8 Schedule of the parameters which are monitored and controlled, including alarms and shut-down devices.

■ *Section 4* Materials

4.1 General

4.1.1 The materials used in the construction of the emissions abatement plant and any associated chemical and effluent storage tanks are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* and/or the Rules for Ships for Liquid Chemicals.

■ *Section 5* Hull construction

5.1 General

5.1.1 The hull structure is to comply with the relevant requirements of Parts 3 and 4, except where stated otherwise in this Section.

5.1.2 All substance and effluent tank structures and their location relative to the ship's hull are to comply with Chapters 2 and 4 of the Rules for Ships for Liquid Chemicals.

5.1.3 Where necessary, the probable temperature variations during operations and the thermal stress considerations are to be stated. Where it is necessary either to heat or cool chemical storage tanks, the arrangements are to meet the requirements of Chapter 7 of the Rules for Ships for Liquid Chemicals.

5.1.4 Where independent tanks are used for chemical substances, these are to be bunded to contain spillage. The bund is to comply with the following:

(a) the bund is dimensioned so as to contain the maximum contents of the tank at the angles of inclination required for main and auxiliary machinery in Table 1.3.2 in Chapter 1; or
(b) there is a drain arrangement meeting the requirements of 5.1.6; or
(c) the tank is located in a dedicated compartment containing no equipment other than that required by the tank with permanent access and floor plates positioned above the liquid level if the tank were to discharge its full contents into the compartment. Any valves, equipment and emergency stop functions are to be operable from outside this compartment and are to meet the requirements of 5.2.

Tanks and spill containment arrangements are to be fitted with alarms and safeguards, in accordance with Table 9.1.9.

5.1.5 Proposals are to be made for the dimensioning of containment arrangements, relative to the potential leakage which may require containment. Where it is not practicable to contain the potential leakage fully and where this leakage can pose a hazard to personnel, proposals are to be submitted, demonstrating that leakage will be transferred to a suitable retention tank, and the means of transfer shall be capable of operating in a dead ship condition and shall be fitted with a flow detection alarm, in accordance with Table 9.1.9.

5.1.6 Tanks are to be arranged such that any residues and slops can be pumped out, drained or otherwise removed from the tank without exposing personnel to these residues and slops.

5.1.7 Chemical tanks are not to be located in the same space as essential machinery and equipment.

5.1.8 Arrangements for venting and gas-freeing chemical tanks required by emissions abatement plant are to meet the requirements of Chapter 8 of the Rules for Ships for Liquid Chemicals.

5.2 Location service and control spaces

5.2.1 Where flammable or toxic chemicals, gases or vapours are present, as identified in 3.3.1 and 3.3.2, service and control stations essential to the operation of the plant are to meet the requirements of 9.1.4, and should, wherever possible, be located so that access thereto is from a defined safe space. If such a location is not possible, the station is to be specially ventilated.

Arrangements are to be made in spaces occupied by emissions abatement plant, in order that substances which are flammable, corrosive, toxic or likely to present a hazard due to reaction when mixed are kept separate unless they are fully contained within a part of the emissions abatement system which has been designed for the safe mixing of such substances.

5.3 Integrity of water and gastightness between compartments

5.3.1 Where integrity of water or gastightness is required between compartments containing the plant, it is to be maintained in way of pipe tunnels or duct keels where these traverse such compartments.

5.3.2 Installations and the spaces in which they are installed are to be, in all cases, compliant with applicable National and International requirements for prevention, detection and extinction of fire.

5.4 Cofferdams

5.4.1 Cofferdams are to be sited as required by the Rules for Ships for Liquid Chemicals, as applicable, segregating any spaces in which chemicals, substances or effluents are stored or retained in bulk.

5.5 Plant support structure

5.5.1 Decks and other structures supporting the plant are, in general, to comply with the requirements of Part 3. Such structures can, however, be considered on the basis of an agreed uniformly distributed loading in association with local loads at plant support points, provided that adequate transverse strength of the ship is maintained.

5.5.2 Where the nature and dispositions of heavy plant items are such that forces on the ship and support structure due to ship motions are significant (whether underway with or without working fluids, or moored with working fluids), calculations of the loading and the structural response are to be submitted.

5.6 Loading due to wave-induced motions

5.6.1 In cases where the mass distribution of large columnar equipment items is such that the centre of action of the dynamic force differs significantly from the centre of gravity of the item, due account of this is to be taken in the calculation of the forces and moments at the support positions.

5.7 Integrity of weather deck

5.7.1 The integrity of the weather deck is to be maintained. Where items of plant penetrate the weather deck and are intended to constitute the structural barrier to prevent the ingress of water to spaces below the freeboard deck, their structural strength is to be equivalent to the Rule requirements for this purpose. Otherwise, such items are to be enclosed in superstructures or deckhouses fully complying with the Rules.

Section 6
Mechanical equipment

6.1 General

6.1.1 Emissions abatement plant associated with oil engines, gas turbine and boilers is to comply with the requirements of Chapters 2, 4 and 10 respectively, as applicable.

6.1.2 The mounting arrangements for the equipment is to be capable of withstanding the forces and moments stated in 5.5 and 5.6.

6.1.3 The design is to take account of the risk of fire or explosion hazards which may arise from deposition of chemicals, unburnt fuel, particulates or any by-products of chemical reactions which may arise during normal operation.

6.1.4 The emissions abatement plant is to be capable of being started in a hot condition without risk of failure due to thermal shock.

6.1.5 Safety or pressure-relief devices are to discharge to a place which will not present a hazard to the ship's occupants or to any machinery.

6.1.6 Where bursting discs or rupture panels are used as safety and pressure-relief devices, these are to be dimensioned and designed in accordance with a recognised National or International Standard.

6.1.7 Where it can be expected that there will be deposition of materials, caking and waste, arrangements are to be provided for the safe cleaning of such systems.

6.1.8 Where there is a possibility of operating conditions in the system falling below the dew point temperature of any gases or vapours present in the system, suitable drains are to be provided to permit the discharge of any condensate formed.

6.2 By-pass or equivalent arrangements

6.2.1 The emissions abatement plant is to be provided with a by-pass capable of transmitting the minimum and maximum exhaust gas flows from the combustion machinery to which it is connected. Where a by-pass is considered unnecessary, the emissions abatement plant is to be capable of safely transmitting the minimum and maximum exhaust gas flows with the emissions abatement plant out of operation, such that the combustion machinery to which it is connected can continue to operate.

6.2.2 Where a by-pass is fitted, there is to be a flow path for exhaust gas at all times.

6.2.3 A means of measuring differential pressure across the emissions abatement plant is to be provided.

6.3 Shared emissions abatement plant

6.3.1 Where emissions abatement plant is connected to more than one engine or source of exhaust gas, valves or equivalent means of isolating the exhaust systems of individual engines from common manifolds are to be provided to prevent reverse flow of exhaust gas into the exhaust manifolds of engines which have been shut down.

6.3.2 Where isolating valves are fitted, a means to verify the effectiveness of the isolation is to be provided.

6.4 Maintenance of back-pressure

6.4.1 The exhaust back-pressure, after installation of emissions abatement plant, is to remain within the allowable limits stated by engine and combustion machinery manufacturers under all expected operating conditions, unless it is intended to operate the system at a negative pressure by means of an induced draught fan.

6.4.2 Where an induced draught fan is fitted to maintain the required exhaust back-pressure, a fan failure is not to prevent the combustion machinery from operating.

6.4.3 Where the emissions abatement plant is fed from multiple exhaust gas inlet streams, the back-pressure is to be maintained within the allowable limits provided by engine machinery manufacturers for all engine or combustion machinery operating configurations.

6.5 Protection of combustion machinery

6.5.1 Measures are to be implemented to ensure that water from the emissions abatement plant cannot flow back into engine turbo-charger(s) or other machinery.

6.5.2 Means are to be provided for protecting critical engine components from foreign object damage resulting from failure of, or damage to, the emissions abatement plant. Where such damage is considered unlikely, evidence is to be submitted accordingly.

6.5.3 Where chemicals or substances are injected into the exhaust gas stream before turbo-charger(s) or emissions abatement plant are fitted, this is not to present a risk of damage, chemical attack or performance degradation to the turbo-charger(s) or engine(s) or machinery with which they are associated.

6.5.4 Where fuel treatments, additives or emulsification are used as a primary means of abating exhaust emissions, machinery is to be compatible with such additives, treatments and emulsified fuel.

6.5.5 Where exhaust gas is re-circulated as a means of emission abatement, the re-circulated exhaust gas is not to cause fouling and corrosion of critical engine components and scavenge air temperature is to be maintained at a level which does not adversely affect engine performance.

6.5.6 Where a wet scrubber is used to clean and cool re-circulated exhaust gas, the scrubber is to satisfy the requirements of 7.1.9.

■ *Section 7* Pumping and piping

7.1 General

7.1.1 Pipe work and transfer systems which may carry chemical substances are to meet the requirements of Chapter 5 of the Rules for Ships for Liquid Chemicals. Lining steel pipe systems with corrosion-resistant materials is subject to special approval. The elasticity of the lining is not to be less than that of the supporting boundary material.

7.1.2 Pipe systems carrying sea-water or fresh water are to meet the requirements of Chapters 12, 13 and 14. Where there is a risk of fresh water or sea-water systems becoming contaminated with process chemicals, substances or effluent, pipe systems are to comply with 7.1.1.

7.1.3 Chemical transfer and control arrangements are to meet the requirements of Ch 5,5.6 of the Rules for Ships for Liquid Chemicals.

7.1.4 Bilge and effluent pumping and piping systems in the emissions abatement plant spaces are to be constructed of material suitable for any chemicals or substances used by the emissions abatement plant, effluent that is produced or any combination of substances on board which might result from accidental admixture.

7.1.5 Arrangements are to be provided for the control of the bilge and effluent pumping and piping system. They are to be installed in the emissions abatement plant spaces from within these spaces and also from a position outside the spaces.

7.1.6 Bilge and effluent pumping and piping systems for hazardous materials should, wherever possible, be installed in the space associated with the particular hazard.

7.1.7 Piping systems carrying chemical substances or effluents and by-products are to meet the requirements of Chapter 6 of the Rules for Ships for Liquid Chemicals. This requirement includes exhaust piping where such substances are injected into exhaust gas or where the exhaust gas passes through a liquid scrubber which uses chemical substances.

7.1.8 Where filters are used, they are to be capable of being safely removed for cleaning and replacement safely without interrupting emissions abatement plant or engine operations.

7.1.9 Where scrubbers are used, the following apply:

(a) Closed loop wet scrubbers are to have natural gravity fall drainage from the wet sump of the scrubber to the process tank or circulating pump suction, with the drain line dimensioned to accommodate 125 per cent of the maximum pumping capacity of the installed water pump(s). No valves are to be fitted to the drain line from the scrubber sump to the process tank unless it can be demonstrated that suitable precautions are in place to prevent the possibility of the scrubber filling with water and reverse-flowing into the engine exhaust duct. Where a valve is fitted to this line, the system is to be protected as for the overboard discharge valve of an open loop system, in accordance with Table 9.1.9.

(b) For open loop wet scrubbers, the overboard discharge valve and any other sea-water valves downstream of the scrubber are to be protected in accordance with Table 9.1.9. The sea suction valve(s) are also to have position indicators which are to give remote indication of valve position. The scrubber is to be mounted above the waterline under all operating conditions to prevent sea-water ingress into the scrubber from the natural flow.

(c) For wet scrubbing systems (open loop and closed loop), an overflow line is to be fitted to prevent the risk of reverse flow of water to engines, boilers and other machinery. This overflow is to be dimensioned to accommodate 125 per cent of maximum capacity of installed water pumps and is to have no impairment to flow. This overflow line is to be directed to the process tank in closed loop or hybrid installations. On open loop installations, it is to be directed overboard. The overboard discharge is to have an effective means of preventing reverse flow of sea-water. Alternative arrangements to prevent the risk of reverse flow are subject to special consideration.

(d) Overboard discharge connections from scrubbers are to be positioned below the lowest operating waterline and are to be internally protected from effluent-induced corrosion.

7.1.10 Where applicable, tanks are to be maintained within the temperature limits of the chemicals and substances they contain so as to avoid risks of boiling, stress corrosion, freezing and other temperature-sensitive processes.

■ *Section 8* Pressure vessels

8.1 General

8.1.1 Pressure vessels are to be in accordance with the requirements of the relevant Sections of Chapter 10 or Chapter 11 as applicable, or with agreed Codes and specifications normally used for similar plants in land installations, suitably modified and/or adapted for the marine environment.

8.1.2 Mounting arrangements are to take account of forces and moments generated at the supports. Mounting arrangements are to take account of thermal expansion and contraction.

8.1.3 Access is to be provided for inspection, and checking of mountings, fittings, controls and pressure-relief devices.

8.1.4 Arrangements are to allow the pressure settings of pressure-relief devices to be checked.

8.1.5 Where provision is made to isolate pressure-relief devices from pressure vessels for maintenance purposes, at least two such pressure-relief devices are to be fitted.

The isolating or blocking valves are to be arranged such that at least one pressure-relief device remains operational at all times.

■ *Section 9*
Electrical and control equipment

9.1 General

9.1.1 Electrical system(s) associated with emissions abatement plant are to meet the requirements of Pt 6, Ch 2.

9.1.2 Control system(s) associated with the emissions abatement plant are to meet the requirements of Pt 6, Ch 1.

9.1.3 Electrical and control equipment associated with the emissions abatement plant is to be compatible with any chemicals used and meet the requirements of Chapter 10 of the Rules for Ships for Liquid Chemicals.

9.1.4 Where flammable or toxic chemicals, gases or vapours are present, as identified in 3.3.1 and 3.3.2, or where there is a possibility that flammable gases and vapours can be produced as a result of deviations from normal operation, the defining of hazardous zones is to be in accordance with Pt 6, Ch 2,14.

As a minimum, for the detection of gas and vapours, a gas detection system is to be fitted which is to activate at a concentration corresponding to the substance safe occupational level. The locations of the detectors are to be determined relative to the layouts of the individual spaces and are to be indicated on the plan submission required by 3.3.9. Where it is not practicable to install a detection system where gas detection equipment is not appropriate, e.g., for substances not emitting gases or vapours, alternative proposals are to be submitted to ensure the safety of persons from exposure to such substances.

9.1.5 Process tanks which form part of the operating loop of any emissions abatement equipment are to have a high level alarm, in accordance with Table 9.1.9. Effluent tanks which are not part of the normal process loop and which are used for storage of effluent or substances prior to discharge from the vessel are to be protected, in accordance with Table 9.1.9.

Tank alarm and trip sensors are to be positioned at a point which will allow the system shut-down to operate before the tank overflows, based on the maximum design flow rates and shut-down response time. Where a low level is identified as presenting a risk to crew or machinery, tanks are to have a low level alarm and a low level trip. These are to be positioned so as to operate before a low level results in a hazardous condition, based on system design flow rates and a system shut-down response time.

9.1.6 An emergency stop function is to be provided, which is to:

- Close quick-closing valves on chemical tank(s) (where applicable).
- Stop chemical feed pump(s) (where applicable).
- Where fitted, open exhaust gas cleaning by-pass valve.
- Stop scrubber water pumps and close scrubber water inlet valve (where applicable).

9.1.7 The emergency stop function is to be capable of being actuated from the machinery control room, the navigating bridge and from within compartments containing exhaust gas cleaning plant.
In order to mitigate the risk of chemical release, spaces containing chemical storage tanks or chemical pumping equipment are to have an emergency stop which is to shut down the chemical supply to the emissions abatement plant. Other parts of the emissions abatement plant such as wash water pumps need only be stopped by this emergency stop where loss of chemical injection could result in further risks arising from operating the plant without chemical injection. This is to form part of the submission required in 3.1.6.

9.1.8 Alarms and safeguards are to be provided for the critical system parameters in order to avoid danger to crew and machinery. As a minimum, the alarms and safeguards listed in Table 9.1.9 are to be fitted. Where these Rules require alarms and also trip protection to be fitted, the alarm and trip are to be independent of each other.

9.1.9 Where emissions abatement plant makes use of chemical substances, a means of monitoring abnormal flows of such chemicals is to be provided.

Table 9.1.9 Machinery emissions to air abatement plant: alarms and safeguards

Item	Alarm	Note
Exhaust gas outlet temperature	High	
Exhaust gas inlet temperature	High	
Exhaust gas inlet temperature	Low	Only for selective catalytic reduction
Differential pressure across abatement plant unit	High	
Abatement plant by-pass valve in exhaust duct	Valve movement	*See* Note 1
Machinery exhaust duct isolating valve	Valve movement	*See* Note 2
Wet emissions abatement unit overboard discharge valve	Closed	Emissions abatement plant is to be shut down automatically, *see* Note 6
Wet emissions abatement unit overflow line flow detection	Flow present	Emissions abatement plant is to be shut down automatically, *see* Note 6
Wet emissions abatement water pressure	Low	
Wet emissions abatement unit water level	1st Stage high	
Wet emissions abatement unit water level	2nd Stage high	Emissions abatement plant is to be shut down automatically, *see* Note 6
Chemical feed flow	High	Chemical feed pump is to be shut down automatically
Chemical feed flow	1st Stage low	
Chemical feed flow	2nd Stage low	Chemical feed pump is to be shut down automatically
Process tank level	1st Stage high	*See* Note 3
Process tank level	2nd Stage high	Emissions abatement plant is to be shut down automatically, *see* Note 3
Chemical storage tank level	1st Stage high	
Chemical storage tank level	2nd Stage high	
Chemical storage tank level	Low	
Chemical storage tank temperature	High	*See* Note 4
Chemical storage tank temperature	Low	*See* Note 4
Chemical tank containment bund level	High	Tank outlet quick closing valve is to close automatically, *see* Note 5
Chemical tank containment drain line flow detection	Flow present	Tank outlet quick closing valve is to close automatically, *see* Note 5
Exhaust gas recirculating fan failure	Failure	
Recirculating exhaust gas temperature return to engine	High	
Induced draught fan failure	Failure	Where fitted

NOTES
1. Only where a by-pass valve is fitted, *see* 3.3.5. This valve shall open to the by-pass position as part of the unit shut-down logic.
2. Only where fitted, *see* 5.1.
3. The process tank is any tank forming part of a wet abatement system flow loop or effluent tanks which receive bleed-off from the main flow loop, or such tanks not forming part of the system flow loop but which are essential for operation of the system, including those on exhaust gas recirculating installations, *see* 7.1.9. Where low level can present a hazard, process tanks are also to have low level protection.
4. Where chemical substances are to be kept within a defined temperature range, alarms will be fitted, based on the allowable temperature range, *see* 5.1.2 and 7.1.10.
5. Chemical spillage detection alarm will depend on the means of spill containment fitted, *see* 5.1.2.
6. Wet emissions abatement unit shall include such systems fitted as part of the exhaust gas recirculating installations.

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Rules and Regulations for the Classification of Ships

Part 6
Control, Electrical, Refrigeration and Fire

July 2014

Lloyd's Register

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Section 1
General requirements

1.1 General

1.1.1 This Chapter applies to all ships intended to be classed with Lloyd's Register (hereinafter referred to as 'LR'), and is in addition to other relevant Sections of the Rules.

1.1.2 Control engineering systems are to:
- provide control of required services and habitability requirements during defined operational conditions. This is to include, but is not limited to, power generation, propulsion and their associated services;
- provide control of the engineering systems necessary to ensure availability of essential and emergency safety systems during all normal and reasonably foreseeable abnormal conditions;
- provide control of the engineering systems necessary to ensure transitional power supplies remain available;
- be suitably protected against damage to itself under fault conditions and to prevent injury to personnel; and
- not fail in a way which may cause machinery and systems located in hazardous areas to create additional fire or explosion risk.

1.1.3 Control engineering systems on passenger ships having a length of 120 m or more or having three or more main vertical zones (*see* Pt 5, Ch 23,1.2.4 for definitions) are, in addition to the requirements of this Chapter, to be located, designed and arranged to comply with Pt 5, Ch 23, as applicable.

1.1.4 LR will be prepared to give consideration to special cases or to arrangements which are equivalent to the Rules where sufficient technical justification is provided. For unconventional designs, *see also* Pt 7, Ch 15.

1.2 Documentation required for design review

1.2.1 The documentation described in 1.2.2 to 1.2.9 is to be submitted for design review.

1.2.2 Where control, alarm and safety systems are intended for the machinery or equipment as defined in 1.2.3 the following are to be submitted:
- Description of operation with explanatory diagrams.
- Line diagrams of control circuits.
- List of monitored points.
- List of control points.
- Details of alarms and warnings to be presented by the user interface, including:
  - (i) an approach to category assignments which is in accordance with the IMO *Code on Alerts and Indicators, 2009*; and
  - (ii) for alarms required by these Rules, the intended operator response and the message to be presented.
- Test schedules (for both works testing and sea trials) which should include methods of testing and test facilities provided, *see* 1.3.1.
- Failure Mode and Effects Analysis (FMEA) where required by other sections of the Rules.
- List of safety functions and details of any overrides, including consequences of use, *see* 2.4.8 and 2.6.8.

1.2.3 Plans for the control, alarm and safety systems of the following are to be submitted:
- Air compressors.
- Bilge and ballast systems.
- Cargo pumping systems for tankers.
- Cargo and ballast pumps in hazardous areas.
- Cargo tank, cargo hold, ballast tank and void space instrumentation where such arrangements are specified by other sections of the Rules (e.g., water ingress detection, gas detection).
- Controllable pitch propellers.
- Electric generating plant.
- Fixed water based local application fire-fighting systems, *see* 2.9.
- Incinerators.
- Inert gas generators.
- Main propelling machinery including essential auxiliaries.
- Miscellaneous machinery or equipment (where control, alarm and safety systems are specified by other Sections of the Rules).
- Oil fuel transfer and storage systems.
- Steam raising plant. (Boilers and their ancillary equipment).
- Steering gear.
- Thermal fluid heaters.
- Transverse thrust units.
- Valve position indicating systems.
- Waste-heat boiler.
- Waterjets for propulsion purposes.
- Windlasses.

1.2.4 **System operational concept**. A description of the intended operation of the control, alarm and safety systems for the main and auxiliary machinery, and other systems essential for the propulsion and safety of the ship. This description is to include a demonstration that the design provides an effective means of operation and control for all ship operating conditions.

1.2.5 **Alarm systems**. Details of the overall alarm system linking the main control station, subsidiary control stations, the bridge area and accommodation are to be submitted.

1.2.6 **Programmable electronic systems**. In addition to the documentation required by 1.2.2 the following is to be submitted:

(a) System requirements specification.
(b) System functional description.
(c) System integration plan, *see* 2.14.2.
(d) Failure Mode and Effects Analysis (FMEA), *see* 2.14.5.
(e) Details of the hardware configuration in the form of a system block diagram, including input/output schedules.
(f) Hardware certification details, *see* 2.10.5 and 2.13.3.
(g) Software production plans, including applicable procedures, *see* 2.15.4.
(h) Factory acceptance, integration and sea trial test schedules for hardware and software.
(j) Details of data storage arrangements, *see* 2.10.10 and 2.13.6.

1.2.7 For wireless data communication equipment:

(a) Details of manufacturer's installation and maintenance recommendations;
(b) network plan with arrangement and type of aerials and identification of location;
(c) specification of wireless communication system protocols and management functions, *see* 2.12.4; and
(d) details of radio frequency and power levels, including details of those permitted by the National Administration.

1.2.8 Plans showing the location and details of control stations, e.g., control panels and consoles. Location and details of controls and displays on each panel. Detailed user interface specifications. A general arrangement plan of control rooms showing the position of consoles, handrails, operator area, lighting, door and window arrangements. Drawing of HVAC systems including vent arrangements.

1.2.9 **Fire detection systems**. Plans showing the system operation and the type and location of all machinery space fire detector heads, manual call points and the fire detector indicator panel(s) are to be submitted. The plans are to indicate the position of the fire detectors in relation to significant items of machinery, ventilation and extraction openings.

1.3 Control, alarm and safety equipment

1.3.1 Equipment associated with control, alarm and safety systems as defined in 1.2.3 are to be surveyed at the manufacturers' works in accordance with the approved test schedule *see* 1.2.2, and the inspection and testing are to be to the Surveyor's satisfaction.

1.3.2 Equipment used in control, alarm and safety systems is to be suitable for its intended purpose, and accordingly, whenever practicable, be selected from the *List of Type Approved Products* published by LR. A copy of the *Procedure for LR Type Approval System* will be supplied on application. For fire detection alarm systems, *see* 2.8.2 and for programmable electronic systems, *see* 2.10.5 and 2.13.3.

1.3.3 Where equipment requires a controlled environment, an alternative means is to be provided to maintain the required environment in the event of a failure of the normal air conditioning system, *see also* Table 14.12.3 in Pt 5, Ch 14.

1.3.4 Assessment of performance parameters, such as accuracy, repeatability, etc., are to be in accordance with an acceptable National or International Standard, e.g., IEC 60051: *Direct acting indicating analogue electrical measuring instruments and their accessories* (all parts).

1.3.5 Special consideration will be given to arrangements that comply with a relevant and acceptable National or International Standard, such as IEC 60092-504: *Electrical installations in ships – Part 504: Special features – Control and instrumentation*.

1.4 Alterations and additions

1.4.1 When an alteration or addition to the approved system(s) is proposed, plans are to be submitted for approval. The alterations or additions are to be carried out under survey and the installation and testing are to be to the Surveyor's satisfaction.

1.4.2 Details of proposed software modifications are to be submitted for consideration. Modifications are to be undertaken in accordance with defined modification processes which are part of the supplier's or system integrator's quality management system. The following documentation is to be submitted:

(a) Project-specific software modification plan.
(b) An impact analysis which identifies the effect(s) of the proposed modification. The results of the analysis are to be used to inform the extent of verification and validation that is to be applied. This analysis is to consider both the local impact and, where applicable, the system level impact of the modification.
(c) Configuration management records that satisfy the requirements of ISO 10007, to demonstrate the traceability of the proposed modification.
(d) Factory acceptance, integration and sea trial test schedules as determined by the impact analysis in (b).
(e) Updated documentation as detailed in 1.2.5.

1.4.3 Verification and validation activities are to demonstrate that the modified functionality performs as expected and that the modification has not unintentionally modified functionality outside the scope of the modification.

1.4.4 Software versions are to be uniquely identified by number, date or other appropriate means. Modifications are not to be made without also changing the version identifier. A record of changes to the system since the original issue (and their identification) is to be maintained and made available to the LR Surveyor on request.

1.5 Definitions

1.5.1 An Emergency Stop (E-Stop) is a safeguard instigated by a single human action. It requires a stop of all movement within the controlled system as rapidly as possible to prevent a hazard occurring or to reduce an existing hazard to persons, machinery or the vessel.

1.5.2 An Emergency Trip (E-Trip) is a safeguard instigated by a single human action and means the disconnection of fuel, electrical, hydraulic or other power source from the

controlled system to prevent a hazard occurring or to reduce an existing hazard to persons, machinery or the vessel. Movement within the system may be allowed to continue.

1.5.3 An Emergency Stop Function may be either an Emergency Stop or Emergency Trip, as appropriate to the system and risk being controlled.

1.5.4 Alarm System: a system which will alert relevant personnel to faults, abnormal situations and other conditions requiring attention in the machinery and the safety and control systems.

1.5.5 Control System: a system which responds to input signals from the process and/or operator and generates output signals causing the equipment under control to operate in the desired manner.

1.5.6 Failure: a loss of the ability of a structure, system or element to function within acceptance criteria.

1.5.7 Fail safe: a system design such that, when a failure occurs, the system reverts to the least hazardous state.

1.5.8 A reasonably foreseeable abnormal condition is an event, incident or failure that:

- has happened and could happen again;
- is planned for (e.g., emergency actions cover such a situation, maintenance is undertaken to prevent it, etc.).

They should be identified by:

- using analysis processes that were capable of revealing abnormal conditions;
- employing a mix of personnel including competent safety/risk professionals and those with relevant domain knowledge and understanding to apply the processes;
- referencing relevant events and historic data; and
- documenting the results of the analysis.

1.5.9 Safety System: a designated system that:

- implements the required safety functions necessary to achieve or maintain a safe state for the equipment under control; and
- is intended to achieve, on its own or with other safety systems, the necessary safety needed for the required safety functions.

1.5.10 Safe State: the state of equipment under control when safety is achieved. For some situations, a safe state only exists so long as the equipment under control is continuously controlled. Such continuous control may be for a short or indefinite period.

1.5.11 System: a set of elements which interact according to a design, where an element of a system can be another system, called a sub-system, which may be a controlling system or a controlled system, and may include hardware, software and human interaction.

■ *Section 2* Essential features for control, alarm and safety systems

2.1 General

2.1.1 Systems complying with ISO 17894, *Ships and marine technology – Computer applications – General principles for the development and use of programmable electronic systems in marine applications*, may be accepted as meeting the requirements of this Section, in which case evidence of compliance is to be submitted for consideration.

2.2 Control stations for machinery

2.2.1 A system of alarm and warning displays and controls is to be provided which readily ensures identification of faults in the machinery and satisfactory supervision of related equipment by duty personnel. This may be provided at a main control station or, alternatively at subsidiary control stations. In the latter case, a master alarm display is to be provided at the main control station showing which of the subsidiary control stations is indicating a fault condition.

2.2.2 At the main control station (if provided) or close to the subsidiary stations (if fitted) means of communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery space are to be provided.

2.2.3 Where operator interfaces are installed in the wheelhouse, illumination should not interfere with night vision. All illumination and lighting of instruments, keyboards and controls are to be adjustable to zero illumination, except for lighting for visual indication of alarms and the controls of dimmers, which are to remain readable.

2.2.4 Provision is to be made at the main control station, or subsidiary control stations as appropriate, for the operation of an engineers' alarm which is to be clearly audible in the engineers' accommodation.

2.2.5 Provision is to be made at the main control station and any other subsidiary control station from which the main propulsion and auxiliary machinery or associated equipment may be controlled to indicate which station is in control.

2.2.6 Control of machinery and associated equipment is to be possible only from one station at a time.

2.2.7 Changeover between control stations is to be arranged so that it may only be effected with the acceptance of the station taking control. The system is to be provided with interlocks or other suitable means to ensure effective transfer of control.

2.3 Alarm systems, general requirements

2.3.1 Machinery, safety and control system faults are to be indicated at the relevant control stations to advise duty personnel of a fault condition. The presence of unrectified faults is to be clearly indicated at all times.

2.3.2 Alarms and warnings associated with machinery and equipment required to satisfy this sub-Section are to be categorised according to the urgency and type of response required by the crew, as described in the IMO *Code on Alerts and Indicators, 2009*. The assignment of a category to each alert is to be evaluated on the basis not only of the machinery or equipment being monitored, but also the complete installation. Categories not included in an alarm system may be omitted from the system design. Details of alternative alert management proposals supported with evidence of service experience may be submitted for consideration by LR.

2.3.3 Where the facility to provide messages in association with alarms and warnings exists, messages accompanying alarms and warnings are to describe the condition and indicate the intended response required by the crew.

2.3.4 Where the facility to provide messages in association with alarms and warnings exists, messages of different categories are to be clearly distinguishable from each other. Alarms associated with machinery, safety and control system faults are to be clearly distinguishable from other alarms (e.g., fire, general alarm).

2.3.5 Where alarms are displayed as group alarms provision is to be made to identify individual alarms at the main control station (if fitted) or alternatively at subsidiary control stations.

2.3.6 All alarms are to be both audible and visual. If arrangements are made to silence audible signals they are not to extinguish visual indications.

2.3.7 Acknowledgement of visual alarms is to be clearly indicated.

2.3.8 Acknowledgement of alarms at positions outside a machinery space is not to silence the audible signal or extinguish the visual indication in that machinery space.

2.3.9 If an alarm has been acknowledged and a second fault occurs prior to the first being rectified, audible signals and visual indications are again to operate. Where alarms are displayed at a local panel adjacent to the machinery and with arrangements to provide a group or common fault alarm in the control room, the occurrence of a second fault prior to the first alarm being rectified need only be displayed at the local panel; however, the group alarm is to be re-initiated. Unacknowledged alarms on monitors are to be distinguished by either flashing text or a flashing marker adjacent to the text. A change of colour will not in itself be sufficient to distinguish between acknowledged and unacknowledged alarms.

2.3.10 For the detection of transient faults which are subsequently self-correcting, alarms are required to lock in until accepted.

2.3.11 The alarm system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply. Where an alarm system could be adversely affected by an interruption in power supply, changeover to the standby power supply is to be achieved without a break.

2.3.12 Failure of any power supply to the alarm system is to operate an audible and visual alarm.

2.3.13 The alarm system should be designed with self-monitoring properties. Insofar as practicable, any fault in the alarm system should cause it to fail to the alarm condition.

2.3.14 The alarm system is to be capable of being tested during normal machinery operation, *see* 7.1.2.

2.3.15 The alarm system is to be designed as far as practicable to function independently of control and safety systems such that a failure or malfunction in these systems will not prevent the alarm system from operating.

2.3.16 Disconnection or manual overriding of any part of the alarm system is to be clearly indicated.

2.3.17 When alarm systems are provided with means to adjust their set point, the arrangements are to be such that the final settings can be readily identified.

2.3.18 Where monitors are provided at the station in control and, if fitted, in the duty engineer's accommodation, they are to provide immediate display of new alarm information regardless of the information display page currently selected. This may be achieved by provision of a dedicated alarm monitor, a dedicated area of screen for alarms or other suitable means.

2.3.19 Where practicable, alarms displayed on monitors are to be displayed in the order in which they occur. Alarms requiring manual shut-down or slow-down action are to be given visual prominence.

2.4 Safety systems, general requirements

2.4.1 Safety systems are to operate automatically in case of serious faults endangering the machinery, so that:

(a) normal operating conditions are restored, e.g., by the starting of standby machinery, or
(b) the operation of the machinery is temporarily adjusted to the prevailing conditions, e.g., by reducing the output of the machinery, or
(c) the machinery is protected from critical conditions by shutting off the fuel or power supplies thereby stopping the machinery.

2.4.2 The safety system required by 2.4.1(c) is to be designed as far as practicable to operate independently of the control and alarm systems, such that a failure or malfunction in the control and alarm systems will not prevent the safety system from operating, *see* Pt 5, Ch 14,12.1.4.

2.4.3 For safety systems required by 2.4.1(a) and (b) complete independence from other control systems is not necessary.

2.4.4 Safety systems for different items of the machinery plant are to be arranged so that failure of the safety system of one part of the plant will not interfere with the operation of the safety system in another part of the plant.

2.4.5 The safety system is to be designed to 'fail-safe'. The characteristics of the 'fail-safe' operation are to be evaluated on the basis not only of the safety system and its associated machinery, but also the complete installation. Failure of a safety system is to initiate an audible and visual alarm.

2.4.6 When a safety system is activated, an audible and visual alarm is to be provided to indicate the cause of the safety action.

2.4.7 The safety system is to be manually reset before the relevant machinery can be restarted.

2.4.8 Where arrangements are provided for overriding a safety system, they are to be such that inadvertent operation is prevented. Visual indication is to be given at the relevant control station(s) when a safety override is operated. The consequences of overriding a safety system are to be established and documented.

2.4.9 The safety system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply.

2.4.10 Failure of any power supply to a safety system is to operate an audible and visual alarm.

2.4.11 When safety systems are provided with means to adjust their set point, the arrangements are to be such that the final settings can be readily identified.

2.4.12 As far as practicable, the safety system required by 2.4.1(b) is to be arranged to effect a rapid reduction in speed or power.

2.5 Control systems, general requirements

2.5.1 Control systems for machinery operations are to be stable throughout their operating range.

2.5.2 Failure of any power supply to a control system is to operate an audible and visual alarm.

2.5.3 Control systems should be designed to 'fail-safe'. The characteristics of the 'fail-safe' operation are to be evaluated on the basis not only of the control system and its associated machinery, but also the complete installation.

2.5.4 The control system is to be designed such that normal operation of the controls cannot induce detrimental mechanical or thermal overloads in the machinery.

2.5.5 Remote or automatic controls are to be provided with suitable instrumentation at the relevant control stations to ensure effective control by duty personnel and to indicate that the system is functioning correctly.

2.5.6 When control systems are provided with means to adjust their sensitivity or set point, the arrangements are to be such that the final settings can be readily identified.

2.5.7 Failure of a control system is not to result in the loss of ability to provide essential services by alternative means. This may be achieved by manual control or redundancy within the control system or redundancy in machinery and equipment, *see also* 2.13.2. Instrumentation is to be provided at local manual control stations to ensure effective operation of the machinery by duty personnel.

2.6 Bridge control for main propulsion machinery

2.6.1 Means are to be provided to ensure satisfactory control of propulsion from the bridge in both the ahead and astern directions.

2.6.2 The following indications are to be provided on the bridge:

(a) Propeller speed.
(b) Direction of rotation of propeller for a fixed pitch propeller or pitch position for a controllable pitch propeller, *see also* Pt 5, Ch 7,5.3.
(c) Direction and magnitude of thrust.
(d) Clutch position, where applicable.
(e) Shaft brake position, where applicable.

2.6.3 The propeller speed, direction of rotation and, if applicable, the propeller pitch are to be controlled from the bridge under all sea-going and manoeuvring conditions.

2.6.4 Remote control of the propulsion machinery is to be from only one control station at any one time, *see also* 2.2.6. Main propulsion control units on the navigating bridge may be interconnected. Means are to be provided at the control station to ensure smooth transfer of control between the bridge and other control stations.

2.6.5 Means of control, independent of the bridge control system, are to be provided on the bridge to enable the watch-keeper to stop the propulsion machinery in an emergency.

2.6.6 Audible and visual alarms are to operate on the bridge and in the alarm system required by 4.2 if any power supply to the bridge control system fails. Where practicable, the preset speed and direction of thrust are to be maintained until corrective action is taken.

2.6.7 Two means of communication are to be provided between the bridge and the main control station in the machinery space. One of these means may be the bridge control system; the other is to be independent of the main electrical power supply, *see also* 2.2.2 and Pt 5, Ch 1,4.

2.6.8 Automation systems are to be designed in a manner such that a threshold warning of impending or imminent slow-down or shut-down of the propulsion system is given to the officer in charge of the navigational watch in time to assess navigational circumstances in an emergency. In particular, the systems are to control, monitor, report, alert and take safety action to slow down or stop propulsion while providing the officer in charge of the navigational watch an opportunity to intervene manually, except for those cases where manual intervention will result in total failure of the engine and/or propulsion equipment within a short time, for example, in the case of overspeed.

2.7 Valve control systems

2.7.1 Where cargo, bilge, ballast, oil fuel transfer and sea valves for engine services are operated by remote or automatic control, the requirements of 2.7.2 to 2.7.5 are to be satisfied.

2.7.2 Failure of control system power or actuator power is not to permit a valve to move to an unsafe condition.

2.7.3 Positive indication is to be provided at the remote control station for the service to show the actual valve position or alternatively that the valve is fully open or closed.

2.7.4 Equipment located in places which may be flooded is to be capable of operating when submerged.

2.7.5 A secondary means of operating the valves, which may be by local manual control, is to be provided.

2.7.6 For requirements applicable to closing appliances on scuppers and sanitary discharges, *see* Pt 3, Ch 12,4.2. For power supplies on passenger ships, *see* Ch 2,3.2.

2.8 Fire detection alarm systems

2.8.1 Fire detection and fire alarm systems are to comply with Chapter 9 of the *Fire Safety Systems Code* (FSS) and 2.8.2 to 2.8.23 as applicable.

2.8.2 Fire detection control units, indicating panels, detector heads, manual call points and short-circuit isolation units are to be Type Approved in accordance with Test Specification Number 1 given in LR's Type Approval System for an environmental category appropriate for the locations in which they are intended to operate. For addressable systems, *see also* 2.10.

2.8.3 The alarm system is to be designed with self-monitoring properties. Power or system failures are to initiate an audible alarm distinguishable from the fire alarm. This alarm may be incorporated in the machinery alarm system as required by 2.3.

2.8.4 When fire detectors are provided with means to adjust their sensitivity, the arrangements are to be such that the set point can be fixed and readily identified.

2.8.5 The fire detector heads are to be of a type which can be tested and reset without the renewal of any component. Facilities are to be provided on the fire-control panel for functional testing and reset of the system.

2.8.6 When it is intended that a particular loop is to be temporarily switched off, this state is to be clearly indicated at the fire detection indicating panels.

2.8.7 When it is intended that a particular detector(s) is (are) to be temporarily switched off locally, this state is to be clearly indicated at the local position. Reactivation of the detector(s) is to be performed automatically after a preset time.

2.8.8 It is to be demonstrated to the Surveyor's satisfaction that detector heads are so located that air currents will not render the system ineffective whether the ship is at sea or in port.

2.8.9 An audible fire alarm is to be provided having a characteristic tone which distinguishes it from the alarm system required by 2.3 or any other alarm system.

2.8.10 Where an automatic fire detection system is to be fitted in a machinery space, the requirements of 2.8.11 to 2.8.15 are also to be satisfied. *See also* SOLAS 1974, as amended Reg. II-2/C.7, or Chapter 4 as applicable.

2.8.11 Detector heads are to be located in the machinery spaces so that all potential fire outbreak points are guarded. A combination of detectors is to be provided to ensure that the system will react to all possible fire characteristics.

2.8.12 Fire detection indicating panels are to denote the section in which a detector or manually operated call point has operated. At least one indicating panel is to be so located that it is easily accessible to responsible members of the crew at all times. An indicating panel is to be located on the navigating bridge.

2.8.13 A fire detection control unit is to be located in the navigating bridge area, the fire-control station, or in some other position such that a fire in the machinery spaces will not render it inoperable.

2.8.14 The audible fire-alarm is to be immediately audible on all parts of the navigating bridge, the fire-control station, the crew accommodation areas and the machinery spaces.

2.8.15 Facilities are to be provided in the fire detection system to initiate manually the fire alarm from the following locations:

(a) Positions adjacent to all exits from machinery spaces.
(b) Navigating bridge.
(c) Control station in engine room.
(d) Fire-control station.

2.8.16 Fire detection systems within the accommodation spaces and cabin balconies are also to comply with 2.8.17 to 2.8.22.

2.8.17 In passenger ships, the fixed fire detection and fire alarm systems are to be capable of remotely and individually identifying each detector and manually operated call point. On other ships, indicating units are to denote, as a minimum, the section in which a detector or manually operated call point has operated. At least one indication unit is to be so located that it is easily accessible to responsible members of the crew. One indicating unit is to be located on the navigating bridge if the control panel is located in the central control station.

2.8.18 Clear information is to be displayed on or adjacent to each indicating unit about the spaces covered and the location of the section and, for passenger ships, each detector and manually operated call point.

2.8.19 The fire detection system is not to be used for any other purpose, except that closing of fire doors and similar functions may be permitted at the control panel.

2.8.20 The fire-control panel is to be located on the navigating bridge or in a central fire-control station and may form part of that panel specified in 2.8.13. For passenger ships carrying more than 36 passengers, the fire-control panel is to be located in the continuously manned central control station.

2.8.21 Detectors and manually operated call points are to be grouped into sections. The activation of any detector or manually operated call point is to initiate a visual and audible fire signal at the control panel and indicating units. If the signals have not received attention within two minutes an audible alarm is to be automatically sounded throughout the crew accommodation and service spaces, control stations and machinery spaces of Category A. This alarm sounder system need not be an integral part of the detection system.

2.8.22 A section of fire detectors and manually operated call points which covers a control station, a service space or an accommodation space is not to include a machinery space of Category A.

2.8.23 For electrical engineering requirements, *see* Ch 2,17.1.

2.9 Fixed water-based local application fire-fighting systems

2.9.1 Where fixed water-based local application fire-fighting systems are installed in accordance with SOLAS as amended Ch. II-2/C, Reg. 10.5.6, arrangements are to be in accordance with this sub-Section.

2.9.2 Systems are to be available for immediate use and arranged for manual activation from inside and outside the protected space. *See also* Ch 2,17.3.4.

2.9.3 The activation of a system is not to result in loss of electrical power or reduction of the manoeuvrability of the ship and is not to require confirmation of space evacuation or sealing, *see also* Ch 2,17.3.12.

2.9.4 System zones and protected areas are to be arranged to allow essential services to be provided by machinery and/or equipment located outside areas affected by direct spray or extended water in the event of a system activation, where the machinery and/or equipment is duplicated or otherwise replicated to provide redundancy.

2.9.5 A control panel is to be provided for managing actions such as opening of valves, starting of pumps and initiation of alarms and warnings and processing information from detectors. This panel is to be independent of the fire detection control unit required by 2.8.

2.9.6 Alarms are to be initiated upon activation of a system and are to indicate the specific zone activated at the control panel. Alarms are to be provided in each protected space, at an attended machinery control station and in the wheelhouse. The audible alarm signal is to be distinguishable from other safety system signals.

2.9.7 A failure in a manual system activation switch circuit is not to prevent system activation using other installed manual system activation switches or, where installed, automatic activation. The means of activation are to be provided with self-monitoring facilities which will activate an alarm at an attended control station in the event of failure detection.

2.9.8 Where SOLAS requires the system, additionally, to be capable of automatic release, the arrangements are to be in accordance with 2.9.9 to 2.9.12.

2.9.9 A minimum of two fire detectors are to be provided for each protected area. One is to be a flame detector and the other is to be a smoke or heat detector, as considered appropriate to the nature of the risk and ambient conditions. The system is to be activated upon detection by two of the detectors. A fault in one detector is to initiate an alarm at an attended control station and is not to inhibit activation of the system under the control of the other detector or manually.

2.9.10 The fire detectors are to be arranged (located, oriented, guarded, etc.) to ensure that a fire in one protected area will not result in the inadvertent automatic activation of a system for another protected area. Guards or barriers provided to comply with this requirement are not to reduce the ability to detect a fire in the protected area.

2.9.11 A fire detection alarm system panel in accordance with 2.8 may be used for receiving fire detection signals. Separate loops are not required provided that the address of the initiating device can be identified at the control panel. The received signals are then to be sent to the control panel required by 2.9.5 for processing and action.

2.9.12 The system's fire detection systems and control units are to meet the performance criteria of SOLAS Ch II/C, Reg. 7 and are to be Type Approved in accordance with *Test Specification Number 1* given in LR's *Type Approval System* for an environmental category appropriate for the locations in which they are intended to operate.

2.10 Programmable electronic systems – General requirements

2.10.1 The requirements of this sub-Section are to be complied with where control, alarm or safety systems incorporate programmable electronic equipment. Systems for essential services and safety critical applications, systems incorporating shared data communication links and systems which are integrated are to comply with the additional requirements of 2.11, 2.13 and 2.14 as applicable. For systems complying with ISO 17894, *Ships and marine technology – Computer applications – General principles for the development and use of programmable electronic systems in marine applications*, *see* 2.1.2.

2.10.2 Where programmable electronic systems share resources, any components that can affect the ability to provide effectively required control, alarm or safety functions are to fulfil the requirements of 2.10 to 2.14 related to providing those required functions.

2.10.3 Programmable electronic equipment is to revert to a defined safe state on initial start-up or re-start in the event of failure.

2.10.4 In the event of failure of any programmable electronic equipment, the system, and any other system to which it is connected, is to fail to a defined safe state or maintain safe operation, as applicable.

2.10.5 Programmable electronic equipment is to be certified by a recognised authority as suitable for the environmental conditions in which it is intended to operate, *see also* 2.13.3.

2.10.6 Emergency stop functions are to be hard-wired and independent of any programmable electronic equipment. Alternatively, the system providing emergency stop functions is to comply with the requirements of 2.13.2 and/or 2.13.8.

2.10.7 Programmable electronic equipment is to be provided with self-monitoring capabilities such that hardware and functional failures will initiate an audible and visual alarm in accordance with the requirements of 2.3 and, where applicable, 4.2. Hardware failure indications are to enable faults to be identifiable at least down to the level of the lowest replaceable unit and the self-monitoring capabilities are to ensure that diagnostic information is readily available.

2.10.8 Means are to be provided to recover or replace data required for safe and effective system operation lost as a result of component failure. The submission required by 1.2.6 is to address reinstatement of system operation following data loss.

2.10.9 System configuration, programs and data are to be protected against loss or corruption in the event of failure of any power supply. For essential services and safety critical systems, *see* 2.13.6.

2.10.10 Where it is necessary to store data required for system operation in volatile memory, a back-up power supply is to be provided that prevents data loss in the event of loss of the normal power supply. The submission required by 1.2.6 is to include details of any routine maintenance necessary and the measures necessary to restore system operation in the event of data loss as a result of power supply failure.

2.10.11 Back-up power supplies required by 2.10.10 are to be rated to supply the connected load for a defined period of time that allows sufficient time to restore the supply in the event of loss of the normal power supply as a result of failure of a main source of electrical power. This period is not to be less than 30 minutes.

2.10.12 Where regular battery replacement is required to maintain the availability of volatile memory back-up power supply required by 2.10.10, these are to be included in the schedule of batteries required by Ch 2,1.2.15 and 12.7, irrespective of battery type and size. Applicable entries in this schedule are to note that these batteries are not for safety critical systems or essential or emergency services.

2.10.13 Access to system configuration, programs and data is to be restricted by physical and/or logical means providing effective security against unauthorised alteration.

2.10.14 Where date and time information is required by the equipment, this is to be provided by means of a battery backed clock with restricted access for alteration. Date and time information is to be fully represented and utilised.

2.10.15 Displays and controls are to be protected against liquid ingress due to spillage.

2.10.16 Display units are to comply with the requirements of an acceptable National or International Standard, e.g., IEC 60950-*1: Information technology equipment – Safety - Part 1: General requirements,* in respect of emission of ionising radiation.

2.10.17 Where systems detect fault conditions, any affected mimic diagrams are to ensure that the status of unreliable and incorrect data is clearly identified.

2.10.18 Multi-function displays and controls are to be duplicated and interchangeable where used for the control or monitoring of more than one system, machinery item or item of equipment. At least one unit at the main control station is to be supplied from an independent uninterruptible power system (UPS).

2.10.19 The number of multi-function display and control units provided at the main control station and their power supply arrangements are to be sufficient to ensure continuing safe operation in the event of failure of any unit or any power supply.

2.10.20 Software lifecycle activities, e.g., design, development, supply and maintenance, are to be carried out in accordance with an acceptable quality management system. Software quality plans are to be submitted. These are to demonstrate that the provisions of ISO/IEC 90003: Software engineering – *Guidelines for the application of ISO 9001:2000 to computer software*, or equivalent, are incorporated. The plans are to define responsibilities for the lifecycle activities, including verification, validation, module testing and integration with other components or systems.

2.11 Data communication links

2.11.1 Where control, alarm or safety systems use shared data communication links to transfer data, the requirements of 2.11.2 to 2.11.10 are to be complied with. The requirements apply to local area networks, fieldbuses and other types of data communication link which make use of a shared medium to transfer control, alarm or safety related data between distributed programmable electronic equipment or systems.

2.11.2 Data communication is to be automatically restored within 45 seconds in the event of a single component failure. Upon restoration, priority is to be given to updating safety critical data and control, alarm and safety related data for essential services. Components comprise all items required to facilitate data communication, including cables, switches, repeaters, software components and power supplies.

2.11.3 Loss of a data communication link is not to result in the loss of ability to operate any essential service by alternative means, *see also* 2.13.2.

2.11.4 The properties of the data communication link (e.g., bandwidth, access control method, etc.) are to ensure that all connected systems will operate in a safe, stable and repeatable manner under all operating conditions. The latency of control, alarm and safety related data is not to exceed two seconds.

2.11.5 Protocols are to ensure the integrity of control, alarm and safety related data, and provide timely recovery of corrupted or invalid data.

2.11.6 Means are to be provided to monitor performance and identify hardware and functional failures. An audible and visual alarm is to operate in accordance with the requirements of 2.3 and, where applicable, 4.2 in the event of a failure of an active or standby component.

2.11.7 System self-monitoring capabilities are to be arranged to initiate transition to a defined safe state for the complete installation in the event of data communication failure, *see also* 2.5.3.

2.11.8 Means are to be provided to prevent unintended connection or disconnection of any equipment where this may affect the performance of any other systems in operation.

2.11.9 Data cables are to comply with the applicable requirements of Ch 2,11. Other media will be subject to special consideration.

2.11.10 The installation is to provide adequate protection against mechanical damage and electromagnetic interference.

2.11.11 Components are to be located with appropriate segregation such that the risk of mechanical damage or electromagnetic interference resulting in the loss of both active and standby components is minimised. Duplicated data communication links are to be routed to give as much physical separation as is practical.

2.12 Additional requirements for wireless data communication links

2.12.1 The requirements of this sub-Section are in addition to 2.11 and apply to systems incorporating wireless data communication links.

2.12.2 Wireless data communication links are not to be used for safety critical systems or essential services that are required for the propulsion or safety of the ship, except as permitted by 2.12.3.

2.12.3 For services not required to operate continuously, wireless data communication links may be considered where an alternative means of operation can be brought into action within an acceptable period of time.

2.12.4 Wireless data communication is to employ recognised international wireless communication system protocols that incorporate the following:

(a) Message integrity: fault prevention, detection, diagnosis and correction, ensuring that the received message is not corrupted or altered when compared to the transmitted message.
(b) Configuration and device authentication: is to permit connection only of devices that are included in the system design.
(c) Message encryption: protection of the confidentiality and/or criticality of the data content.
(d) Security management: protection of network assets and prevention of unauthorised access to network assets.

2.12.5 The wireless system is to comply with the radio frequency and power level requirements of the International Telecommunications Union and any requirements of the National Administration with which the ship is registered.

2.12.6 Compliance with different port state and local regulations pertaining to the use of radio-frequency transmission that would prohibit the operation of a wireless data communication link, due to frequency and power level restrictions, is not addressed by these requirements and is the responsibility of the Owner and Operator.

2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems

2.13.1 The requirements of 2.13.2 to 2.13.10 are to be complied with where control, alarm or safety systems for essential services, as defined by Ch 2,1.6, or safety critical systems, incorporate programmable electronic equipment.
(a) Safety critical systems are those which provide functions intended to protect persons from physical hazards (e.g., fire, explosion, etc.), or to prevent mechanical damage which may result in the loss of an essential service (e.g., main engine low lubricating oil pressure shut-down).
(b) Applications that are not essential services may also be considered to be safety critical (e.g., domestic boiler low water level shut-down).

2.13.2 Alternative means of safe and effective operation are to be provided for essential services and, wherever practicable, these are to be provided by a fully independent hard-wired back-up system. Where these alternative means are not independent of any programmable electronic equipment, the software is to satisfy the requirements of LR's *Software Conformity Assessment System – Assessment Module GEN1 (1994)*.

2.13.3 Items of programmable electronic equipment used to implement control, alarm or safety functions are to be Type Approved in accordance with LR's *Type Approval System Test Specification Number 1 (2002)*. Type approval to an alternative and relevant National or International Standard may be submitted for consideration.

2.13.4 The system is to be configured such that control, alarm and safety function groups are independent. A failure of the system is not to result in the loss of more than one of these function groups. Proposals for alternative arrangements providing an equivalent level of safety will be subject to special consideration.

2.13.5 For essential services, the system is to be arranged to operate automatically from an alternative power supply in the event of a failure of the normal supply.

2.13.6 Volatile memory is not to be used to store data required for:

- an essential service or safety critical functions; or
- ensuring safety or preventing damage, including during start-up or re-start.

Alternative proposals which demonstrate that an equivalent level of system integrity will be achieved may be submitted for consideration.

2.13.7 Failure of any power supply is to initiate an audible and visual alarm in accordance with the requirements of 2.3 and, where applicable, 4.2.

2.13.8 Where it is intended that the programmable electronic system implements an emergency stop function or safety critical functions, the software is to satisfy the requirements of LR's *Software Conformity Assessment System – Assessment Module GEN1 (1994)*. Alternative proposals providing an equivalent level of system integrity will be subject to special consideration, e.g., fully independent hard-wired back-up system, redundancy with design diversity, etc.

2.13.9 Control, alarm and safety related information is to be displayed in a clear, unambiguous and timely manner, and, where applicable, is to be given visual prominence over other information on the display.

2.13.10 Means of access to safety critical functions are to be dedicated to the intended function and readily distinguishable.

2.14 Programmable electronic systems – Additional requirements for integrated systems

2.14.1 The requirements of 2.14.2 to 2.14.7 apply to integrated systems providing control, alarm or safety functions in accordance with the Rules, including systems capable of independent operation interconnected to provide co-ordinated functions or common user interfaces. Examples include integrated machinery control, alarm and monitoring systems, power management systems and safety management systems providing a grouping of fire, passenger, crew or ship safety functions, *see* Ch 2,17 to 19.

2.14.2 System integration is to be managed by a single designated party, and is to be carried out in accordance with a defined procedure identifying the roles, responsibilities and requirements of all parties involved. This procedure is to be submitted for consideration where the integration involves control functions for essential services or safety functions including fire, passenger, crew, and ship safety.

2.14.3 The system requirements specification, *see* 1.2.6, is to identify the allocation of functions between modules of the integrated system, and any common data communication protocols or interface standards required to support these functions.

2.14.4 Reversionary modes of operation are to be provided to ensure safe and graceful degradation in the event of one or more failures. In general, the integrated system is to be arranged such that the failure of one part will not affect the functionality of other parts, except those that require data from the failed part.

2.14.5 Where the integration involves control functions for essential services or safety functions, including fire, passenger, crew, and ship safety, a Failure Mode and Effects Analysis (FMEA) is to be carried out in accordance with IEC 60812: *Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)*, or an equivalent and acceptable National or International Standard and the report and worksheets submitted for consideration. The FMEA is to demonstrate that the integrated system will 'fail-safe', *see* 2.4.5 and 2.5.3, and that essential services in operation will not be lost or degraded beyond acceptable performance criteria where specified by these Rules.

2.14.6 The quantity and quality of information presented to the operator are to be managed to assist situational awareness in all operating conditions. Excessive or ambiguous information that may adversely affect the operator's ability to reason or act correctly is to be avoided, but information needed for corrective or emergency actions is not to be suppressed or obscured in satisfying this requirement.

2.14.7 Where information is required by the Rules or by National Administration requirements to be continuously displayed, the system configuration is to be such that the information may be viewed without manual intervention, e.g., the selection of a particular screen page or mode of operation. *See also* 2.10.16.

■ *Section 3* Ergonomics of control stations

3.1 Objectives

3.1.1 In order to take account of operator tasks at control stations, enhance usability and reduce human error, the layout arrangements are to comply with the requirements set out in 3.2.

3.1.2 In order to establish a working environment that has minimum distractions, is sufficiently comfortable, helps maintain vigilance and maximises communication amongst operators at main control stations, the requirements of 3.3 are to be complied with.

3.1.3 The requirements of 3.4 to 3.6 apply to operator interfaces for essential engineering systems located either locally, remotely or within the main control room. The requirements are intended to enhance the usability of systems and equipment, reduce human error, enhance situational awareness and support safe and effective monitoring and control under normal and abnormal modes of operation.

3.2 Control station layout

3.2.1 Control stations are to provide sufficient space and access for the intended number of operators in the expected operating conditions.

3.2.2 Local control stations are to be positioned to minimise the risk of harm to the operator.

3.2.3 Controls, displays and indicators are to be both logically and physically grouped, according to their function.

3.2.4 Where a function may be accessed from more than one interface, the arrangement of displays and controls is to be consistent.

3.2.5 Frequently used controls and displays are to be within easy reach and visible to the operator from the normal working position.

3.2.6 Controls and displays used infrequently and which may be used in an emergency are to be clearly identifiable, clearly visible, easily accessible and positioned to allow safe operability.

3.2.7 The relationship of a control with a display is to be immediately apparent.

3.2.8 The relationship of controls and displays with the equipment under control is to be immediately apparent.

3.2.9 There is to be adequate spacing between controls and between controls and obstructions.

3.2.10 Controls and their associated displays are to be located such that the information on the displays can be easily read during the operation of the controls.

3.2.11 Indicators related to controls are to be visible during their operation.

3.2.12 Instruments are to face the operator's intended working position.

3.3 Physical environment

3.3.1 Control stations are to be positioned, as far as practicable, away from, or insulated against, sources of structurally transmitted vibration and noise, such as ventilation fans, engine intake fans and other noise sources.

3.3.2 In general, noise levels are to comply with IMO Res. A.468(XII) *Code on Noise Levels on Board Ships*, and take into account IMO Res. A.343(IX), *Recommendation on Methods of Measuring Noise Levels at Listening Posts*.

3.3.3 Where provided, the heating, ventilation and air conditioning system is to be capable of maintaining the temperature between 18°C and 27°C.

3.3.4 The flow of air from heating or air conditioning systems is not to be guided directly to the operator, or means are to be provided to adjust the direction of airflow from those systems.

3.3.5 Lighting is to be located to avoid glare from working and display surfaces, and is to be flicker-free. Surfaces are to have a non-reflective or matt finish.

3.3.6 Placement of controls, displays and indicators are to consider the position of light sources relative to the operator, with respect to reflections and evenness of lighting.

3.3.7 Where a transparent cover is fitted over a control, display or indicator, it is to be designed to minimise reflections.

3.3.8 The level of lighting is to be sufficient to enable operation of user interfaces. Lighting levels in accordance with Table 1.3.1 will be considered to satisfy this requirement.

Table 1.3.1 Specific lighting levels

Work area	Ideal Lux	Minimum Lux
General Lighting	540	220
Control room consoles (front)	540	320
Control room consoles (rear)	325	110
Local operating panels	540	320
Remote operating panels	540	320

3.3.9 Seating provided for use at control stations is to allow for varying height and/or reach needs of operators. Seating arrangements are to minimise the need for twisting and/or turning motions by the operator.

3.3.10 Physical hazards, e.g., sharp edges, protuberances and trip hazards, are to be avoided.

3.3.11 Sufficient handrails or equivalent are to be fitted to enable operators to move and stand safely in rough seas.

3.3.12 Work surfaces are to be capable of withstanding oils and solvents common to ships and are to be easy to clean.

3.4 Operator interface

3.4.1 The design of the operator interface is to permit the satisfactory monitoring, control and supervision of the machinery and equipment.

3.4.2 Information is to be presented to the operator consistently, both within and between different interfaces, *see* 3.6.2 to 3.6.4.

3.4.3 The response of the machinery and equipment to operator input is to be consistent between interfaces for the same function.

3.4.4 Visual, audible or mechanical feedback is to be provided to indicate that operator input has been acknowledged.

3.4.5 Functions requested by the operator are to be confirmed by the displays on completion.

3.4.6 Indications and documentation are to be in English or the language of the crew.

3.5 Controls

3.5.1 Operator inputs are to be checked for errors, for example, out of range data or incorrect actions, and the operator is to be alerted when they occur.

3.5.2 Means are to be provided to correct wrong inputs or commands rapidly and safely.

3.5.3 Assistance is to be provided to the operator to recover from operator errors, for example, through advisory screens where the automation system has this facility.

3.5.4 Operator confirmation is to be provided for any control action that could affect the safety of the ship, i.e., they should not rely on single keystrokes.

3.5.5 The purpose of each control is to be clearly indicated. Where standard symbols have been internationally adopted, they should be used.

3.5.6 The settings of mechanical controls are to be immediately evident.

3.5.7 The means of operation of mechanical controls is to be consistent with expectations.

3.5.8 Controls or combined controls and indicators are to be distinguishable from indicators.

3.5.9 Where control is provided by touch screens, the soft keys are to be of a sufficient size for operation in areas where vibration occurs or gloves are likely to be worn.

3.5.10 Where virtual keypads/keyboards or dialogue boxes are used on touch screens, they are not to obscure status or alarm areas of the display.

3.5.11 Keyboards are to be divided logically into functional areas. Alphanumeric, paging and specific system keys are to be grouped separately.

3.5.12 Controls that affect the safe operation of the ship should be arranged so as to minimise the possibility of inadvertent operation.

3.6 Displays

3.6.1 The displays and indicators are to present the operator with clear, timely and relevant information.

3.6.2 Graphical symbols and colour coding are to be consistent. The graphical symbols of display functions are to be in accordance with a recognised International Standard, for example, ISO 14617 (all parts) *Graphical symbols for diagrams*. Colour coding of functions and signals is to be in accordance with a recognised International Standard, for example, ISO 2412: *Shipbuilding – Colours of indicator lights*.

3.6.3 The symbols used in mimic diagrams for the services listed in Pt 6, Ch 2,1.6.1 are to be consistent across all displays.

3.6.4 The display of information is to be consistent with respect to screen layout and arrangement of information.

3.6.5 Flashing of information is to be reserved for unacknowledged alerts or transient states, for example, valve moving.

3.6.6 The functions supported by a display are to be clearly indicated. For displays that can support multiple functions, it is to be possible to select the display associated with the primary function or an overview by a simple operator action.

3.6.7 The operating mode of the machinery and equipment is to be clearly indicated.

3.6.8 In general, indications provided by instrumentation which are displayed digitally are not to change more frequently than twice per second.

3.6.9 To indicate an increasing value in a single direction, on a fixed circular scale, the pointer is to move clockwise. If the pointer is fixed, the scale is to move anticlockwise to indicate an increase in value.

3.6.10 To indicate an increasing value on a horizontal linear scale, the pointer is to move from left to right. On a vertical linear scale, the pointer is to move upwards to indicate an increase in value.

3.6.11 The pointer is not to obscure the numbers on the scale.

3.6.12 Alphanumeric data, text, symbols and other graphical information is to be readable from relevant operator positions under lighting conditions, as specified in 3.3.8. Character height in millimetres is to be not less than three and a half times the reading distance in metres and character width is to be 0,7 times the character height.

3.6.13 A simple sans-serif character font is to be used in displays. In descriptive text, lower case letters are to be used, where appropriate, as opposed to capitals, to improve readability.

3.6.14 Where information related to the safe operation of machinery and equipment is provided, it is to be continuously available to the operator.

3.6.15 Failures are to be indicated in a clear and unambiguous manner. Sufficient information is to be provided for the operator to identify the cause of the failure.

■ *Section 4* Unattended machinery space(s) – UMS notation

4.1 General

4.1.1 Where it is proposed to operate the following machinery in an unattended space, no matter what period is envisaged, the controls, alarms and safeguards required by Part 5, together with those given in 4.2 to 4.7 are to be provided:
(a) Air compressors.
(b) Controllable pitch propellers and transverse thrust units.
(c) Electric generating plant.
(d) Inert gas generators.
(e) Incinerators.
(f) Main propelling machinery including essential auxiliaries.
(g) Oil fuel transfer and storage systems (purifiers and oil heaters).
(h) Steam raising plant (boilers and their ancillary equipment).
(j) Thermal fluid heaters.
(k) Waste heat boilers.

4.2 Alarm system for machinery

4.2.1 An alarm system which will provide warning of faults in the machinery is to be installed. The system is to satisfy the requirements of 2.3.

4.2.2 Audible and visual indication of machinery alarms is to be relayed to the engineers' accommodation so that engineering personnel are made aware that a fault has occurred.

4.2.3 The engineers' alarm required by 2.2.4 is to be activated automatically in the event that a machinery alarm or warning has not been acknowledged in the space within a predetermined time.

4.2.4 Audible and visual indication of machinery alarms is to be relayed to the navigating bridge control station in such a way that the navigating officer of the watch is made aware when:
(a) a machinery fault has occurred;
(b) the machinery fault is being attended to; and
(c) the machinery fault has been rectified.
Alternative means of communication between the bridge area, accommodation for engineering personnel and machinery spaces will be considered.

4.2.5 Group alarms may be arranged on the bridge to indicate machinery faults, but alarms associated with faults requiring speed or power reduction or the automatic shut-down of propulsion machinery are to be identified by separate group alarms or by individual alarms.

4.3 Bridge control for main propulsion machinery

4.3.1 A bridge control system for the main propulsion machinery is to be fitted. The system is to satisfy the requirements of 2.6.

4.4 Control stations for machinery

4.4.1 A control station(s) is to be provided in the space and on the bridge which satisfies the requirements of 2.2.

4.5 Fire detection alarm system

4.5.1 An automatic fire detection system is to be fitted in the space together with an audible and visual alarm system. The system is to satisfy the requirements of 2.8.

4.6 Bilge level detection

4.6.1 An alarm system is to be provided to warn when liquid in machinery space bilges has reached a predetermined level, and is to comply with 2.3. This level is to be sufficiently low to prevent liquid from overflowing from the bilges onto the tank top. The number and location of detectors are to be such that accumulation of liquids will be detected at all angles of heel and trim. In ships above 2000 gross tons there are to be two independent systems of bilge level detection in the machinery space, arranged such that each branch bilge as required by Pt 5, Ch 13 is provided with a level detector.

4.6.2 Local or remote controls of any valve within the space serving a sea inlet, a discharge below the waterline, a bilge injection or a direct bilge system, should be so sited as to be readily accessible and to allow adequate time for operation in case of influx of water to the space, having regard to the time which could be taken to reach and operate such controls, *see also* 2.7 and Pt 5, Ch 13,2 and Ch 13,4.

4.6.3 Where the bilge pumps are arranged to start automatically, means are to be provided to indicate if the influx of liquids is greater than the pump capacity or, if the pump is operating more frequently than would be expected. Special attention should be given to oil pollution prevention requirements.

4.7 Supply of electric power, general

4.7.1 For ships operating with one generator set in service, arrangements are to be such that a standby generator will automatically start and connect to the switchboard in as short a time as practicable, but in any case within 45 seconds, on loss of the service generator. For ships operating with two or more generator sets in service, arrangements are to be such that on loss of one generator the remaining one(s) are to be adequate for continuity of essential services. For the detailed requirements of these arrangements, *see* Ch 2,2.2.

■ *Section 5* Machinery operated from a centralised control station – CCS notation

5.1 General requirements

5.1.1 Where it is proposed to operate the machinery as listed in 4.1.1 with the continuous supervision from a centralised control station, the control station is to be such that the machinery operation will be as effective as it would be under direct supervision.

5.1.2 The arrangements are to be such that corrective actions can be taken at the control station in the event of machinery faults, e.g., stopping of machinery, starting of standby machinery, adjustment of operating parameters, etc. These actions may be effected by either remote manual or automatic control.

5.1.3 The controls, alarms and safeguards required by Section 3 and by 4.6 together with a fire detection system satisfying the requirements of 2.8 are to be provided. However, the automatic operation of machinery and certain safeguards required by Section 3 may be omitted.

5.1.4 Additional requirements for controls, alarms and safeguards are given in 5.2.

5.2 Centralised control station for machinery

5.2.1 A centralised control station which satisfies the requirements of 5.2.2 to 5.2.7 is to be provided at a suitable location.

5.2.2 A system of alarm displays and controls is to be provided which readily ensures identification of faults in the machinery and satisfactory supervision of related equipment. The alarm and control systems are to satisfy the requirements of 2.3 and 2.5, as applicable.

5.2.3 Indication of all essential parameters necessary for the safe and effective operation of the machinery is to be provided, e.g., temperatures, pressures, tank levels, speeds, powers, etc.

5.2.4 Indication of the operational status of running and standby machinery is to be provided.

5.2.5 At the centralised control station, means of communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery space are to be provided.

5.2.6 In addition to the communication required by 5.2.5, a second means of communication is to be provided between the bridge and the centralised control station. One of these means is to be independent of the main electrical power supply, *see also* Pt 5, Ch 1.

5.2.7 Arrangements are to be provided in the centralised control station so that the normal supply of electrical power may be restored in the event of failure.

■ *Section 6* Integrated computer control – ICC notation

6.1 General

6.1.1 Integrated Computer Control class notation **ICC** may be assigned where an integrated computer system in compliance with 6.1 to 6.3 provides fault tolerant control and monitoring functions for one or more of the following services:

(a) Propulsion;
(b) Electrical generation and distribution (power management systems);
(c) Cargo and ballast.

6.1.2 A Failure Mode and Effects Analysis (FMEA) is to be carried out in accordance with IEC 60812: *Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)* and the report and worksheets submitted for consideration. *See also* 2.14.5. The FMEA is to demonstrate that control and monitoring functions required by 6.2 will remain available at each operator station in the event of a single fault of the integrated computer control system, including input error, without adverse effect on the service(s).

6.1.3 Special consideration will be given to integrated computer control systems for other applications, except where these are addressed by other control engineering class notations. In particular, *see* Pt 7, Ch 9 for requirements of the optional class notation **IBS** – Integrated Bridge Navigation Systems.

6.2 General requirements

6.2.1 The integrated computer control system is to comply with the programmable electronic system requirements of 2.10 to 2.13 and the control and monitoring requirements of the Rules applicable to particular equipment, machinery or systems.

6.2.2 Alarm displays are to be provided, in compliance with the requirements of 2.3, which ensure ready identification of faults in the equipment under control.

6.2.3 Alarm and indication functions required by 2.4 are to be provided by the integrated computer control system in response to the activation of any safety function for associated machinery. Systems providing the safety functions are in general to be independent of the integrated computer system. *See also* 2.13.7.

6.2.4 Controls are to be provided, in compliance with 2.5, to ensure the safe and effective operation of equipment and response to faults, e.g., stopping, starting, adjustment of parameters, etc. Indication of operational status and other such parameters necessary to satisfy this requirement, is to be provided for all equipment under control by the integrated computer control system.

6.3 Operator stations

6.3.1 Each operator station allowing control of equipment is to be provided with a minimum of two multi-function display and control units. The number of units is to be sufficient to allow simultaneous access to control and monitoring functions required by 6.2.2 to 6.2.4. *See also* 2.10.19 to 2.10.16.

6.3.2 Each multi-function display and control unit is to include a monitor, keyboard and tracker ball. Alternative arrangements will be considered where these enable each unit to be configured by the user to provide required control or monitoring functions.

6.3.3 Where the integrated computer control system is arranged such that control and monitoring functions may be accessed at more than one operator station, the selected mode of operation of each station (e.g., in control, standby, etc.) is to be clearly indicated. *See also* 2.2.

6.3.4 Means of communication are to be provided between operator stations and any other stations from which the equipment may be controlled. The arrangements are to be permanently installed and are to remain operational in the event of failure of the main electrical power supply to the integrated control system.

■ *Section 7* Trials

7.1 General

7.1.1 Before a new installation (or any alteration or addition to an existing installation) is put into service, trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturers' works and are to be based on the approved test schedules list as required by 1.2.2. In the case of new construction it will be expected that most of these trials will be carried out before the official sea trials of the ship. During sea trials, system dynamic tests are to be carried out to demonstrate overall satisfactory performance of the control engineering installation.

7.1.2 Means are to be provided to facilitate testing during normal machinery operation, e.g., by the provision of three-way test valves or equivalent.

7.1.3 Acceptance tests and trials for programmable electronic systems are to include verification of software lifecycle activities appropriate to the stage in the system's lifecycle at the time of system examination. The documentation required by 1.2.6 is to be in accordance with the current configuration and the testing and trials are to address software modifications and configuration management procedures to the Surveyor's satisfaction.

7.1.4 Wireless data communication links are to be operational and tested during trials. Tests are to demonstrate that radio-frequency transmission does not interfere with the operation of equipment required by this Chapter or other Sections of the Rules and does not itself malfunction as a result of electromagnetic interference during expected operating conditions. Reversionary modes are to be activated to demonstrate continued safe and effective operation in the event of fault conditions.

7.2 Unattended machinery space operation – UMS notation

7.2.1 In addition to the tests required by 7.1 the suitability of the installation for operation in the unattended mode is to be demonstrated during sea trials over a four to six hour period observing the following:

(a) Occurring alarms and the frequency of operation both during steady steaming and under manoeuvring conditions using bridge control.
(b) Any intervention by personnel in the operation of the machinery.

7.3 Operation from a centralised control station – CCS notation

7.3.1 In addition to the tests required by 7.1, the suitability of the installation for operation from the centralised control station is to be demonstrated during sea trials.

7.4 Record of trials

7.4.1 Two copies of the alarm and control equipment test schedules signed by the Surveyor and Builder are to be provided on completion of the survey. One copy is to be placed on board the vessel and the other submitted to LR.

■ *Section 1* General requirements

1.1 General

1.1.1 The requirements of this Chapter apply to passenger ships and cargo ships except where otherwise stated.

1.1.2 Whilst these requirements are considered to meet those of the *International Convention for the Safety of Life at Sea, 1974*, and applicable amendments, attention should also be given to any relevant Statutory Regulations of the National Administration of the country in which the ship is to be registered. Compliance with the Statutory Regulations of the National Administration may be accepted as meeting the requirements of the *International Convention for the Safety of Life at Sea, 1974*, and applicable amendments.

1.1.3 Electrical services required to maintain the ship in a normal sea-going, operational and habitable condition are to be capable of being maintained without recourse to the emergency source of electrical power.

1.1.4 Electrical services essential for safety are to be maintained under declared normal and reasonably foreseeable abnormal conditions.

1.1.5 The safety of passengers, crew and ship from electrical hazards is to be ensured.

1.1.6 Electrical installations on passenger ships having a length of 120 m or more or having three or more main vertical zones (*see* Pt 5, Ch 23,1.2.4 for definitions) are, in addition to the requirements of this Chapter, to be located, designed and arranged to comply with Pt 5, Ch 23, as applicable.

1.1.7 Lloyd's Register (hereinafter referred to as 'LR') will be prepared to give consideration to special cases or to arrangements which are equivalent to the Rules. For unconventional designs, *see also* Pt 7, Ch 15. Consideration will also be given to electrical arrangements of small ships and ships to be assigned class notation for restricted or special services.

1.2 Documentation required for design review

1.2.1 The documentation described in 1.2.2 to 1.2.17 is to be submitted for design review.

1.2.2 Single line diagrams of main, emergency and transitional power and lighting systems which are to include:
(a) ratings of machines, transformers, batteries and semi-conductor converters;
(b) all feeders connected to the main and emergency switchboards;
(c) section boards and distribution boards;
(d) insulation type, size and current loadings of cables;
(e) make, type and rating of circuit-breakers and fuses;
(f) details of harmonic filters (where fitted); and
(g) details of power supply arrangements used for control systems.

1.2.3 A functional description of operation of the main, emergency and transitional electrical power systems, which is to include:
(a) the operating philosophy of the main, emergency and transitional electrical power systems under normal and reasonably foreseeable abnormal conditions;
(b) degraded modes of operation;
(c) load management and load sharing philosophy; and
(d) protection philosophy.

1.2.4 An earthing philosophy document that defines the basic approach to be taken for earthing the electrical power systems and all electrical loads.

1.2.5 Simplified diagrams of generator circuits, interconnector circuits and feeder circuits showing:
(a) protective devices, e.g., short-circuit, overload, reverse power protection;
(b) instrumentation and synchronising devices;
(c) preference tripping;
(d) remote stops and fire safety stops; and
(e) earth fault indication/protection.

1.2.6 Calculations of short-circuit currents at main, emergency and transitional switchboards and section boards including those fed from transformers, details of circuit-breaker and fuse operating times and discrimination curves showing compliance with 6.1 and 11.6.2.

1.2.7 Where required by 8.1.1, the hazards resulting from electric arcs within electrical equipment and their consequences for personnel are to be identified, and at least the following supporting evidence is to be submitted:
(a) system design;
(b) operating philosophies, e.g., manual or automatic control, local or remote operation;
(c) general arrangement plans for switchboards, section boards and distribution boards, *see also* 1.3.4;
(d) general arrangement plans for the space in which the electrical equipment to be assessed are located showing:
  (i) access to adjacent spaces;
  (ii) the location of the electrical equipment;
  (iii) ventilation arrangements for air conditioning and/or the extraction of smoke, gas and vapours resulting from electric arcs; and
  (iv) positions within the space in which the electrical equipment is located where personnel will be performing tasks, e.g., switching, equipment maintenance, instrument observation or cleaning, or where personnel could reasonably be expected to enter;
(e) calculations in accordance with 8.3;
(f) system operating procedures; and
(g) details of defined additional safety measures to be taken during activities.

1.2.8 For ships in which explosive gas atmospheres and/or combustible dusts occur, a general arrangement of the ship showing hazardous zones and spaces, as defined within Section 14, is to be submitted. Where the explosive gas or combustible dust is not associated with the ship's cargo, arrangement drawings for the hazardous locations only may be submitted in place of the complete ship general arrangement.

1.2.9 A schedule of electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts giving details, as appropriate, of:
(a) type of equipment;
(b) type of protection, e.g., Ex 'd';
(c) apparatus group, e.g., IIB;
(d) temperature class, e.g., T3;
(e) enclosure ingress protection, e.g., IP55;
(f) certifying authority;
(g) certificate number;
(h) location of equipment.
Details may be included on arrangement drawings for the hazardous locations, in place of a separate schedule. Where uncertified equipment is permitted by 14.2 or 14.3 or the Rules relevant to the specific type of ship, details of other documentation confirming (b) to (d) may be submitted in place of those listed under (f) and (g).

1.2.10 For ships with electrical propulsion systems, a functional description is to be provided which includes:
(a) the operating philosophy of the propulsion control systems under normal and reasonably foreseeable abnormal operating conditions;
(b) degraded modes of operation;
(c) protection philosophy;
(d) earthing philosophy; and
(e) harmonic analysis, including loss of harmonic filters. *See also* 1.8.3.

1.2.11 Simplified circuit diagram of electrical propulsion system (where fitted) giving details of:
(a) ratings of electrical machines, transformers, batteries, harmonic filters, dynamic braking assemblies and semi-conductor converters;
(b) lubrication and cooling arrangements, where provided;
(c) insulation type, size and current loadings of cables;
(d) make, type and rating of circuit-breakers and fuses;
(e) instrumentation and protective devices;
(f) earth fault indication/protection;
(g) propulsion control systems, and the procedures used to ensure that there is satisfactory control of the design in relation to the requirements of Section 16,4; and
(h) harmonic analysis.

1.2.12 Details of electrically operated fire, ship, crew and passenger emergency safety systems which are to include typical single line diagrams and arrangements, showing main vertical and, where applicable, horizontal fire zones, spaces along the ship bottom that are not fitted with a double bottom and the location of equipment and cable routes, including identification of relevant high fire risk areas, to be employed for:
(a) emergency lighting;
(b) accommodation fire detection, alarm and extinction systems;
(c) fixed water-based local application fire-fighting systems;
(d) public address system;
(e) general emergency alarm;
(f) watertight doors, bow, stern and shell doors and other electrically operated closing appliances; and
(g) low location lighting.

NOTE
A general arrangement plan of the complete ship showing the main vertical fire zones, spaces along the ship bottom that are not fitted with a double bottom and the location of equipment and cable routes, including identification of relevant high fire risk areas, for the above systems, is to be made available for the use of the Surveyor on board.

1.2.13 Evidence of the suitability of electrical and electronic equipment for use in protected areas and adjacent areas, as required by 17.3.9 and 17.3.10, including a schedule of electrical and electronic equipment located in protected areas and adjacent areas, and general arrangement plans showing the coverage of the protected areas and adjacent areas. *See also* 1.11.

1.2.14 For battery installations, arrangement plans and calculations are to show compliance with 12.5.

1.2.15 A schedule of batteries fitted for use for emergency and essential services, giving details of:

- type and manufacturer's type designation;
- voltage and ampere-hour rating;
- location;
- equipment and/or system(s) served;
- maintenance/replacement cycle dates;
- date(s) of maintenance and/or replacement; and
- for replacement batteries in storage, the date of manufacture and shelf life; with accompanying battery replacement procedure documentation to show compliance with 12.7.

NOTE

The above includes all batteries fitted as part of an uninterruptible power system (UPS) used for any essential or emergency services.

1.2.16 For high voltage rotating machines, type test reports for stator insulation systems, *see* 9.1.14.

1.3 Documentation required for supporting evidence

1.3.1 The documentation and particulars in 1.3.2 to 1.3.5 are to be submitted as supporting evidence.

1.3.2 Plans for all cables that pass through atria or equivalent spaces, and for vertical runs in trunks or other restricted spaces. The information supplied is to show compliance with 11.8.10.

1.3.3 In order to establish compliance with 1.11.2 and 5.1.4 to 5.1.6, a general arrangement plan of the ship showing the location of major items of electrical equipment, for example:

- main and emergency generators;
- transitional source of supply (where fitted);
- switchboards;
- section boards and distribution boards supplying essential and emergency services;
- emergency batteries;
- motors for emergency services;
- propulsion motors;
- propulsion transformers;
- propulsions semiconductor converters;
- dynamic braking equipment;
- reactors;
- harmonic filters; and
- cable routes between these items of equipment.

1.3.4 Arrangement plans of main and emergency switchboards, section boards and documentation that demonstrates that creepage and clearance distances are in accordance with 7.5. The form factor of internal separation of low-voltage switchgear and controlgear assemblies is to be in accordance with IEC 61439-2: *Low-voltage switchgear and controlgear assemblies — Part 2: Power switchgear and controlgear assemblies*, or an alternative acceptable and relevant National Standard. The form factor is to be stated, and the arrangement plans are to show how the form factor has been achieved.

1.3.5 Schedule of normal and emergency operating loads on the system estimated for the different operating conditions expected. The following details are to be provided to meet this requirement:

(a) a description of the expected operating profiles (e.g., the number of generating sets connected when manoeuvring at sea, etc.), including that required by Pt 5, Ch 2,1.1.1; and

(b) a schedule of the normal and emergency operating loads, which is to state the kilowatt rating of each load and a load factor between 0 and 1 that reflects:

  (i) the duty cycle of the load; and

  (ii) the proportion of its maximum rating at which the load is expected to operate.

1.3.6 In order to establish compliance with the requirements of 1.7.3, when requested, evidence is to be submitted to demonstrate the suitability of electrical equipment for its intended purpose in the conditions in which it is expected to operate.

1.3.7 For non-metallic cable support systems or protective casings, test evidence, details of installation procedures and manufacturer's recommendations that show compliance with 11.13.

1.4 Surveys

1.4.1 Electrical propelling machinery and associated equipment together with auxiliary services essential for the safety of the ship are to be installed in accordance with the relevant requirements of this Chapter, surveyed and have tests witnessed by the Surveyors.

1.4.2 The following equipment, where intended for use for essential and emergency services, is to be surveyed by the Surveyors during manufacture and testing:

- Converting equipment of 100 kW and over;
- Rotating machines of 100 kW and over;
- Switchboards and section boards; and
- UPS units of 50 kVA and over.

1.4.3 For electric propulsion systems, in addition to the equipment listed in 1.4.2, the following equipment is to be surveyed by the Surveyors during manufacture and testing:

- dynamic braking assemblies, *see* 16.5.8;
- exciters;
- filters;
- reactors;
- pre-magnetisation transformers; and
- slip ring assemblies.

1.4.4 For refrigerating cargo installations having an **RMC** notation, motors are to be tested and certificates furnished by the manufacturer. Motors of 100 kW or over are to be surveyed by the Surveyors during manufacture and testing.

1.4.5 All other electrical equipment, not specifically referenced in 1.4.2 to 1.4.4, intended for use for essential or emergency services is to be supplied with a manufacturer's works test certificate showing compliance with the constructional Standard(s) as referenced by the relevant requirements of this Chapter.

1.5 Additions or alterations

1.5.1 No addition, temporary or permanent, is to be made to the approved load of an existing installation until it has been ascertained that the current carrying capacity and the condition of the existing equipment including cables and switchgear are adequate for the increased load.

1.5.2 Plans are to be submitted for consideration, and the alterations or additions are to be carried out under the survey, and to the satisfaction of the Surveyors.

1.5.3 When it is proposed to replace permanently installed secondary valve-regulated sealed batteries with vented batteries, details are to be submitted for consideration to ensure continued safety in the presence of the products of electrolysis and evaporation being allowed to escape freely from the cells to the atmosphere. These details are to demonstrate that there will be adequate ventilation in accordance with 12.5.9 and that the location and installation requirements of 12.3 and 12.4 are complied with.

1.5.4 Proposed modifications to the electrical protection settings are to be developed in accordance with 6.1.4 and plans submitted are also to address the updating of approved version of the details required by 1.2.5 and 1.2.6.

1.5.5 Where it is intended to replace an existing incandescent lamp type navigation light with a light emitting diode type navigation light, details are to be submitted for consideration that demonstrate compliance with 15.6. Light emitting diode type navigation lights failure detection arrangements are to satisfy the requirements of 15.6.5 and 15.6.6.

1.6 Definitions

1.6.1 Essential services are those necessary for the propulsion and safety of the ship, such as the following:

- air compressors for oil engines;
- air pumps;
- automatic sprinkler systems;
- ballast pumps;
- bilge pumps;
- circulating and cooling water pumps;
- communication systems;
- condenser circulating pumps;
- electric propulsion equipment;
- electric starting systems for oil engines;
- extraction pumps;
- fans for forced draught to boilers;
- feed water pumps;
- fire detection and alarm systems;
- fuel valve cooling pumps;
- hydraulic pumps for controllable pitch propellers and those serving essential services here listed that would otherwise be directly electrically driven;
- lubricating oil pumps;
- inert gas fans and scrubber and deck seal pumps;
- lighting systems for those parts of the ship normally accessible to and used by personnel and passengers;
- liquefied gas cargo handling;
- navigational aids where required by Statutory Regulations;
- navigation lights and special purpose lights where required by Statutory Regulations;
- oil fuel pumps and oil fuel burning units;
- oil separators;
- pumps for fire-extinguishing systems;
- scavenge blowers;
- steering gear;
- thrusters for dynamic positioning;
- valves which are required to be remotely operated;
- ventilating fans for engine and boiler rooms;
- watertight doors, shell doors and other electrical operated closing appliances;
- windlasses;
- power sources and supply systems for supplying the above services; and
- steam raising plant, where steam is required for other essential services.

1.6.2 Services such as the following are considered necessary for minimum comfortable conditions of habitability:

- cooking;
- heating;
- domestic refrigeration;
- mechanical ventilation;
- sanitary and fresh water.

1.6.3 Services such as the following, which are additional to those in 1.6.1 and 1.6.2, are considered necessary to maintain the ship in a normal sea-going operational and habitable condition:

- cargo handling and cargo care equipment;
- hotel services, other than those required for habitable conditions;
- thrusters, other than those for dynamic positioning.

1.6.4 A 'high voltage' is a voltage exceeding 1000 V a.c. or 1500 V d.c. between conductors, *see also* 5.1.3.

1.6.5 A 'switchboard' is a switchgear and controlgear assembly for the control of power generated by a source of electrical power and its distribution to electrical consumers.

1.6.6 A 'section board' is a switchgear and controlgear assembly for controlling the supply of electrical power from a switchboard and distributing it to other section boards, distribution boards or final sub-circuits.

1.6.7 A 'distribution board' is an assembly of one or more protective devices arranged for the distribution of electrical power to final sub-circuits.

1.6.8 A 'final sub-circuit' is that portion of a wiring system extending beyond the final overcurrent device of a board.

1.6.9 'Special category spaces' are those enclosed spaces above or below the bulkhead deck intended for the carriage of motor vehicles with fuel, for their own propulsion, in their tanks, into and from which such vehicles can be driven, and to which passengers have access. Special category spaces may be accommodated on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m.

1.6.10 'Machinery spaces of Category A' are those spaces and trunks to such spaces which contain:
(a) internal combustion machinery used for main propulsion; or
(b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
(c) any oil-fired boiler or oil fuel unit.

1.6.11 'Dead ship condition' means that the entire machinery installation, including the power supply, is out of operation and that the auxiliary services for bringing the main propulsion systems into operation (e.g., compressed air, starting current from batteries, etc.) and for the restoration of the main power supply are not available. Means are to be available to start the emergency generator at all times, *see* Pt 5, Ch 2,9.4.

1.6.12 Protected space is a machinery space where a fixed water-based local application fire-fighting system is installed.

1.6.13 Protected areas are areas within a protected space which are protected by a fixed water-based local application fire-fighting system.

1.6.14 Adjacent areas are areas, other than protected areas, exposed to direct spray or other areas where water may extend when a fixed water-based local application fire-fighting system is activated.

1.6.15 For emergency services and their emergency power supplies required to be capable of being operated under fire conditions, 'high fire risk areas' are:
(a) machinery spaces, as defined by SOLAS 1974 as amended, Ch II-2;
(b) spaces containing fuel treatment equipment;
(c) galleys and pantries containing cooking appliances;
(d) laundries containing drying equipment;
(e) hazardous zones and spaces; and
(f) for passenger ships carrying more than 36 passengers:
  (i) public spaces containing furniture and furnishings of other than restricted fire risk and having a deck area of 50 m^2 or more;
  (ii) barber shops and beauty parlours; and
  (iii) saunas.

Requests to exempt spaces identified in (f) may be considered when evidence is submitted that demonstrates emergency services will remain available in the event of a fire in the space (e.g., studies of fire protection measures, installation locations, system redundancy, etc.).

1.6.16 An 'electric arc' is an electrical discharge or a short-circuit through ionised air caused by isolation or insulation integrity failure.

1.6.17 'Incident energy' is the amount of energy impressed on a surface, a certain distance from the source, generated during an electric arc event.

1.7 Design and construction

1.7.1 Electrical propelling machinery and associated equipment together with equipment for services essential for the propulsion and safety of the ship are to be constructed in accordance with the relevant requirements of this Chapter.

1.7.2 The design and installation of other equipment is to be such that risk of fire due to its failure is minimised. It is, as a minimum, to comply with a National or International Standard revised where necessary for ambient conditions.

1.7.3 Electrical equipment is to be suitable for its intended purpose and accordingly, whenever practicable, be selected from the *List of Type Approved Products* published by LR. A copy of the Procedure for LR Type Approval System will be supplied on application.

1.7.4 For areas susceptible to deluge or submersion, cable entries are to prevent water ingress. In general, cable entries are to be in accordance with IEC 60092-101: *Electrical Installations in Ships – Part 101: Definitions and General Requirements*.

1.8 Quality of power supplies

1.8.1 All electrical equipment supplied from the main and emergency sources of electrical power and electrical equipment for essential and emergency services supplied from d.c. sources of electrical power is to be so designed and manufactured that it is capable of operating satisfactorily under normally occurring variations of voltage and frequency.

1.8.2 Unless specified otherwise, a.c. electrical equipment is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals:
(a) voltage:
permanent variations +6 per cent, –10 per cent
transient variations due to step changes in load ±20 per cent
recovery time 1,5 seconds
(b) frequency:
permanent variations ±5 per cent
transient variations due to step changes in load ±10 per cent
recovery time 5 seconds
A maximum rate of change of frequency not exceeding ±1,5 Hz per second during cyclic frequency fluctuations.

1.8.3 **Harmonics**. Unless specified otherwise, the total harmonic distortion (THD) of the voltage waveform at any a.c. switchboard or section board is not to exceed 8 per cent of the fundamental for all frequencies up to 50 times the supply frequency and no voltage at a frequency above 25 times supply frequency is to exceed 1,5 per cent of the fundamental of the supply voltage. THD is the ratio of the rms value of the harmonic content to the rms value of the fundamental, expressed in per cent and may be calculated using the expression:

$$THD = \frac{\sqrt{\sum_{h=2}^{\infty} V_h^2}}{V_1} \times 100$$

where

V_h = rms amplitude of a harmonic voltage of order h

V_1 = rms amplitude of the fundamental voltage.

1.8.4 Unless specified otherwise, d.c. electrical equipment is to operate satisfactorily with the following simultaneous variations from its nominal value, when measured at the consumer input terminals:

(a) When supplied by d.c. generator(s) or a rectified a.c. supply:

Voltage tolerance (continuous)	±10 per cent
Voltage cyclic variation deviation	5 per cent
Voltage ripple	10 per cent

(a.c. rms over steady state d.c. voltage);

(b) When supplied by batteries:
  (i) Equipment connected to the batteries during charging:
  Voltage tolerance +30 per cent, –25 per cent;
  (ii) Equipment not connected to batteries during charging:
  Voltage tolerance +20 per cent, –25 per cent.

Different voltage variations as determined by the charging/discharging characteristics, including ripple voltage from the charging device, may be considered. When battery chargers/battery combinations are used as d.c. power supply systems adequate measures are to be taken to keep the voltage within the specified limits during charging, boost charging and discharging of the battery.

1.9 Ambient reference and operating conditions

1.9.1 The rating for classification purposes of essential electrical equipment intended for installation in ships to be classed for unrestricted (geographical) service is to be based on an engine room ambient temperature of 45°C, and a sea-water temperature at the inlet of 32°C. The equipment manufacturer is not expected to provide simulated ambient reference conditions at a test bed.

1.9.2 In the case of a ship to be classed for restricted service, the rating is to be suitable for the ambient conditions associated with the geographical limits of the restricted service, *see* Pt 1, Ch 2.

1.9.3 Main and essential auxiliary machinery and equipment is to operate satisfactorily under the conditions shown in Pt 5, Ch 1,3.6. Electrical equipment satisfying alternative ambient operating condition requirements for installation on ships contained in an acceptable and relevant National or International Standard may be considered to satisfy this requirement.

NOTE

Details of local environmental conditions are stated in Annex B of IEC 60092-101-2002: *Electrical installations in ships – Part 101: Definitions and general requirements*.

1.9.4 Where electrical equipment is installed within environmentally controlled spaces, the ambient temperature for which the equipment is suitable for operation at its rated capacity may be reduced to a value not less than 35°C provided:

- the equipment is not for use for emergency services and is located outside of machinery space(s);
- temperature control is achieved by at least two cooling units so arranged that, in the event of loss of one cooling unit, for any reason, the remaining unit(s) will be capable of satisfactorily maintaining the design temperature;
- the equipment is able to be initially set to work safely within a 45°C ambient temperature until such a time that the lesser ambient temperature may be achieved; the cooling equipment is to be rated for an ambient temperature of not less than 45°C; and
- alarms are provided, at a continually attended control station, to indicate any malfunction of the cooling units.

See also Ch 1,1.3.3.

1.9.5 Where equipment is to comply with 1.9.4, it is to be ensured that electrical cables for their entire length are adequately rated for the maximum ambient temperature to which they are exposed along their length.

1.9.6 Equipment used for cooling and maintaining the lesser ambient temperature in accordance with 1.9.4 are considered essential services and are to satisfy the requirements of 5.2.

1.10 Inclination of ship

1.10.1 Emergency and essential electrical equipment is to operate satisfactorily under the conditions as shown in Table 2.1.1.

1.10.2 In ships for the carriage of liquefied gas the emergency source of electrical power is also to remain operable under the conditions described in the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk* (hereinafter referred to as the Rules for Ships for Liquefied Gases), Chapter 10, LR 10.1-05 General. In ships for the carriage of liquid chemicals the emergency source of electrical power is also to remain operable under the conditions described in the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquid Chemicals in Bulk* (hereinafter referred to as the Rules for Ships for Liquid Chemicals), Chapter 10, LR 10.1(e) General.

Table 2.1.1 Inclination of ship

Installations, components	Angle of inclination, degrees, *see* Note 2			
	Athwartships		Fore-and-aft	
	static	dynamic	static	dynamic
Essential electrical equipment	15	22,5	5 *see* Note 3	7,5
Safety systems, e.g., emergency power installations, crew and passenger safety systems Switchgear, electrical and electronic appliances *see* Note 1	22,5	22,5	10	10

NOTES
1. Up to an angle of 45° no undesired switching operations or operational changes may occur.
2. Athwartships and fore-and-aft inclinations may occur simultaneously.
3. Where the length of the ship exceeds 100 m, the fore-and-aft static angle of inclination may be taken as:

$\frac{500}{L}$ degrees

where L = Rule length, in metres, *see* Pt 3, Ch 1,6.1.

1.10.3 Any proposal to deviate from the angles given in Table 2.1.1 will be specially considered taking into account the type, size and service of the ship.

1.10.4 The dynamic angles of inclination in Table 2.1.1 may be exceeded in certain circumstances dependent upon ship type and operation. The Shipbuilder is, therefore, to ensure that the electrical equipment is capable of operating under these angles of inclination.

1.11 Location and construction

1.11.1 All electrical equipment is to be constructed or selected, and installed such that:

(a) live parts cannot be inadvertently touched, unless they are supplied at the safety voltage specified in 1.12.2(h);

(b) it does not cause injury when handled or touched in the normal manner; and

(c) it is unaffected by any water, steam or oil and oil vapour to which it is likely to be exposed.

Electrical equipment having, as a minimum, the degrees of protection as specified in IEC 60092-201: *Electrical installations in ships – Part 201: System design – General* for the relevant location will satisfy these requirements.

1.11.2 Switchboards, section boards and distribution boards supplying essential and emergency services, as well as cables from the respective generators to and between these boards, are to be arranged to avoid areas of high fire risk and elevated temperatures, for example, in close proximity to incinerators and boilers.

1.11.3 Electrical equipment, as far as is practicable, is to be located:

(a) such that it is accessible for the purpose of maintenance and survey;

(b) clear of flammable material;

(c) in spaces adequately ventilated to remove the waste heat liberated by the equipment under full load conditions, at the ambient conditions specified in 1.9;

(d) where flammable gases cannot accumulate. If this is not practicable, electrical equipment is to be of the appropriate 'safe-type', *see* Section 14;

(e) where it is not exposed to the risk of mechanical injury or damage from water, steam or oil.

1.11.4 Equipment design and the choice of materials are to reduce the likelihood of fire, ensuring that:

(a) where the electrical energised part can cause ignition and fire, it is contained within the bounds of the enclosure of the electrotechnical product;

(b) the design, material(s) and construction of the enclosure minimises, as far as is practicable, any internal ignition causing ignition of adjacent materials; and

(c) where surfaces of the electrotechnical products can be exposed to external fire, they do not, as far as practicable, contribute to the fire growth.

NOTE

Compliance with IEC 60695: *Fire hazard testing* (all parts), or an alternative and acceptable Standard, will satisfy this require-ment.

1.11.5 Insulating materials and insulated windings are to be resistant to tracking, moisture, sea air, oil and oil vapour unless special precautions are taken to protect them.

1.11.6 The minimum creepage and clearance distances provided for electrical connections, terminals and similar bare live parts are to be in accordance with a relevant International or National Standard for the equipment or apparatus concerned. In cases where the rated voltage is outside that given in the Standard or where no Standard is available, the minimum creepage and clearance distances provided are to be in accordance with 7.5. Details of alternatives proposals including supporting design rationale and demonstration may be submitted for consideration.

1.11.7 Studs, screw-type or spring-type clamp terminations, satisfactory for the normal operating currents and voltages, are to be provided in electrical equipment for the connection of external cable, or busbar conductors, as appropriate, *see also* 11.15. There is to be adequate space and access for the terminations.

1.11.8 The design of equipment is to enable ease of access to all parts requiring inspection or replacement in service.

1.11.9 Equipment is not to remain alive through the control circuits and/or pilot lamps when switched off by the control switch. This does not apply to synchronising switches and/or plugs.

1.11.10 The operation of all electrical equipment and the lubrication arrangements are to be efficient under such conditions of vibration and shock as arise in normal practice.

1.11.11 All nuts, screws and clamping devices used in connection with current-carrying, supporting and working parts are to be provided with means to ensure that they cannot work loose by vibration and shock as arise in normal practice.

1.11.12 To allow ease of access, connectors are to be spaced far enough apart to permit connection and disconnection. At test points, adequate clearance is to be provided between connection points and controls to provide access for testing.

1.11.13 Conductors and equipment are to be placed at such a distance from the magnetic compasses, or are to be so disposed, that the interfering magnetic field is negligible when circuits are switched on and off.

1.11.14 Where electrical power is used for propulsion, the equipment is to be so arranged that it will operate satisfactorily in the event of partial flooding by bilge water above the tank top up to the bottom floor plate level, under the normal angles of inclination given in 1.9 for essential electrical equipment, *see* Pt 5, Ch 13.

1.12 Earthing of non-current carrying parts

1.12.1 Except where exempted by 1.12.2, all non-current-carrying exposed metal parts of electrical equipment and cables are to be earthed for personal protection against electric shock.

1.12.2 The following parts may be exempted from the requirements of 1.12.1:
(a) lamp-caps, where suitably shrouded;
(b) shades, reflectors and guards supported on lampholders or light fittings constructed of, or shrouded in, non-conducting material;
(c) metal parts on, or screws in or through, non-conducting materials, which are separated by such material from current-carrying parts and from earthed non-current carrying parts in such a way that in normal use they cannot become live or come into contact with earthed parts;
(d) apparatus which is constructed in accordance with the principle of double insulation;
(e) bearing housings which are insulated in order to prevent circulation of current in the bearings;
(f) clips for fluorescent lamps;
(g) cable clips and short lengths of pipes for cable protection;
(h) apparatus supplied at a safety voltage not exceeding 50 V d.c. or 50 V a.c., between conductors, or between any conductor and earth in a circuit isolated from the supply. Autotransformers are not to be used for the purpose of achieving the alternating current voltage;
(j) apparatus or parts of apparatus which although not shrouded in insulating material is nevertheless otherwise so guarded that it cannot be touched and cannot come in contact with exposed metal.

1.12.3 Where extraneous-conductive parts (i.e., parts not forming part of the electrical installation and liable to introduce an electric potential) are not bonded by separate earthing conductors, details are to be submitted that demonstrate that a permanent, metal-to-metal connection of negligible impedance, which will not degrade due to corrosion or vibration, will be achieved.

1.12.4 Armouring, braiding and other metal coverings of cables are to be effectively earthed. Where the armouring, braiding and other metal coverings are earthed at one end only, they are to be adequately protected and insulated at the unearthed end with the insulation being suitable for the maximum voltage that may be induced. *See* 14.9.3 for earthing of cables in hazardous zones or spaces.

1.12.5 The electrical continuity of all metal coverings of cables throughout the length of the cable, particularly at joints and tappings, is to be ensured.

1.12.6 Metal parts of portable appliances, other than current-carrying parts and parts exempted by 1.12.2 are to be earthed by means of an earth-continuity conductor in the flexible cable or cord through the associated plug and socket-outlet.

1.12.7 Earthing conductors are to be of copper or other corrosion-resistant material and be securely installed and protected where necessary against damage and also, where necessary, against electrolytic corrosion. Connections are to be so secured that they cannot work loose under vibration.

1.12.8 The nominal cross-section areas of copper earthing conductors for electrical equipment are in general to be equal to the cross-section of the current-carrying conductor up to 16 mm^2, with a minimum of 1,5 mm^2. Above this figure they are to be equal to at least half the cross-section of the current-carrying conductor with a minimum of 16 mm^2.

1.12.9 The nominal cross-section areas of copper earthing conductors for armouring, braiding and other metal coverings of cables are, in general, to be equal to the equivalent cross-section of the armouring, braiding and other metal coverings with a minimum of 1,5 mm^2.

1.12.10 Earthing conductors of materials other than copper are to have a conductance not less than that specified for an equivalent copper earthing conductor.

1.12.11 The connection of the earthing conductor to the hull of the ship is to be made in an accessible position, and is to be secured by a screw or stud of a diameter appropriate for the size of earthing conductor, but not less than 6 mm, which is to be used for this purpose only. Bright metallic surfaces at the contact areas are to be ensured immediately before the nut or screw is tightened and, where necessary, the joint is to be protected against electrolytic corrosion. The connection is to remain unpainted.

1.13 Bonding for the control of static electricity

1.13.1 Bonding straps for the control of static electricity are required for cargo tanks, process plant and piping systems, for flammable products and solids liable to release flammable gas and/or combustible dust, which are not permanently connected to the hull of the ship either directly or via their bolted or welded supports and where the resistance between them and the hull exceeds 1 MΩ.

1.13.2 Where bonding straps are required for the control of static electricity, they are to be robust, that is, having a cross-sectional area of at least 10 mm^2, and are to comply with 1.12.7 and 1.12.11.

1.14 Alarms

1.14.1 Where alarms are required by this Chapter they are to be arranged in accordance with Ch 1,2.3. Sound signal equipment, fire and general alarm bells are not required to be supplemented by visual indications, except in areas having high levels of background noise, such as machinery spaces.

1.14.2 The alarms in this Chapter are additional to those required by Chapter 1. They may however form part of the alarm system that is required by Chapter 1.

1.14.3 Cables for emergency alarms and their power sources are to be in accordance with 1.16.

1.14.4 Electrical equipment and cables for emergency alarms are to be so arranged that the loss of alarms in any one area due to localised fire, collision, flooding or similar damage is minimised, *see* 1.16 and 1.17.

1.14.5 Electric system: Alarms and safeguards are indicated in Table 2.1.2.

Table 2.1.2 Electric system: Alarms and safeguards

Item	Alarm	Note
Busbar voltage	High and low	–
Busbar frequency	Low	–
Operation of load shedding	Warning	–
Generator cooling air temperature	High	For closed air circuit water-cooled machines

1.15 Labels, signs and notices

1.15.1 Labels, signs and notices required by this Chapter are to be positioned in clearly visible locations which will not be obscured.

1.15.2 Labels, signs and notices are to be easy to read under the expected operating conditions. Character height in accordance with Table 2.1.3 will be considered to satisfy this requirement.

Table 2.1.3 Character height and viewing distance

Viewing distance (mm)	Minimum character height (mm)
Less than 500	2,3
500 – 1000	4,7
1000 – 2000	9,4
2000 – 4000	19
4000 – 8000	38

1.15.3 Controls, indicators and displays required by this Chapter are to be labelled to indicate their function. Labels are to be positioned in a manner that associates the label with the item being labelled.

1.15.4 Labels, signs and notices are to use short, clear messages. In general, warning signs and notices are to comprise:
- a signal word to convey the gravity of the risk (e.g., Danger, Warning or Caution);
- a statement of the nature and/or consequence of the hazard; and
- wherever practical, an instruction giving appropriate behaviour to avoid the hazard.

1.16 Operation under fire conditions

1.16.1 As a minimum, the following emergency services and their emergency power supplies, are required to be capable of being operated under fire conditions:
- Control and power systems to power-operated fire doors and status indication for all fire doors.
- Control and power systems to power-operated watertight doors and their status indication.
- Emergency lighting.
- Fire and general emergency alarms.
- Fire detection systems.
- Fire-extinguishing systems and fire-extinguishing media release alarms.
- Fire safety stops, *see also* 17.6.
- Low location lighting, *see also* 18.4.3.
- Public address systems.
- Emergency fire pump.

1.16.2 Where cables for the emergency services listed in 1.16.1 pass through high fire risk areas, main vertical or horizontal fire zones other than those which they serve, they are to be so arranged that a fire in any of these areas or zones does not affect the operation of the emergency service in any other area or zone. This may be achieved either by:
- cables being of a fire resistant type complying with 11.5.3, and at least extending from the main control/monitoring panel to the nearest local distribution panel serving the relevant area or zone; or
- there being at least two-loops/radial distributions run as widely apart as is practicable and so arranged that in the event of damage by fire at least one of the loops/radial distributions remains operational.

1.16.3 Where the cables for the power supplies for the emergency services listed in 1.16.1 pass through high fire risk areas, main vertical or horizontal fire zones other than those which they serve, they are to be of a fire resistant type complying with 11.5.3, extending at least to the local distribution panel serving the relevant area or zone.

1.16.4 Fire resistant electrical cables for the emergency services listed in 1.16.1, including their power supplies, are to be run as directly as is practicable, having regard to any special installation requirements, for example those concerning minimum bend radii.

1.16.5 In addition to 1.11.4, materials used for electrical equipment, cables and accessories within passenger accommodation areas are not to be capable of producing excessive quantities of smoke and toxic products.

NOTE

Compliance with IEC 60695: *Fire hazard testing* (all parts), or an alternative and acceptable Standard, will satisfy this requirement.

1.17 Operation under flooding conditions

1.17.1 Flooding of spaces along the ship bottom that are not fitted with a double bottom is not to result in the loss of the ability to provide electrically operated fire, ship, crew and passenger emergency safety systems outside of the spaces.

1.17.2 Installation of electrical equipment necessary to provide fire, ship, crew and passenger emergency safety systems in spaces along the ship bottom not fitted with a double bottom is to be avoided, wherever practical. Where it is proposed to install electrical equipment, including cabling, necessary to provide fire, ship, crew and passenger emergency safety systems in such spaces, evidence is to be submitted to demonstrate that required emergency services will be available in other spaces in the event of flooding of the space not fitted with a double bottom.

1.18 Protection of electrical equipment against the effects of lightning strikes

1.18.1 Precautions are to be taken to protect essential electronic equipment that may be susceptible to damage from voltage pulses attributable to the secondary effects of lightning. This may be achieved by suitable design and/or the use of additional protective devices, such as surge arrestors. Resultant induced voltages may be further reduced by the use of earthed metallic screened cables. *See also* Section 19.

1.19 Programmable electronic systems

1.19.1 Where programmable electronic systems are implemented and used to control the electrical installation, or to provide safety functions in accordance with the requirements of this Chapter (e.g., electric propulsion, circuit-breaker settings, switchgear and controlgear controllers, etc.), the arrangements are to satisfy the applicable requirements of Ch 1,2.10 to 2.13.

1.19.2 Where 1.18.1 applies, proposed modifications to software and acceptance testing and trials are to be in accordance with Ch 1,1.4 and Section 7 as applicable.

■ *Section 2* Main source of electrical power

2.1 General

2.1.1 The main source of electrical power is to comply with the requirements of this Section without recourse to the emergency source of electrical power.

2.2 Number and rating of generators and converting equipment

2.2.1 Under sea-going conditions, the number and rating of service generating sets and converting sets, such as transformers and semi-conductor converters, when any one generating set or converting set is out of action, are:

(a) to be sufficient to ensure the operation of electrical services for essential equipment, habitable conditions, cargo refrigeration machinery of ships having a **RMC** notation and the container socket outlets and ventilation system of container ships having a **CRC** notation. *See* 16.3.5 for electric propulsion systems;

(b) to have sufficient reserve capacity to permit the starting of the largest motor without causing any motor to stall or any device to fail due to excessive voltage drop on the system;

(c) to be capable of providing the electrical services necessary to start the main propulsion machinery from a dead ship condition. The emergency source of electrical power may be used to assist if it can provide power at the same time to those services required to be supplied by Section 3, *see also* 2.3.2.

2.2.2 The arrangement of the ship's main source of power is to be such that the operation of electrical services for essential equipment, habitable conditions and cargo refrigeration machinery of ships having a **RMC** notation can be maintained regardless of the speed and direction of the propulsion machinery shafting.

2.2.3 Where the electrical power requirement to maintain the ship in a normal operational and habitable condition is usually supplied by one generating set, arrangements are to be provided to prevent overloading of the running generator, *see* 6.9. On loss of power there is to be provision for automatic starting and connecting to the main switchboard of the standby set in as short a time as practicable, but in any case within 45 seconds, and automatic sequential restarting of essential services, *see* 1.6.1, in as short a time as is practicable.

NOTE

Where the prime mover starting time will result in exceeding this starting and connection time, details are to be submitted for consideration.

2.3 Starting arrangements

2.3.1 The starting arrangements of the generating sets prime movers are to comply with the requirements of Pt 5, Ch 2,16 as applicable.

2.3.2 Where the emergency source of electrical power is required to be used to restore propulsion from a 'dead ship condition', the emergency generator is to be capable of providing initial starting energy for the propulsion machinery within 30 minutes of the 'dead ship condition'. The emergency generator capacity is to be sufficient for restoring propulsion in addition to supplying those services in 3.2.7(a), 3.2.7(b), 3.2.7(c) for passenger ships and 3.3.7(a), 3.3.7(b), 3.3.7(c) and 3.3.7(d) for cargo ships. *See* Pt 5, Ch 2,9.11.1 for dead ship condition starting arrangements.

2.4 Prime mover governors

2.4.1 The governing accuracy of the generating sets prime movers is to meet the requirements of Pt 5, Ch 2,7.3.

2.4.2 The maximum electrical step load switched on or off is not to cause the frequency variation of the electrical supply to exceed the parameters given in 1.8.2.

2.5 Main propulsion driven generators not forming part of the main source of electrical power

2.5.1 Generators and generator systems having the ship's propulsion machinery as their prime mover but not forming part of the ship's main source of electrical power may be used whilst the ship is at sea to supply electrical services required for normal operational and habitable conditions provided that the requirements of 2.5.2 to 2.5.4 are satisfied.

2.5.2 Within the declared operating range of the generators and/or generator system, the specified voltage and frequency variations of the Rules are to be met.

2.5.3 Where there is remote control of the propulsion machinery, arrangements are to ensure that essential machinery power supplies are maintained during manoeuvring conditions in order to prevent a blackout situation.

2.5.4 In addition to the requirements of 2.2.3, arrangements are to be fitted to automatically start one of the generators forming the main source of power should the frequency variations exceed those permitted by the Rules.

■ *Section 3*
Emergency source of electrical power

3.1 General

3.1.1 The requirements of this Section apply to passenger and cargo ships to be classed for unrestricted service. They do not apply to cargo ships of less than 500 tons gross tonnage.

3.1.2 For ships assigned a Service Restriction Notation in accordance with Pt 1, Ch 2, a lesser period than the 36 hour period and 18 hour period specified in 3.2.7 and 3.3.7 respectively may be considered, but not less than 12 hours.

3.1.3 The emergency source of power for cargo ships of less than 500 tons gross tonnage will be the subject of special consideration.

3.2 Emergency source of electrical power in passenger ships

3.2.1 A self-contained emergency source of electrical power is to be provided.

3.2.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the uppermost continuous deck and be readily accessible from the open deck. They are not to be located forward of the collision bulkhead.

3.2.3 The location of:
- the emergency source of electrical power and associated transforming equipment, if any;
- the transitional source of emergency power;
- the emergency switchboard; and
- the emergency lighting switchboard;

in relation to:
- the main source of electrical power, associated transforming equipment, if any; and
- the main switchboard;

is to be such as to ensure that a fire or other casualty in spaces containing:
- the main source of electrical power, associated transforming equipment, if any, and the main switchboard; or
- in any machinery space of Category A;

will not interfere with the supply, control and distribution of emergency electrical power.

3.2.4 The space containing:

- the emergency source of electrical power, associated transforming equipment, if any;
- the transitional source of emergency electrical power; and
- the emergency switchboard;

is not to be contiguous to the boundaries of machinery spaces of Category A or those spaces containing:

- the main source of electrical power, associated transforming equipment, if any; or
- the main switchboard.

3.2.5 Where compliance with 3.2.3 or 3.2.4 is not practicable, details of the proposed arrangements are to be submitted.

3.2.6 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used exceptionally, and for short periods, to supply non-emergency circuits.

3.2.7 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) For a period of 36 hours, emergency lighting:
 (i) at every survival craft preparation station, muster and embarkation station and oversides;
 (ii) in alleyways, stairways and exits, giving access to the muster and embarkation stations;
 (iii) in all service and accommodation alleyways, stairways and exits, personnel lift cars;
 (iv) in the machinery spaces and main generating stations including their control positions;
 (v) in all control stations, machinery control rooms, and at each main and emergency switchboard;
 (vi) at all stowage positions for fireman's outfits;
 (vii) at the steering gear; and
 (viii) at the fire pump, the sprinkler pump and the emergency bilge pump and at the starting position of their motors;

(b) For a period of 36 hours:
 (i) the navigation lights and other lights, as required by the *International Regulations for Preventing Collisions at Sea* in force; and
 (ii) the radiocommunications, as required by Amendments to SOLAS 1974, Chapter IV.

(c) For a period of 36 hours:
 (i) all internal communication equipment required in an emergency;
 (ii) the navigational aids as required by Amendments to SOLAS 1974 Reg V/19 ; where such provision is unreasonable or impracticable this requirement may be waived for ships of less than 5000 tons gross;
 (iii) the fire detection, fire alarm and sample extraction smoke detection systems, and the fire door holding and release system; and
 (iv) for intermittent operation of the daylight signalling lamp, the ship's whistle, the manually operated call points and all internal signals that are required in an emergency;

 unless such services have an independent supply for the period of 36 hours from an accumulator battery suitably located for use in an emergency.

(d) For a period of 36 hours:
 (i) emergency fire pump;
 (ii) the automatic sprinkler pump, if any; and
 (iii) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves.

(e) The steering gear for the period of time required by Pt 5, Ch 19,6.

(f) For a period of half an hour:
 (i) any watertight doors if electrically operated together with their control, indication and alarm circuits;
 (ii) the emergency arrangements to bring the lift cars to deck level for the escape of persons. The passenger lift cars may be brought to deck level sequentially in an emergency.

(g) Where applicable, the services required by 2.3.2.

(h) Where connected, the supplementary lighting required by 3.2.16 and, where applicable, the air compressors for breathing apparatus cylinders referred to in 17.11.1.

3.2.8 The emergency source of electrical power may be either a generator or an accumulator battery, which are to comply with the following:

(a) Where the emergency source of electrical power is a generator it is to be:
 (i) driven by a suitable prime mover with an independent supply of fuel having a flashpoint (closed-cup test) of not less than 43°C;
 (ii) started automatically upon failure of the electrical supply from the main source of electrical power and is to be automatically connected to the emergency switchboard; those services referred to in 3.2.7 are then to be transferred automatically to the emergency generating set. The automatic starting system and the characteristics of the prime mover are to be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 seconds; and
 (iii) provided with a transitional source of emergency electrical power according to 3.2.9.

(b) Where the emergency source of electrical power is an accumulator battery, it is to be capable of:
 (i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;
 (ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and
 (iii) immediately supplying at least those services specified in 3.2.9.

3.2.9 The transitional source of emergency electrical power required by 3.2.8 is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and so arranged as to supply automatically in the event of failure of either the main or emergency source of electrical power for half an hour at least the following services, if they depend upon an electrical source for their operation:

(a) the lighting required by 3.2.7(a) and (b);
(b) all services required by 3.2.7(c)(i), (iii) and (iv) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.
(c) Where connected, the supplementary lighting required by 3.2.16.
(d) Power to operate the watertight doors at least three times, i.e., closed-open-closed against an adverse list of 15°, but not necessarily all of them simultaneously, together with their control, indication and alarm circuits as required by 3.2.7(f)(i).

3.2.10 The emergency switchboard is to be installed as near as is practicable to the emergency source of electrical power.

3.2.11 Where the emergency source of electrical power is a generator, the emergency switchboard is to be located in the same space unless the operation of the emergency switchboard would thereby be impaired.

3.2.12 No accumulator battery except for engine starting, fitted in accordance with this Section, is to be installed in the same space as the emergency switchboard. An indicator is to be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of emergency electrical power are being discharged.

3.2.13 The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be adequately protected at the main switchboard against overload and short-circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power. Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short-circuit.

3.2.14 In order to ensure the ready availability of the emergency source of electrical power to supply circuits required to provide emergency services, arrangements are to be made, where necessary, to automatically disconnect non-emergency circuits from the emergency switchboard in the event of overloading to ensure that electrical power is available to the emergency circuits.

3.2.15 Provision is to be made for the periodic testing of the complete emergency system and is to include the testing of automatic starting arrangements.

3.2.16 In passenger ships, supplementary lighting is to be provided in all cabins to indicate the exit clearly so that occupants will be able to find their way to the door. Such lighting, which may be connected to an emergency source of power or have a self-contained source of electrical power in each cabin, is to illuminate automatically when power to the normal cabin lighting is lost and remain on for a minimum of half an hour.

3.2.17 In addition to the emergency lighting required by 3.2.7(a) passenger ships with roll on-roll off cargo spaces or special category spaces are to be provided with the following:

(a) in all passenger public spaces and alleyways supplementary electric lighting that can operate for at least three hours when all other sources of electric power have failed and under any condition of heel. The illumination provided is to be such that the approach to the means of escape can be readily seen. The source of power for the supplementary lighting is to consist of accumulator batteries within the lighting units that are continuously charged where practicable, from the emergency switchboard. Consideration may be given to other means of lighting which is at least as effective. The supplementary lighting is to be such that any failure of the lamp will be immediately apparent. Any accumulator battery provided is to be replaced at intervals having regard to the specified service life in the ambient conditions that they are subject to in service.
(b) A portable rechargeable battery operated lamp is to be provided in every crew space alleyway, recreational space and every working space which is normally occupied unless supplementary emergency lighting, as required by (a) is provided.

3.3 Emergency source of electrical power in cargo ships

3.3.1 A self-contained emergency source of electrical power is to be provided.

3.3.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the uppermost continuous deck and be readily accessible from the open deck. They are not to be located forward of the collision bulkhead.

3.3.3 The location of:

- the emergency source of electrical power and associated transforming equipment, if any;
- the transitional source of emergency power;
- the emergency switchboard; and
- the emergency lighting switchboard;

in relation to:

- the main source of electrical power, associated transforming equipment, if any; and
- the main switchboard;

is to be such as to ensure that a fire or other casualty in spaces containing:

- the main source of electrical power, associated transforming equipment, if any, and the main switchboard; or

- in any machinery space of Category A;

will not interfere with the supply, control and distribution of emergency electrical power.

3.3.4 The space containing:
- the emergency source of electrical power, associated transforming equipment, if any;
- the transitional source of emergency electrical power; and
- the emergency switchboard;

is not to be contiguous to the boundaries of machinery spaces of Category A or those spaces containing:
- the main source of electrical power, associated transforming equipment, if any; or
- the main switchboard.

3.3.5 Where compliance with 3.3.3 or 3.3.4 is not practicable, details of the proposed arrangements are to be submitted.

3.3.6 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used, exceptionally, and for short periods, to supply non-emergency circuits.

3.3.7 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) For a period of three hours, emergency lighting at every survival craft preparation station, muster and embarkation station and over the sides. Remotely located stations for a liferaft installed in accordance with SOLAS 1974 as amended, CH III/B, Regulation 31.1.4 that is provided with portable means of illumination acceptable to the National Administration with which the Ship is registered may be considered to satisfy this requirement;

(b) For a period of 18 hours, emergency lighting:
   - (i) in all service and accommodation alleyways, stairways and exits, personnel lift cars and personnel lift trunks;
   - (ii) in the machinery spaces and main generating stations including their control positions;
   - (iii) in all control stations, machinery control rooms, and at each main and emergency switchboard;
   - (iv) at all stowage positions for fireman's outfits;
   - (v) at the steering gear; and
   - (vi) at the emergency fire pump, at the sprinkler pump, if any, and at the emergency bilge pump, if any, and at the starting positions of their motors;
   - (vii) in all cargo pump-rooms of tankers.

(c) For a period of 18 hours:
   - (i) the navigation lights and other lights, as required by the *International Regulations for Preventing Collisions at Sea* in force; and
   - (ii) the radiocommunications, as required by Amendments to SOLAS 1974, Chapter IV.

(d) For a period of 18 hours:
   - (i) all internal communication equipment as required in an emergency;
   - (ii) the navigational aids as required by Amendments to SOLAS 1974 Reg V/19; where such provision is unreasonable or impracticable this requirement may be waived for ships of less than 5000 tons gross;
   - (iii) the fire detection and fire-alarm system; and
   - (iv) intermittent operation of the daylight signalling lamp, the ship's whistle, the manually operated call points and all internal signals that are required in an emergency;

   unless such services have an independent supply for the period of 18 hours from an accumulator battery suitably located for use in an emergency.

(e) For a period of 18 hours the emergency fire pump if dependent upon the emergency generator for its source of power.

(f) The steering gear for the period of time required by Pt 5, Ch 19,6.

(g) Where applicable, the services required by 2.3.2.

3.3.8 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:

(a) Where the emergency source of electrical power is a generator it is to be:
   - (i) driven by a suitable prime mover with an independent supply of fuel, having a flashpoint (closed-cup test) of not less than 43°C;
   - (ii) started automatically upon failure of the main source of electrical power supply unless a transitional source of emergency electrical power in accordance with 3.3.9 is provided; where the emergency generator is automatically started, it is to be automatically connected to the emergency switchboard; those services referred to in 3.3.9 are to be connected automatically to the emergency generator; and
   - (iii) provided with a transitional source of emergency electrical power as specified in 3.3.9 unless an emergency generator is provided capable both of supplying the services mentioned in that paragraph and of being automatically started and supplying the required load as quickly as is safe and practicable subject to a maximum of 45 seconds.

(b) Where the emergency source of electrical power is an accumulator battery it is to be capable of:
   - (i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;
   - (ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and
   - (iii) immediately supplying at least those services specified in 3.3.9.

3.3.9 The transitional source of emergency electrical power where required by 3.3.8 is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and is to be so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power for half an hour at least the following services if they depend upon an electrical source for their operation:

(a) the lighting required by 3.3.7(a), (b) and (c). For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps; and
(b) all services required by 3.3.7(d)(i), (iii) and (iv) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

3.3.10 The emergency switchboard is to be installed as near as is practicable to the emergency source of electrical power.

3.3.11 Where the emergency source of electrical power is a generator, the emergency switchboard is to be located in the same space unless the operation of the emergency switchboard would thereby be impaired.

3.3.12 No accumulator battery fitted in accordance with this Section, unless for engine starting, is to be installed in the same space as the emergency switchboard. An indicator shall be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of electrical power are being discharged.

3.3.13 The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be adequately protected at the main switchboard against overload and short-circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power. Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short-circuit.

3.3.14 In order to ensure the ready availability of the emergency source of electrical power to supply circuits required to provide emergency services, arrangements are to be made, where necessary, to disconnect automatically non-emergency circuits from the emergency switchboard in the event of overloading to ensure that electrical power is available to the emergency circuits.

3.3.15 Provision is to be made for the periodic testing of the complete emergency system and is to include the testing of automatic starting arrangements.

3.4 Starting arrangements

3.4.1 Where the emergency source of power is a generator, the starting arrangements are to comply with the requirements given in Pt 5, Ch 2,9.4.

3.5 Prime mover governor

3.5.1 Where the emergency source of power is a generator, the governor is to comply with 2.4.

3.6 Radio installation

3.6.1 Every radio installation as required by SOLAS 1974 as amended, Chapter IV, Part C, is to be provided with reliable, permanently arranged electrical lighting, independent of the main and emergency sources of electrical power, for the adequate illumination of the radio controls for operating the radio installation.

3.6.2 A reserve source or sources of energy is to be provided on every ship, for the purpose of conducting distress and safety radiocommunications, in the event of failure of the ship's main and emergency sources of electrical power. The reserve source or sources of energy is to be capable of simultaneously operating the VHF radio installation and, as appropriate for the sea or sea area for which the ship is equipped, either the MF radio installation, the MF/HF radio installation, or the INMARSAT ship earth station and any of the additional loads mentioned in 3.6.4, 3.6.5 and 3.6.7 for a period of at least one hour. The reserve source or sources of energy need not supply independent HF and MF radio installations at the same time.

3.6.3 The reserve source or sources of energy is to be independent of the propelling power of the ship and the ship's electrical system.

3.6.4 Where, in addition to the VHF radio installation, two or more of the other radio installations, referred to in 3.6.2, can be connected to the reserve source or sources of energy, the reserve source or sources are to be capable of simultaneously supplying, for the period specified by 3.6.2, the VHF radio installation and:

(a) all other radio installations which can be connected to the reserve source or sources of energy at the same time; or
(b) whichever of the other radio installations will consume the most power, if only one of the other radio installations can be connected to the reserve source or sources of energy at the same time as the VHF radio installation.

3.6.5 The reserve source or sources of energy may be used to supply the electrical lighting required by 3.6.1.

3.6.6 Where a reserve source of energy consists of a rechargeable accumulator battery or batteries a means of automatically charging the batteries is to be provided which is to be capable of recharging them to minimum capacity requirements within 10 hours.

3.6.7 If an uninterrupted input of information from the ship's navigational or other equipment to a radio installation as referred to in 3.6.2 is needed to ensure its proper performance, means are to be provided to ensure the continuous supply of such information in the event of failure of the ship's main or emergency source of electrical power.

■ *Section 4* External source of electrical power

4.1 Temporary external supply

4.1.1 Where arrangements are made for the supply of electricity from a source on shore or elsewhere, a connection box is to be installed in a position suitable for the convenient reception of flexible cables from the external source and containing a circuit-breaker or isolating switch and fuses and terminals including one earthed, of ample size and suitable shape to facilitate a satisfactory connection of three-phase external supplies with earthed neutrals.

4.1.2 Suitable cables, permanently fixed, are to be provided, connecting the terminals in the connection box to a linked switch and/or a circuit-breaker at the main switchboard. An indicator is to be provided at the main switchboard in order to show when the cables are energised.

4.1.3 Means are to be provided for checking the phase sequence of the incoming supply.

4.1.4 At the connection box a notice is to be provided giving full information on the system of supply, the normal voltage and frequency of the installation's system and the procedure for carrying out the connection.

4.1.5 Alternative arrangements may be submitted for consideration. *See also* Pt 7, Ch 13 for class notation **OPS**.

4.2 Permanent external supply

4.2.1 Details are to be submitted.

■ *Section 5* Supply and distribution

5.1 Systems of supply and distribution

5.1.1 The following systems of generation and distribution are acceptable, other than for tankers intended for the carriage in bulk of oil, liquefied gases and other hazardous liquids having a flash point not exceeding 60°C (closed-cup test):

(a) d.c., two-wire;
(b) a.c., single-phase, two-wire;
(c) a.c., three-phase:
  (i) three-wire;
  (ii) four-wire with neutral solidly earthed but without hull return.

5.1.2 For tankers intended for the carriage in bulk of oil, liquefied gases and other hazardous liquids having a flash point not exceeding 60°C (closed-cup test) only the following systems of generation and distribution are acceptable:

(a) d.c., two-wire, insulated;
(b) a.c., single-phase, two-wire, insulated;
(c) a.c., three-phase, three-wire, insulated;
(d) earthed systems, a.c. or d.c., limited to areas outside any hazardous space or zone, and arranged so that no current arising from an earth-fault in any part of the system could pass through a hazardous space or zone;
(e) earthed systems, complying with 5.1.1 and 5.5.7, provided the Government of the Flag State permits such an arrangement in accordance with the '*Equivalents*' provisions of SOLAS Chapter I, Regulation 5, *see* Ch 1,1.4 of the Rules for Ships for Liquid Chemicals and/or the Rules for Ships for Liquefied Gases, as appropriate, *see also* 14.1.2.

Earthed intrinsically safe circuits are permitted to pass into and through hazardous spaces and zones.

5.1.3 System voltages for both alternating current and direct current in general are not to exceed:

- 15 000 V for generation and power distribution;
- 500 V for cooking and heating equipment permanently connected to fixed wiring;
- 250 V for lighting, heaters in cabins and public rooms, and other applications not mentioned above.

Voltages above these will be the subject of special consideration.

5.1.4 The arrangement of the main system of supply is to be such that a fire or other casualty in any space containing the main source of electrical power, associated converting equipment, if any, the main switchboard and the main lighting switchboard will not render inoperable any emergency service, other than those located within the space where the fire or casualty has occurred.

5.1.5 The main switchboard is to be so placed relative to the main source of power that, as far as is practicable, the integrity of the main system of supply will be affected only by a fire or other casualty in one space.

5.1.6 The arrangement of the emergency system of supply is to be such that a fire or other casualty in spaces containing the emergency source of electrical power, associated converting equipment, if any, the emergency switchboard and the emergency lighting switchboard, will not cause loss of services required to maintain the propulsion and safety of the ship.

5.1.7 Distribution systems required in an emergency are to be so arranged that a fire in any one main fire zone, as defined by SOLAS 1974 as amended Reg II-2/A, 3.32, will not interfere with the emergency distribution in any other such zone.

5.2 Essential services

5.2.1 Essential services that are required by Part 5 to be duplicated are to be served by individual circuits, separated in their switchboard or section board and throughout their length as widely as is practicable without the use of common feeders, protective devices, control circuits or controlgear assemblies, so that any single fault will not cause the loss of both services.

5.2.2 Where 5.2.1 is applicable the main busbars of the switchboard, or section boards, are to be capable of being split, by a multipole linked circuit-breaker, disconnector or switch-disconnector, into at least two independent sections, each supplied by at least one generator, either directly or through a converter. The essential services are to be equally divided, as far as is practicable, between the independent sections.

5.2.3 Where 5.2.2 is applicable provision is to be made to transfer to a temporary circuit those essential services which are not required to be, and have not been, duplicated in the event of loss of their normal section of switchboard or section board.

5.3 Isolation and switching

5.3.1 The incoming and outgoing circuits from every switchboard or section board are to be provided with a means of isolation and switching to permit each circuit to be switched off:
(a) on load;
(b) for mechanical maintenance;
(c) in an emergency to prevent or remove danger.
In addition the requirements of 5.3.2 and 5.3.3 are to be complied with.

5.3.2 Isolation and switching is to be by means of a circuit-breaker or switch arranged to open and close simultaneously all insulated poles. Where a switch is used as the means of isolation and switching, it is to be capable of:
(a) switching off the circuit on load;
(b) withstanding, without damage, the overcurrents which may arise during overloads and short-circuit.
In addition, these requirements do not preclude the provision of single pole control switches in final sub-circuits, for example light switches. For circuit-breakers, *see* 6.5 and 7.3.

5.3.3 Provision is to be made, in accordance with one of the following, to prevent any circuit being inadvertently energised:
(a) the circuit-breaker or switch can be withdrawn, or locked in the open position;
(b) the operating handle of the circuit-breaker or switch can be removed;
(c) the circuit fuses, where fitted, can be readily removed and retained by authorised personnel.

5.3.4 Where arrangements are in place for automatic changeover between two or more supplies of electrical power in the event of failure of one supply, the arrangements are to be such that a fault in one feeder does not result in the loss of all supplies to the automatic changeover switch.

5.3.5 Where a section board, distribution board or item of equipment can be supplied by more than one circuit, a switching device is to be provided to permit each incoming circuit to be isolated and the supply transferred to the alternative circuit. In addition, the requirements of 5.3.6 and 5.3.7 are to be complied with.

5.3.6 The switching device required by 5.3.5 is to be situated within or adjacent to the section board, distribution board or item of equipment. Where necessary, interlocking arrangements are to be provided to prevent circuits being inadvertently energised.

5.3.7 A notice is to be fixed to any section board, distribution board or item of equipment to which 5.3.5 applies warning personnel before gaining access to live parts of the need to open the appropriate circuit-breakers or switches, unless an interlocking arrangement is provided so that all circuits concerned are isolated before access is gained.

5.3.8 Tankers designed in accordance with IEC 60092-502: *Electrical installations in ships – Part 502: Tankers – Special features, see* 14.1.2, are to meet the requirements of 5.3 of that Standard.

5.3.9 Where high voltage equipment is contained in a room or protected area which also forms its enclosure, the access door(s) of the space is to be so interlocked that it cannot be opened until:
- the high voltage supply(ies) to the equipment is switched off;
- the equipment and its cable(s) are earthed down to dissipate stored energy sufficient to ensure personnel safety.

5.3.10 The access to the space(s) described in 5.3.9 are to be suitably marked to indicate the danger of high voltage.

5.4 Insulated distribution systems

5.4.1 A device(s) is to be installed for every insulated distribution system, whether primary or secondary, for power, heating and lighting circuits, to continuously monitor the insulation level to earth and to operate an alarm in the engine control room, or equivalent attended position, in the event of an abnormally low level of insulation resistance, *see also* Ch 1,4.2.

5.4.2 Where any insulated lower voltage system is supplied through transformers from a high voltage system, adequate precautions are to be taken to prevent the low voltage system being charged by capacitive leakage from the high voltage system.

5.4.3 Tankers designed in accordance with IEC 60092-502: *Electrical installations in ships – Part 502: Tankers – Special features* (*see* 14.1.2) are to meet the requirements of 5.3 of that Standard.

5.4.4 Where filters are fitted, for example to reduce EMC susceptibility, these are not to cause distribution systems to be unintentionally connected to earth.

5.5 Earthed distribution systems

5.5.1 No fuse, non-linked switch or non-linked circuit-breaker is to be inserted in an earthed conductor. Any switch or circuit-breaker fitted is to operate simultaneously in the earthed conductor and the insulated conductors. These requirements do not preclude the provision (for test purposes) of an isolating link to be used only when the other conductors are isolated.

5.5.2 For high voltage systems, where the earthed neutral system of generation and primary distribution is used, earthing is to be through an impedance in order to limit the total earth fault current to a magnitude which does not exceed that of the three phase short-circuit current for which the generators are designed.

5.5.3 Generator neutrals may be connected in common, provided that the third harmonic content of the voltage waveform of each generator does not exceed five per cent.

5.5.4 Where a switchboard is split into sections operated independently or where there are separate switchboards, neutral earthing is to be provided for each section or for each switchboard. Means are to be provided to ensure that the earth connection is not removed when generators are isolated.

5.5.5 A means of isolation is to be fitted in the earthing connection of each generator so that generators can be completely isolated for maintenance.

5.5.6 All earthing impedances are to be connected to the hull. The connections to the hull are to be so arranged that any circulating currents in the earth connections do not interfere with radio, radar, communication and control equipment circuits.

5.5.7 Tankers designed in accordance with IEC 60092-502: *Electrical installations in ships – Part 502: Tankers – Special features* (*see* 14.1.2) are to meet the requirements of 5.3 of that Standard.

5.6 Diversity factor

5.6.1 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justified, to the application of a diversity factor. Where spare ways are provided on a section or distribution board, an allowance for future increase of load is to be added to the total connected load before application of any diversity factor.

5.6.2 A diversity factor may be applied to the calculation for size of cable and rating of switchgear and fusegear, taking into account the duty cycle of the connected loads and the frequency and duration of any motor starting loads.

5.6.3 For winches and crane motors the diversity factor is to be calculated and submitted when required.

5.7 Lighting circuits

5.7.1 Lighting circuits are to be supplied by final sub-circuits separate from those for heating and power. This does not preclude the supply from a lighting circuit supplying a single fixed appliance, such as a cabin fan, a dry shaver, a wardrobe or anti-condensation heater, taking a maximum current of 2 A.

5.7.2 Lighting for the following spaces is to be supplied from at least two final sub-circuits in such a way that failure of one of the circuits does not leave the space in darkness. One of these circuits may be an emergency circuit provided it is normally energised.

- Spaces that are required to be lit for the safe working of the ship, such as control stations, normal working spaces, etc.
- Spaces where there may be a hazard due to movement of crew, passengers and/or equipment, such as in corridors, working passage ways, stairways leading to boat decks, public rooms, etc.
- Spaces where there may be a hazard due to moving machinery and hot parts, such as in machinery spaces, workshops, large galleys, laundries, etc.

5.7.3 Lighting for enclosed hazardous spaces is to be supplied from at least two final sub-circuits to permit light from one circuit to be retained while maintenance is carried out on the other. One of these circuits may be an emergency circuit, provided it is normally energised in which case the arrangements are to comply with Section 3.

5.7.4 Emergency lighting is to be fitted in accordance with Section 3, *see also* Section 18.

5.7.5 Lighting of unattended spaces, such as cargo spaces, is to be controlled by multipole linked switches situated outside such spaces. Provision is to be made for the complete isolation of these circuits and locking the means of control in the off position.

5.7.6 Where lighting circuits in the cargo pump-rooms of tankers are also used for emergency lighting, and have been interlocked with the ventilation, the interlocking arrangements are:

- not to cause the lighting to go out following a failure of the ventilation system; and
- not to prevent operation of the emergency lighting following the loss of the main source of electrical power.

5.8 Motor circuits

5.8.1 A separate final sub-circuit is to be provided for every motor for essential services, *see* 1.6.1.

5.9 Motor control

5.9.1 Every electric motor is to be provided with efficient means for starting and stopping so placed as to be easily operated by the person controlling the motor. Every motor above 0,5 kW is to be provided with control apparatus as given in 5.9.2 to 5.9.4.

5.9.2 Means to prevent undesired restarting after a stoppage due to low volts or complete loss of volts are to be provided. This does not apply to motors where a dangerous condition might result from the failure to restart automatically, e.g., steering gear motor.

5.9.3 Means for automatic disconnection of the supply in the event of excess current due to mechanical overloading of the motor are to be provided, *see also* 6.10.

5.9.4 Motor controlgear is to be suitable for the starting current and for the full load rated current of the motor.

■ *Section 6* System design – Protection

6.1 General

6.1.1 Installations are to be protected against over-currents including short-circuits, and other electrical faults. The tripping/fault clearance times of the protective devices are to provide complete and co-ordinated protection to ensure:

(a) availability of essential and emergency services under fault conditions through discriminative action of the protective devices; as far as practicable the arrangements are also to secure the availability of other services;
(b) elimination of the fault to reduce damage to the system and hazard of fire.

6.1.2 Short-circuit and overload protection are to be provided in each non-earthed line of each system of supply and distribution, unless exempted under the provisions of any paragraph in this Section.

6.1.3 The protection of circuits is to be such that a fault in a circuit does not cause the interruption of supplies used to provide emergency or essential services other than those dependent on the circuit where the fault occurred. For circuits used to provide essential services which need not necessarily be in continuous operation to maintain propulsion and steering but which are necessary for maintaining the vessel's safety, arrangements that ensure that a fault in a circuit does not cause the sustained interruption of supply to healthy circuits may be accepted. Such arrangements are to ensure the supply to healthy circuits is automatically re-established in sufficient time after a fault in a circuit.

6.1.4 Protection systems are to be developed using a systematic design procedure incorporating verification and validation methods to ensure successful implementation of the requirements above. Details of the procedures used are to be submitted when requested. An approved copy of the details required by 1.2.5 and 1.2.6 is to be retained on board and made available to the Surveyor on request. Access to protection relays setpoints is to be restricted, such that they will generally only be adjusted by authorised personnel to avoid accidental operation. A record is to be kept of the initial setpoints and any subsequent changes made to them. These details are to be made available to the Surveyor on request.

6.1.5 Short-circuit protection is to be provided for each source of power and at each point at which a distribution circuit branches into two or more subsidiary circuits.

6.1.6 Where protection for generator power circuits is provided at the associated switchboard, the cabling between generator and switchboard is to be of a type, and installed in a manner such as to minimise the risk of short-circuit.

6.1.7 Protection for battery circuits is to be provided at a position external and adjacent to the battery compartments. Where arrangements comply with 12.3.5, the protection may be installed at a suitable location in the battery compartment.

6.1.8 Protection may be omitted from the following:

(a) Engine starting battery circuits.
(b) Circuits for which it can be shown that the risk resulting from spurious operation of the protective device may be greater than that resulting from a fault.

6.1.9 Short-circuit protection may be omitted from cabling or wiring to items of equipment internally protected against short-circuit or where it can be shown that they are unlikely to fail to a short-circuit condition and where the cabling or wiring is installed in a manner such as to minimise the risk of short-circuit.

6.1.10 Overload protection may be omitted from the following:

(a) one line of circuits of the insulated type;
(b) circuits supplying equipment incapable of being overloaded, or overloading the associated supply cable, under normal conditions, and unlikely to fail to an overload condition.

6.2 Protection against short-circuit

6.2.1 Protection against short-circuit currents is to be provided by circuit-breakers or fuses.

6.2.2 The rated short-circuit making and breaking capacity of every protective device is to be adequate for the prospective fault level at its point of installation; the requirements for circuit-breakers and fuses are detailed in 6.5 and 6.6 respectively.

6.2.3 The prospective fault current is to be calculated for the following set of conditions:

(a) all generators, motors and, where applicable, all transformers, connected as far as permitted by any interlocking arrangements;
(b) a fault of negligible impedance close up to the load side of the protective device.

6.2.4 In the absence of precise data, the prospective fault current may be taken to be:

(a) for alternating current systems at the main switchboard: 10 x f.l.c. (rated full load current) for each generator that may be connected, or, if the subtransient direct axis reactance, X''_d, of each generator is known,

$$\frac{\text{f.l.c.}}{X''_d\ \text{(p.u.)}}$$ for each generator, and 3 x f.l.c. for motors simultaneously in service.

The value derived from the above is an approximation to the r.m.s. symmetrical fault current; the peak asymmetrical fault current may be estimated to be 2,5 times this figure (corresponding to a fault power factor of approximately 0,1).

(b) battery-fed direct current systems at the battery terminals:
  (i) 15 times ampere hour rating of the battery for vented lead-acid cells, or of alkaline type intended for discharge at low rates corresponding to a battery duration exceeding three hours, or
  (ii) 30 times ampere hour rating of the battery for sealed lead-acid cells having a capacity of 100 ampere hours or more, or of alkaline type intended for discharge at high rates corresponding to a battery duration not exceeding three hours and,
  (iii) 6 x f.l.c. for motors simultaneously in service (if applicable).

6.3 Protection against overload

6.3.1 The characteristics of protective devices provided for overload protection are to ensure that cabling and electrical machinery are protected against overheating resulting from mechanical or electrical overload.

6.3.2 Fuses of a type intended for short-circuit protection only (e.g., fuse links complying with IEC 60269-1: *Low-voltage fuses – Part 1: General requirements*, of type 'a') are not to be used for overload protection.

6.4 Protection against earth faults

6.4.1 Every distribution system that has an intentional connection to earth, by way of an impedance, is to be provided with a means to continuously monitor and indicate the current flowing in the earth connection.

6.4.2 If the current in the earth connection exceeds 5 A there is to be an alarm and the fault current is to be automatically interrupted or limited to a safe value.

6.4.3 The rated short-circuit capacity of any device used for interrupting earth fault currents is to be not less than the prospective earth fault current at its point of installation.

6.4.4 Insulated neutral systems with harmonic distortion of the voltage waveform, which may result in earth fault currents exceeding the level given in 6.4.2 because of capacitive effects, are to be provided with arrangements to isolate the faulty circuit(s).

6.5 Circuit-breakers

6.5.1 Circuit-breakers for alternating current systems are to satisfy the following conditions:

(a) the r.m.s. symmetrical breaking current for which the device is rated is to be not less than the r.m.s. value of the a.c. component of the prospective fault current, at the instant of contact separation (i.e., first half cycle, or time of interruption where an intentional time delay is provided to ensure suitability);

(b) the peak asymmetrical making current for which the device is rated is not to be less than the peak value of the prospective fault current at the first half cycle, allowing for maximum asymmetry;

(c) the power factor at which the device short-circuit ratings are assigned is to be no greater than that of the prospective fault current; alternatively for high voltage, the rated percentage d.c. component of the short-circuit breaking current of the device is to be not less than that of the prospective fault current.

6.5.2 Circuit-breakers for d.c. systems are to have a breaking current not less than the initial prospective fault current. The time constant of the fault current is not to be greater than that for which the circuit-breaker was tested.

6.5.3 The fault ratings considered in 6.5.1 and 6.5.2, are to be assigned on the basis that the device is suitable for further use after fault clearance.

6.5.4 Circuit-breaker selection is, and ratings are, to be in accordance with the relevant requirements of IEC 60092-202: *Electrical installations in ships – Part 202: System design – Protection*. Alternative methods acceptable to LR of selecting suitable circuit-breakers may be considered.

6.6 Fuses

6.6.1 Fuses for a.c. systems are to have a breaking current rating not less than the initial r.m.s. value of the a.c. component of the prospective fault current.

6.6.2 Fuses for d.c. systems are to have a d.c. breaking current rating not less than the initial value of the prospective fault current.

6.7 Circuit-breakers requiring back-up by fuse or other device

6.7.1 The use of a circuit-breaker having a short-circuit current capacity less than the prospective short-circuit current at the point of installation is permitted, provided that it is preceded by a device having at least the necessary short-circuit capacity. The generator circuit-breakers are not to be used for this purpose.

6.7.2 The same device may back up more than one circuit-breaker provided that no essential or emergency service is supplied from there, or that any such service is duplicated by arrangements unaffected by tripping of the device.

6.7.3 The combination of back-up device and circuit-breaker is to have a short-circuit performance at least equal to that of a single circuit-breaker satisfying the requirements of 6.5.

6.7.4 Evidence of testing of the combination is to be submitted for consideration; alternatively, consideration may be given to arrangements where it can be shown that:

(a) the takeover current, above which the back-up device would clear a fault, is not greater than the rated short-circuit breaking capacity of the circuit-breaker and;
(b) the characteristics of the back-up device, and the prospective fault level, are such that the peak fault current rating of the circuit-breaker cannot be exceeded and;
(c) the Joule integral of the let-through current of the back-up device does not exceed that corresponding to the rated breaking current and opening time of the circuit-breaker.

6.8 Protection of generators

6.8.1 The protective gear required by 6.8.2 and 6.8.3 is to be provided as a minimum.

6.8.2 Generators not arranged to run in parallel are to be provided with a circuit-breaker arranged to open simultaneously, in the event of short-circuit, overload or under-voltage, all insulated poles. In the case of generators rated at less than 50 kW, a multipole linked switch with a fuse, complying with 5.3.2, in each insulated pole will be acceptable.

6.8.3 Generators arranged to operate in parallel are to be provided with a circuit-breaker arranged to open simultaneously, in the event of a short-circuit, an overload or an under-voltage, all insulated poles. This circuit-breaker is to be provided with reverse power protection with time delay, selected or set within the limits of 2 per cent to 15 per cent of full load to a value fixed in accordance with the characteristics of the prime mover; a fall of 50 per cent in the applied voltage is not to render the reverse power mechanism inoperative, although it may alter the amount of reverse power required to open the breakers.

6.8.4 The generator circuit-breaker short-circuit and overload tripping arrangements, or fuse characteristics, are to be such that the machine's thermal withstand capability is not exceeded.

6.8.5 Generators having a capacity of 1500 kVA or above are to be equipped with a protective device which, in the event of a short-circuit in the generator or in the cables between the generator and its circuit-breaker, will instantaneously open the circuit-breaker and de-excite the generator.

6.8.6 The voltage and time delay settings of the under-voltage release mechanism(s) required by 6.8.2 and 6.8.3 are to be chosen to ensure that the discriminative action required by 6.1.1(a) is maintained.

6.9 Load management

6.9.1 Arrangements are to be made to disconnect automatically, after an appropriate time delay, circuits of the following categories, when the generator(s) is/are overloaded, sufficient to ensure the connected generating set(s) is/are not overloaded:
(a) non-essential circuits;
(b) circuits feeding services for habitability, *see* 1.6.2;
(c) in cargo ships, circuits for cargo refrigeration.

NOTE
For emergency generators *see* 3.2.14 and 3.3.14 as applicable.

6.9.2 If required, this load switching may be carried out in one or more stages, in which case the non-essential circuits are to be included in the first group to be disconnected.

6.9.3 The load management of power systems supplying electric propulsion motors is to satisfy the requirements of 16.3.

6.9.4 Consideration is to be given to providing means to inhibit automatically the starting of large motors, or the connection of other large loads, until sufficient generating capacity is available to supply them.

6.10 Feeder circuits

6.10.1 Isolation and protection of each feeder circuit is to be ensured by a multipole circuit-breaker or linked switch with a fuse in each insulated conductor. Protection is to be in accordance with 6.2 and 6.3. The protective devices are to allow excess current to pass during the normal accelerating period of motors.

6.11 Motor circuits

6.11.1 Motors of rating exceeding 0,5 kW and all motors for essential services are to be protected individually against overload and short-circuit. For motors which for essential services are duplicated, the overload protection may be replaced by an overload alarm; arrangements for steering gear motors are to comply with 14.1.

6.11.2 Protection for both the motor and its supply cable may be provided by the same device, provided that due account is taken of any differences between ratings of cable and motor.

6.11.3 Where operation of an item of equipment is dependent upon a number of motors, consideration may be given to the provision of a common means of short-circuit protection.

6.11.4 For motors for intermittent service, the characteristics of the arrangements for overload protection are to be chosen in relation to the load factor(s) of the motor(s).

6.11.5 Where fuses are used to protect polyphase motor circuits, means are to be provided to protect the motor from unacceptable overcurrent in the case of single phasing.

6.12 Protection of transformers

6.12.1 Short-circuit protection for transformers is to be provided by circuit-breakers or fuses in the primary circuit and in addition, overload protection is to be provided either in the primary or secondary circuit.

6.12.2 Arrangements are to be made to prevent the primary windings of transformers being inadvertently energised from their secondary side when disconnected from their source of supply.

6.13 Harmonic filters

6.13.1 Harmonic filters' final sub-circuits are to be protected individually against overload and short-circuit.

6.13.2 An alarm is to be initiated in the event of protective device operation.

6.13.3 Where parallel harmonic filters are used, an alarm is to be initiated in the event of current imbalance that could lead to failure of a harmonic filter.

■ *Section 7* Switchgear and controlgear assemblies

7.1 General requirements

7.1.1 Switchgear and controlgear assemblies and their components are to comply with one of the following standards, amended where necessary for ambient temperature and other environmental conditions:

(a) IEC 61439: *Low-voltage switchgear and controlgear assemblies* (relevant parts);
(b) IEC *62271-200: High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*;
(c) IEC 62271-201: *High-voltage switchgear and controlgear — Part 201: AC insulation-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV;*
(d) IEC 60255: *Measuring relays and protection equipment*;
(e) acceptable and relevant National Standard.

In addition, the requirements of 7.2 to 7.19 are to be complied with.

7.2 Busbars

7.2.1 Busbars and their connections are to be of copper or aluminium, all connections being so made as to inhibit corrosion/oxidisation between current-carrying mating faces, which may result in poor electrical contact giving rise to overheating. Busbars and their supports are to be designed to withstand the mechanical stresses which may arise during short-circuits. A test report or calculation to verify the short-circuit withstand strength of the busbar system is to be submitted for consideration when required.

7.2.2 For bare conductors, where no precautions are taken against surface oxidisation, the temperature rise limit at rated normal current is not to exceed 45°C. Where suitable precautions are taken against surface oxidisation, e.g., by using silver, nickel or tin coated terminations, a temperature rise limit not exceeding 60°C is permitted. Where the busbar temperature rises are above 45°C it is to be ensured that there is no adverse effect on equipment adjacent to and/or connected to the busbars and that the temperature rise limits of any materials in contact with the busbars are not exceeded. A test report or calculation to verify the rated current assigned to the busbar system is to be submitted for consideration when required.

7.3 Circuit-breakers

7.3.1 Circuit-breakers are to comply with one of the following standards amended where necessary for ambient temperature:

(a) IEC 60947-2: *Low-voltage switchgear and controlgear – Part 2: Circuit-Breakers*; or
(b) IEC 62271-100: *High-voltage switchgear and controlgear – Part 100: Alternating current circuit-breakers;* or
(c) an acceptable and relevant National Standard.

Type test reports to verify the characteristics of a circuit-breaker are to be submitted for consideration when required.

7.3.2 Circuit-breakers are to be capable of isolation.

7.3.3 Circuit-breakers are to be of the trip free type and, where applicable, be fitted with anti-pumping control.

7.3.4 High-voltage circuit-breakers are to be of the withdrawable type or with equivalent means or arrangements permitting safe maintenance whilst the busbars are live.

7.3.5 Where the means of setting adjustable protection characteristics are not durably marked and locked in position and cannot be visually inspected (e.g., electronic storage), the settings of characteristics are to be recorded and a copy of the records included in the details retained on board, *see* 6.1.4.

7.3.6 Air circuit-breakers for essential or emergency services and rated at 800 A and above are to have a cumulative count kept of the switching operations of the electrical contacts. This count, along with the manufacturer's details for the circuit-breaker, including the maximum number of switching operations for the electrical contacts, is to be retained on board. These details are to be made available to the Surveyor on request.

7.4 Contactors

7.4.1 High-voltage contactors are to comply with one of the following standards amended where necessary for ambient temperature:

(a) IEC 62271-106: *High-voltage switchgear and controlgear – Part 106: Alternating current contactors, contactor-based controllers and motor-starters*; or
(b) an acceptable and relevant National Standard.

Type test reports to verify the characteristics of a contactor are to be submitted for consideration when required.

7.4.2 High-voltage contactors are to be of the withdrawable type or with equivalent means or arrangements permitting safe maintenance whilst the busbars are live.

7.5 Creepage and clearance distances

7.5.1 The shortest distances between conductive parts and between conductive parts and earth, in air or along the surface of an insulating material, are to be suitable for the rated voltage having regard to:

- the nature of the insulating material;
- the transient over voltages developed by switching and fault conditions; and
- the environment into which the assembly will be installed.

Each assembly type is to be subjected to an impulse voltage test in accordance with its constructional Standard or, alternatively, the minimum distances for bare conductive parts in switchgear and control gear assemblies given in Table 2.7.1 are to be used.

Table 2.7.1 Minimum clearance distances

Nominal voltage (V)	Minimum clearance distance (mm)		
	Verified assemblies, *see* Note 2		Non-verified assemblies
	Main switchboards	Other switchgear and control gear	Main switchboards and other switch and control gear
≤ 250 (*see* Note 1)	8	8	15
≤ 690 (*see* Note 1)	8	8	20
≤ 1000 (*see* Note 1)	8	8	25
< 3,300	32	26	55
< 6,600	60	50	90
< 11,000	100	80	120
≤15,000	*See* Note 3	*See* Note 3	160

NOTES
1. For assemblies installed in spaces where the pollution degree is > 3, *see* 7.5.2.
2. For the verification requirements for a verified assembly refer to IEC 61439-2.
3. Clearance distances with reference to the applicable relevant National or International Standards, are to be submitted for approval, *see* 1.3.4.

7.5.2 For assemblies with a rated voltage of up to and including 1kV, the requirement of 7.5.1 may be met by complying with IEC 60092-302 *Electrical installations in ships – Part 302: Low-voltage switchgear and control gear assemblies*.

- Tables 2.7.1 and 2.7.2 indicate the minimum clearance and creepage distances normally allowed.
- For assemblies installed in spaces where the environmental conditions are in excess of pollution degree 3 (that is conductive pollution occurs or dry, non conductive pollution occurs which is expected to be conductive due to condensation) as defined in IEC 61439-1, *Low-voltage switchgear and control gear assemblies – Part 1: General requirements*; the clearance distances for non-verified assemblies are to be used.
- A minimum creepage distance of 16 mm is permitted for assemblies verified in accordance with the requirements of IEC 61439-2, *Low-voltage switchgear and control gear assemblies – Part 2: Power switchgear and control gear assemblies*.
- An alternative relevant National or International Standard may be used when an acceptable justification is submitted as part of the documentation required by 1.3.4.

7.5.3 For assemblies with a rated voltage above 1kV, the requirement of 7.5.1 may be met by complying with IEC 60092-503 *Electrical installations in ships – Part 503: Special features – AC supply systems with voltages in the range of above 1 kV up to and including 15 kV*.

- Tables 2.7.1 and 2.7.2 indicate the minimum clearance and creepage distances normally allowed.
- For main switchboards rated at above 1kV, a minimum clearance distance of 25 mm is required for busbars and other bare conductors.

An alternative relevant National or International Standard may be used when an acceptable justification is submitted as part of the documentation required by 1.3.4.

Table 2.7.2 Minimum creepage distances

Nominal voltage (V)	Minimum creepage distance (mm)	
	Main switchboards	Other switchgear and control gear
≤ 250 (*see* Note 1)	20	20
≤ 690 (*see* Note 1)	25	25
≤ 1000 (*see* Note 1)	35	35
< 3,300	48	*See* Note 2
< 6,600	90	70
< 11,000	150	120
≤15,000	*See* Note 2	*See* Note 2

NOTES
1. For verified assemblies a minimum creepage distance of 16 mm is permitted for LV switchboards, *see* 7.5.2.
2. Creepage distances, with reference to the applicable relevant National or International Standards, are to be submitted for approval, *see* 1.3.3.

7.5.4 Suitable shrouding or barriers are to be provided in way of connections to equipment, where necessary, to maintain the minimum distances in Table 2.7.1.

7.6 Degree of protection

7.6.1 Low voltage assemblies where the rated voltage between conductors or to earth exceeds 55 V a.c. or 250 V d.c. are to be of the deadfront or enclosed type. High-voltage assemblies are to be of the enclosed type.

7.6.2 Where switchboards or section boards are required to comply with 5.2.2, barriers are to be installed to provide protection for the independent sections against contamination due to the products of arcing, which may result in a fault.

7.7 Distribution boards

7.7.1 Distribution boards are to be suitably enclosed unless they are installed in a cupboard or compartment to which only authorised persons have access in which case the cupboard may serve as an enclosure, *see* 7.16.4.

7.8 Earthing of high-voltage switchboards

7.8.1 High-voltage switchboards are to be provided with suitable means to earth isolated circuits so that they are discharged and so maintained that they are safe to touch.

7.8.2 Protective shutters associated with withdrawable parts are to be clearly marked to indicate the incoming and outgoing circuits and bus tie connections. The colour coding shall be as follows:
- Incoming (busbar side) – red;
- Outgoing (circuit side) – yellow; and
- Bus ties – red.

7.9 Fuses

7.9.1 Fuses are to comply with one of the following Standards, amended where necessary for ambient temperature:
(a) IEC 60269 (all parts): *Low-voltage fuses*;
(b) IEC 60282-1: *High-voltage fuses – Part 1: Current-limiting fuses*;
(c) acceptable and relevant National Standard for enclosed current-limiting fuses.
Type test reports to verify the characteristics of a fuse are to be submitted for consideration when required.

7.10 Handrails or handles

7.10.1 All main and emergency switchboards are to be provided with an insulated handrail or insulated handles suitably fitted on the front of the switchboard. Where access to the rear is required, a horizontal insulated handrail is to be suitably fitted on the rear of the switchboard.

7.11 Instruments for alternating current generators

7.11.1 For alternating current generators not operated in parallel, each generator is to be provided with at least one voltmeter, one frequency meter, and one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase. Generators above 50 kVA are also to be provided with a wattmeter.

7.11.2 For alternating current generators operated in parallel, each generator is to be provided with a wattmeter, and one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase.

7.11.3 For parallelling purposes, two voltmeters, two frequency meters and two synchronising devices, of which one at least is to be a synchroscope or a set of lamps are to be provided. One voltmeter and one frequency meter are to be connected to the busbars, the other voltmeter and frequency meter are to be switched to enable the voltage and frequency of any generator to be measured. Where the electrical power requirement to maintain the ship in a normal operational and habitable condition is usually supplied by two or more generators operating in parallel, the two synchronising devices are to be independent of each other *see also* 2.2.1.

7.11.4 The indicators and displays required by 7.11.1 to 7.11.3 are to be located and arranged such that they may be viewed at a single operating position. Where manual paralleling is provided, generators are to have controls to adjust their voltage and frequency located at the single operating position. Access to voltage adjustment is to be restricted, such that it will generally only be used by authorised personnel to avoid accidental operation.

7.11.5 Where the indications of voltage, frequency, current and power are displayed digitally, the indications are to be separately displayed.

7.12 Instrument scales

7.12.1 The upper limit of the scale of every voltmeter is to be approximately 120 per cent of the nominal voltage of the circuit, and the nominal voltage is to be clearly indicated.

7.12.2 The upper limit of the scale of every ammeter is to be approximately 130 per cent of the normal rating of the circuit in which it is installed. Normal full load is to be clearly indicated.

7.12.3 Kilowatt meters for use with alternating current generators which may be operated in parallel are to be capable of indicating 15 per cent reverse power.

7.12.4 Where the indications provided by the instrumentation required by 7.11 are displayed digitally, nominal voltage, over voltage, over current and reverse power indications are to be indicated by an appropriate means. The information provided is to be clearly visible and immediately available.

7.12.5 In general, indications provided by instrumentation which are displayed digitally are not to change more frequently than twice per second.

7.13 Labels

7.13.1 The identification of individual circuits and their devices is to be made on labels of durable material. The ratings of fuses and settings of protective devices are also to

be indicated. Section and distribution boards are to be marked with the rated voltage.

7.14 Protection

7.14.1 *See* Section 6.

7.15 Wiring

7.15.1 Insulated wiring connecting components are to be stranded, flame retardant and manufactured in accordance with a relevant and acceptable National Standard.

7.16 Position of switchboards

7.16.1 An unobstructed space not less than 1 m wide is to be provided in front of switchboards and section boards. When switchboards and section boards contain withdrawable equipment the unobstructed space is to be not less than 0,4 m wide with this equipment in its fully withdrawn position.

7.16.2 Where necessary, the space at the rear of switchboards and section boards is to be ample to permit maintenance and in general not less than 0,6 m except that this may be reduced to 0,5 m in way of stiffeners or frames.

7.16.3 The spaces defined in 7.16.1 and 7.16.2 are to have non-slip surfaces. Where access to live parts within switchboards and section boards is normally possible the surface is, in addition, to be electrically insulated.

7.16.4 So far as is practicable, pipes are not to be installed directly above or in front of or behind switchboards, section boards and distribution boards. If such placing is unavoidable, suitable protection is to be provided in these positions, *see* Pt 5, Ch 13,2.

7.16.5 For switchgear and controlgear assemblies, for rated voltages above 1 kV, arrangements are to be made to protect personnel in the event of gases or vapours escaping under pressure as the result of arcing due to an internal fault. Where personnel may be in the vicinity of the equipment when it is energised, this may be achieved by an assembly that has been tested in accordance with Annex A of IEC 62271-200:2011: *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV* and qualified for classification **IAC** (internal arc classification).

7.17 Switchboard auxiliary power supplies

7.17.1 Where the operation of a protective device relies upon a power supply, an alarm is to be provided to indicate failure of the power supply, unless its failure causes automatic tripping of the protected circuit.

7.18 Testing

7.18.1 Tests in accordance with 7.18.2 to 7.18.4 are to be satisfactorily carried out on all assemblies, complete or in sections, at the manufacturer's premises, and a test report issued by the manufacturer, *see also* 1.4.2.

7.18.2 A high voltage test, *see* Section 21.

7.18.3 Calibration of protective devices and indicating instruments is to be verified by means of current and/or voltage injection.

7.18.4 Demonstration of the satisfactory operation of protection circuits, control circuits and interlocks by means of simulated functional tests.

7.18.5 For switchgear and controlgear assemblies, for rated voltages above 1 kV, type tests are to be carried out, in accordance with Annex A of IEC 62271-200:2011: *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV* and **IAC** (internal arc classification) assigned, to verify that the assembly will withstand the effects of an internal arc occurring within the enclosure at a prospective fault level equal to, or in excess of, that of the installation.

7.19 Disconnectors and switch-disconnectors

7.19.1 Disconnectors, switch-disconnectors and their components are to comply with one of the following standards, amended where necessary for ambient temperature and other environmental conditions:

(a) IEC 60947-3: *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*;
(b) IEC 62271-102: *High-voltage switchgear and controlgear – Part 102: High-voltage alternating current disconnectors and earthing switches*;
(c) acceptable and relevant National Standard.

Type test reports to verify the characteristics of a disconnector or switch-disconnector are to be submitted for consideration when required.

Section 8
Protection from electric arc hazards within electrical equipment

8.1 General

8.1.1 An assessment is to be carried out in accordance with 8.2.1 for all electrical equipment within which an arcing fault could occur, such as:
- harmonic filters;
- motor starter panels;
- semiconductor converters;
- switchboards, section boards and distribution boards; or
- transformers.

8.2 Hazard identification and assessment

8.2.1 An assessment is to be carried out to identify the hazards and their consequences for personnel resulting from electric arcs within the electrical equipment identified in 8.1.1. The purpose of the assessment is to demonstrate that the design incorporates adequate measures to reduce the risk of injury to personnel should an arcing fault occur within the electrical equipment, and that this will help to ensure both personnel and ship safety.
Details of the following are to be submitted:
(a) each task to be performed, e.g., switching, equipment maintenance, instrument observation or cleaning;
(b) the hazards to personnel that could result from an electric arc occurring during each task, and the hazards to personnel that could result from the electric arc;
(c) the methods to be used to help to prevent electric arcs; and
(d) the methods to be used to protect personnel from hazards resulting from electric arcs within electrical equipment.

8.3 Calculations to be submitted

8.3.1 The following calculations are to be conducted and used in the hazard identification and assessment:
(a) calculations of the maximum current that would flow through an electric arc between each conductor and its adjacent conductor, and between each conductor and the exposed conductive parts of the enclosure, in the case of an arcing fault;
(b) the maximum incident energy at the intended working distance in the case of an arcing fault; and
(c) the distance from each conductor at which the incident energy would be 5 Joules (1,2 calories) per centimetre squared in the case of an arcing fault when the enclosure door is open.
These calculations may be made in accordance with a relevant Standard acceptable to LR, for example, IEEE Standard 1584, *IEEE Guide for Performing Arc-Flash Hazard Calculations*.

8.4 Testing and trials

8.4.1 It is to be demonstrated that, where provided, arrangements to detect arcing faults function correctly.

Section 9
Rotating machines

9.1 General requirements

9.1.1 Rotating machines are to comply with the relevant parts of IEC 60092: *Electrical installations in ships* or an acceptable and relevant National Standard, and the requirements of this Section.

9.1.2 For all the rotating machines a manufacturer's test certificate is to be provided, *see also* 1.4.2 to 1.4.4.

9.1.3 All machines of 100 kW and over, intended for essential services, are to be surveyed by the Surveyor during manufacture and test.

9.1.4 Shaft materials for rotating machines for essential services are to comply with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) and be manufactured under LR survey for the following applications:
(a) shaft material for dynamic positioning and electric propulsion motors;
(b) shaft material for main engine driven generators where the shaft is part of the propulsion shafting; and
(c) shaft material for machines with power ratings of 250 kW or greater.
Shaft material for machines with power ratings less than 250 kW is to have a manufacturer's certificate as detailed in Chapter 1 of the Rules for Materials.

9.1.5 Where welding is applied to shafts of machines for securing arms or spiders, stress relieving is to be carried out after welding. The finalised assembly is to be visually examined by the Surveyors, crack detection carried out by an appropriate method and the finished welds found sound and free from cracks.

9.1.6 The rotating parts of machines are to be so balanced that when running at any speed in the normal working range the vibration does not exceed the levels of IEC 60034-14: *Rotating electrical machines – Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher – Measurement, evaluation and limits of vibration severity*.

9.1.7 The lubrication arrangement for bearings are to be effective under all operating conditions including the maximum ship inclinations defined by 1.10 and there are to be effective means provided to ensure that lubricant does not reach the machine windings or other conductors and insulators.

9.1.8 Means are to be taken to prevent the ill effects of the flow of currents circulating between the shaft and machine bearings or bearings of connected machinery.

9.1.9 Alternating current machines are to be constructed such that, under any operating conditions, they are capable of withstanding the effects of a sudden short-circuit at their terminals without damage.

9.1.10 Propulsion motors, and generators that form part of electrical propulsion systems, are to have at least one embedded temperature detector (ETD) in each phase of the machine winding in locations which may be subjected to the highest temperature. Where there are two coil sides per slot the ETD's are to be located between the insulated coil sides in the slot, *see* 16.1.3.

9.1.11 A high bearing temperature alarm is to be provided for generators of 100 kW and above, and electric propulsion motors, which are supplied with forced lubrication.

9.1.12 A low lubricating oil pressure alarm is to be provided for generators and electric propulsion motors that are supplied with forced lubrication.

9.1.13 A high lubricating oil temperature alarm is to be provided for electric propulsion motors that are supplied with forced lubrication.

9.1.14 For high voltage machines, the stator insulation system is to be of a type that has undergone sample testing in accordance with the following International Standards, or relevant alternatives acceptable to LR, to demonstrate its suitability for the operating voltage in the presence of an LR Surveyor:

(a) IEC 60894, *Guide for test procedure for the measurement of loss tangent of coils and bars for machine windings*, at the insulation class rated temperature; and
(b) IEC 60034-15: *Rotating electrical machines – Part 15: Impulse voltage withstand levels of form-wound stator coils for rotating a.c. machines*, with power-frequency voltage withstand testing conducted.

Test samples are to be representative in terms of the number and size of conductors, coil construction, combination of materials and manufacturing process.

9.1.15 For testing required by 9.1.14 on coils relating to global vacuum pressure impregnated systems, test samples representing the unimpregnated state and the impregnated state of the final winding and stator core are to be used as appropriate for testing.

9.2 Rating

9.2.1 Generators, including their excitation systems, and continuously rated motors are to be suitable for continuous duty at their full rated output at maximum cooling air or water temperature for an unlimited period, without the limits of temperature rise in 9.3 being exceeded. Generators are to be capable of an overload power of not less than 10 per cent at their rated power factor for a period of 15 minutes without injurious heating. Other machines are to be rated in accordance with the duty which they have to perform and, when tested under rated load conditions, the temperature rise is not to exceed the values in 9.3.

9.2.2 When a rotating machine is connected to a supply system with harmonic distortion the rating of the machine is to allow for the increased heating effect of the harmonic loading.

9.2.3 The design and construction of smoke extraction fan motors are to be suitable for the ambient temperature and operating time required. Type test reports to verify the performance of the electric motor are to be submitted for consideration.

9.3 Temperature rise

9.3.1 The limits of temperature rise specified in Table 2.9.1, are based on the cooling air temperature and cooling water temperature given in 1.9.

9.3.2 If it is known that the temperature of cooling medium exceeds the values given in 1.9 the permissible temperature rise is to be reduced by an amount equal to the excess temperature of the cooling medium.

9.3.3 If it is known that the temperature of cooling medium will be permanently less than the values given in 1.9 the permissible temperature rise may be increased by an amount equal to the difference between the declared temperature and that given in 1.9 up to a maximum of 15°C.

9.4 Generator control

9.4.1 Each alternating current generator, unless of the self-regulating type, is to be provided with automatic means of voltage regulation; voltage build-up is not to require an external source of power. Provision is to be made to safeguard the distribution system should there be a failure of the voltage regulating system resulting in a high voltage.

9.4.2 The voltage regulation of any alternating current generator with its regulating equipment is to be such that at all loads, from zero to full load at rated power factor, the rated voltage is maintained within ±2,5 per cent under steady conditions. There is to be provision at the voltage regulator to adjust the generator no load voltage.

9.4.3 Generators, and their excitation systems, when operating at rated speed and voltage on no-load are to be capable of absorbing the suddenly switched, balanced, current demand of the largest motor or load at a power factor not greater than 0,4 with a transient voltage dip which does not exceed 15 per cent of rated voltage. The voltage is to recover to rated voltage within a time not exceeding 1,5 seconds.

9.4.4 The transient voltage rise at the terminals of a generator is not to exceed 20 per cent of rated voltage when rated kVA at a power factor not greater than 0,8 is thrown off.

Table 2.9.1 Limits of temperature rise of machines cooled by air

Limits of temperature rise of machines cooled by air, °C						
Part of machine	Method of temperature measurement	Insulation class				
		A	E	B	F	H
1. (a) a.c. windings of machines having output of 5000 kVA or more	ETD R	55 50	– –	75 70	95 90	115 110
(b) a.c. windings of machines having output of less than 5000 kVA	ETD R	55 50	– 65	80 70	100 95	115 110
2. Windings of armatures having commutators	R T	50 40	65 55	70 60	95 75	115 95
3. Field windings of a.c. and d.c. machines having d.c. excitation other than those in item 4	R T	50 40	65 55	70 60	95 75	115 95
4. (a) Field windings of synchronous machines with cylindrical rotors having d.c. excitation	R	–	–	80	100	125
(b) Stationary field windings of d.c. machines having more than one layer	R T	50 40	65 55	70 60	95 75	115 95
(c) Low resistance field windings of a.c. and d.c. machine and compensating windings of d.c. machines having more than one layer	R, T	50	65	70	90	115
(d) Single-layer windings of a.c. and d.c. machines with exposed bare or varnished metal surfaces and single-layer compensating windings of d.c. machines	R, T	55	70	80	100	125
5. Permanently short-circuited insulated windings	T	50	65	70	90	115
6. Permanently short-circuited uninsulated windings	T	The temperature rise of these parts shall in no case reach such a value that there is a risk to any insulation or other materials on adjacent parts or to the item itself				
7. Magnetic cores and other parts not in contact with windings	T					
8. Magnetic cores and other parts in contact with windings	T	50	65	70	90	110
9. Commutators and slip-rings open and enclosed	T	50	60	70	80	90

NOTES
1. Where water cooled heat exchangers are used in the machine cooling circuit the temperature rises are to be measured with respect to the temperature of the cooling water at the inlet to the heat exchanger and the temperature rises given in this Table shall be increased by 10°C provided the inlet water temperature does not exceed the values given in 1.9.
2. T = thermometer method
   R = resistance method
   ETD = embedded temperature detector.
3. Temperature rise measurements are to use the resistance method whenever practicable.
4. The ETD method may only be used when the ETDs are located between coil sides in the slot.

9.4.5 Generators and their voltage regulation systems are to be capable of maintaining, without damage, under steady state short-circuit conditions a current of at least three times the full load rated current for a duration of at least two seconds or where precise data is available for the duration of any time delay which may be provided by a tripping device for discrimination purposes.

9.4.6 Generators required to run in parallel are to be stable from no load (kW) up to the total combined full load (kW) of the group, and load sharing is to be such that the load on any generator does not normally differ from its proportionate share of the total load by more than 15 per cent of the rated output (kW) of the largest machine or 25 per cent of the rated output (kW) of the individual machine, whichever is less.

9.4.7 When generators are operated in parallel, the kVA loads of the individual generating sets are not to differ from the proportionate share of the total kVA load by more than five per cent of the rated kVA output of the largest machines.

9.5 Overloads

9.5.1 Machines are to withstand on test, without injury, the following momentary overloads:

(a) **Generators**. An excess current of 50 per cent for 15 seconds after attaining the temperature rise corresponding to rated load, the terminal voltage being maintained as near the rated value as possible. The foregoing does not apply to the overload torque capacity of the prime mover.

(b) **Motors**. At rated speed or, in the case of a range of speeds, at the highest and lowest speeds, under gradual increase of torque, the appropriate excess torque given below. Synchronous motors and synchronous induction motors are required to withstand the excess torque without falling out of synchronism and without adjustment of the excitation circuit preset at the value corresponding to rated load:

d.c. motors	50 per cent for 15 seconds;
polyphase a.c. synchronous motors	50 per cent for 15 seconds;
polyphase a.c. synchronous induction motors	35 per cent for 15 seconds;
polyphase a.c. induction motors	60 per cent for 15 seconds.

(c) **Propulsion machines**. The overload tests for propulsion machines will be specially considered for each installation.

(d) **Windlasses**. For the design and testing of windlass electric motors, *see* Pt 3, Ch 13,8.8.

9.6 Machine enclosure

9.6.1 Where liquid-cooled heat exchangers are used in the machine cooling circuit there is to be provision to detect leakage of the liquid, and the system is to be arranged so as to prevent the entry of liquid into the machine.

9.7 Direct current machines

9.7.1 The final running position of brushgear is to be clearly and permanently marked.

9.7.2 Direct current machines are to work with fixed brush setting from no load to the momentary overload specified without injurious sparking.

9.8 Survey and testing

9.8.1 On machines for essential services tests are to be carried out and a certificate furnished by the manufacturer. The tests are to include temperature rise, momentary overload, high voltage, and commutation. The insulation resistance and the temperature at which it was measured are to be recorded, *see also* 1.4.2 to 1.4.4.

9.8.2 In the case of duplicate machines, type tests of temperature rise, excess current and torque and commutation taken on a machine identical in rating and in all other essential details may be accepted in conjunction with abbreviated tests on each machine. Type tests for propulsion machines will be specially considered, *see also* Section 16. For the abbreviated tests, each machine is to be run and is to be found electrically and mechanically sound and is to have a high voltage test and insulation resistance recorded.

9.8.3 A high voltage test, in accordance with Section 21, is to be applied to new machines, preferably at the conclusion of the temperature rise test. Where both ends of each phase are brought out to accessible separate terminals each phase is to be tested separately.

9.8.4 Survey during manufacture, *see* 1.4, is to be conducted prior to testing of the completed machine and is to include inspection of rotor and stator assemblies to assess compliance with the constructional requirements of the relevant standards and this Section.

9.8.5 For high voltage machines, a description of rotor and stator insulation system application procedures (taping, impregnation, pressing and curing, etc.) with application process records, including details of checks and tests conducted to verify successful application, is to be made available to the LR Surveyor during manufacture, *see also* 9.1.14.

9.8.6 Routine impulse tests are to be carried out on the coils of high voltage machines in accordance with IEC 60034-15: *Rotating electrical machines – Part 15: Impulse voltage withstand levels of form-wound stator coils for rotating a.c. machines*, in order to demonstrate a satisfactory withstand level of the inter-turn insulation to voltage surges. The test is to be carried out on all coils after they have been inserted in the slots and after wedging and bracing. Each coil shall be subjected to at least five impulses of injected voltage, the peak value of the injected voltage being given by the formula:

$V_{peak} = 2,45V$

where

V = rated line voltage r.m.s.

Alternative proposals to demonstrate the withstand level of inter-turn insulation will be considered.

■ Section 10
Converter equipment

10.1 Transformers

10.1.1 Paragraphs 10.1.2 to 10.1.13 apply to transformers rated for 5 kVA upwards.

10.1.2 Transformers are to comply with the requirements of IEC 60076 (all parts): *Power transformers*, or an acceptable and relevant National Standard amended where necessary for ambient temperature, *see* 1.9.

10.1.3 Transformers may be of the dry type, encapsulated or liquid-filled type.

10.1.4 The temperature rise of the winding of transformers above the ambient temperatures given in 1.9, when measured by resistance during continuous operation at the maximum rating, is not to exceed:

(a) For dry type transformers, air cooled:
insulation of Class A – 50°C
insulation of Class E – 60°C
insulation of Class B – 70°C
insulation of Class F – 90°C
insulation of Class H – 110°C

(b) For liquid filled transformers:
50°C – where air provides cooling of the fluid
65°C – where water provides cooling of the fluid.

10.1.5 When a transformer is connected to a supply system with harmonic distortion, the rating of the transformer is to allow for the increased heating effect of the harmonic loading. Special attention is to be given to transformers connected for the purpose of reducing harmonic distortion.

10.1.6 The inherent regulation of transformers at their rated output is to be such that the total voltage drop to any point in the installation does not exceed that allowed by 1.8.

10.1.7 Transformers, except those for motor starting, are to be double wound.

10.1.8 Liquid fillings for transformers are to be non-toxic and of a type which does not readily support combustion. Liquid filled transformers are to have a pressure relief device with an alarm and there is to be a suitable means provided to contain any liquid which may escape from the transformer due to the operation of the relief device or damage to the tank.

10.1.9 All transformers are to be capable of withstanding for two seconds, without damage, the thermal and mechanical effects of a short-circuit at the terminals of any winding.

10.1.10 When forced cooling is used, whether air or liquid, there is to be monitoring of the cooling medium and transformer winding temperatures with an alarm should these exceed preset limits. There are to be arrangements so that the load may be reduced to a level commensurate with the cooling available.

10.1.11 Transformers for propulsion power are to be provided with arrangements such that, in the event of excessive winding temperature, an alarm is initiated and:
- the load is reduced to a level commensurate with the cooling arrangements; or
- automatic shut-down of the transformer occurs.

10.1.12 Where liquid-cooled heat exchangers are used in transformer cooling circuits, there is to be provision to detect leakage of the liquid and the system is to be arranged so as to prevent the entry of liquid into the transformer.

10.1.13 The following tests are to be carried out on all transformers at the manufacturer's works, and a certificate of tests issued by the manufacturer, *see also* 1.4.2 and 1.4.3:
(a) measurement of winding resistances, voltage ratio, impedance voltage, short-circuit impedance, insulation resistance, load loss, no load loss and current;
(b) dielectric tests;
(c) temperature rise test on one transformer of each size and type; and
(d) where evidence of compliance with 10.1.9 is not submitted for consideration, short-circuit withstand on one transformer of each size and type.

10.2 Semiconductor converters

10.2.1 The requirements of 10.2.2 to 10.2.18 apply to semiconductor converters rated for 5 kW upwards.

10.2.2 Semiconductor converters are to comply with the requirements of IEC 60146 (all parts): *Semiconductor converters*, or an acceptable and relevant National Standard amended where necessary for ambient temperature, *see* 1.9.

10.2.3 Semiconductor static power converters are to be rated for the required duty having regard to peak loads, system transients and overvoltage.

10.2.4 Converter equipment may be air or liquid cooled and is to be so arranged that it cannot remain loaded unless effective cooling is maintained. Alternatively the load may be automatically reduced to a level commensurate with the cooling available.

10.2.5 Liquid cooled converter equipment is to be provided with leakage alarms and there is to be a suitable means provided to contain any liquid which may leak from the system in order to ensure that it does not cause an electrical failure of the equipment. Where the semiconductors and other current carrying parts are in direct contact with the cooling liquid, the liquid is to be monitored for satisfactory resistivity and an alarm initiated at the relevant control station should the resistivity be outside the agreed limits.

10.2.6 Where forced cooling is used there is to be temperature monitoring of the heated cooling medium with an alarm and shut-down when the temperature exceeds a preset value.

10.2.7 Cooling fluids are to be non-toxic and of low flammability.

10.2.8 Converter equipment is to be so arranged that the semiconductor devices, fuses, control and firing circuit boards may be readily removed from the equipment for repair or replacement.

10.2.9 Test and monitoring facilities are to be provided to permit identification of control circuit faults and faulty components.

10.2.10 Protection devices fitted for converter equipment protection are to ensure that, under fault conditions, the protective action of circuit-breakers, fuses or control systems is such that there is no further damage to the converter or the installation.

10.2.11 Converter equipment, including any associated transformers, reactors, capacitors and filters, if provided, is to be so arranged that the harmonic distortion, and voltage spikes, introduced in to the ship's electrical system are within the limits of 1.8.3 or restricted to a lower level necessary to ensure that it causes no malfunction of equipment connected to the electrical installation.

10.2.12 Overvoltage spikes or oscillations caused by commutation or other phenomena, are not to result in the supply voltage waveform deviating from a superimposed equivalent sine wave by more than 10 per cent of the maximum value of the equivalent sine wave.

10.2.13 When converter equipment is operated in parallel, load sharing is to be such that under normal operating conditions overloading of any unit does not occur and the

combination of paralleled equipment is stable throughout the operating range.

10.2.14 When converter equipment has parallel circuits there is to be provision to ensure that the load is distributed uniformly between the parallel paths.

10.2.15 Transformers, reactors, capacitors and other circuit devices associated with converter equipment, or associated filters, are to be suitable for the distorted voltage and current waveforms to which they may be subjected and filter circuits are to be provided with facilities to ensure that their capacitors are discharged before the circuits are energised.

10.2.16 Any regenerated power developed during the operation of converter equipment is not to result in disturbances to the supply system voltage and frequency which exceeds the limits of 1.8.

10.2.17 Where control systems form an integral part of semiconductor equipment, they are to be designed and manufactured with regard to the environmental conditions to which they will be exposed in service and their performance is to be demonstrated during the test and trials programme.

10.2.18 Tests at the manufacturer's works of converter equipment and any associated reactors or filters are to include the high voltage test of 21.1, a temperature rise test on one of each size and type of converter equipment, and such other tests as may be necessary to demonstrate the suitability of the equipment for its intended duty. Details of tests are to be submitted for consideration when required, *see also* 1.4.2.

10.3 Uninterruptible power systems

10.3.1 The requirements of this sub-Section apply to all uninterruptible power systems (UPS) intended to maintain essential services or provide emergency services. This sub-Section is in addition to the requirements of 10.1 to 10.2 and Section 12, as applicable.

10.3.2 UPS units are to be constructed in accordance with IEC 62040: *Uninterruptible power systems (UPS)* (all parts), or an acceptable and relevant National or International Standard.

10.3.3 The operation of a UPS is not to depend upon external services.

10.3.4 The type of UPS unit employed, whether off-line, line-interactive or on-line, is to be appropriate to the power supply requirements of the connected load equipment.

10.3.5 An external bypass, that is hardwired and manually operated, is to be provided for UPS to allow isolation of UPS for safety during maintenance and maintain continuity of load power.

10.3.6 UPS units are to be monitored and an audible and visual alarm is to be initiated in the navigating bridge or the engine control room, or an equivalent attended location for:

- power supply failure (voltage and frequency) to the connected load;
- earth fault;
- operation of battery protective device;
- battery discharge; and
- bypass in operation for on-line UPS units.

10.3.7 UPS units required to provide emergency services are to be suitably located for use in an emergency.

10.3.8 UPS units utilising valve-regulated sealed batteries may be located in compartments with standard marine or industrial electrical equipment provided that the arrangements comply with 12.3.5. Ventilation arrangements in accordance with IEC 62040-1: *Uninterruptible power systems (UPS) – Part 1: General and safety requirements for UPS*, or an acceptable and relevant National or International Standard, may be considered to satisfy the requirements of 12.5.10.

10.3.9 Output power is to be maintained for the duration required for the connected equipment.

10.3.10 The UPS battery capacity is, at all times, to be capable of supplying the designated loads for the time specified. Where it is proposed that additional circuits are connected to the UPS unit, details verifying that the UPS unit has adequate capacity are to be submitted for consideration, *see* 1.5.

10.3.11 On restoration of the input power, the rating of the charge unit is to be sufficient to recharge the batteries while maintaining the output supply to the load equipment.

10.3.12 Tests at the manufacturer's works or after installation on board are to include such tests necessary to demonstrate, to the Surveyor's satisfaction, the suitability of the UPS unit for its intended duty and location. As a minimum the following tests are required:

- a temperature rise test;
- a battery capacity test;
- a ventilation rate test of both the equipment housing and the space into which it is to be located, *see also* 12.5; and
- functional testing, including operation of alarms.

Details of tests are to be submitted for consideration when required, *see also* 1.4.2.

10.3.13 Where the supply is to be maintained without a break following a power input failure, this is to be verified after installation by practical testing.

Section 11
Electric cables, optical fibre cables and busbar trunking systems (busways)

11.1 General

11.1.1 The requirements of 11.1 to 11.16 apply to all electric and optical fibre cables for fixed wiring unless otherwise exempted. The requirements of 11.17 apply to busbar trunking systems (busways) where they are used in place of electric cables.

11.1.2 Electric cables for fixed wiring are to be designed, manufactured and tested in accordance with the relevant IEC Standard stated in Table 2.11.1 or an acceptable and relevant National Standard.

Table 2.11.1 Electric cables

Application	IEC Standard	Title
General constructional and testing requirements	60092–350	Electrical installations in ships – Part 350: General construction and test methods of power, control and instrumentation cables for shipboard and offshore applications
Fixed power and control circuits	60092–353	Electrical installations in ships – Part 353: Power cables for rated voltages 1 kV and 3 kV
Fixed power circuits	60092–354	Electrical installations in ships – Part 354: Single- and three-core power cables with extruded solid insulation for rated voltages 6 kV (Um = 7,2 kV) up to 30 kV (Um = 36 kV)
Instrumentation, control and communication circuits up to 60 V	60092-370	Electrical installations in ships – Part 370: Guidance on the selection of cables for telecommunication and data transfer including radio-frequency cables
Control circuits and instrumentation up to 250 V	60092–376	Electrical installations in ships – Part 376: Cables for control and instrumentation circuits 150/250 V (300 V)
Mineral insulated	60702 (all parts)	Mineral insulated cables and their terminations with a rated voltage not exceeding 750 V

11.1.3 Details of optical fibre cables for fixed installation are to be submitted to assess compliance with applicable international or National Standards. These are to include:

- Flame retardancy;
- Fire resistance (if applicable);
- Smoke density;
- Halogen content;
- Mechanical properties;

Suitability for use in the marine environment.

11.1.4 Electric cables for electric propulsion systems are to be Type Approved in accordance with LR's *Type Approval System Test Specification Number 3* or, alternatively, surveyed by the Surveyors during manufacture and testing to assess compliance with the applicable International or National Standards and application of an acceptable quality management system.

11.1.5 Provided that adequate flexibility of the finished cable is assured, conductors of nominal cross-section area 2,5 mm^2 and less need not be stranded.

11.1.6 Electric and optical fibre cables for non-fixed applications are to comply with a relevant National or International Standard.

11.1.7 For the purpose of this Section, pipes, conduits, trunking or any other system for the additional mechanical protection of cables are hereafter referred to under the generic name 'protective casings'.

11.1.8 Electrical cables for telecommunications and data transfer are, whenever practicable, to be selected in accordance with the recommendations of IEC TR 60092-370: *Guidance on the selection of cables for telecommunication and data transfer including radio-frequency cables*.

11.2 Testing

11.2.1 Routine tests, consisting of at least:

(a) measurement of electrical resistance of conductors;
(b) high voltage test, *see also* Section 21;
(c) insulation resistance measurement;
(d) for high voltage cables, partial discharge tests are to be made in accordance with the requirements of IEC 60885-2: *Electrical test methods for electric cables – Part 2: Partial discharge tests*, or an acceptable and relevant National Standard, at the manufacturer's works prior to despatch.

Evidence of successful completion of routine tests is to be provided by the manufacturer, *see also* 11.1.4.

11.2.2 Particular, special and type tests are to be made, when required, in accordance with the requirements of the relevant publication or National Standard referred to in 11.1.2 and a test report issued by the manufacturer.

11.3 Voltage rating

11.3.1 The rated voltage of any electric cable is to be not lower than the nominal voltage of the circuit for which it is used. The maximum sustained voltage of the circuit is not to exceed the maximum voltage for which the cable has been designed.

11.3.2 Electric cables used in unearthed systems are to be suitably rated to withstand the additional stresses imposed on the insulation due to an earth fault.

11.4 Operating temperature

11.4.1 The maximum rated conductor temperature of the insulating material for normal operation is to be at least 10°C higher than the maximum ambient temperature liable to be produced in the space where the cable is installed.

11.4.2 The maximum rated conductor temperatures for normal and short-circuit operation, for the insulating materials included within the standards referred to in 11.1.2 is not to exceed the values stated in Table 2.11.2.

11.4.3 Electric cables constructed of an insulating material not included in Table 2.11.2 are to be rated in accordance with the National Standard chosen in compliance with 11.1.2.

Table 2.11.2 Maximum rated conductor temperature

Type of insulating compound	Maximum rated conductor temperature, °C	
	Normal operation	Short-circuit
Thermoplastic, based upon:		
Polyvinyl chloride or co-polymer of vinyl chloride and vinyl acetate	70	150
Elastomeric or thermosetting, based upon:		
Ethylene-propylene rubber or similar (EPM or EPDM)	90	250
High modulus or hard grade ethylene propylene rubber	90	250
Cross-linked polyethylene	90	250
Ethylene-propylene rubber or similar (EPM or EPDM) halogen free	90	250
High modulus or hard grade halogen-free ethylene propylene rubber	90	250
Halogen-free cross-linked polyethylene	90	250
Cross-linked polyolefin material for halogen-free cables	90	250
Silicone rubber	95	350
Halogen-free silicone rubber	95	350

11.5 Construction

11.5.1 Electric and optical fibre cables are to be at least of a flame-retardant type. IEC 60332-1-2: *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame*,will be acceptable.

11.5.2 Exemption from the requirements of 11.5.1 for applications such as radio frequency or digital communication systems, which require the use of particular types of cable, will be subject to special consideration.

11.5.3 Where electric or optical fibre cables are required to be of a 'fire resistant type', they are in addition to be easily distinguishable and comply with the performance requirements of the appropriate part of IEC 60331: *Tests for electric cables under fire conditions – Circuit integrity,* when tested with a minimum flame application time of 90 minutes, as follows:

- IEC 60331-1: *Tests for electric cables under fire conditions – Circuit integrity – Part 1: Test method for fire with shock at a temperature of at least 830°C for cables of rated voltage up to and including 0,6/1,0 kV and with an overall diameter exceeding 20 mm*;
- IEC 60331-21: *Tests for electric cables under fire conditions – Circuit integrity – Part 21: Procedures and requirements – Cables of rated voltage up to and including 0,6/1,0 kV*;
- IEC 60331-23: *Tests for electric cables under fire conditions – Circuit integrity – Part 23: Procedures and requirements – Electric data cables*; or
- IEC 60331-25: *Tests for electric cables under fire conditions – Circuit integrity – Part 25: Procedures and requirements – Optical fibre cables*.

11.5.4 Where electric or optical fibre cables are installed in locations exposed to the weather, in damp and in wet situations, in machinery compartments, refrigerated spaces or exposed to harmful vapours including oil vapour they are to have the conductor insulating materials or optical fibres enclosed in an impervious sheath of material appropriate to the expected ambient conditions.

11.5.5 Where electric or optical fibre cables are installed in locations which are totally submerged for extended periods of time, they are to have the conductor insulating materials or fibres enclosed in an impervious sheath of material appropriate to the expected submerged conditions and duration.

11.5.6 Where it is required that the construction of electric or optical fibre cables includes metallic sheaths, armouring or braids, they are to be provided with an overall impervious sheath or other means to protect the metallic elements against corrosion, *see also* 11.8.7 and 11.8.8.

11.5.7 Where cables are installed in an area where contamination by oil is likely to occur, the oversheath is to be of an enhanced oil resistance grade.

11.5.8 Where single core electric cables are used in circuits rated in excess of 20 Amps and are armoured the armour is to be of a non-magnetic material.

11.5.9 Electric cables are to be constructed such that they are capable of withstanding the mechanical and thermal effects of the maximum short-circuit current which can flow in any part of the circuit in which they are installed, taking into consideration not only the time/current characteristics of the circuit protective device but also the peak value of the prospective short-circuit current. Where electric cables are to be used in circuits with a maximum short-circuit current in excess of 70 kA, evidence is to be submitted for consideration when required demonstrating that the cable construction can withstand the effects of the short-circuit current.

11.5.10 All high voltage electric cables are to be readily identified by suitable marking.

11.6 Conductor size

11.6.1 The maximum continuous load carried by a cable is not to exceed its continuous current rating. It is to be chosen such that the maximum rated conductor temperature for normal operation for the insulation is not exceeded. In assessing the current rating the correction factors in 11.7 may be applied as required.

11.6.2 The cross-sectional area of the conductors is to be sufficient to ensure that, under short-circuit conditions, the maximum rated conductor temperature for short-circuit operation is not exceeded, taking into consideration the time current characteristics of the circuit protective device and the peak value of the prospective short-circuit current.

11.6.3 The cable current ratings given in Tables 2.11.3 and 2.11.4 are based on the maximum rated conductor temperatures given in Table 2.11.2. When cable sizes are selected on the basis of precise evaluation of current rating based upon experimental and calculated data, details are to be submitted for consideration. Alternative short-circuit temperature limits, other than those given in Table 2.11.4, may be applied using the data provided in:

- IEC 60724: *Short-circuit temperature limits of electric cables with rated voltages of 1kV (Um=1,2kV) and 3kV (Um=3,6kV);* or
- IEC 60986: *Short-circuit temperature limits of electric cables with rated voltages from 6kV (Um=7,2kV) and up to 30kV (Um=36kV)*.

Alternative short-circuit temperature limits provided in an acceptable and relevant National Standard may also be considered.

Table 2.11.3 Electric cable current ratings, normal operation, based on ambient 45°C

Nominal cross-section (mm^2)	Continuous r.m.s current rating, in amperes								
	Thermoplastic, (70°C)			Elastomeric (90°C)			Elastomeric or thermosetting, based on silicon rubber (95°C)		
	Single Core	2 core	3 or 4 core	Single Core	2 core	3 or 4 core	Single Core	2 core	3 or 4 core
0,75	10	8	7	15	13	11	17	14	12
1	12	10	8	18	15	13	20	17	14
1,25	13	11	9	21	18	14	23	20	16
1,5	15	13	11	23	20	16	26	22	18
2	18	15	12	28	24	19	31	26	22
2,5	21	18	15	30	26	21	32	27	22
3,5	26	22	18	37	32	26	39	33	28
4	29	25	20	40	34	28	43	37	30
5,5	35	30	24	49	42	35	52	44	37
6	37	31	26	52	44	36	55	47	39
8	44	37	31	62	53	44	66	56	46
10	51	43	36	72	61	50	76	65	53
14	62	53	44	88	75	62	94	80	66
16	68	58	48	96	82	67	102	87	71
22	83	70	58	117	100	82	124	106	87
25	90	77	63	127	108	89	135	115	95
30	101	85	70	142	121	100	151	128	106
35	111	94	78	157	133	110	166	141	116
38	117	99	82	165	140	116	175	149	122
50	138	117	97	196	167	137	208	177	146
60	155	132	109	220	187	154	233	198	163
70	171	145	120	242	206	169	256	218	179
80	186	158	130	263	224	184	278	237	195
95	207	176	145	293	249	205	310	264	217
100	213	181	149	302	257	212	320	272	224
120	239	203	167	339	288	237	359	305	251
125	245	209	172	348	295	243	368	313	258
150	275	234	193	389	331	272	412	350	288
185	313	266	219	444	377	311	470	400	329
200	329	280	230	466	396	326	494	420	346
240	369	314	258	522	444	365	553	470	387
300	424	360	297	601	511	421	636	541	445

Table 2.11.4 Electric cable current ratings, r.m.s. short-circuit current

Nominal cross-section (mm^2)	Fault current (kA) at 150°C			Fault current (kA) at 250°C			Fault current (kA) at 350°C		
	1 s duration	0,5 s duration	0,1 s duration	1 s duration	0,5 s duration	0,1 s duration	1 s duration	0,5 s duration	0,1 s duration
0,75	0,1	0,1	0,3	0,1	0,2	0,3	0,1	0,2	0,4
1	0,1	0,2	0,3	0,1	0,2	0,5	0,2	0,2	0,5
1,25	0,1	0,2	0,4	0,2	0,3	0,6	0,2	0,3	0,7
1,5	0,2	0,2	0,5	0,2	0,3	0,7	0,3	0,4	0,8
2	0,2	0,3	0,7	0,3	0,4	0,9	0,3	0,5	1,1
2,5	0,3	0,4	0,9	0,4	0,5	1,1	0,4	0,6	1,4
3,5	0,4	0,5	1,2	0,5	0,7	1,6	0,6	0,8	1,9
4	0,4	0,6	1,4	0,6	0,8	1,8	0,7	1,0	2,2
5,5	0,6	0,8	1,9	0,8	1,1	2,5	0,9	1,3	3,0
6	0,7	0,9	2,1	0,9	1,2	2,7	1,0	1,5	3,2
8	0,9	1,2	2,8	1,1	1,6	3,6	1,4	1,9	4,3
10	1,1	1,5	3,5	1,4	2,0	4,5	1,7	2,4	5,4
14	1,5	2,2	4,8	2,0	2,8	6,3	2,4	3,4	7,6
16	1,7	2,5	5,5	2,3	3,2	7,2	2,7	3,9	8,7
22	2,4	3,4	7,6	3,1	4,5	10,0	3,8	5,3	11,9
25	2,7	3,9	8,6	3,6	5,1	11,3	4,3	6,0	13,5
30	3,3	4,6	10,4	4,3	6,1	13,6	5,1	7,3	16,2
35	3,8	5,4	12,1	5,0	7,1	15,8	6,0	8,5	18,9
38	4,1	5,9	13,1	5,4	7,7	17,2	6,5	9,2	20,6
50	5,5	7,7	17,3	7,2	10,1	22,6	8,6	12,1	27,1
60	6,5	9,3	20,7	8,6	12,1	27,1	10,3	14,5	32,5
70	7,6	10,8	24,2	10,0	14,2	31,7	12,0	16,9	37,9
80	8,7	12,3	37,6	11,4	16,2	36,2	13,7	19,4	43,3
95	10,4	14,7	32,8	13,6	19,2	43,0	16,3	23,0	51,4
100	10,9	15,4	34,5	14,3	20,2	45,2	17,1	24,2	54,1
120	13,1	18,5	41,4	17,2	24,3	54,3	20,5	29,0	64,9
125	13,6	19,3	43,1	17,9	25,3	56,6	21,4	30,2	67,6
150	16,4	23,2	51,8	21,5	30,4	67,9	25,7	36,3	81,2
185	20,2	28,6	63,9	26,5	37,4	83,7	31,7	44,8	100,1
200	21,8	30,9	69,0	28,6	40,5	90,5	34,2	48,4	108,2
240	26,2	37,0	82,8	34,3	48,6	108,6	41,1	58,1	129,9
300	32,7	46,3	103,6	42,9	60,7	135,7	51,3	72,6	162,3

11.6.4 The cross-sectional area of the conductors is to be sufficient to ensure that at no point in the installation will the voltage variations stated in 1.8 be exceeded when the conductors are carrying the maximum current under their normal conditions of service.

11.6.5 The size of earth conductors is to comply with 1.12.8.

11.6.6 The cross-sectional area of conductors used in circuits supplying cyclic or non-continuous loads is to be sufficient to ensure that the cables maximum rated conductor temperature for normal operation is not exceeded when the conductors are operating under their normal conditions of service, *see* 11.7.4.

11.7 Correction factors for cable current rating

11.7.1 The correction factors of 11.7.2 to 11.7.5 provide a guide for general applications in assessing a current rating. A more precise evaluation based upon experimental and calculated data may be submitted for consideration.

11.7.2 **Bunching of cables**. Where more than six electric cables, which may be expected to operate simultaneously at their full rated capacity, are laid close together in a cable bunch in such a way that there is an absence of free air circulation around them, a correction factor of 0,85 is to be applied. Signal cables may be exempted from this requirement.

11.7.3 **Ambient temperature**. The current ratings of Table 2.11.3 are based on an ambient temperature of 45°C. For other values of ambient temperature the correction factors shown in Table 2.11.5 are to be applied.

11.7.4 **Short time duty**. When the load is not continuous, i.e., operates for periods of half an hour or one hour and the periods of no load are longer than three times the cable's time constant, T in minutes, the cable's continuous rating may be increased by a duty factor, calculated in accordance with:

$$\text{Duty factor} = \sqrt{\frac{1{,}12}{1 - e^{\frac{-t_s}{T}}}}$$

When the load is not continuous, is repetitive and has periods of no-load less than three times the cable's time constant, so that the cable has insufficient time to cool down between the applications of load, the cable's continuous rating may be increased by an intermittent factor, calculated in accordance with:

Table 2.11.5 Correction factors

Insulation material	Correction factor for ambient air temperature of °C										
	35	40	45	50	55	60	65	70	75	80	85
Thermoplastic (70°C)	1,18	1,10	1,00	0,89	0,77	0,63	—	—	—	—	—
Elastomeric or thermosetting (90°C)	1,10	1,05	1,00	0,94	0,88	0,82	0,74	0,67	0,58	0,47	—
Elastomeric or thermosetting, based on silicone rubber (95°C)	1,10	1,05	1,00	0,95	0,89	0,84	0,77	0,71	0,63	0,55	0,45

$$\text{Intermittent factor} = \sqrt{\frac{1 - e^{\frac{-t_p}{T}}}{1 - e^{\frac{-t_s}{T}}}}$$

where

t_p = the intermittent period, in minutes, i.e., the total period of load and no-load before the cycle is repeated

T = $0{,}245d^{1{,}35}$ where d is the overall diameter of the cable, in mm

t_s = the service time of the load current in minutes

11.7.5 **Diversity**. Where cables are used to supply two or more final sub-circuits account may be taken of any diversity factors which may apply, *see* 5.6.

11.8 Installation of electric cables

11.8.1 Electric and optical fibre cable runs are to be as far as practicable fixed in straight lines and in accessible positions.

11.8.2 Bends in fixed electric and optical fibre cable runs are to be in accordance with the cable manufacturer's recommendations. The minimum internal radius of bend for the installation of fixed electric cables is to be chosen according to the construction and size of the cable and is not to be less than the values given in Table 2.11.6.

11.8.3 The installation of electric and optical fibre cables across expansion joints in any structure is to be avoided. Where this is not practicable, a loop of electric cable of length sufficient to accommodate the expansion of the joint is to be provided. For electric cables, the internal radius of the loop is to be at least 12 times the external diameter of the cable. For optical fibre cables, the internal radius of the loop is to meet the manufacturers' minimum recommendations.

Table 2.11.6 Minimum internal radii of bends in cables for fixed wiring

Cable construction		Overall diameter of cable	Minimum internal radius of bend (times overall diameter of cable)
Insulation	Outer covering		
Thermoplastic and elastomeric 600/1000 V and below	Metal sheathed Armoured and braided	Any	6*D*
	Other finishes	≤ 25 mm > 25 mm	4*D* 6*D*
Mineral	Hard metal sheathed	Any	6*D*
Thermoplastic and elastomeric above 600/1000 V – single core	Any	Any	12*D*
– multicore	Any	Any	9*D*

11.8.4 Electric and optical fibre cables for essential and emergency services are to be arranged, so far as is practicable, to avoid galleys, machinery spaces and other enclosed spaces and high fire risk areas except as is necessary for the service being supplied. Such cables are also, so far as reasonably practicable, to be routed clear of bulkheads to preclude their being rendered unserviceable by heating of the bulkheads that may be caused by a fire in an adjacent space.

11.8.5 Electric cables having insulating materials with different maximum rated conductor temperatures are to be so installed that the maximum rated conductor temperature for normal operation of each cable is not exceeded.

11.8.6 Electric and optical fibre cables having a protective covering which may damage the covering of other cables are not to be bunched with those other cables.

11.8.7 Cables having an exposed metallic screen, braid or armour are to be installed in such a manner that galvanic corrosion by contact with other metals is prevented. Sufficient measures are also to be taken to prevent damage to exposed galvanised coatings during installation.

11.8.8 Protection is to be provided for cable oversheaths in areas where cables are likely to be exposed to damaging substances under normal circumstances or areas where the spillage or release of harmful substances is likely.

11.8.9 Electric and optical fibre cables are to be as far as practicable installed remote from sources of heat. Where installation of cables near sources of heat cannot be avoided and where there is consequently a risk of damage to the cables by heat, suitable shields, insulation or other precautions are to be installed between the cables and the heat source. The free air circulation around the cables is not to be impaired.

11.8.10 Where electric and optical fibre cables are installed in bunches, provision is to be made to limit the propagation of fire. This requirement is considered satisfied when cables of the bunch have been tested in accordance with the requirements of IEC 60332-3-22: *Tests on electric and optical fibre cables under fire conditions – Part 3-22: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category A*, and are installed in the same configuration(s) as are used for the test(s). If the cables are not so installed, information is to be submitted to demonstrate satisfactorily that suitable measures have been taken to ensure that an equivalent limit of fire propagation will be achieved for the configurations to be used. Particular attention is to be given to cables in:

- atria or equivalent spaces; and
- vertical runs in trunks and other restricted spaces.

In addition, cables that comply with the requirements of IEC 60332-3-22 are also required to meet the requirements of IEC 60332-1-2: *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame*.

11.8.11 Electric and optical fibre cables are not to be coated or painted with materials which may adversely affect their sheath or their fire performance.

11.8.12 Where electric and optical fibre cables are installed in refrigerated spaces they are not to be covered with thermal insulation but may be placed directly on the face of the refrigeration chamber, provided that precautions are taken to prevent the electric cables being used as casual means of suspension.

11.8.13 All metal coverings of electric and optical fibre cables are to be earthed in accordance with 1.12.

11.8.14 High voltage cables may be installed as follows:

(a) in the open, (e.g., on carrier plating), when they are to be provided with a continuous metallic sheath or armour which is effectively bonded to earth to reduce danger to personnel. The metallic sheath or armour may be omitted provided that the cable sheathing material has a longitudinal electric resistance high enough to prevent sheath currents which may be hazardous to personnel;

(b) contained in earthed metallic protective casings when the cables may be as in (a) or the armour or metal sheath may be omitted. In the latter case care is to be taken to ensure that protective casings are electrically continuous and that short lengths of cable are not left unprotected.

11.8.15 High voltage electric cables are not to be run in the open through accommodation spaces.

11.8.16 High voltage electric cables are to be segregated as far as is practicable from electric cables operating at lower voltages.

11.8.17 Electric and optical fibre cables are to be, so far as reasonably practicable, installed remote from sources of mechanical damage. Where necessary the cables are to be protected in accordance with the requirements of 11.9.

11.8.18 Electric and optical fibre cables with the exception of those for portable appliances and those installed in protective casings are to be fixed securely in accordance with the requirements of 11.10.

11.8.19 Electric and optical fibre cables serving any essential services and any glands through which they pass must be able to withstand flooding for a period of 36 hours, based on the water pressure that may occur at the location.

11.8.20 Where electric and optical fibre cables penetrate bulkheads and decks the requirements of 11.11 are to be complied with.

11.8.21 Where electric and optical fibre cables are installed in protective casings the requirements of 11.12 are to be complied with.

11.8.22 a.c. wiring is to be carried out using multicore cables wherever reasonably practicable. Where it is necessary to install single core electric cables for alternating current circuits in excess of 20 Amps the requirements of 11.14 are to be complied with, *see also* 11.5.8.

11.9 Mechanical protection of cables

11.9.1 Electric cables exposed to risk of mechanical damage are to be protected by suitable protective casings unless the protective covering (e.g., armour or sheath) is sufficient to withstand the possible cause of damage.

11.9.2 Electric cables installed in spaces where there is exceptional risk of mechanical damage such as holds, storage spaces, cargo spaces, etc., are to be suitably protected by metallic protective casings, even when armoured, unless the ship's structure affords adequate protection.

11.9.3 Metal protective casings are to be efficiently protected against corrosion, and effectively earthed in accordance with 1.12.

11.10 Cable support systems

11.10.1 Electric cables are to be effectively supported and secured, without being damaged, to the ship's structure, either indirectly by a cable support system, or directly by means of clips, saddles or straps to bulkheads etc., *see* 11.8.4.

11.10.2 Cable support systems, which may be in the form of trays or plates, separate support brackets, hangers or ladder racks, together with their fixings and accessories, are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection. The cable support system is to be effectively secured to the ship's structure, the spacing of the fixings taking account of the probability of vibration and any heavy external forces, e.g., where located in areas subject to impact by sea-water.

11.10.3 The distances between the points at which the cable is supported (e.g., distances between ladder rungs, support brackets, hangers, etc.) are to be chosen according to the construction of cable (i.e., size and rigidity) and the probability of vibration and are to be generally in accordance with those given in Table 2.11.7.

Table 2.11.7 Maximum spacing of supports or fixings for securing cables

External diameter of cable		Non-armoured cables	Armoured cables
exceeding	not exceeding		
mm	mm	mm	mm
–	8	200	250
8	13	250	300
13	20	300	350
20	30	350	400
30	–	400	450

11.10.4 Where the cables are laid on top of their support system, the spacings of fixings may be increased beyond those given in Table 2.11.7, but should take account of the probability of movement and vibration and in general is not to exceed 900 mm. This relaxation is not to be applied where cables can be subjected to heavy external forces, e.g., where they are run on, or above, open deck or in areas subject to impact by sea-water.

11.10.5 Single core electric cables are to be firmly fixed, using supports of strength adequate to withstand forces corresponding to the values of the peak prospective short-circuit current.

11.11 Penetration of bulkheads and decks by cables

11.11.1 Where electric or optical fibre cables pass through watertight, fire insulated or gastight bulkheads or decks separating hazardous zones or spaces from non-hazardous zones or spaces, the arrangements are to be such as to ensure the integrity of the bulkhead or deck is not impaired. The arrangements chosen are to ensure that the cables are not adversely affected.

11.11.2 Where cables pass through non-watertight bulkheads or structural steel, the holes are to be bushed with suitable material. If the steel is at least 6 mm thick, adequately rounded edges may be accepted as the equivalent of bushing.

11.11.3 Electric and optical fibre cables passing through decks are to be protected by deck tubes or ducts.

11.11.4 Where cables pass through thermal insulation they are to do so at right angles, in tubes sealed at both ends.

11.12 Installation of electric and optical fibre cables in protective casings

11.12.1 Protective casings are to be mechanically continuous across joints and effectively supported and secured to prevent damage to the electric or optical fibre cables.

11.12.2 Protective casings are to be suitably smooth on the interior and have their ends shaped or bushed in such a manner as not to damage the cables.

11.12.3 The internal radius of bends of protective casings are to be not less than that required for the largest cable installed therein, *see* 11.8.2.

11.12.4 The space factor (ratio of the sum of the cross-sectional areas corresponding to the external diameters of the cables to the internal cross-sectional area of the protective casings) is not to exceed 0,4.

11.12.5 Where necessary, ventilation openings are to be provided at the highest and lowest points of protective casings to permit air circulation and to prevent accumulation of water.

11.12.6 Expansion joints are to be provided in protective casings where necessary.

11.12.7 Protective casings containing high voltage electric cables are not to contain other electric or optical fibre cables and are to be clearly identified, defining their function and voltage.

11.13 Non-metallic cable support systems, protective casings and fixings

11.13.1 Where it is proposed to use non-metallic cable support systems, protective casings or fixings, the additional requirements of this sub-Section apply. For high voltage installations, metallic protective casings are required where 11.8.14(b) applies.

11.13.2 Non-metallic cable support systems and protective casings are to be installed in accordance with the manufacturer's recommendations. The support systems and protective casings are to have been tested in accordance with an acceptable test procedure for:

(a) ambient operating temperatures;
(b) safe working load;
(c) impact resistance;
(d) flame retardancy;
(e) smoke and toxicity; and
(f) use in explosive gas atmospheres or in the presence of combustible dusts, electrical conductivity;

with satisfactory results.

11.13.3 Non-metallic cable support systems, protective casings and fixings installed on the open deck are to be protected from degradation caused by exposure to solar radiation.

11.13.4 Where the cable support system, protective casing or fixings are manufactured from a material other than metal, suitable supplementary metallic fixings or straps spaced at regular distances are to be provided such that, in the event of a fire or failure, the cable support system, protective casing and the affixed cables are prevented from falling and causing an injury to personnel and/or an obstruction to any escape route. Alternatively, the cables may be routed away from such areas.

11.13.5 The load on non-metallic cable support systems or protective casings is not to exceed the tested safe working load.

11.13.6 When a cable support system or protective casing is secured by means of clips or straps manufactured from a material other than metal the fixings are to be supplemented by suitable metal clips or straps spaced at regular distances each not exceeding 2 m and, for non-metallic cable support systems or protective casings, that used during safe working load testing.

11.13.7 Non-metallic fixings are to be flame retardant in accordance with the requirements of IEC 60092-101: *Electrical installations in ships – Part 101: Definitions and general requirements* or an alternative relevant National or International Standard.

11.14 Single-core electric cables for alternating current

11.14.1 When installed in protective casings, electric cables belonging to the same circuit are to be installed in the same casing, unless the casing is of non-magnetic material.

11.14.2 Cable clips are to include electric cables of all phases of a circuit unless the clips are of non-magnetic material.

11.14.3 Single-core cables of the same circuit are to be in contact with one another, as far as possible. In any event the distance between adjacent electric cables is not to be greater than one cable diameter.

11.14.4 If single-core cables of current rating greater than 250 A are installed near a steel bulkhead, the clearance between the cables and the bulkhead is to be at least 50 mm unless the cables belonging to the same a.c. circuit are installed in trefoil formation.

11.14.5 Magnetic material is not to be used between single core cables of a group. Where cables pass through steel plates, all the conductors of the same circuit are to pass through a plate or gland, so made that there is no magnetic material between the cables, and the clearance between the cables and the magnetic material is not to be less than 75 mm, unless the cables belonging to the same a.c. circuit are installed in trefoil formation.

11.14.6 Electric cables are to be installed such that the induced voltages, and any circulating currents, in the sheath or armour are limited to safe values.

11.15 Electric cable ends

11.15.1 Where screw-clamp or spring-clamp type terminations are used in electrical apparatus for external cable connections, *see* 1.11.7, cable conductors of the solid or stranded type may be inserted directly into the terminals. Where flexible conductors are used, a suitable termination is to be fitted to the cable conductor to prevent 'whiskering' of the strands.

11.15.2 If compression type conductor terminations are used on the cable ends, they are to be of a size to match the conductor and to be made with a compression type tool with the dies selected to suit the termination and conductor sizes and having a ratchet action to ensure completion of the compression action.

11.15.3 Soldered sockets may be used in conjunction with non corrosive fluxes provided that the maximum conductor temperature at the joint, under short-circuit conditions, does not exceed 160°C.

11.15.4 High voltage cables of the radial field type (i.e., having a conducting layer to control the electric field within the insulation) are to have terminations which provide electrical stress control.

11.15.5 Electric cables having hygroscopic insulation (e.g., mineral insulated) are to have their ends sealed against ingress of moisture.

11.15.6 Cable terminations are to be of such a design and dimensions that the maximum current likely to flow through them will not result in degradation of the contacts or damage to insulation as the result of overheating.

11.15.7 The fixing of conductors in terminals at joints and at tappings is to be capable of withstanding the thermal and mechanical effects of short-circuit currents.

11.16 Joints and branch circuits in cable systems

11.16.1 If a joint is necessary it is to be carried out so that all conductors or fibres are adequately secured, insulated and protected from atmospheric action. The flame retardant properties of the cable are to be retained, the continuity of metallic sheath, braid or armour is to be maintained and the current carrying capacity or transmission of data through the cable is not to be impaired.

11.16.2 Tappings (branch circuits) are to be made in suitable boxes of such a design that the conductors and fibres remain suitably insulated, protected from atmospheric action and fitted with terminals or busbars of dimensions appropriate to the current rating.

11.16.3 Tappings and splices of optical fibre cables are to be made in accordance with the manufacturers' recommendations and to be provided with appropriate fittings. In addition they are to be located within suitably designed enclosures to ensure that the protection of the optical fibres is maintained.

11.16.4 Cables of a fire resistant type, *see* 11.5.3, are to be installed so that they are continuous throughout their length without any joints or tappings.

11.17 Busbar trunking systems (bustrunks)

11.17.1 Where busbar trunking systems are used in place of electric cables, they are to comply with the requirements of 11.17.2 to 11.17.6, in addition to the applicable requirements in Section 7.

11.17.2 The busbar trunking, or enclosure system, is to have a minimum ingress protection of IP54, according to IEC60529: *Degrees of protection provided by enclosures* (IP Code).

11.17.3 The internal and external arrangements of the busbar trunking, or enclosure system, are to ensure that the fire and/or watertight integrity of any structure through which it passes is not impaired.

11.17.4 Where the busbar trunking system is employed for circuits on and below the bulkhead deck, arrangements are to be made to ensure that circuits on other decks are not affected in the event of partial flooding under the normal angles of inclination given in 1.10 for essential electrical equipment.

11.17.5 Supports and accessories are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection. The support system is to effectively secure the busbar trunking system to the ship's structure.

11.17.6 When accessories are fixed to the busbar system by means of clips or straps manufactured from a material other than metal, the fixings are to be supplemented by suitable metal clips or straps, such that, in the event of a fire or failure, the accessories are prevented from falling and causing injury to personnel and/or an obstruction to any escape route. Alternatively, the busbar system may be routed away from such areas.

■ *Section 12* **Batteries**

12.1 General

12.1.1 The requirements of this Section apply to permanently installed secondary batteries of the vented and valve-regulated sealed type.

12.1.2 A vented battery is one in which the cells have a cover provided with an opening through which the products of electrolysis and evaporation are allowed to escape freely from the cells to the atmosphere.

12.1.3 A valve-regulated sealed battery is one in which the cells are closed but have an arrangement (valve) which allows the escape of gas if the internal pressure exceeds a predetermined value. The electrolyte cannot normally be replaced.

12.2 Construction

12.2.1 Batteries are to be constructed so as to prevent spilling of the electrolyte due to motion and to minimise the emission of electrolyte spray.

12.3 Location

12.3.1 Vented batteries connected to a charging device with a power output of more than 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, are to be housed in an adequately ventilated compartment assigned to batteries only, or in an adequately ventilated suitable box on open deck.

12.3.2 Vented batteries connected to a charging device with a power output within the range 0,2 kW to 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, are to be installed in accordance with 12.3.1, or may be installed within a well ventilated machinery or similar space.

12.3.3 Vented batteries connected to a charging device with a power output of less than 0,2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, may be installed in an open position or in a battery box in any suitable space.

12.3.4 Where more than one charging device is installed for any battery or group of batteries in one location, the total power output is to be used to determine the installation requirements of 12.3.1, 12.3.2 or 12.3.3.

12.3.5 Valve-regulated sealed batteries may be located in compartments with standard marine or industrial electrical equipment provided that the ventilation requirements of 12.5.11 and the charging requirements of 12.6.4 and 12.6.5 are complied with. Equipment that may produce arcs, sparks or high temperatures in normal operation is not to be in close proximity to battery vent plugs or pressure relief valve outlets.

12.3.6 Where lead-acid and nickel-cadmium batteries are installed in the same compartment precautions are to be taken, such as the provision of screens, to prevent possible contamination of electrolytes.

12.3.7 Where batteries may be exposed to the risk of mechanical damage or falling objects they are to be suitably protected.

12.3.8 Batteries installed in crew and passenger cabins, together with their associated corridors, are to be of the hermetically sealed type.

12.3.9 A permanent notice prohibiting smoking and the use of naked lights or equipment capable of creating a source of ignition is to be prominently displayed adjacent to the entrances of all compartments containing batteries.

12.3.10 Only electrical equipment necessary for operational reasons and for the provision of lighting is to be installed in compartments provided in compliance with 12.3.1, the compartment ventilation exhaust ducts and zones within a 1,5 m radius of the ventilation outlet(s). Such electrical equipment is to be certified for group IIC gases and temperature Class T1 in accordance with the applicable parts of IEC 60079: *Explosive atmospheres*, or an acceptable and relevant National Standard.

12.3.11 A permanent notice is to be prominently displayed adjacent to battery installations advising personnel that replacement batteries are to be of an equivalent performance type. For valve-regulated sealed batteries, the notice is to advise of the requirement for replacement batteries to be suitable with respect to products of electrolysis and evaporation being allowed to escape from cells to the atmosphere, *see also* 1.5.3.

12.4 Installation

12.4.1 Batteries are to be arranged such that each cell or crate of cells is accessible from the top and at least one side and it is to be ensured that they are suitably secured to move with the ship's motion.

12.4.2 The materials used in the construction of a battery rack or stand are to be resistant to the battery electrolyte or suitably protected by paint or a coating.

12.4.3 Measures are to be taken to minimise the effect of any electrolyte spillage and leakage, for example the use of rubber capping around the top of the cells and the provision of a tray of electrolyte-resistant material below the cells, unless the deck is suitably protected with paint or a coating.

12.4.4 The interiors of all compartments for batteries, including crates, trays, boxes, shelves and other structural parts therein, are to be of an electrolyte-resistant material or suitably protected, for example with paint or a coating.

12.5 Ventilation

12.5.1 Battery compartments and boxes are to be ventilated to avoid accumulation of dangerous concentrations of flammable gas.

12.5.2 Where a battery compartment ventilator is required to be fitted with a closing device in accordance with Pt 3, Ch 12,2.3.9, a warning notice clearly stating the purpose of the closing device, for example:

> 'This closing device is to be kept open and only closed in the event of a fire or flooding – Explosive gas atmosphere'

is to be provided at the closing device to mitigate the possibility of inadvertent closing of the ventilator. Furthermore, means to lock the battery compartment ventilators in the open position are to be provided.

12.5.3 Ducted natural ventilation may be employed for battery installations connected to a charging device with a power output of 2 kW or less, provided the exhaust duct can be run directly from the top of the compartment or box to the open air above, with no part of the duct more than 45° from the vertical. A suitable opening is also to be provided below the level of the top of the batteries, so as to ensure a free ventilation air flow. The ventilation duct is to have an area not less than 50 cm^2 for every 1 m^3 of battery compartment or box volume.

12.5.4 Where natural ventilation is impracticable or insufficient, mechanical ventilation is to be provided, with the air inlet located near the floor and the exhaust at the top of the compartment.

12.5.5 Mechanical exhaust ventilation complying with 12.5.9 is to be provided for battery installations connected to a charging device with a total maximum power output of more than 2 kW. Also, to minimise the possibility of oxygen enrichment, compartments and spaces containing batteries with boost charging facilities are to be provided with mechanical exhaust ventilation irrespective of the charging device power output.

12.5.6 The ventilation system for battery compartments and boxes, other than boxes located on open deck or in spaces to which 12.3.2, 12.3.3 and 12.3.5 refer, is to be separate from other ventilation systems. The exhaust ducting is to be led to a location in the open air, where any gases can be safely diluted, away from possible sources of ignition and openings into spaces where gases may accumulate.

12.5.7 Fan motors associated with exhaust ducts from battery compartments are to be placed external to the ducts and the compartments.

12.5.8 Ventilating fans for battery compartments are to be so constructed and be of material such as to minimise risk of sparking in the event of the impeller touching the casing. Non-metallic-impellers are to be of an anti-static material.

12.5.9 Battery boxes are to be provided with sufficient ventilation openings located so as to avoid accumulation of flammable gas whilst preventing the entrance of rain or spray.

12.5.10 The ventilation arrangements for all installations of vented type batteries are to be such that the quantity of air expelled is at least equal to:

$Q = 110 I n$

where

n = number of cells in series

I = maximum current delivered by the charging equipment during gas formation, but not less than 25 per cent of the maximum obtainable charging current in amperes

Q = quantity of air expelled in litres/hr.

12.5.11 The ventilation rate for compartments containing valve-regulated sealed batteries may be reduced to 25 per cent of that given in 12.5.10.

12.6 Charging facilities

12.6.1 Charging facilities are to be provided for all secondary batteries such that they may be completely charged from the completely discharged state in a reasonable time having regard to the service requirements.

12.6.2 Suitable means, including an ammeter and a voltmeter, are to be provided for controlling and monitoring charging of batteries, and to protect them against discharge into the charging circuits.

12.6.3 For floating circuits or any other conditions where the load is connected to the battery whilst it is on charge, the maximum battery voltage is not to exceed the safe value for any connected apparatus.

12.6.4 Where valve-regulated sealed batteries are installed, the charging facilities are to incorporate independent means such as overvoltage protection to prevent gas evolution in excess of the manufacturer's design quantity.

12.6.5 Boost charge facilities, where provided, are to be arranged such that they are automatically disconnected should the battery compartment ventilation system fail.

12.7 Recording of batteries for emergency and essential services

12.7.1 A schedule of batteries fitted for use for essential and emergency services is to be compiled and maintained.

12.7.2 Procedures are to be put in place and documented to ensure that, where batteries are replaced, they are of an equivalent performance type, *see also* 1.5.3.

12.7.3 When additions or alterations are proposed to the existing batteries for essential and emergency services, the schedule and replacement procedure documentation are to be updated to reflect the proposed installation and submitted in accordance with 1.5.2.

12.7.4 The schedule and replacement procedure documentation are to be made available to the LR Surveyor on request.

■ *Section 13*
Equipment – Heating, lighting and accessories

13.1 Heating and cooking equipment

13.1.1 The construction of heaters is to give a degree of protection according to IEC 60529: *Degrees of protection provided by enclosures (IP Code)*, or an acceptable and relevant National Standard, suitable for the intended location.

13.1.2 Heating elements are to be suitably guarded.

13.1.3 Heating and cooking equipment is to be installed such that adjacent bulkheads and decks are not subjected to excessive heating.

13.2 Lighting – General

13.2.1 Lampholders are to be constructed of flame retarding non-hygroscopic materials.

13.2.2 Lighting fittings are to be so arranged as to prevent temperature rises which overheat or damage surrounding materials. They must not impair the integrity of fire divisions.

13.3 Incandescent lighting

13.3.1 Tungsten filament lamps and lampholders are to be in accordance with Table 2.13.1.

13.3.2 Lampholders of type E40 are to be provided with a means of locking the lamp in the lampholder.

13.4 Fluorescent lighting

13.4.1 Fluorescent lamps and lampholders are to be in accordance with Table 2.13.1.

13.4.2 Fittings, reactors, capacitors and other auxiliaries are not to be mounted on surfaces which are subject to high temperatures. If mounted separately they are additionally to be enclosed in an earthed conductive casing.

13.4.3 Where capacitors of 0,5 microfarads and above are installed, means are to be provided to promptly discharge the capacitors on disconnection of the supply.

Table 2.13.1 Lamps and lampholders

Designation	Maximum lamp rating		Maximum lampholder current, A
	Voltage, V	Power, W	
Screw cap lamps			
E40	250	3000	16
E27	250	200	4
E14	250	15	2
E10	24	—	2
Bayonet cap lamps			
B22	250	200	4
B15d	250	15	2
B15s	55	15	2
Tubular fluorescent lamps			
G13	250	115	—
G5	250	80	—
NOTE Other lamp types are to be in accordance with IEC 60092-306: *Electrical installations in ships - Part 306: Equipment - Luminaires and lighting accessories.*			

13.5 Discharge lighting

13.5.1 Discharge lamps operating in excess of 250 V are only acceptable as fixed fittings. Warning notices calling attention to the voltage are to be permanently displayed at points of access to the lamps and where otherwise necessary.

13.6 Socket outlets and plugs

13.6.1 The temperature rise on the live parts of socket outlet and plugs is not to exceed 30°C. Socket outlets and plugs are to be so constructed that they cannot be readily short-circuited whether the plug is in or out, and so that a pin of the plug cannot be made to earth either pole of the socket outlet.

13.6.2 All socket outlets of current rating in excess of 16 A are to be provided with a switch, and be interlocked such that the plug cannot be inserted or withdrawn when the switch is in the ‘on’ position.

13.6.3 Where it is necessary to earth the non-current carrying parts of portable or transportable equipment, an effective means of earthing is to be provided at the socket outlet.

13.6.4 On weather decks, galleys, laundries, machinery spaces and all wet situations socket outlets and plugs are to be effectively shielded against rain and spray and are to be provided with means of maintaining this quality after removal of the plug.

13.7 Enclosures

13.7.1 Enclosures for the containing and mounting of electrical accessories are to be of metal, effectively protected against corrosion, or of flame retardant insulating materials.

■ *Section 14*
Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts

14.1 General

14.1.1 The installation of electrical equipment in spaces and locations in which flammable mixtures are liable to collect, e.g., areas containing flammable gas or vapour and/or combustible dust, is to be minimised as far as is consistent with operational necessity and the provision of lighting, monitoring, alarm or control facilities enhancing the overall safety of the ship.

14.1.2 In order to eliminate potential sources of ignition from spaces and locations in which flammable mixtures are liable to collect, in accordance with SOLAS 1974 as amended, Chapter II-1, Regulation 45, such dangerous or hazardous areas are to be identified and electrical equipment within these areas is to be selected and installed in accordance with the requirements of this Section.

14.1.3 Equipment that is to be installed in an area where both explosive gases and combustible dusts can be present is to be selected in accordance with both 14.2 and 14.3.

14.1.4 For permanent secondary battery installations, *see* Section 12.

14.2 Selection of equipment for use in explosive gas atmospheres

14.2.1 When equipment is to be installed in areas where an explosive gas atmosphere may be present, it is generally to be of a type providing protection against ignition of the gases encountered and compliant with the relevant Parts of IEC 60079: *Explosive atmospheres*, or an acceptable and relevant National Standard, unless permitted otherwise by 14.2.4, 14.2.5 or 14.2.6.

14.2.2 The equipment protection type permitted depends on the hazardous zone where the equipment is to be located, as defined in 14.5. For certain locations on the ship other requirements may limit installations to specific equipment types and/or particular applications.

14.2.3 Equipment for **zone 0** or **zone 1**, with the exception of simple apparatus as defined in 14.2.4 or 14.2.5, is to be certified or approved by a National or other appropriate authority. Equipment without independent certification or approval may be considered for installation in **zone 2**.

14.2.4 In **zone 0**, the following may be considered:
(a) intrinsically safe, category ‘a’ (Ex ‘ia’); or
(b) simple electrical apparatus and components (for example thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically safe circuits of category ‘ia’, not capable of storing or generating electrical power or energy in excess of the limits given in IEC 60079-14: *Explosive atmospheres — Part 14: Electrical installations design, selection and erection*.

14.2.5 In **zone 1**, the following may be considered:
(a) apparatus permitted within **zone 0**;
(b) intrinsically safe, category ‘b’ (Ex ‘ib’);
(c) simple apparatus as defined above, included in intrinsically safe circuits of category ‘ib’;
(d) increased safety (Ex ‘e’);
(e) flameproof (Ex ‘d’);
(f) pressurised enclosure (Ex ‘p’);
(g) powder filled (Ex ‘q’); or
(h) encapsulated (Ex ‘m’).

14.2.6 In **zone 2**, the following may be considered:
(a) apparatus permitted within **zone 0** or **zone 1**;
(b) type of protection ‘n’ or ‘N’;
(c) equipment such as control panels, protected by purging and pressurisation and capable of being verified by inspection as meeting the requirements of IEC 60079-2: *Explosive atmospheres – Part 2: Equipment protection by pressurized enclosures "p"*or
(d) radio aerials having robust construction, meeting the relevant requirements of IEC 60079-15: *Explosive atmospheres – Part 15: Equipment protection by type of protection "n"*. Additionally, in the case of transmitter aerials, it is to be shown, by detailed study or measurement, or by limiting the peak radiated power and field strength to 1 W and 30 V/m, respectively, that they present negligible risk of inducing incendive sparking in adjacent structures or equipment.

14.2.7 Apparatus having type of protection ‘ia’, ‘ib’, or ‘d’, is to be of a Group (IIA, IIB or IIC) meeting or exceeding that required for safe operation in the presence of any gas or vapour that can be present, or is to be certified specifically for such gases or vapours.

14.2.8 All apparatus is to be of a temperature classification (T1 to T6) that confirms, or is to be assessed so as to confirm, that its maximum surface temperature will not reach the ignition temperature of any gas or vapour, or mixture of gases or vapours, which can be present. The surface temperature considered may be that of an internal or external part, according to the type of protection of the apparatus.

14.2.9 Consideration may also be given to other types of protection, selected in accordance with the requirements of IEC 60079-14: *Explosive atmospheres – Part 14: Electrical installations design, selection and erection* or arrangements complying with IEC 60092-502: *Electrical installations in ships – Part 502: Tankers – Special features*, *see also* 14.10 to 14.12.

14.3 Selection of equipment for use in the presence of combustible dusts

14.3.1 Where apparatus is to be installed in **hazardous areas**, as defined by 14.5.3, associated with the presence of combustible dusts, it is, when practicable, to be of a type certified or approved by a National or other appropriate authority for the dusts and, additionally, any explosive gases encountered.

14.3.2 Electrical equipment for use in such **hazardous areas** is to be so designed and installed as to minimise the accumulation of dust which may interfere with the safe dissipation of heat from the enclosure.

14.3.3 Where apparatus is to be installed in **extended hazardous areas**, as defined by 14.5.3, associated with the presence of combustible dust, the following may be considered:
(a) apparatus permitted within a hazardous area associated with the combustible dust(s) that can be present;
(b) apparatus having degree of protection IP5X, or better, and having a surface temperature under normal operating conditions not exceeding the auto-ignition temperature of the dust(s) that can be present; and
(c) apparatus of a type which ensures absence of sparks or arcs and hot spots during normal operation.

14.3.4 Where equipment certified for combustible dusts is not available, consideration will be given to the use of apparatus complying as a minimum, with the following requirements provided no explosive gases will be present:
(a) the enclosure is to be at least dust protected (IP5X) having, when type tested, an ingress of fine dust within the enclosure not exceeding 10 g per m^3 of free air space, and
(b) the surface temperature of the apparatus, under the most onerous combination of normal operating conditions, but in the absence of a dust layer, is not to exceed two-thirds of the minimum ignition temperature in degrees Celsius of the dust/air mixture(s) that can be present, or
(c) the equipment is to be certified intrinsically safe having a temperature classification ensuring compliance with (b), or
(d) pressurised and operated in accordance with procedures ensuring, prior to its re-energisation, the absence of dust within the enclosure following loss of pressurisation and consequent shut-down, and having surface temperature complying with (b), or
(e) simple apparatus included in intrinsically safe circuits or radio aerials, complying with 14.2.5 or 14.2.6 respectively.

14.3.5 Consideration may also be given to arrangements complying with IEC 60092-506: *Electrical Installation in ships – Part 506: Special features – Ships carrying specific dangerous goods and materials hazardous only in bulk*.

14.4 Installation of electrical equipment

14.4.1 The method of installation and application of electrical equipment suitable for use in explosive gas atmospheres or in the presence of combustible dusts is to be in accordance with IEC 60079-14: *Explosive atmospheres – Part 14: Electrical installations design, selection and erection*, or the national code of practice relevant to the standard with which the equipment complies. The ambient temperature range for which the apparatus is certified is to be taken to be –20°C to 40°C, unless otherwise stated, and account is to be taken of this when assessing the suitability of the equipment for the auto-ignition temperature of the gases and dusts encountered. Any special requirements laid down by the equipment certification documentation are also to be observed.

14.4.2 All switches and protective devices from which equipment located in hazardous zones or spaces is supplied are to interrupt all poles or phases and, where practicable are to be located in a non-hazardous zone or space. Such equipment, switches and protective devices are to be suitably labelled for identification purposes.

14.5 Hazardous zones and spaces

14.5.1 Hazardous zones or spaces and sources of hazard for ships intended for the carriage in bulk of oil, liquefied gases and other hazardous substances, the requirements for ships carrying vehicles with fuel in their tanks and the requirements for ships with spaces for storing paint, are defined (either directly, or by reference to other documents) in 14.10 to 14.15.

14.5.2 Hazardous areas associated with flammable liquids or gases are classified into zones based upon the frequency of the occurrence and duration of an explosive gas atmosphere, as follows:

- **zone 0**: place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is present continuously or for long periods or frequently
- **zone 1**: place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally
- **zone 2**: place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

See IEC 60079-10-1: *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*.

14.5.3 Hazardous areas associated with solid substances or packaged liquids to which 14.14 applies are classified into zones based upon the frequency of the occurrence and duration of an explosive atmosphere due to the presence of gas and/or dust, as follows:

- **hazardous area**: area in which an explosive atmosphere is likely to occur in normal operation (comparable with **zone 1**)
- **extended hazardous area**: area in which an explosive atmosphere is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only (comparable with **zone 2**).

See IEC 60079-10-2: *Explosive atmospheres — Part 10-2: Classification of areas – Combustible dust atmospheres*, or IEC 60092-506: *Electrical Installation in ships – Part 506: Special features – Ships carrying specific dangerous goods and materials hazardous only in bulk*. An explosive atmosphere may exist due to gas and/or dust.

14.5.4 The following principles are to apply in general, and where any specific arrangement does not fall into any of the categories covered by 14.10 to 14.15.

14.5.5 A hazardous zone or space may arise from the presence of any of the following:

(a) spaces or tanks containing either:
  (i) flammable liquid having a flashpoint (closed-cup test) not exceeding 60°C;
  (ii) flammable liquid having a flashpoint exceeding 60°C, heated or raised by ambient conditions to a temperature within 15°C of its flashpoint; or
  (iii) flammable gas;
(b) piping systems or equipment containing fluid defined by (a) and having flanged joints or glands or other openings through which leakage of fluid may occur under normal operating conditions;
(c) spaces containing solids, such as coal or grain, liable to release flammable gas and/or combustible dust;
(d) spaces containing dangerous goods in packaged form, of the following Classes as defined in the IMDG Code: 1 (with the exception of goods in division 1.4, compatibility group S), 2.1 (inclusive of applicable gas bottles for on board use), 3, 6.1 and 8;
(e) piping systems or equipment associated with processes (such as electrochlorination) generating flammable gas as a by-product and having openings from which the gas may escape under normal operating conditions; or
(f) piping systems or equivalent containing flammable liquids not defined by (a), having flanged joints, glands or other openings through which leakage of fluid in the form of a mist or fine spray may occur under normal operating conditions.

14.5.6 The following zones or spaces are regarded as hazardous, **zone 0**:

(a) the interiors of those spaces, tanks, piping systems and equipment defined by 14.5.5(a) and (b); and
(b) enclosed, unventilated spaces containing pipework or equipment defined by 14.5.5(b) and (e).

14.5.7 The following zones or spaces are regarded as hazardous, **zone 1**:
(a) unventilated spaces separated by a single bulkhead or deck from a cargo defined by 14.5.5(a);
(b) ventilated spaces containing pipework or equipment defined by 14.5.5(b) and (e);
(c) zones within a 1,5 m radius of ventilation outlets, hatches or doorways or other openings into spaces defined by (a) or (b), or within 1,5 m of the ventilation outlets of spaces regarded by 14.7 as open areas and which contain the pipework or equipment defined by 14.5.5(b) or (e). Where the hazard results from flammable gas or vapour having a density relative to that of air of more than 0,75, the hazardous zone is considered to extend vertically downward to solid deck, or for a distance of 9 m, whichever is the lesser;
(d) zones on open deck, or semi-enclosed spaces on open deck, within 3 m of the ventilation outlets of cargo tanks defined in 14.5.5 (a), which permit the flow of small volumes of vapour or gas mixtures caused by thermal variation;
(e) zones within a 1,5 m radius of flanged joints, or glands or other openings defined by 14.5.5(b); in the case of gas or vapour having a relative density of more than 0,75, the hazardous zone is considered to extend vertically downwards as described under (c);
(f) zones within a 1,5 m radius of flanged joints, or glands or other openings defined by 14.5.5(e) and (f);
(g) zones within a 1,5 m radius of bunds or barriers intended to contain spillage of liquids defined by 14.5.5(a);
(h) zones on open deck within a 1,5 m radius of any opening into a space defined by (a); and
(j) enclosed or semi-enclosed spaces with direct opening into a **zone 1** hazardous location.

14.5.8 The following zones or spaces are regarded as hazardous, **zone 2**:
(a) ventilated spaces separated by a single bulkhead or deck from a **zone 0** space;
(b) zones on open deck extending 1,5 m beyond those defined by 14.5.7(c), (d), (e), (f), (g) or (h);
(c) zones on open deck extending 2 m beyond those defined by 14.5.7(d);
(d) zones within a 1,5 m radius of ventilation inlets serving spaces defined by 14.5.7(b); and
(e) enclosed or semi-enclosed spaces with direct opening into a **zone 2** hazardous location.

14.6 Semi-enclosed spaces

14.6.1 Semi-enclosed spaces are considered to be spaces limited by decks and/or bulkheads in such a manner that the natural conditions of ventilation are sensibly different from those obtained on open deck.

14.7 Ventilation

14.7.1 Where an enclosed or semi-enclosed space is provided with mechanical ventilation ensuring at least 12 air changes/hour, and leaving no areas of stagnant air, it may be regarded in consideration of hazardous zones as would otherwise be defined by 14.5.6(b), 14.5.7(b) or (h) and 14.5.8(d), as an open area.

14.7.2 Where the rate of ventilation air flow, in relation to the maximum rate of release of flammable substances reasonably to be expected under normal conditions, is sufficient to prevent the concentration of flammable substances approaching their lower explosive limit, consideration may be given to regarding as non-hazardous, the space, ventilation and other openings into it, and the zone around the equipment contained within.

14.7.3 An alarm is to be provided on the navigating bridge, engine control room, and where applicable, cargo control room to indicate any loss of the required ventilation capacity.

14.8 Pressurisation

14.8.1 A space having access to a hazardous space or zone defined as **zone 1** or **zone 2** may be regarded as non-hazardous if fulfilling all the following conditions:
(a) access is by means of an air-lock, having gastight steel doors, the inner of which as a minimum, is self-closing without any hold-back arrangement;
(b) it is maintained at an overpressure relative to the external hazardous area by ventilation from a non-hazardous area;
(c) the relative air pressure within the space is continuously monitored and so arranged that, in the event of loss of overpressure, an alarm is given and the electrical supply to all equipment not of a type suitable for **zone 1** is automatically disconnected. Where the shut-down of equipment could introduce a hazard, an alarm may be given, in lieu of shutdown, upon loss of overpressure, and a means of disconnection of electrical equipment not of a type suitable for **zone 1**, capable of being controlled from an attended station, provided in conjunction with an agreed operational procedure; where the means of disconnection is located within the space then it is to be effected by equipment of a type suitable for **zone 1**;
(d) any electrical equipment required to operate upon loss of overpressure, lighting fittings (*see* 5.7.3) and equipment within the air-lock, is to be of a type suitable for **zone 1**; and
(e) means are to be provided to prevent electrical equipment, other than of a type suitable for **zone 1**, being energised until the atmosphere within the space is made safe, by air renewal of at least 10 times the capacity of the space.

14.8.2 A space having access to a hazardous space or zone defined as **zone 2** may be regarded as non-hazardous if fulfilling all the following conditions:
(a) access is by means of a self-closing gastight steel door without any hold-back arrangement;

(b) it is maintained at an overpressure relative to the external hazardous area by ventilation from a non-hazardous area;
(c) the relative air pressure within the space is continuously monitored and so arranged that, in the event of loss of overpressure, an alarm is given. A means of disconnection of electrical equipment not of a type suitable for **zone 2** is to be provided; where the means of disconnection is located within the space then it is to be effected by equipment of a type suitable for **zone 2**;
(d) any electrical equipment required to operate upon loss of overpressure (e.g., lighting fittings, *see* 5.7.3), is to be of a type suitable for **zone 2**.

14.9 Cable and cable installation

14.9.1 Electric cables are not, as far as is practicable, to be installed in hazardous zones or spaces, except where serving equipment installed within the zone or space. Through runs of cable may be accepted in locations classified as **zone 1** or **zone 2**, where alternative routes are impracticable.

14.9.2 In addition to the requirements of Section 11, cables for circuits that are not intrinsically safe, which are located in hazardous zones or spaces, or which may be exposed to cargo oil, oil vapour or gas, are to be either:
(a) mineral insulated with copper sheath, or
(b) armoured or braided for earth detection.
(c) otherwise adequately protected against mechanical or chemical damage, within **zone 2** or non-hazardous locations only, or
(d) as otherwise specifically permitted elsewhere within this Section.

14.9.3 Armouring, braiding and other metal coverings of cables installed in dangerous zones or spaces are to be effectively earthed at least at both ends.

14.9.4 Where there is risk of intermittent contact between armour and exposed metalwork, non-metallic impervious sheath is to be applied over metallic armour of cables.

14.9.5 Cables associated with intrinsically safe circuits are to be used only for such circuits. They are to be physically separated from cables associated with non-intrinsically safe circuits, e.g., neither installed in the same protective casing nor secured by the same fixing clip. Consideration may be given to other arrangements complying with IEC 60079-14, *Explosive atmospheres — Part 14: Electrical installations design,selection and erection*.

14.9.6 In **zone 0**, cable joints may only be used in intrinsically safe circuits.

14.9.7 Cable runs in **zone 1** or **zone 2** are, where practicable, to be uninterrupted. Where discontinuities cannot be avoided, cable joints are, additionally, to:
- be made in an enclosure with a type of protection appropriate to the location; or
- provided the joint is not subject to mechanical stress, be epoxy filled, compound-filled or sleeved with heat-shrunk tubing, in accordance with the manufacturer's instructions.

14.10 Requirements for tankers intended for the carriage in bulk of oil cargoes having a flash point not exceeding 60°C (closed-cup test)

14.10.1 In order to eliminate potential sources of ignition from hazardous areas on board tankers in accordance with SOLAS 1974 as amended, Chapter II-1, Regulation 45.11, electrical equipment is to be selected and installed in accordance with IEC 60092: *Electrical installations in ships – Part 502: Tankers – Special features*.

14.10.2 The relevant group and temperature class for electrical equipment in hazardous zones are, respectively, IIA and T3.

14.11 Requirements for ships for the carriage of liquefied gases in bulk

14.11.1 *See* Chapter 10 of the Rules for Ships for Liquefied Gases.

14.12 Requirements for ships intended for the carriage in bulk of other flammable liquid cargoes

14.12.1 *See* Chapter 10 of the Rules for Ships for Liquid Chemicals.

14.13 Special requirements for ships with spaces for carrying vehicles with fuel in their tanks, for their own propulsion

14.13.1 **Passenger ships with special category spaces above the bulkhead deck for carrying vehicles**:
(a) electrical equipment fitted within a height of 45 cm above the vehicle deck, or any platform on which vehicles are carried, or within the exhaust ventilation trunking for the space, is to be of a type acceptable for **zone 1**;
(b) electrical equipment situated elsewhere within the space is to be of a type acceptable for **zone 2**, or is to have an enclosure of ingress protection rating of at least IP55, *see* IEC 60529: *Degrees of protection provided by enclosures (IP Code)*. Smoke and gas detector heads are exempt from this requirement.

14.13.2 **Passenger ships with special category spaces below the bulkhead deck for carrying vehicles**: electrical equipment fitted within the space and within the exhaust ventilation trunking for the space, is to be of a type acceptable for **zone 1**.

14.13.3 **Passenger ships with cargo spaces, other than special category spaces, for carrying vehicles**:
(a) electrical equipment within such a cargo space, or within the exhaust ventilation trunking for the space, is to be of a type acceptable for **zone 1**;

(b) all electrical circuits terminating in the cargo space are to be provided with multipole linked isolating switches located outside the cargo hold. Provision is to be made for locking in the off position. This does not apply to safety circuits such as those for fire, smoke or gas detection.

14.13.4 **Cargo ships with closed ro-ro cargo spaces for carrying vehicles**:

(a) except where exempted by (b) electrical equipment fitted within the space and within the exhaust ventilation trunking for the space is to be of a type acceptable for **zone 1**;

(b) where the ventilation system required by SOLAS 1974 as amended, Chapter II-2, Regulation 20.3.1.1.1 is arranged to operate continuously and is sufficient to provide at least ten air changes per hour, whenever vehicles are on board, above a height of 45 cm from the vehicle deck, or any platform on which vehicles are carried, electrical equipment is to be of a type acceptable for **zone 2**, or is to have an enclosure of ingress protection rating of at least IP 55;

(c) all electrical circuits terminating in the cargo space are to be provided with multipole linked isolating switches located outside the cargo hold. Provision is to be made for locking in the off position. This does not apply to safety circuits such as those for fire, smoke or gas detection.

14.14 Special requirements for ships intended for the carriage of dangerous goods and materials hazardous only in bulk

14.14.1 In order to eliminate potential sources of ignition in enclosed cargo spaces or vehicle spaces in accordance with SOLAS 1974 as amended, Chapter II-2, Regulation 19.3.2, and from associated hazardous areas (*see* 14.5.3), electrical equipment is to be selected in accordance with 14.14.2 and 14.14.3 and installed in accordance with 14.4 and 14.14.4 to 14.14.7.

14.14.2 Electrical equipment essential for the safety and operation of the ship is to be of a type providing protection against ignition of the gases and/or dusts that can be present, selected in accordance with IEC 60092-506: *Electrical installations in ships – Part 506: Special features – Ships carrying specific dangerous goods and materials hazardous only in bulk*.

14.14.3 In addition to the requirements of IEC 60092-506: *Electrical installations in ships – Part 506: Special features – Ships carrying specific dangerous goods and materials hazardous only in bulk*, pipes such as ventilation and bilge pipes having ends opening into a hazardous area are to be considered a hazardous area. Enclosed spaces such as pipe tunnels and bilge pump-rooms containing such pipes and with equipment and components such as pumps, valves and flanges are to be considered as extended hazardous areas unless protected by overpressure.

14.14.4 Electrical equipment not essential for the safety or operation of the ship and which is not of a type providing protection against ignition of the gases and/or dusts that can be present is to be completely disconnected and protected against unauthorised re-connection. Disconnection is to be made outside the hazardous areas and be effected with isolating links or lockable switches.

14.14.5 Electrical equipment and all cables, including through runs and terminating cables, are to be protected against mechanical damage. Cables are to be either enclosed in screwed heavy gauge steel drawn or seam-welded and galvanised conduit, or protected by electrically continuous metal sheathing or metallic wire armour braid or tape.

14.14.6 Cable penetrations of decks and bulkheads are to be sealed against the passage of gas or vapour.

14.15 Requirements for ships with spaces for storing paint

14.15.1 In order to eliminate potential sources of ignition in paint stores, electrical equipment is to be selected as follows:

(a) electrical equipment fitted within the space and within the exhaust ventilation trunking for the space is to be of a type acceptable for **zone 1**;

(b) electrical equipment situated within 1 m of inlet and exhaust ventilation openings or within 3 m of exhaust mechanical ventilation outlets is to be of a type acceptable for **zone 2**, or is to have an enclosure of ingress protection rating of at least IP55, *see* IEC 60529, *Classification of Degrees of Protection Provided by Enclosures*. *See* 1.11.1 for degrees of protection required for equipment on open deck.

14.15.2 A space having access to a paint store may be regarded as non-hazardous if fulfilling all of the following conditions:

(a) access is by means of a self-closing gastight steel door without any hold-back arrangement;

(b) the paint store is ventilated from a non-hazardous area and;

(c) warning notices are fitted adjacent to the paint store entrance warning of flammable liquids contained in paint store.

NOTE

A watertight door may be considered as being gastight.

14.15.3 The relevant group and temperature class for electrical equipment in hazardous zones are, respectively, IIB and T3.

Section 15
Navigation and manoeuvring systems

15.1 Steering gear

15.1.1 The requirements of 15.1.2 to 15.1.7 are to be read in conjunction with those in Pt 5, Ch 19,5.

15.1.2 Two exclusive circuits, fed from the main source of electrical power and each having adequate capacity to supply all the motors which may be connected to it simultaneously are to be provided for each electric or electrohydraulic steering gear arrangement consisting of one or more electric motors. One of these circuits may pass through the emergency switchboard, *see also* Pt 5, Ch 19,6.

15.1.3 The main and auxiliary steering gear motors are to be capable of being started from a position on the navigating bridge and also arranged to restart automatically when power is restored after a power failure.

15.1.4 The motor of an associated auxiliary electric or electrohydraulic power unit may be connected to one of the circuits supplying the main steering gear.

15.1.5 Only short-circuit protection is to be provided for each main and auxiliary steering gear motor circuit.

15.1.6 In ships of less than 1600 gross tonnage, if an auxiliary steering gear is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering gear may be fed by one circuit from the main switchboard. Consideration would be given to other protective arrangements other than described in 15.1.5 for such a motor primarily intended for other services.

15.1.7 Each main and auxiliary steering gear electric control system which is to be operated from the navigating bridge is to be served with electric power by a separate circuit supplied from the associated steering gear power circuit, from a point within the steering gear compartment, or directly from the same section of switchboard busbars, main or emergency, to which the associated steering gear power circuit is connected. Each separate circuit is to be provided with short-circuit protection only.

15.2 Thruster systems for steering

15.2.1 Where azimuth or rotatable thruster units, used as the sole means of steering, are electrically driven the requirements of Pt 5, Ch 20,5.1 are to be complied with.

15.3 Thruster systems for dynamic positioning

15.3.1 For ships having a **DP** notation the requirements of Pt 7, Ch 4 are to be complied with.

15.4 Thruster systems for manoeuvring

15.4.1 Where a thruster unit is fitted solely for the purpose of manoeuvring, and is electrically driven, its starting and operation is not to cause the loss of any essential services.

15.4.2 In order to ensure that the thruster system is not tripped inadvertently whilst manoeuvring the ship, overload protection in the form of an alarm is to be provided for the electric motor and any associated supply converters, in lieu of tripping.

15.4.3 The thruster unit electric motor is not to be disconnected as part of a load management switching operation.

15.5 Transverse thrust units

15.5.1 Where transverse thrust units are remotely controlled, means are to be provided at the remote control station to stop the propulsion unit.

15.5.2 Transverse thrust units are to be provided with indications of direction and magnitude of thrust and propeller pitch at each station from which it is possible to control justify the propeller pitch.

15.6 Navigation lights

15.6.1 Navigation lights are to be connected separately to a distribution board reserved for this purpose only and accessible to the officer of the watch. This distribution board is to be connected directly or through transformers to the emergency source of electrical power in compliance with, for passenger ships, 3.2.7(b) and 3.2.9(a) or, for cargo ships, 3.3.7(c) and 3.3.9(a). An alarm is to be activated in the event of failure of a power supply from the distribution board.

15.6.2 Each navigation light is to be controlled and protected in each insulated pole by a switch and fuse or circuit-breaker mounted on the distribution board.

15.6.3 Provision is to be made on the navigating bridge for the navigation lights to be transferred to an alternative circuit fed from the main source of electrical power.

15.6.4 Each navigation light is to be provided with an automatic indicator giving audible and/or visual indication of failure of the light. If an audible device alone is fitted, it is to be connected to an independent source of supply, e.g., a battery, with means provided to test this supply. If a visual signal is used connected in series with the navigation light, means are to be provided to prevent extinction of the navigation light due to failure of the signal. The requirements of this paragraph do not apply to tugs, trawlers and similar small vessels.

15.6.5 For navigation lights using light emitting diodes (consisting of multiple light sources) means to ensure that the overall luminous intensity of the navigation light is sufficient are to be provided in addition to the alarm to indicate the complete loss of the navigation light illumination required by 15.6.4. For replacement navigation lights, *see* 1.5.5.

15.6.6 To satisfy 15.6.5, an audible and visual alarm is to be activated to notify the Officer of the Watch when the luminous intensity of the light reduces below the level required by the IMO *Convention on the International Regulations for Preventing Collisions at Sea*. Alternative measures to ensure continuing acceptable performance of navigation lights using light emitting diodes may be considered that are in accordance with:

- IMO Res. MSC.253(83), *Performance Standards for Navigation Lights, Navigation Light Controllers and associated Equipment*, and
- EN 14744, *Inland navigation vessels and sea-going vessels – Navigation light*, or a relevant National or International Standard.

Where alternative measures are proposed that require verification by personnel of the luminous intensity of navigation lights using light emitting diodes, details of the inspection implementation in the ship's safety management system and acceptance by the National Administration are to be submitted for consideration.

15.6.7 Navigation light power supply units installed to convert, control and/or monitor the distribution board power supply required by 15.6.1 above for connection to the light source(s) (e.g., for LED type navigation lights) are, in the event of a short-circuit on the unit output, to disconnect or limit the supply to prevent further damage and activate an alarm.

15.6.8 Navigation light power supply units are to be self-checking, detecting failures of the unit itself and activating an alarm. These are to include:

- detection of system lock-ups (program hangs);
- means to detect failure of navigation light switching command input circuits or links; and
- means to detect failure of the navigation light monitoring arrangements required to provide the alarms required by 15.6.4 and 15.6.5, as applicable.

15.6.9 The navigation light power supply failure alarms required by 15.6.1 are not to be displayed as a group alarm. Other navigation light alarms may be grouped for each navigation light where means are provided for personnel to determine the cause of the alarm. Activation of more than one of the navigation light alarms as a result of a single failure is to be prevented.

15.6.10 Any statutory requirements of the country of registration are to be complied with and may be accepted as an alternative to the above.

15.7 Navigational aids

15.7.1 Navigational aids as required by SOLAS are to be fed from the emergency source of electrical power, *see also* 3.2.7(c)(ii) and 3.3.7(d)(ii).

15.7.2 For ships having a notation **NAV 1** navigational aids are to have an alternative supply fed from the main source of electrical power, independent of the emergency switchboard, with automatic changeover facilities.

■ *Section 16* **Electric propulsion**

16.1 General

16.1.1 Where the arrangements permit a propulsion motor to be connected to a generating plant having a continuous rating greater than the motor rating, means are to be provided to limit the continuous input to the motor to a value not exceeding the continuous full load torque for which the motor and shafts are approved.

16.1.2 The ventilation and cooling systems for electrical propulsion equipment are to be provided with monitoring devices arranged to operate an alarm if the temperature of the heated cooling medium exceeds a predetermined safe value.

16.1.3 The embedded temperature detectors required by 9.1.10 are to be arranged to operate an alarm if the temperature exceeds a predetermined safe value.

16.1.4 Propulsion motors, generators and converters are to be provided with means to prevent the accumulation of moisture and condensate when operating at low power levels, or when idle.

16.2 System design and arrangement

16.2.1 In general, for a ship to be assigned an unrestricted service notation, it is to have two independently driven propellers or other propulsion devices, each connected with at least one electric motor, where these form the sole means of propulsion.

16.2.2 For vessels where a propulsion device driven by electric motors is proposed as the sole means of propulsion, at least two effective, independent electric propulsion motors are to be provided and the system is to be designed in accordance with Pt 7, Ch 14. The risk management is to identify components where a failure could cause loss of propulsion power or other essential services and the proposed arrangements for preventing and mitigating the effects of such a failure.

16.3 Power requirements

16.3.1 The propulsion system is to have sufficient power for manoeuvring the ship and for going astern. With the ship travelling at maximum service speed the propulsion equipment is to be capable of stopping and reversing the ship in an agreed time.

16.3.2 The propulsion system is to have adequate torque and power margins for all operating conditions including manoeuvring and rough weather with due regard to propeller and ship characteristics.

16.3.3 The electric power for the propulsion system may be derived from generating sets dedicated to propulsion duty or from a central power generation plant which serves both propulsion and ship service loads.

16.3.4 Where propulsion power is derived from a central, common, power plant the control system is to ensure a safe distribution of power between propulsion and ship services, with tripping of non-essential loads and/or reduction in propulsion power if necessary.

16.3.5 Where a central power generation system is employed the number and rating of generator sets is to be such that with one set out of action the remaining sets are capable of providing all essential and normal ship service loads whilst maintaining an effective level of propulsion power.

16.3.6 Where, in a central power generation system, the electrical power requirements are normally supplied by two or more generating sets operating in parallel, on sudden loss of power from one set, the rating of the remaining set(s) in service is to be sufficient to ensure uninterrupted operation of essential services and an effective level of propulsion power.

16.3.7 Where a central power generation system is employed, means are to be provided to connect available generator sets to meet the power requirement of the electric propulsion system. Arrangements are to be in place to prevent generator sets being automatically disconnected during ship manoeuvres.

16.3.8 Where forced cooling is used on propulsion motors it is to be possible to operate the motor at a defined reduced power level in the event of failure of the forced cooling.

16.3.9 Total harmonic distortion of the a.c. voltage waveform up to 10 per cent on electric propulsion circuits, not directly connected to the main source of electrical power, may be considered where details are submitted which demonstrate that the equipment and systems are capable of operating under such conditions.

16.4 Propulsion control

16.4.1 Propulsion control systems are to be stable throughout their normal operating range and arranged to attenuate any effects of cyclic propeller load fluctuations caused by wave action.

16.4.2 Step-less control of propeller speed, and/or pitch, from zero to full power ahead or astern is to be provided.

16.4.3 The control system is to ensure that there is no dangerous overspeeding of propulsion motors upon loss of load.

16.4.4 Interlocks are to be provided in the control system to ensure that ahead and astern circuits are not energised simultaneously.

16.4.5 Any single fault in either the propulsion machine excitation or power distribution systems is not to result in a total loss of propulsion power.

16.4.6 Control, alarm and safety systems for the propulsion system are to satisfy the requirements of Chapter 1.

16.4.7 Each control station is to be provided with an emergency stop function for the propulsion motors. The emergency stop function is to be independent of the normal control system.

16.4.8 The control system is to limit the propulsion power if the power available from the generator(s) is not sufficient to supply the demand level of propulsion power. In the event of a power limitation, there is to be a visual indication at the control stations.

16.4.9 Means are to be provided to identify the cause of propulsion motor power limitation or automatic reduction (e.g., excessive load torque, cooling failure, high temperature, power availability).

16.4.10 Local controls are to be provided, independent of any remote or automatic system, to permit effective control of the propulsion equipment.

16.4.11 Control systems are not to share hardware or data communication links with control, safety and alarm systems not associated with propulsion control, *see also* Ch 1,2.11.

16.5 Protection of propulsion system

16.5.1 Provision is to be made for protection against severe overloads, and electrical faults likely to result in damage to plant.

16.5.2 Propulsion motors are to be capable of withstanding, without damage, the thermal and mechanical effects of a short-circuit at the terminals.

16.5.3 Electric motors of podded propulsion units, and/or having permanent magnet excitation, are to be provided with a protective device which, in the event of a short-circuit in the motor or in the cables between the motor and its circuit-breaker, will instantaneously open the circuit-breaker and, in motors with electromagnetic excitation, de-excite the motor. Motors with permanent magnet main excitation are to be provided with means to prevent further damage as a result of continued rotation after disconnection (e.g., shaft brake).

16.5.4 Safeguards for protecting propulsion equipment against damage resulting from earth faults are to be as specified by the equipment manufacturer. Where the fault current flowing is liable to cause damage to the electrical equipment there are to be arrangements for interrupting the current automatically.

16.5.5 For the protection of electrical equipment and cables against overvoltages means are to be provided for limiting the induced voltage when field windings, and other inductive circuits are opened. Protective resistors and devices are to be sized to cater for the likely extreme operating conditions.

16.5.6 An alarm is to be initiated when the excitation system of electric generators providing propulsion power is overloaded such that damage due to heating could occur in the generator or its cabling.

16.5.7 Where, on stopping or reversing the propeller, regenerated energy is produced by the propulsion motor this is not to cause a dangerous increase of speed in the prime mover or a dangerous overvoltage condition on the supply system. Where a central power generation system is used then the voltage and frequency fluctuations are not to exceed the limits given in 1.8.

16.5.8 Dynamic braking resistors are to be suitably rated for their expected operation.

16.5.9 Propulsion converters are to be capable of withstanding, without damage, the thermal and mechanical effects of a short-circuit at the terminals or connection to a propulsion motor with a stalled or locked rotor.

16.5.10 Loss of flow of air or liquid cooling of propulsion converters, where used, is to initiate an alarm at an attended control position. Loss of flow of air or liquid cooling is not to result in immediate damage to the propulsion converter, *see* 10.2.4.

16.5.11 Alarms and safeguards for electric propulsion equipment are indicated in Table 2.16.1.

Table 2.16.1 Electric propulsion equipment: Alarms and safeguards

Item	Alarm	Note
Electric propulsion equipment ventilation and cooling medium temperature	High	*See* 16.1.2 and 16.3.8
Electric propulsion transformer winding temperature	High	*See* 10.1.11
Electric propulsion generator excitation	Overload	*See* 16.5.6
Electric propulsion generators and motors winding temperature	High	*See* 16.1.3
Electric propulsion generator and motor bearing temperature	High	*See* 9.1.11
Electric propulsion generator and motor lubricating oil supply pressure	Low	*See* 9.1.12
Electric propulsion generator and motor lubricating oil temperature	High	*See* 9.1.13

16.6 Instruments

16.6.1 The main control station is to be provided with the following instruments:

(a) a.c. systems:
- (i) an ammeter for each generator, propulsion motor and propulsion transformer primary; voltmeter, wattmeter and frequency meter for each generator and ammeter for each excitation circuit; and
- (ii) a temperature indicator for each generator, propulsion transformer and propulsion motor windings and bearings, the indicator is to read stator winding temperature of the rotating machines and cooling system temperature.

(b) d.c. systems:
- (i) a voltmeter and ammeter for each generator and propulsion motor; and
- (ii) an ammeter for each excitation circuit.

16.6.2 Each control station is to be provided with instruments to indicate:

(a) propeller speed;
(b) direction of rotation for a fixed pitch propeller or pitch position for a controllable pitch propeller;
(c) visual indication of power limitation; and
(d) indication of station in control.

■ *Section 17* Fire safety systems

17.1 Fire detection and alarm systems

17.1.1 Fire detection and alarm systems are to comply with Chapter 9 of the *Fire Safety Systems Code* (FSS Code) and 17.1.2 to 17.1.10.

17.1.2 Fire detection and alarm systems are to be provided with at least two power supplies. One supply is to be connected to the main source of electrical power and another supply is to be connected to the emergency source of electrical power required by 3.2 or 3.3, or an accumulator battery capable of supplying power for the same period of time as the emergency source of electrical power. All power supply feeders for fire detection and alarm systems are to be in accordance with 11.6.4.

17.1.3 Automatic changeover facilities in accordance with 5.3.5 are to be located in, or adjacent to, the main fire-control panel. Power supply changeover is to be achieved without adverse effect. Failure of any power supply is to operate an audible and visual alarm. *See also* 1.14 and 1.16.

17.1.4 Where an accumulator battery provides a power supply, on restoration of the main source of electrical power, the rating of the charge unit is to be sufficient to recharge the battery while maintaining the output supply to the fire detection and alarm system.

17.1.5 Power supplies from the main and emergency switchboards are to be supplied by separate feeders that are reserved solely for this purpose. Where the emergency feeder for the electrical equipment used in the operation of the fixed fire detection and alarm system is supplied from the emergency switchboard, it is to be run from this switchboard to the automatic changeover switch without passing through any other switchboard.

17.1.6 A loop circuit of an addressable fire detection system, capable of remotely identifying from either end of the loop each detector and manually operated call point served

by the circuit, may serve spaces on both sides of the ship and on several decks, but is not to be situated in more than one main vertical or horizontal fire zone, nor is a loop circuit which covers an accommodation space, service space and/or control station to include a machinery space of Category A.

17.1.7 A loop circuit of an addressable fire detection system may comprise one or more sections. Where the loop comprises more than one section, the sections are to be separated by devices which will ensure that, if a short-circuit occurs anywhere in the loop, only the affected section will be isolated from the control panel. No section of detectors and manually operated call points is in general to include more than 50 detectors.

17.1.8 Where the fire detection system does not include means of remotely identifying each detector and manually operated call point individually, no section covering more than one deck within accommodation, service spaces and control stations is normally to be permitted except a section which covers an enclosed stairway. The number of enclosed spaces in each section is to be limited to the minimum considered necessary in order to avoid delay in identifying the source of fire. In no case are more than fifty spaces permitted in any section.

17.1.9 A section of fire detectors and manually operated call points is not to be situated in more than one main vertical zone.

17.1.10 The wiring for each section of detectors and manually operated call points in an addressable fire detector system is to be separated as widely as practicable from that of all other sections on the same loop. Where practicable no loop is to pass through a space twice. When this is not practicable, such as in large public spaces, the part of the loop which by necessity passes through the space for a second time is to be installed at the maximum possible distance from other parts of the loop.

17.2 Automatic sprinkler system

17.2.1 Any electrically driven power pump, provided solely for the purpose of continuing automatically the discharge of water from the sprinklers, is to be brought into action automatically by the pressure drop in the system before the standing fresh water charge in the pressure tank is completely exhausted.

17.2.2 For **passenger ships**, electrically driven sea-water pumps for automatic sprinkler systems are to be served by not less than two circuits reserved solely for this purpose, one fed from the main source of electrical power and one from the emergency source of electrical power. Such feeders are to be connected to an automatic changeover switch situated near the sprinkler pump and the switch is to be normally closed to the feeder from the main source of electrical power. No other switches are permitted in the feeders. The switches on the main and emergency switchboards are to be clearly labelled and normally kept closed.

17.2.3 The automatic alarm and detection system is to be fed by exclusive feeders from two sources of electrical power, one of which is to be an emergency source, with automatic changeover facilities located in, or adjacent to, the main alarm and detection panel.

17.2.4 Feeders for the sea-water pump and the automatic alarm and detection system are to be arranged so as to avoid galleys, machinery spaces and other enclosed spaces of high fire risk, except in so far as it is necessary to reach the appropriate switch boards. The cables are to be of a fire resistant type where they pass through such high risk areas.

17.3 Fixed water-based local application fire-fighting systems

17.3.1 Where fixed water-based local application fire-fighting system pressure sources are reliant on external power they need only be supplied by the main source of electrical power.

17.3.2 The fire detection, control and alarm systems are to be provided with an emergency source of electrical power required by 3.2 or 3.3 and are also to be connected to the main source of electrical power. Separate feeders, reserved solely for this purpose, with automatic changeover facilities located in, or adjacent to, the main control panel are to be provided.

17.3.3 Failure of any power supply is to operate an audible and visual alarm. *See also* 1.14 and 1.15.

17.3.4 Means to activate a system are to be located at easily accessible positions inside and outside the protected space. Arrangements inside the space are to be situated such that they will not be cut off by a fire in the protected areas and are suitable for activation in the event of escape. Where it is proposed to install local activation means outside of the protected space, details are to be submitted for consideration.

17.3.5 For the electrical safety of electrical and electronic equipment in areas protected by fixed water-based local application fire-fighting systems and adjacent areas where water may extend, the requirements of 17.3.6 to 17.3.10 apply.

17.3.6 As far as is practicable, electrical and electronic equipment is not to be located within protected areas or adjacent areas. The system pump, its electrical motor and the sea valve if any, may be in a protected space provided that they are outside areas where water or spray may extend.

17.3.7 High voltage equipment and their enclosures are not to be installed in protected areas or adjacent areas. For high voltage generators enclosures which cannot be fully located outside of adjacent areas due to close proximity, a technical justification, including proposed degree of protection ratings that are normally not to be lower that IP54, may be submitted for consideration that demonstrates the overall safety of the installation in the event of system operation.

17.3.8 In addition to the degree of protection requirements of 1.11.1, electrical and electronic equipment enclosures located within protected areas and within adjacent areas are to provide adequate protection in the event of system operation.

17.3.9 To demonstrate compliance with 17.3.8, evidence of the suitability of electrical and electronic equipment for use in protected areas and adjacent areas is to be submitted in accordance with 1.2.13. The evidence is to demonstrate that additional precautions have been taken, where necessary, in respect of:

(a) satisfying 17.3.6 and 17.3.7;
(b) personnel protection against electric shock;
(c) cooling airflow, where necessary, for equipment required to operate during system operation; and
(d) maintenance requirements for equipment before return to operation following system activation.

Any test evidence submitted is to consider the overall installation, including equipment types, system configuration and nozzles and the potential effects of airflows in the protected space.

17.3.10 The evidence required by 17.3.9 is to demonstrate the safe and effective operation of the overall arrangements in the event of system operation. This evidence is to demonstrate that exposure to system spray and/or water:

- cannot result in loss of essential services (e.g., unintended activation of automatic machinery shut-down);
- cannot result in loss of availability of emergency services;
- will not affect the continued safe and effective operation of electrical and electronic equipment required to operate during the required period of system operation;
- does not present additional electrical or fire hazards; and
- would require only identified readily replaceable components to be repaired or replaced.

The installation of electrical and electronic equipment required to provide essential or emergency services in enclosures with a degree of protection less than IP44 within areas exposed to direct spray is to be acceptable to LR, and evidence of suitability is to be submitted accordingly.

17.3.11 Fixed water-based local application fire-fighting system electrically driven pumps may be shared with:

- equivalent automatic sprinkler systems;
- equivalent main machinery space fire-fighting systems; or
- local fire-fighting systems for deep-fat cooking equipment;

provided that the shared use is accepted by the National Administration as complying with applicable statutory regulations and the arrangements comply with the requirements of 17.3.12 to 17.3.14.

17.3.12 Shared electrically driven sea-water pumps are to be served by not less than two circuits reserved solely for this purpose, one fed from the main source of electrical power and one from the emergency source of electrical power. Such feeders are to be connected to an automatic changeover switch situated near the pumps and the switch is to be normally closed to the feeder from the main source of electrical power. No other switches are permitted in the feeders. The switches on the main and emergency switchboards are to be clearly labelled and normally kept closed.

17.3.13 Failure of a component in the power and control system is not to result in a reduction of the total available pump capacity below that required by any of the areas which the system is required to protect. For equivalent automatic sprinkler systems, a failure is not to prevent automatic release or reduce sprinkler pump capacity by more than 50 per cent.

17.3.14 Where fire-fighting systems share fire-fighting pumps, failure of one system is not to prevent activation of the pumps by any other system.

17.4 Fire pumps

17.4.1 When the emergency fire pump is electrically driven, the power is to be supplied by a source other than that supplying the main fire pumps. This source is to be located outside the machinery spaces containing the main fire pumps and their source of power and drive units.

17.4.2 The cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source of power and drive units. The cables are to be of a fire-resistant type where they pass through other high fire risk areas.

17.5 Refrigerated liquid carbon dioxide systems

17.5.1 Where there are electrically driven refrigeration units for carbon dioxide fire-extinguishing systems, one unit is to be supplied by the main source of electrical power and the other unit from the emergency source of electrical power.

17.5.2 Each electrically driven carbon dioxide refrigerating unit is to be arranged for automatic operation in the event of loss of the alternative unit.

17.6 Fire safety stops

17.6.1 In order to limit the fire growth potential in every space of the ship, means for controlling the air supply to the spaces and flammable liquids within the spaces are to be provided.

17.6.2 To control air supply, a means of stopping all forced and induced draught fans, and all ventilation fans serving accommodation spaces, service spaces, control stations and machinery spaces from an easily accessible position outside of the space being served is to be provided. The position is not to be readily cut off in the event of a fire in the spaces served by the fans.

17.6.3 In passenger ships carrying more than 36 passengers, a second means of stopping ventilation fans serving accommodation spaces, service spaces and control stations is to be provided at a position as far apart from the position required by 17.6.2 as is practicable. At both positions, the controls are to be grouped so that all fans can be stopped from either of the two positions.

17.6.4 A second means of stopping ventilation fans serving machinery spaces is to be provided at a position as far apart from the position required by 17.6.2 as is practicable. At both positions the controls are to be grouped so that all fans are operable from either of the two positions. The means for stopping machinery space ventilation fans are to be entirely separate from the means for stopping fans serving all other spaces.

17.6.5 In passenger ships, the means of stopping machinery ventilation fans required by 17.6.2 is to be located at the central control station which is to have safe access from the open deck. The central control station is to be provided with ventilation fan OFF status indications together with a means for restarting the ventilation fans.

17.6.6 In passenger ships carrying 36 passengers or more, exhaust ducts from main laundries are to be fitted with additional remote-control arrangements for shutting off the exhaust fans and supply fans from within the space and for operating electrically operated fire dampers fitted at the lower end of the duct.

17.6.7 To control flammable liquids, a means of stopping all fuel oil, lubricating oil, hydraulic oil, cargo oil and thermal oil pumps, oil purifiers from outside the spaces being served is to be provided. The position is not to be cut off in the event of a fire.

17.6.8 Means of cutting off all electrical power to the galley except lighting circuits, in the event of a fire, is to be provided outside the galley exits, at positions which will not readily be rendered inaccessible by such a fire. Consideration may be given to relaxing this requirement for supplies to equipment not used for heating or cooking (e.g., alarm and clock systems) that do not present an electrical shock risk to fire-fighting personnel.

17.6.9 Following activation of any fire safety stops, a manual reset is to be provided in order to restart the associated equipment.

17.6.10 Fire safety stop systems are to be designed on the fail safe principle or alternatively the power supplies to, and the circuits of, the fire safety stop systems are to be continuously monitored and an alarm initiated in the event of a fault. Cables are to be of a fire-resistant type, *see* 11.5.3. *See also* 5.2.1.

17.7 Fire doors

17.7.1 The electrical power required for the control, indication and alarm circuits of fire doors is to be provided by an emergency source of electrical power as required by 3.2. In passenger ships carrying more than 36 passengers an alternative supply fed from the main source of electrical power, with automatic changeover facilities, is to be provided at the central control station. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.14 and 1.16.

17.7.2 The control and indication systems for the fire doors are to be designed on the fail-safe principle with the release system having a manual reset.

17.8 Fire dampers

17.8.1 The electrical power required for the control and indication circuits of fire dampers is to be supplied from the emergency source of electrical power.

17.8.2 The control and indication systems for the fire dampers are to be designed on the fail-safe principle with the release system having a manual reset.

17.8.3 In passenger ships carrying 36 passengers or more, where electrically operated fire dampers are fitted at the lower end of exhaust ducts from main laundries, they are to be capable of automatic and remote operation.

17.9 Fire-extinguishing media release

17.9.1 Where it is required that alarms be provided to warn of the release of a fire-extinguishing medium, and these are electrically operated, they are to be provided with an emergency source of electrical power, as required by 3.2 or 3.3, and also connected to the main source of electrical power, with automatic changeover facilities located in, or adjacent to, the fire-extinguishing media release panel, *see also* 1.14. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.14 and 1.16.

17.9.2 The opening of the fire-extinguishing media control cabinet door, or panel, for any purpose, other than for the release of the fire-extinguishing media, is not to cause the loss of any essential services, *see* 1.6.1.

17.10 Safety centre on passenger ships

17.10.1 Passenger ship safety centres required by SOLAS Ch II/2, Reg. 23 to provide a control station dedicated to assist with the management of emergency situations are to satisfy the requirements of this sub-Section.

17.10.2 The safety centre is to be either a part of the navigation bridge or to be located in a separate adjacent space having direct access to the navigation bridge.

17.10.3 Except where located in the same space, means of communication between the safety centre, the central control station, the navigation bridge, the engine control room, the storage room(s) for fire extinguishing system(s) and fire equipment lockers are to be provided.

17.10.4 The operation, control and monitoring of the following arrangements, where they are required to be installed by the National Administration, is to be additionally available from the safety centre:
- all powered ventilation systems;
- fire doors;
- general emergency alarm system;
- public address system;
- electrically powered escape route lighting or low location lighting for evacuation guidance;
- watertight and semi-watertight doors;
- indicators for bow and inner doors and stern and side shell doors and their closing appliances;

- water ingress detection for bow and inner doors and stern and side shell doors;
- remote surveillance systems for bow and inner doors and stern and side shell doors;
- fire detection and alarm systems;
- fixed water-based local application fire-fighting systems;
- automatic sprinkler systems, or equivalents;
- water-based fixed fire-extinguishing systems for machinery spaces;
- alarm to summon the crew;
- atrium smoke extraction system;
- flooding detection systems; and
- fire pumps and emergency fire pumps.

Operation, control and/or monitoring facilities provided at the safety centre are additional to any dedicated facilities required at other locations by the Rules or the National Administration.

17.10.5 Where arrangements are operated, controlled and/or monitored from the safety centre in accordance with 17.10.4, they are to comply with the relevant requirements of Ch 1,2 in respect of control, alarm and programmable electronic systems.

17.11 Electrically powered air compressors for breathing air cylinders

17.11.1 In passenger ships carrying more than 36 passengers where electrically powered air compressors are installed as part of the means required by SOLAS 1974 as amended, Chapter II-2/C, for recharging breathing apparatus air cylinders for fire-fighters' outfits, the compressors are to be supplied by the main and emergency sources of electrical power. Details of the emergency supply electrical load, supply changeover arrangements and operation under fire conditions are to be submitted for consideration. The arrangements are to be to the satisfaction of the National Administration with which the ship is registered.

■ *Section 18* Crew and passenger emergency safety systems

18.1 Emergency lighting

18.1.1 For the purpose of this Section emergency lighting, transitional emergency lighting and supplementary emergency lighting are hereafter referred to under the generic name 'emergency lighting'.

18.1.2 Emergency lighting provided in compliance with Section 3 is to be arranged so that a fire or other casualty in the spaces containing the emergency source of electrical power, associated transforming equipment and the emergency lighting switchboard does not render the main lighting system inoperative.

18.1.3 The level of illumination provided by the emergency lighting is to be adequate to permit safe evacuation in an emergency, having regard to the possible presence of smoke, *see* 18.4.

18.1.4 The exit(s) from every main compartment occupied by passengers or crew is to be continuously illuminated by an emergency lighting fitting.

18.1.5 Switches are not to be installed in the final sub-circuits to emergency light fittings unless the light fittings are serving normally unmanned spaces (e.g., storage rooms, cold rooms, etc.), or they are normally required to be extinguished for operational reasons (e.g., for night visibility from the navigating bridge). Where switches are fitted they are to be accessible only to ship's crew with provision made to ensure that the emergency lighting is energised when such spaces are manned and/or during emergency conditions.

18.1.6 Where emergency lighting fittings are connected to dimmers, provision is to be made, upon the loss of the main lighting, to automatically restore them to their normal level of illumination.

18.1.7 Fittings are to be specially marked to indicate that they form part of the emergency lighting system.

18.2 General emergency alarm system

18.2.1 An electrically operated bell or klaxon or air-operated whistle with independent air supply or other equivalent warning system installed in addition to the ship's whistle or siren, for sounding the general emergency alarm signal is to comply with the *International Life-Saving Appliances (LSA) Code* and with the requirements of this Section, *see also* 1.14 and 1.16.

18.2.2 The general emergency alarm system is to be provided with an emergency source of electrical power as required by 3.2 or 3.3 and also connected to the main source of electrical power with automatic changeover facilities located in, or adjacent to, the main alarm signal distribution panel. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.14.

18.2.3 The general emergency alarm distribution system is to be so arranged that a fire or casualty in any one main vertical zone, as defined by SOLAS 1974 as amended Reg II-2/A, 3.32, other than the zone in which the public address control station is located, will not interfere with the distribution in any other such zone.

18.2.4 There are to be segregated cable routes to public rooms, alleyways, stairways, control stations and on passenger ships on open decks, so arranged that any single electrical fault, localised fire or casualty will not cause the loss of the facility to sound the general emergency alarm in any public rooms, alleyways, stairways, control stations and on passenger ships on open decks, albeit at a reduced capacity.

18.2.5 Where the special alarm fitted to summon the crew, operated from the navigation bridge, or fire-control station, forms part of the ship's general alarm system, it is to be capable of being sounded independently of the alarm to the passenger spaces.

18.2.6 The sound pressure levels are to be measured during a practical test and documented, *see* 21.2.

18.3 Public address system

18.3.1 Public address systems on passenger ships and public address systems used on cargo ships to sound the general emergency alarm or the fire-alarm, are to comply with the *International Life-Saving Appliances (LSA) Code* and the requirements of this Section.

18.3.2 The public address system is to be provided with an emergency source of electrical power as required by 3.2 or 3.3 and also connected to the main source of electrical power with automatic changeover facilities located adjacent to the public address system. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.14 and 1.16.

18.3.3 The public address system is to have multiple amplifiers having their power supplies so arranged that a single fault will not cause the loss of the facility to broadcast emergency announcements in public rooms, alleyways, stairways and control stations, albeit at a reduced capacity.

18.3.4 The public address distribution system is to be so arranged that a fire or casualty in any one main vertical zone, as defined by SOLAS 1974 as amended Reg II-2/A, 3.32, other than the zone in which the public address control station is located, will not interfere with the distribution in any other such zone.

18.3.5 There are to be at least two cable routes, sufficiently separated throughout their length, to public rooms, alleyways, stairways and control stations so arranged that any single electrical fault, fire or casualty will not cause the loss of the facility to broadcast emergency announcements in any public rooms, alleyways, stairways and control stations, albeit at a reduced capacity.

18.3.6 Amplifiers are to be continuously rated for the maximum power that they are required to deliver into the system for audio and, where alarms are to be sounded through the public address system, for tone signals.

18.3.7 Loudspeakers are to be continuously rated for their proportionate share of amplifier output and protected against short-circuits.

18.3.8 Amplifiers and loudspeakers are to be selected and arranged to prevent feedback and other interference. There are also to be means to automatically override any volume controls, so as to ensure the specified sound pressure levels are met.

18.3.9 Where the public address system is used for sounding the general emergency alarm and the fire-alarm, the following requirements are to be met in addition to those of 18.2:

(a) The emergency system is given automatic priority over any other system input.
(b) More than one device is provided for generating the sound signals for the emergency alarms.

18.3.10 Where more than one alarm is to be sounded through the public address system, they are to have recognisably different characteristics and additionally be arranged, so that any single electrical failure which prevents the sounding of any one alarm will not affect the sounding of the remaining alarms.

18.3.11 The sound pressure levels are to be measured during a practical test using speech and, where applicable, tone signals, and documented, *see* 21.2.

18.4 Escape route or low location lighting (LLL)

18.4.1 The escape route or low location lighting (LLL) required by SOLAS 1974 as amended Pt D, Ch II-2, Reg. 13, 3.2.5.1, where satisfied by electric illumination, is to comply with the requirements of this sub-Section.

18.4.2 The LLL system is to be provided with an emergency source of electrical power as required by 3.2 and also be connected to the main source of electrical power, with automatic changeover facilities located adjacent to the control panel, *see also* 1.16.

18.4.3 The power supply arrangements to the LLL are to be arranged so that a single fault or a fire in any one fire zone or deck does not result in loss of the lighting in any other zone or deck. This requirement may be satisfied by the power supply circuit configuration, use of fire-resistant cables complying with 11.5.3, and/or the provision of suitably located power supply units having integral batteries adequately rated to supply the connected LLL for a minimum period of 60 minutes, *see* 12.3.8.

18.4.4 The performance and installation of lights and lighting assemblies are to comply with ISO 15370: *Ships and marine technology – Low location lighting on passenger ships – Arrangement.*

■ *Section 19*
Ship safety systems

19.1 Watertight doors

19.1.1 The electrical power required for power-operated sliding watertight doors is to be separate from any other power circuit and supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the bulkhead deck. The associated control, indication and alarm circuits are to be supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the bulkhead deck and for passenger ships be capable of being automatically supplied by the transitional source of emergency electrical power required by 3.2.8 in the event of failure of either the main or emergency source of electrical power.

19.1.2 A single failure in the power operating or control system of power-operated sliding watertight doors is not to result in a closed door opening or prevent the hand operation of any door.

19.1.3 Availability of the power supply is to be continuously monitored at a point in the electrical circuit adjacent to the door operating equipment. Loss of any such power supply is to activate an audible and visual alarm at the central operating console at the navigating bridge.

19.1.4 Electrical power, control, indication and alarm circuits are to be protected against fault in such a way that a failure in one door circuit will not cause a failure in any other door circuit. Short-circuits or other faults in the alarm or indicator circuits of a door are not to result in a loss of power operation of the door. Arrangements are to be such that leakage of water into the electrical equipment located below the bulkhead deck will not cause the door to open.

19.1.5 The enclosures of electrical components necessarily situated below the bulkhead deck are to provide suitable protection against the ingress of water with ratings as defined in IEC 60529: *Degrees of protection provided by enclosures (IP Code)* or an acceptable and relevant National Standard, as follows:

(a) Electrical motors, associated circuits and control components, protected to IPX7 Standard.
(b) Door position indicators and associated circuit components protected to IPX8 Standard, where the water pressure testing of the enclosures is to be based on the pressure that may occur at the location of the component during flooding for a period of 36 hours.
(c) Door movement warning signals, protected to IPX6 Standard.

19.1.6 Watertight door electrical controls including their electric cables are to be kept as close as is practicable to the bulkhead in which the doors are fitted and so arranged that the likelihood of them being involved in any damage which the ship may sustain is minimised.

19.1.7 An audible alarm, distinct from any other alarm in the area, is to sound whenever the door is closed remotely by power and sound for at least five seconds but no more than ten seconds before the door begins to move and is to continue sounding until the door is completely closed. The audible alarm is to be supplemented by an intermittent visual signal at the door in passenger areas and areas where the noise level exceeds 85 dB(A).

19.1.8 Sliding watertight doors on **cargo ships** are to be capable of being remotely closed from the bridge and are also to be operable locally from each side of the bulkhead. Indicators are to be provided at the control position showing whether the doors are open or closed, and an audible alarm is to be provided at the door closure.

19.1.9 On passenger ships, a central operating console is to be fitted on the navigating bridge and is to be provided with a 'master-mode' switch having:

(a) a 'local control' mode for normal use which is to allow any door to be locally opened and locally closed after use without automatic closure, and;
(b) a 'doors closed' mode for emergency use which is to allow any door that is opened to be automatically closed whilst still permitting any doors to be locally opened but with automatic reclosure upon release of the local control mechanism.

19.1.10 On passenger ships, the 'master mode' switch is to be arranged to be normally in the 'local control' mode position; be clearly marked as to its emergency function and be Type Approved in accordance with LR's Procedure for Type Approved Products.

19.1.11 On passenger ships, the central operating console at the navigating bridge is to be provided with a diagram showing the location of each door, with visual indicators to show whether each door is open or closed. A red light is to indicate a door is fully open and a green light, a door fully closed. When the door is closed remotely a red light is to indicate the intermediate position by flashing. The indicating circuit is to be independent of the control circuit for each door.

19.1.12 The arrangements are to be such that it is not possible to open any door remotely from the central operating console.

19.2 Stern and side shell doors and bow and inner doors

19.2.1 The requirements of 19.2.2 to 19.2.14 apply to all stern and side shell doors, bow doors and inner doors, giving access to vehicle decks, and subdivision doors, in accordance with Pt 4, Ch 2,9, on all ships except where otherwise stated in 19.2.11 and 19.2.12.

19.2.2 A notice is to be displayed at the operating panel stating that the door is to be fully closed, secured and locked preferably before, or immediately the ship leaves the berth and that this operation is to be entered in the ship's log.

19.2.3 Control positions are to be provided with a system of warning indicator lights. The system is to provide positive indication that the door is fully closed, secured and locked. The indication arrangements are to be 'fail-safe' such that in the event of a fault the system cannot incorrectly indicate that the doors are fully closed, secured or locked.

19.2.4 The indication system is to be arranged such that it functions independently of any system for door operation, securing and locking.

19.2.5 The electrical power supply for the indication system is to be independent of any electrical power supply for operating, securing and locking the doors.

19.2.6 The indication system is to be fed from two exclusive circuits, one from the main source of electrical power and one from the emergency source of electrical power with automatic changeover facilities located adjacent to the panel. Loss of either active or standby power supply is to initiate an audible and visual alarm on the navigation bridge.

19.2.7 The indicator panel is to be provided with a lamp test function. It is not to be possible to turn off the indication lights at the panel. Dimming facilities may be provided, but the indications are to remain clearly readable under all operating lighting conditions.

19.2.8 Means are to be provided to prevent unauthorised operation of the doors and associated securing and locking devices.

19.2.9 Detection of door position and securing and locking device status is to be by direct sensing of proximity, contact or equivalent, not inferred from actuator positions. Sensors are to be protected against ice formation, mechanical damage and water ingress to be not less than IPX6 Standard as defined in IEC 60529: *Degrees of protection provided by enclosures (IP Code)*, or an acceptable and relevant National Standard.

19.2.10 Where a strongback or equivalent independent secondary means of securing an inwardly opening door is required, these need not be monitored by the indication system providing their correct positioning can be easily observed from the control position.

19.2.11 Doors with a clear opening area of 12 m^2 or greater are to be provided with closing devices operable from a remote control position. Doors which are located partly or totally below the freeboard deck with a clear opening area greater than 6 m^2 are to be provided with an arrangement for remote control from a position above the freeboard deck. This remote control is to provide centralised control for:

(a) The closing and opening of the doors.
(b) Associated securing and locking devices.

19.2.12 Bow doors and inner doors, giving access to vehicle decks, and subdivision doors are to be provided with an arrangement for remote control from a position above the freeboard deck, providing centralised control for:

(a) the closing and opening of the doors; and
(b) associated securing and locking devices.

19.2.13 The location of the remote control panel is to be such that door operation can be easily observed by the operator or by other suitable means such as closed circuit television. Where remote control is required, television surveillance or other such means may satisfy this requirement.

19.2.14 A drainage system is to be arranged in the area between bow door and ramp or, where no ramp is fitted, between the bow door and inner door. The system is to be equipped with an audible alarm function on the navigation bridge being set off when the water levels in these areas exceed 0,5 m.

19.2.15 The additional requirements of 19.2.16 to 19.2.22 apply to stern and side shell doors in the boundaries of special category spaces or ro-ro cargo spaces through which such spaces may be flooded, and to bow doors and inner doors. For cargo ships, where no part of the door is below the uppermost waterline and the area of the door opening is not greater than 6 m^2, the requirements of 19.2.16 to 19.2.22 need not be applied.

19.2.16 An indicator panel is to be located on the navigating bridge, providing separate visual indications of the position of each door and the status of their associated securing/locking devices.

19.2.17 The indication system is to be provided with a 'harbour/sea voyage' mode selection function, with means of operation located on or adjacent to the navigating bridge indication panel. The selected mode is to be displayed on all indicator panels. An audible alarm is to be initiated on the navigating bridge if the ship leaves the harbour with any door not fully closed or not fully secured. Where practical, the alarm should be initiated immediately the ship leaves the berth. Audible alarms are to be silenced in the 'harbour' mode. Visual indications are to remain operational in either mode.

19.2.18 An audible and visual alarm is to be given on the navigation bridge in the event of any fault within the indication system.

19.2.19 An audible and visual alarm is to be initiated on the navigation bridge and the engine control room, or an equivalent attended position, in the event of leakage through the doors.

19.2.20 Television surveillance arrangements are to be provided to enable the positions of bow doors and inner doors, and a sufficient number of their closing devices, to be monitored from the navigation bridge and the engine control room, or an equivalent attended position. The television surveillance arrangements are also to allow leakage through the bow doors and inner doors to be assessed from the same positions in the event of leakage through the doors. Special consideration is to be given to the lighting and contrasting colour of objects under surveillance.

19.2.21 For passenger ships, television surveillance arrangements are to be provided to allow leakage through stern and side shell doors below the freeboard deck to be assessed from the navigation bridge and the engine control room, or equivalent attended position.

19.2.22 The electrical power supply for surveillance lighting is to be independent of any electrical power supply for operating, securing and locking the doors.

19.3 Subdivision doors on vehicle decks

19.3.1 Where subdivision doors are provided on passenger ship vehicle decks in accordance with Pt 4, Ch 2,9, the control and monitoring arrangements for these doors are to generally comply with 19.2.

19.4 Bilge pumps

19.4.1 Where the bilge pumps for the holds of open-top container ships are electrically driven one pump is to be supplied from the emergency switchboard, the remaining pumps are to be supplied from the main source of electrical power, independent of the emergency switchboard.

■ *Section 20*
Lightning conductors

20.1 General

20.1.1 In order to minimise the risks of damage to the ship and its electrical installation due to lightning, ships having non-metallic masts or topmasts are to be fitted with lightning conductors in accordance with the applicable requirements of IEC 60092-401: *Electrical installations in ships — Part 401: Installation and test of completed installation* or an alternative and relevant National Standard.

■ *Section 21*
Testing and trials

21.1 Testing

21.1.1 Tests in accordance with 21.1.2 to 21.1.4 are to be satisfactorily carried out on all electrical equipment, complete or in sections, at the manufacturer's premises and a test report issued by the manufacturer.

21.1.2 A high voltage at any frequency between 25 and 100 Hz is to be applied between:

(a) all current carrying parts connected together and earth;

(b) all current carrying parts of opposite polarity or phase.

For rotating machines the value of test voltage is to be 1000 V plus 2 x rated voltage with a minimum of 2000 V, and for other electrical equipment, it is to be in accordance with Table 2.21.1. Items of equipment included in the assembly for which a test voltage lower than the above is specified may be disconnected during the test and tested separately at the appropriate lower test voltage. The test is to be commenced at a voltage of about one-third the test voltage and is to be increased to full value as rapidly as is consistent with its value being indicated by the measuring instrument. The full test voltage is then to be maintained for 1 minute, and then reduced to one-third full value before switching off. The assembly is considered to have passed the test if no disruptive discharge occurs.

21.1.3 When it is desired to make additional high voltage tests on equipment which has already passed its tests, the voltage of such additional tests is to be 80 per cent of the test voltage the equipment has already passed.

Table 2.21.1 Test voltage

Rated voltage, U_n U_n V	Test voltage a.c. (r.m.s.), V
$U_n \leq 60$	500
$60 < U_n \leq 1000$	$2 \times U_n + 1000$
$1000 < U_n \leq 2500$	6500
$2500 < U_n \leq 3500$	10000
$3500 < U_n \leq 7200$	20000
$7200 < U_n \leq 12000$	28000
$12000 < U_n \leq 15000$	38000

21.1.4 Immediately after the high voltage test, the insulation resistance is to be measured using a direct current insulation tester, between:

(a) all current-carrying parts connected together and earth;

(b) all current-carrying parts of different polarity or phase.

The minimum values of test voltage and insulation resistance are given in Table 2.21.2.

Table 2.21.2 Test voltage and minimum insulation

Rated voltage U_n V	Minimum voltage of the tests, V	Minimum insulation resistance, MΩ
$U_n \leq 250$	$2 \times U_n$	1
$250 < U_n \leq 1000$	500	1
$1000 < U_n \leq 7200$	1000	$\frac{U_n}{1000} + 1$
$7200 < U_n \leq 15000$	5000	$\frac{U_n}{1000} + 1$

21.1.5 Tests in accordance with the Standard with which the equipment complies may be accepted as an alternative to the above.

21.2 Trials

21.2.1 Before a new installation, or any alteration or addition to an existing installation, is put into service the applicable trials in 21.2.2 to 21.2.7 are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturer's works and are to be to the Surveyor's satisfaction.

21.2.2 The insulation resistance is to be measured of all circuits and electrical equipment, using a direct current insulation tester, between:

(a) all current-carrying parts connected together and earth and, so far as is reasonably practicable;

(b) all current-carrying parts of different polarity or phase;

The minimum values of test voltage and insulation resistance are given in Table 2.21.2. The installation may be subdivided and appliances may be disconnected if initial tests produce results less than these figures.

21.2.3 Tests are to be made to verify the effectiveness of:

(a) earth continuity conductor;

(b) the earthing of non-current-carrying exposed metal parts of electrical equipment and cables not exempted by 1.12.2;

(c) bonding for the control of static electricity.

21.2.4 It is to be demonstrated that the Rules have been complied with in respect of:

(a) satisfactory performance of each generator throughout a run at full rated load;

(b) temperature of joint, connections, circuit-breakers and fuses;

(c) the operation of engine governors, synchronising devices, overspeed trips, reverse-current, reverse-power and over-current trips and other safety devices;

(d) voltage regulation of every generator when full rated load is suddenly thrown off and when starting the largest motor connected to the system;

(e) voltage drop at worst case condition;

(f) harmonic distortion of the voltage waveform, where declared;

(g) satisfactory parallel operation, and kW and KVA load sharing of all generators capable of being operated in parallel at all loads up to normal working load;

(h) all essential and other important equipment are to be operated under service conditions, though not necessarily at full load or simultaneously, for a sufficient length of time to demonstrate that they are satisfactory;

(j) propulsion equipment is to be tested under working conditions and operated in the presence of the Surveyors and to their satisfaction. The equipment is to have sufficient power for going astern to secure proper control of the ship in all normal circumstances. In passenger ships the ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manoeuvring conditions, and so bring the ship to rest from maximum ahead service speed, is to be demonstrated at the sea trial; and

(k) operation of power management for electric propulsion.

21.2.5 Measurements are to be taken as part of the trials specified in 21.2.4(c), (d), (e) and (f) to verify that the installation will provide a quality of power supply in accordance with the values listed in 1.8.

21.2.6 Satisfactory load management in accordance with 6.9 is to be demonstrated. The demonstration is to include verification that the requirements of 1.8 will be met following disconnection of a generator under all defined operating profiles as agreed with the operators.

21.2.7 It is to be demonstrated by practical tests that the Rules have been complied with in respect of fire, crew and passenger emergency and ship safety systems.

21.2.8 On completion of the general emergency alarm system and the public address system tests, the Surveyor is to be provided with two copies of the test schedule, detailing the measured sound pressure levels. Such schedules are to be signed by the Surveyor and the Builder.

21.3 High voltage cables

21.3.1 Before a new high voltage cable installation, or an addition to an existing installation, is put into service a voltage withstand test is to be satisfactorily carried out on each completed cable and its accessories. The test is to be carried out after the insulation resistance test required by 21.2.2 and may use either an a.c. voltage at power frequency or a d.c. voltage.

21.3.2 When an a.c. voltage withstand test is carried out, the voltage is to be not less than the normal operating voltage of the cable and it is to be maintained for a minimum of 24 hours.

21.3.3 When a d.c. voltage withstand test is carried out, the voltage is to be not less than:

(a) 1,6 (2,5U_o + 2 kV) for cables of rated voltages (U_o) up to and including 3,6 kV, or

(b) 4,2U_o for higher rated voltages

where U_o is the rated power frequency voltage between conductor and earth or metallic screen, for which the cable is designed.

The test voltage is to be maintained for a minimum of 15 minutes. After completion of the test the conductors are to be connected to earth for a sufficient period in order to remove any trapped electric charge. An insulation resistance test in accordance with 21.2.2 is then to be repeated.

21.4 Hazardous areas

21.4.1 All electric equipment located in hazardous areas is to be examined to ensure that it is of a type permitted by the Rules, has been installed in compliance with its certification, and that the integrity of the protection concept has not been impaired.

21.4.2 Alarms and interlocks associated with pressurised equipment and the ventilation of spaces located in hazardous areas are to be tested for correct operation.

Section 22
Spare gear

22.1 General

22.1.1 It is recommended that adequate spares, together with the tools necessary for maintenance, or repair, be carried. The spares are to be determined by the Owner according to the design and intended service. The maintenance of the spares is the responsibility of the Owner.

Sections

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter apply to the refrigerated cargo installations of refrigerated cargo ships, refrigerated container ships, fish factory ships, fishing vessels, fruit juice carriers, and the reliquefaction/refrigerating plant of liquefied gas carriers and chemical carriers or tankers, where an **RMC** notation is requested.

1.1.2 Ships with refrigerated cargo installations which are approved, installed and tested in accordance with these requirements will be eligible for the applicable class notation specified in Pt 1, Ch 2.

1.1.3 The requirements for the classification of ships for the carriage of liquefied gas are given in Lloyd's Register's (hereinafter referred to as 'LR') *Rules and Regulations for the Construction and Classification of Ships for the Carriage Liquefied Gases in Bulk* (hereinafter referred to as the Rules for Ships for Liquefied Gases). Where reliquefaction or refrigeration equipment is fitted for cargo temperature and pressure control, the equipment is to comply with the requirements of Sections 2 to 11, as applicable.

1.1.4 The requirements for the refrigeration equipment and systems necessary for provision stores and air conditioning are specified in Pt 7, Ch 15.

1.2 Plans and particulars

1.2.1 The following plans and particulars, as applicable, and any others which may be specially requested for the **refrigerating plant and systems**, are to be submitted in triplicate for approval, before construction is commenced:

(a) Schematic plans, including full particulars of piping and instrumentations, for:
- primary and secondary refrigeration systems;
- air cooler defrosting arrangements;
- gas reliquefaction systems; and
- condenser cooling water systems.

(b) Detailed dimensioned plans and material specifications for:
- reciprocating compressor crankshaft and crankcase, where exposed to refrigerant pressure;
- rotary-type compressor rotors and casing;
- condensers shell and tube and plate type;
- evaporators shell and tube and plate type;
- air coolers;
- arrangement of air cooling pipe grids and construction method;
- liquid receivers;
- oil separators; and
- any other pressure vessels, *see* Pt 5, Ch 11,6.1.

(c) General arrangement of refrigerating machinery compartment in elevation and plan, showing location and arrangement of the plant, ventilation details and location of temperature sensors and vapour detectors.

(d) Details of automatic controls, alarms and safety systems, *see* Ch 1,1.

(e) Details of level indicators.

(f) Where provision is made for the manufacture and/or storage of inert gas in liquid form, details of the storage vessel insulation arrangements and the reliquefaction equipment and piping system are to be submitted.

(g) Capacity calculations for pressure relief valves and/or bursting discs, and discharge pipe pressure drop calculations, *see* 4.15.5 to 4.15.21.

(h) Programme of tests to be conducted on completion of the installation, *see* Section 11.

1.2.2 The following plans and particulars, as applicable, and any others which may be specially requested for **refrigerated cargo spaces**, are to be submitted in triplicate for approval, before work is commenced:

(a) Specification of proposed insulation envelope system, including physical, thermal and fire properties.

(b) General arrangement of insulated refrigerated spaces in elevation and plan.
- The plans are to be to a scale adequate for the measurement of the external surfaces and the deck and bulkhead edges.
- Dimensions and spacing of frames, beams and stiffeners, and details of other steel work intruding into the insulation and within the spaces, are to be shown.
- Oil fuel and liquid cargo tanks adjacent to or below the refrigerated spaces are to be shown, and whether heating arrangements are provided for such tanks are to be indicated.
- Ventilating and air-conditioning trunks, and ducts passing through refrigerated spaces are to be shown.

- The plans are to include a diagram showing the position of the spaces in relation to other parts of the ship if this is not otherwise apparent.

(c) Plans showing:
- the thicknesses and methods of attachment of the insulation and linings on all surfaces including girders, hatch coamings and pillars; and
- details of prefabricated panels and their fixings, vapour barriers, insulated doors and hatch access, bilge and manhole plugs and their frames.

(d) Methods of attachment of air cooling grids (if fitted) are to be indicated.
(e) Size and position of refrigerated space pressure equalising devices, where fitted, *see* 9.2.12 and 9.2.13.
(f) Arrangements of the drainage system, and sounding and air pipes that pass through the refrigerated spaces.
(g) Arrangements of air ducts and distribution systems within the refrigerated spaces (including method of cooling spaces within hatch coamings), and air cooler spaces showing location of the coolers and their fans and drive motors.
(h) Details of temperature indicating, and recording and sensing equipment, and arrangement of sensors within the refrigerated spaces.

1.2.3 Single copies of the following plans and particulars are to be submitted:
- LR Data Sheet for refrigerated cargo installations (LR Form 3905).
- Specification of proposed refrigerating system and auxiliary equipment, including the refrigerating capacities of the compressors, condensers, evaporators and air coolers.
- Heat load calculations at all design operating conditions justifying the refrigerating capacity which is to be installed.

1.3 Materials

1.3.1 Steel plating used in ship construction is to be of an appropriate grade corresponding to the proposed temperature notation, *see* Pt 3, Ch 2,2.2.

1.3.2 Materials used in the construction of the refrigerating equipment and associated systems are to be generally manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.3.3 Where it is proposed to use materials other than those specified in Rules for Materials, details of the chemical compositions, heat treatment and mechanical properties are to be submitted for approval. In such cases the values of the mechanical properties used for deriving the allowable stress are to be subject to agreement with LR.

1.3.4 All materials used in refrigerating equipment and systems are to be suitable for use with the selected refrigerants. This includes joints, sealing materials and lubricants. For example, the following materials and refrigerants are not to be combined:
- Copper with ammonia.
- Magnesium with fluorinated hydrocarbons.
- Zinc with ammonia or fluorinated hydrocarbons.

1.3.5 For ammonia systems, the condensers/evaporators are to be manufactured in titanium or a suitable grade of stainless steel.

1.4 Equipment to be constructed under survey

1.4.1 All major items of equipment are to be surveyed at the manufacturer's works. The workmanship is to be to the Surveyor's satisfaction and the Surveyor is to be satisfied that the components are suitable for the intended purpose and duty. Examples of such units are:
- Crankshafts, crankcases, rotor shafts and casings for all compressors.
- Condensers.
- Evaporators (secondary refrigerant coolers).
- Air coolers.
- Pressure vessels (e.g., liquid receivers, surge drums, suction separators, intercoolers, oil separators).
- Cooling water pumps for condensers.
- Valves and other components intended for installation in pressure piping systems having a maximum working pressure greater than 7 bar.
- Thermal insulating panels (factory made).

1.5 Type approved equipment

1.5.1 Where it is proposed to use components (e.g., compressors, condensers, oil separators) which have valid LR Type Approval or General Approval Certificates, the types and model numbers of the components are to be stated. Plans of components that have been so approved need not be re-submitted.

1.6 Notation and temperature conditions

1.6.1 The class notation assigned will state the minimum temperature or a temperature range approved by the Committee for the installation with the maximum sea temperature stated, e.g., '✠Lloyd's RMC to maintain temperature(s) of minus 29°C to plus 14°C with sea temperature plus 32°C maximum'.

1.6.2 For refrigerated installations aboard container ships with approved refrigerating plant and arrangements to supply refrigerated air through ducting to insulated containers, the class notation assigned will additionally specify the maximum number and characteristics of the containers for which the plant is approved, e.g., 'to supply refrigerated air at temperatures of minus 25°C to plus 14°C to 800 certified insulated containers with an average thermal transmittance per container of 27 W/K with sea temperature plus 32°C maximum'.

1.6.3 For reliquefaction or refrigerating plants aboard liquefied gas carriers, the notation assigned will state the minimum cargo temperature for which the installation is approved, unless otherwise qualified, *see* LR III.3 of the Rules for Ships for Liquefied Gases.

1.6.4 On application from an Owner, consideration will be given by the Committee to an alternative temperature notation being assigned to that appearing in the *Register Book*.

1.7 Novel arrangements and design

1.7.1 Where the proposed construction of the refrigerating plant or refrigerated spaces or chambers is novel in design or involves the use of unusual material, special tests may be required, and a suitable class notation may be assigned when the Committee considers this necessary.

1.8 Heat balance tests

1.8.1 A heat balance test will be required as prescribed in Section 11 on a classed installation, or one being considered for reclassification, when extensive repairs or alterations have been carried out, or when the Surveyors consider that an amended temperature condition should be assigned.

1.9 Controlled atmosphere (CA) systems

1.9.1 Where it is intended to install a CA system on a vessel intended for classification, the requirements of Pt 7, Ch 1 are to be complied with.

1.9.2 Where a **CA** notation is requested by an Owner, it is a prerequisite that the refrigeration installation be assigned an **RMC** notation.

1.10 Spare gear and refrigerant charge

1.10.1 It is recommended that adequate spares, together with the tools necessary for maintenance, or repair, be carried. The spares are to be determined by the Owner according to the design and intended service. The maintenance of the spares is the responsibility of the Owner.

1.10.2 For systems complying with 2.5.6 sufficient carbon dioxide is to be carried on board to allow the refrigeration system to be fully recharged. In addition, adequate reserve supplies of refrigerant are to be carried for maintenance purposes. The replacement refrigerant is to be stored in containers complying with 3.3.5.

■ *Section 2* Design criteria

2.1 General

2.1.1 The proposed refrigerating plant, insulation and refrigerants are to be suitable for achieving the designed notation temperature. The refrigerating machinery and all components are to operate satisfactorily under the conditions listed in Table 1.3.1 in Pt 5, Ch 1.

2.1.2 The properties of steel materials used in refrigerated holds are to be suitable for the proposed notation temperature.

2.2 Refrigerants and classes of pipes

2.2.1 These Rules are applicable to the primary refrigerants in Table 3.2.1.

2.2.2 Attention is to be given to any statutory requirements, regarding the use of refrigerants, of the National Authority of the country in which the ship is to be registered.

2.2.3 Within the parameters of pressures, temperatures, toxic nature and flammability, the class of pipe to be used with various refrigerants is shown in Table 3.2.1.

2.2.4 Design conditions as applicable to the classes of pipes are defined in Pt 5, Ch 12,1.5.

2.2.5 The materials of Class I and Class II piping systems are to be manufactured at a works approved by LR and tested in accordance with the appropriate requirements of Rules for Materials. Particular attention is drawn to Ch 6,4 of the Rules for Materials, where testing requirements for pipes used for low temperature service are given.

2.2.6 The materials of Class III piping system are to be manufactured and tested in accordance with the requirements of acceptable National Specifications. The manufacturer's test certificate will be acceptable and is to be provided for each consignment of materials.

2.2.7 Particulars of refrigerating systems using refrigerants other than those listed will be given special consideration.

2.3 Refrigeration units

2.3.1 A refrigerating unit is considered to comprise a compressor, its driving motor and one condenser. Where a secondary refrigerant, such as brine, is employed, the unit is also to include an evaporator (secondary refrigerant cooler) and a brine pump.

2.3.2 Two or more compressors driven by a single motor, or having only one condenser or evaporator (secondary refrigerant cooler) are to be regarded as one unit.

Table 3.2.1 Primary refrigerants and their class of pipe

Refrigerant	Type	Composition	Class I	Class of Pipe Class II	Class III
R-717 (Ammonia)	NH_3	–	✓	–	–
R-22	HCFC	–	–	✓	–
R-290 (Propane)	HC	–	–	✓	–
R-600a (Isobutane)	HC	–	–	✓	–
R-134a	HFC	–	–	–	✓
R-407C	Blend	R-32, R-125, R-134a	–	✓	–
R-410A	Blend	R-32, R-125	–	✓	–
R-507A	Blend	R-125, R-143a	–	✓	–
R-404A	Blend	R-134a, R-125, R-143a	–	✓	–
R-744 (Carbon Dioxide)	CO_2	–		*See* 2.5.6	

NOTES
1. HCFC – Hydrochlorofluorocarbon.
2. HFC – Hydrofluorocarbons.
3. HC – Hydrocarbon.
4. In view of increasing world-wide restrictive legislation and phasing out of the refrigerant R-22, it is recommended that this refrigerant should not be used in any new installation.
5. Although ozone depleting and global warming potentials are not included in these Rules for Classification, these effects are important and need to be considered when selecting the refrigerant for a particular application.

2.3.3 The refrigerating units of a classed cargo installation are to be completely independent of any refrigerating machinery associated with air-conditioning plant, or any domestic refrigerated installation, or any process plant, unless full details of any proposal have been submitted and approved.

2.4 Refrigeration capacity

2.4.1 The refrigeration capacity provided is to be sufficient to maintain the temperatures specified in the class notation when operating 24 hours per day with one unit on standby. The plant is to be able to cool down a complete cargo to its carrying temperature within the time specified by the manufacturer. The standby unit may be considered as an operating unit during the cooling down period of a non-precooled cargo. In order to compensate for deterioration of machinery and insulation over the life of the installation, the equipment is to be designed to have at least five per cent excess capacity over that required for maximum design output.

2.4.2 The proposals of both machinery and insulating contractors will be evaluated by LR in determining the theoretical capabilities of the equipment to maintain the duty temperatures. LR will advise the contractors after appraisal of the specification and plans if it is considered that additional refrigeration or insulating effect is required, but the temperature assigned on completion of the capacity heat balance test will be determined from the actual results of the test.

2.4.3 Where the units are not connected in common to all refrigerated chambers, the equipment serving each group of chambers is to comply with 2.4.1.

2.4.4 In the case of installations having a large number of small units arranged to serve individual chambers or groups of chambers, the question of standby capacity will be specially considered.

2.4.5 Where only two refrigerating units are fitted, the working parts are to be interchangeable.

2.4.6 Where a refrigerating plant is provided for sub-cooling the liquid refrigerant of other units, but is not arranged for cooling the cargo chambers independently, it will not be regarded as a unit.

2.5 Design pressures

2.5.1 The design pressure of the system is to be regarded as equal to its maximum working pressure.

2.5.2 The maximum working pressure is the maximum permissible pressure within the system (or part system) in operation or at rest. No relief valve is to be set to a pressure higher than the maximum working pressure.

2.5.3 The design pressure of the low pressure side of the system is to be the saturated vapour pressure of the refrigerant at plus 46°C. Due regard is to be taken of defrosting arrangements which may cause a higher pressure to be imposed on the low pressure system.

2.5.4 The minimum design pressure of the high pressure side of the system (P_{dh}), is to be 1,11 x P_b, where P_b is an allowance for the compressor high pressure cut-out. P_b is to be at least equal to 1,11 x P_a, where P_a is the condenser working pressure, when operating in tropical zones and equates to the saturation pressure at 46°C.

2.5.5 Design pressures (bar g) applicable to refrigerants are to be not less than the values given in Table 3.2.2 when condensers are sea-water cooled. The design pressure for other refrigerants and condensing arrangements is to be agreed with LR.

Table 3.2.2 Pressure limits

Refrigerant	Pressure (bar g)	
	High	Low
R-717	21,2	17,2
R-22	20,6	16,7
R-290	18,1	14,7
R-600a	6,4	5,2
R-134a	13,4	10,9
R-407C	23,5	19,0
R-410A	33,14	29,9
R-507A	25,3	20,5
R-404A	24,8	20,1
R-744	*See* 2.5.6	

2.5.6 Due to the low critical temperature of carbon dioxide it is inappropriate to determine the design pressure in accordance with 2.5.3. The proposed design pressure for a carbon dioxide system is to be stated, taking account of the maximum working pressure and the maximum pressure at rest conditions. Where the maximum pressure at rest condition is maintained by the fitting of a supplementary refrigeration unit, condensing the vapour in a holding vessel, supporting calculation is to be provided to show that this can be undertaken with a local ambient temperature of 45°C. The holding vessel is to be thermally insulated to prevent the operation of the relief devices within a 24 hour period after stopping the supplementary refrigeration unit at an ambient temperature of 45°C and an initial pressure equal to the starting pressure of the refrigeration unit.

2.5.7 Where a carbon dioxide system is designed for hot gas defrosting, due regard is to be given to the possibility of a higher pressure being imposed on the low pressure system. The design pressure for this section of the system shall be 10 per cent above the maximum pressure experienced during defrosting.

2.6 Insulation

2.6.1 Properties of materials used for thermal insulation are to be verified against known standards for the following parameters, as applicable, to ensure that they are adequate for the intended service. The following test results are to be made available to LR for approval:

- Closed cell content.
- Density.
- Mechanical properties.
- Thermal expansion.
- Abrasion.
- Cohesion.
- Thermal conductivity.
- Resistance to fire and flame spread.
- Ageing.
- Bonding (adhesive and cohesive strength).

2.6.2 Where the *in situ* foam type of insulation is proposed, full details of the process are to be submitted for approval.

2.6.3 Where applicable, having regard to their location and environmental conditions, insulation materials are to be:

- suitably resistant to fire;
- suitably resistant to the spreading of flame;
- adequately protected against penetration of water vapour; and
- adequately protected against mechanical damage.

■ *Section 3* Refrigerating machinery and refrigerant storage compartments

3.1 General

3.1.1 Refrigerating machinery is to be located in a well ventilated compartment. In general, the arrangements are to be such that all components of the refrigerating machinery can be readily opened up for inspection or replacement. Space is to be provided for the withdrawal and renewal of the tubes in 'shell-and-tube' type evaporators (brine coolers) and condensers. Proposals for alternative arrangements are to be submitted for consideration. *See* 3.2 for refrigerating machinery using ammonia.

3.1.2 Refrigerating machinery using toxic and/or flammable refrigerants is to be located outside the main machinery space in a separate gastight compartment.

3.1.3 Where the refrigerating machinery is located in a separate gastight compartment, outside the main machinery space, this compartment is to be equipped with effective mechanical ventilation to provide 30 air changes per hour based upon the total volume of the space. The mechanical ventilation is to have two main controls, one of which is to be operable from a place outside the compartment.

3.1.4 Refrigerating machinery using non-toxic and non-flammable refrigerants will not, in general, be required to be located in a separate compartment outside the main machinery space.

3.1.5 Openings for pipes, electrical cables and other fittings in the bulkheads and deck are to be fitted with gastight seals.

3.1.6 Ammonia piping is not to pass through accommodation spaces.

3.2 Arrangements for compartments housing machinery using ammonia

3.2.1 Where ammonia refrigerant is used, the refrigerating machinery shall be installed in a dedicated gastight compartment. *See also* 3.2.9.

3.2.2 The compartment containing ammonia refrigerating machinery and any access ways are to be provided with independent mechanical ventilation capable of:

- removing the heat generated by the equipment installed in the compartment;
- maintaining the atmosphere in the compartment at acceptable vapour threshold levels under normal operating conditions; and
- disposing of ammonia vapour safely and quickly in the event of a major leakage.

3.2.3 The ventilation system is to be of the negative pressure type where abnormal stoppages of the extraction fans activate an audible and visual alarm.

3.2.4 Compartments containing ammonia refrigerating machinery, including process vessels, are to be provided with:

- a negative ventilation system, independent of ventilation systems serving other spaces, having a capacity of not less than 30 air changes per hour based upon the total volume of the space. Other suitable arrangements which ensure an equivalent effectiveness may be considered;
- fresh air inlets, located at a low level in the machinery compartment and arranged so as to provide a supply of fresh air and to minimise the possibility of re-cycling the exhaust air from the outlet;
- exhaust outlets, located at a high level and arranged so as to promote good air distribution throughout the compartment;
- a fixed ammonia detector system with alarms inside and outside the compartment;
- water screens above all access doors, operable manually from outside the compartment in all ambient conditions;
- an independent bilge system;
- where the charge is greater than 50 kg, emergency body shower and eye wash facilities shall be installed locally outside the compartment. The water for the shower is to be thermostatically controlled so as to avoid low temperature shock.

3.2.5 Compartments are to have at least two access doors, opening outwards, one of which is to be an emergency exit giving direct access to the open deck. The doors are to be fitted with an easily operated opening mechanism to facilitate rapid escape in an emergency. In the case of small compartments where more than one door would be impractical, the emergency exit only is to be provided.

3.2.6 At least two sets of self-contained breathing apparatus and protective clothing are to be provided, readily available in the vicinity of the compartment but external to the area of risk. *See* 8.1.4.

3.2.7 The location of the exhaust duct, from the compartment or area, is to be free from obstruction and be such as not to cause danger. Where practicable, they are to be 10 m, in the horizontal direction from other ventilation intakes and openings to accommodation and other enclosed areas, and at least 2 m above the surrounding deck.

3.2.8 Ventilation fans are not to produce a source of vapour ignition in either the ventilated compartment/area or ventilation system. Ventilation fans and fan ducts, in way of fans only, are to be of non-sparking construction.

3.2.9 In the case of ammonia plants on fishing ships under 55 m overall length, or ammonia plants with a charge of ammonia not greater than 25 kg, the refrigerating machinery may be located in the main machinery space provided it complies with the following requirements:

- The entrance to the machinery space is properly illuminated and marked and has warning signs permanently posted.
- The area where the ammonia machinery is installed is served by a hood with a negative ventilation system, so as not to permit any leakage of ammonia dissipating into other areas.
- A water spray system is provided for the area.
- Coamings, of not less than 150 mm in height, are installed around the ammonia machinery area.
- A fixed ammonia detector system with alarms inside and outside the main machinery space is provided.
- Means are provided for stopping the ammonia compressor prime movers from a position outside the machinery space.
- At least two sets of self-contained breathing apparatus and protective clothing are to be provided readily available in the vicinity of the compartment but external to the area of risk. *See* 8.1.4.
- Air intakes of other machinery are located away from the ammonia machinery area as far as is practicable.

3.3 Gas storage compartments

3.3.1 Portable steel cylinders containing reserve supplies of refrigerant are to be stored in a well ventilated compartment reserved solely for this purpose.

3.3.2 The compartment is to be provided with a mechanical ventilation system providing 10 air changes per hour and is to have at least one door opening outwards giving direct access to open deck.

3.3.3 Bulk storage tanks holding more than 150 kg of replacement carbon dioxide are to be located in a separate compartment. The compartment is to be provided with a mechanical ventilation system having a minimum capacity of 6 air changes per hour. The ventilation system exhaust ducting is to remove air from the base of the compartment. The compartment is to be fitted with a gas tight access door opening outward.

3.3.4 The compartment is to be provided with a refrigerant vapour detection system.

3.3.5 The compartment is to be provided with suitable water drainage arrangements not connected with the main machinery spaces.

3.3.6 Steel storage cylinders are to be of an approved type, supplied by the refrigerant manufacturer and are to be filled to a level suitable for an ambient temperature of plus 46°C.

3.3.7 The compartment is to be provided with racks to facilitate secure stowage of the cylinders.

3.4 Compartments housing carbon dioxide containing equipment

3.4.1 Self closing gas tight access doors are to be provided between each compartment and the dedicated escape routes. *See* 5.1.5.

3.4.2 In compartments which are normally occupied and where the volume of ventilation required by 3.1.3 is not desirable, such as production areas on fishing vessels, a negative pressure ventilation system, capable of 10 air changes per hour, is required to be fitted. This ventilation system is to be automatically activated when, in the event of a leak the concentration of carbon dioxide reaches a predetermined level but in no case higher than the threshold limit value of 5,000 ppm.

■ *Section 4* Refrigeration plant, pipes, valves and fittings

4.1 General requirements for refrigerating compressors

4.1.1 New compressor types or developments of existing types are to be subjected to an agreed programme of type testing to complement the design appraisal and review of documentation.

4.1.2 Where it is proposed to treat the bearing surfaces either by local hardening or by chromium plating, then these processes are to be confined to the bearing area and not extended to the fillets. Particulars of the process are to be submitted.

4.1.3 Where ball or roller bearings are incorporated, they are to have a minimum life expectancy of 25 000 running hours, for the application in question.

4.1.4 A check valve is to be fitted to each compressor discharge.

4.1.5 Where off-loading devices are incorporated, arrangements are to be provided which indicate the extent of the off-loading being effected.

4.1.6 A pressure relief valve and/or safety disc is to be fitted between each compressor and its gas delivery stop valve in accordance with 4.15.5 and 4.15.6.

4.1.7 Stop valves are to be provided on compressor suctions and discharges.

4.1.8 Suction strainers and lubricating oil filters are to be provided and so arranged that they are easily accessible for cleaning or renewal of the filter elements, without substantial loss of refrigerant or lubricating oil.

4.1.9 The correct direction of rotation is to be permanently indicated.

4.1.10 Where any hermetic or semi-hermetic compressor has the electric motor cooled by the circulating refrigerant, the following arrangements are to be provided:

(a) Refrigeration circuits are to contain no more than one hermetic or semi-hermetic compressor.
(b) Every compressor motor is to be fitted with a thermal cut-out device to protect the motor against overheating.
(c) In each refrigeration circuit containing a hermetic or semi-hermetic compressor, suitable arrangements shall be provided to remove debris and contaminants resulting from a motor failure. *See* 4.16.1.
(d) The pressure envelope of any hermetic or semi-hermetic compressor exposed to the refrigerant pressure is to be designed and constructed in accordance with the requirements of Pt 5, Ch 11 and Ch 17 as applicable. Plans are to be submitted for consideration as required by Pt 5, Ch 11,1.6.

4.2 Reciprocating compressors

4.2.1 The specified minimum tensile strength of castings and forgings for crankshafts is to be selected within the following general limits:

(a) Carbon and carbon-manganese steel castings – 400 to 550 N/mm^2.
(b) Carbon and carbon-manganese steel forgings (normalised and tempered) – 400 to 600 N/mm^2.
(c) Carbon and carbon-manganese steel forgings (quenched and tempered) – not exceeding 700 N/mm^2.
(d) Alloy steel castings – not exceeding 700 N/mm^2.
(e) Alloy steel forgings – not exceeding 1000 N/mm^2.
(f) Spheroidal or nodular graphite iron castings – 370 to 800 N/mm^2.

(g) Grey iron castings – not less than 300 N/mm^2.

4.2.2 Where it is proposed to use materials outside the ranges specified in 4.2.1, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

4.2.3 Materials for components of reciprocating compressors such as crankshafts, pistons, piston rods, crank cases, etc., are to be produced at a works approved by LR and in general to be tested in accordance with the Rules for Materials.

4.2.4 A fully documented fatigue strength analysis is to be submitted indicating a factor of safety of 1,5 at the design loads based on a suitable fatigue strength criteria. Alternatively, the requirements of 4.2.5 to 4.2.9 may be used.

4.2.5 The diameter, d, of a compressor crankshaft using one of the refrigerants detailed in 2.5, is to be not less than that determined by the following formula, when all cranks are located between two main bearings:

$$d = V_c \left(\frac{D^2 \, p \, Z}{78{,}5} \left(\frac{S}{16} + \frac{ab}{a+b} \right) \right)^{1/3} \text{ mm}$$

where

a = distance between inner edge of one main bearing and the centreline of the crankpin nearest the centre of the span, in mm

b = distance from the centreline of the same crankpin to the inner edge of the adjacent main bearing, in mm

$a + b$ = span between inner edges of main bearings, in mm

d_p = proposed minimum diameter of crankshaft, in mm

p = design pressure, in bar g, as defined in 2.5

D = diameter of cylinder, in mm

S = length of stroke, in mm

V_c = 1,0 for shafts having one cylinder per crank, or
= 1,05 for 90°
= 1,18 for 60°
= 1,25 for 45°
} between adjacent cylinders on the same crankpin
for the shaft and cylinder arrangements as detailed in Table 3.4.1

$Z = \dfrac{560}{\sigma_u + 160}$ for steel

$Z = \dfrac{700}{\sigma_u + 260 - 0{,}059 d_p}$ for spheroidal or nodular graphite cast iron

$Z = \dfrac{700}{\sigma_u + 260 - 0{,}069 d_p}$ for grey cast iron

σ_u = specified minimum tensile strength of crankshaft material, in N/mm^2.

4.2.6 Where the shaft is supported additionally by a centre bearing, the diameter is to be evaluated from the half shaft between the inner edges of the centre and outer main bearings. The diameter so found for the half shaft is to be increased by six per cent for the full length shaft diameter.

Table 3.4.1 Angle between cylinders

Number of crankpins	Number of cylinders per crank	Angle between cylinders, in degrees		
1 or 2	2	45	60	90
3	2	45	60	—
4	2	45	60	—
1	3	45	60	90
2	3	45	60	—
3	3	45	—	—
1	4	45	60	—
2	4	45	—	—

4.2.7 The dimensions of crankwebs are to be such that Bt^2 is to be not less than given by the following formulae:

0,4d^3, for the web adjacent to the bearing

0,75d^3, for intermediate webs where a single intermediate web is common to two adjacent crankthrows

where

B = breadth of web, in mm

d = minimum diameter of crankshaft as required by 4.2.5, in mm

t = axial thickness of web which is to be not less than 0,45d for the web adjacent to the bearing, or 0,60d for intermediate webs, in mm.

4.2.8 Fillets at the junction of crankwebs with crankpins or journals are to be machined to a radius not less than 0,05d. Smaller fillets, but of a radius not less than 0,025d, may be used provided the diameter of the crankpin or journal is not less than cd,

where

$c = 1{,}1 - 2\dfrac{r}{d}$ but to be taken as not less than 1,0

d = minimum diameter of crankshaft as required by 4.2.5, in mm

r = fillet radius, in mm.

4.2.9 Fillets and oil holes are to be rounded to an even contour and smooth finish.

4.2.10 An oil level sight glass is to be fitted to the crankcase.

4.2.11 Compressors with cylinder bores in excess of 50 mm diameter are to be provided with arrangements to relieve high cylinder pressures such as would result from 'hydraulic lock' (i.e., liquid refrigerant in the cylinders). Alternatively the provision of positive means to prevent liquid refrigerant reaching the compressor may be accepted.

4.2.12 The crankcases of trunk piston compressors are to be designed to withstand a pressure equal to the maximum working pressure of the system. The crankcases of compressors of the crosshead type which are substantially isolated from the refrigerant circuit may be designed for lower pressures but are to be provided with relief valves adjusted to lift at a pressure not exceeding the design pressure, and discharging to a safe place.

4.2.13 A crankcase heater, arranged to be energised when the compressor is stopped, is to be provided.

4.3 Screw compressors

4.3.1 For screw-type compressors, the materials of the rotors and casings are to be produced, and the manufacture is to be carried out, at a works approved by LR, and in general, they are to be tested in accordance with the Rules for general machinery forgings.

4.3.2 The rotor casing is to be designed for the maximum pressure to which it may be subjected, *see* 2.5.

4.3.3 Where gearing is fitted to increase the rotor speed and also to locate the rotors, the gearing is to comply with Pt 5, Ch 5. The manufacturer's maximum allowable tolerances for clearances and backlash between mating rotors are to be stated.

4.4 Pressure vessels and heat exchangers

4.4.1 The term 'pressure vessel' will normally apply to receivers and heat exchangers, and does not include any of the following:

- Compressors.
- Liquid refrigerant pumps.
- Pipes and their fittings.

The use of plate heat exchangers will be specially considered on submission of plans, and special tests may be required.

4.4.2 Fusion welded steel pressure vessels exposed to the pressure of the refrigerants are to be constructed in accordance with the requirements of Pt 5, Ch 11 and Ch 17. Plans are to be submitted for consideration if required by Pt 5, Ch 11,1.6.

4.4.3 Where ammonia is the refrigerant, the pressure vessels are to be constructed to at least Class 2/1 requirements.

4.4.4 Pressure vessels for the containment of primary refrigerants for use in conventional refrigeration circuits where the pressure/saturation temperature relationship applies are not required to be low temperature impact tested unless the design temperature is lower than minus 40°C.

4.4.5 Pressure vessels are to be thermally insulated to an extent which will minimise condensation of moisture from the surrounding atmosphere. The insulation is to be provided with an efficient vapour barrier and adequately protected from mechanical damage. Prior to applying the insulation, the steel surfaces are to be suitably protected against corrosion.

4.4.6 Each pressure vessel which may contain liquid refrigerant and which is capable of being isolated is to be protected with overpressure relief devices, *see* 4.15.

4.5 Condensers, oil coolers and evaporators

4.5.1 In order to minimise the risk of corrosion, where the refrigerant is ammonia, the material interface between the primary refrigerant and cooling water or secondary refrigerant is to be of a suitable grade of stainless steel. Carbon-manganese steel with a suitable inhibitor would also be acceptable.

4.5.2 Space is to be provided for the withdrawal and replacement of condenser and evaporator tubes, *see* 3.1.1.

4.5.3 Where ammonia is used as the refrigerant, the refrigerating plant is to comply with the following additional requirements:

(a) Automatic air purgers are to be provided, with their discharges being led through water before venting to atmosphere.
(b) The cooling water returns from sea-water cooled condensers are not to be led into the main machinery spaces.
(c) Fresh water condenser cooling systems are to be provided with pH meters to activate audible and visual alarms in the event of an ammonia leak.

4.6 Liquid receivers

4.6.1 Primary refrigerating systems are to be provided with liquid receivers with sufficient capacity to hold the complete refrigerant charge to prevent emission of the refrigerant to the atmosphere during servicing or repairs.

4.6.2 Alternatively, in systems using a secondary refrigerant, with a number of units, smaller receivers may be used provided the system includes a common storage receiver with sufficient capacity to hold at least the primary refrigerant charge from two units. The common receiver is to be provided with the necessary crossover connections to facilitate transfer of refrigerant to and from each unit in the system.

4.7 Oil separators

4.7.1 Oil separators are to be provided at compressor discharges and are to be fitted with a control arrangement to enable the separated oil to be returned to the compressor crankcase. Wire gauze used in separators is to be sufficiently robust and well supported.

4.8 Air coolers and cooling grids

4.8.1 Refrigerated spaces may be cooled by air coolers or cooling grids on the ceiling, bulkheads and sides. In order to minimise the dehydration of the cargo and the frosting of the air coolers or cooling grids, the installation is to be designed to maintain the required notation temperatures with a minimum of difference between the refrigerant and space temperatures.

4.8.2 Individual spaces are to have a minimum of two independent air coolers, each comprising one or more fans and one or more refrigerant circuits in a single casing and with isolating valves. Alternatively, multiple circuits each with their own fan(s), in a single cooler casing may each be regarded as a separate cooler, provided stop valves are fitted so that each circuit may be isolated.

4.8.3 For refrigerated spaces having a net volume of 300 m^3 or less, a single cooler with one circuit will be accepted.

4.8.4 The refrigeration capacity of the air cooler arrangement is to be such that the notation temperature conditions can be maintained with any one independent cooler or circuit out of action. The capacities of the fans are also to be such that they can maintain the required air flow rates (*see also* 9.4) and uniform air temperature throughout the refrigerated spaces, when part or fully loaded with cargo, with any one cooler or fan out of action.

4.8.5 Air cooler fan motors are to be suitably enclosed to withstand the effects of moisture.

4.8.6 Means are to be provided for effectively defrosting air coolers. Air coolers are to be provided with trays of suitable depth arranged to collect all condensate. The trays are to be provided with drains at their lowest points to enable the condensate to be drained away when the refrigerated spaces are in service. Provision is to be made for the prevention of freezing of the condensate.

4.8.7 Air coolers are to be located such that when the refrigerated spaces are loaded with cargo, adequate space is provided for the inspection, servicing and renewal of controls, valves, fans and fan motors.

4.8.8 The cooling grids in each refrigerated space are to be arranged in not less than two sections, and each section is to be fitted with valves so that it can be shut off. The notation temperature conditions are to be capable of being maintained with any one section isolated. For spaces having a net volume of 300 m^3 or less, a single section will be acceptable.

4.8.9 Steel air cooler circuits and cooling grids are to be suitably protected against external corrosion.

4.9 Refrigerant pumps

4.9.1 Pumped primary and/or secondary refrigerant systems are to have a minimum of two pumps. Each pump is to be capable of operating on all cargo chambers and maintaining full duty with any one pump out of operation.

4.9.2 Primary and, where appropriate, secondary refrigerant pumps are to be provided with pressure relief valves, *see* 4.15.13.

4.10 Condenser cooling water pumps

4.10.1 At least two separate condenser cooling water pumps are to be installed. One of the pumps may be considered as a standby pump and may be used for other purposes, provided that it is of adequate capacity and its use on other services does not interfere with the supply of cooling water to the condensers.

4.10.2 Not less than two sea inlets are to be provided supplying sea-water to the pumps for condenser cooling. It is recommended that one of the sea inlets be provided on the port side and the other on the starboard side. The sea inlets are to be fitted in accordance with Pt 5, Ch 13,2.6.

4.10.3 The cooling water pumps and sea inlets are to be suitably valved and cross-connected with each condenser.

4.10.4 Suitable spring-loaded safety valves are to be provided in each cooling water circuit, *see* 4.15.13.

4.11 Piping systems

4.11.1 All piping, valves and fittings are to be suitable for the maximum pressure to which the system can be subjected and are to comply with the requirements of Pt 5, Ch 12.

4.11.2 Pipework for ammonia (R-717) is to comply with Class I requirements.

4.11.3 In addition to visual examination of pipe welds, non-destructive examination of pipe welds is to be carried out in accordance with the requirements of Chapter 13 of the Rules for Materials to the satisfaction of the Surveyors.

4.11.4 All steel pipework on the low temperature part of the system is to be protected against external corrosion. Protective coatings are to be removed from pipe surfaces to a distance of not less than 50 mm either side of the joint weld preparations prior to welding. On completion of welding and testing a protective coating is to be applied.

4.11.5 Where brine is the secondary refrigerant, piping and tanks should not be galvanised on the brine side. If any parts of the brine system have been galvanised, the brine cooling and return tanks are to be provided with a ventilating pipe or pipes led to the atmosphere in a location where no damage will arise from the gas discharged. The ventilation pipes are to be fitted with wire gauze diaphragms which can be readily renewed.

4.11.6 Copper piping is to be manufactured in accordance with Pt 5, Ch 12,3 except in the case of small air coolers having finned pipes of sizes not greater than 19 mm outside diameter, and which have been fabricated under workshop conditions. The finned pipes may have a minimum wall thickness of 0,5 mm when used with R-22 and R-134a refrigerants.

4.11.7 Where the use of plastics pipe is proposed in a secondary refrigerant system (e.g., brine), it is to be in accordance with Pt 5, Ch 12,5.

4.11.8 Pipelines are to have ample provision for expansion and contraction in service conditions. In general, expansion bends are to be used for this purpose. However, the use of metallic expansion bellows will be accepted provided test data is produced showing satisfactory strength and fatigue properties under the appropriate conditions.

4.11.9 All pipelines are to be fully supported and secured so as to prevent vibration. Flexible hoses may be used, where necessary, to prevent transmission of vibration provided the documentation in 4.11.8 is provided. Flexible hoses are to be of a type which has been approved by LR, *see* Pt 5, Ch 12,6.

4.11.10 Pipework, which may contain low temperature refrigerant, except within secondary refrigerant cooler rooms, is to be thermally insulated to an extent which will minimise condensation of moisture. Insulation in pre-formed sections is recommended. If *in situ* foamed insulation is employed, pre-production testing on site is to be carried out to the satisfaction of the Surveyor, using a 'mock-up' representative of the system to be employed.

4.11.11 All pipe insulation is to be provided with an efficient vapour barrier, care being taken to ensure that it is not interrupted in way of supports, valves, etc. Also adequate protection of insulation surfaces from mechanical damage is to be provided.

4.11.12 Where refrigerating piping is embedded in the cargo chamber insulation, the locations of the pipe joints are to be marked on the outside of the insulation lining.

4.12 Joints

4.12.1 Butt welded pipe joints are to be employed as far as practicable. Socket welded pipe joints are acceptable up to 25 mm diameter. Flanged or other joints are to be kept to a minimum and, in general, are to be restricted to connections with items of machinery or components which may have to be removed for maintenance purposes. Connections to valves are normally to be welded unless they are of a type, or in a position, which precludes *in situ* maintenance.

4.12.2 Pipe connections to fittings (e.g., gauge lines, level controls) which are likely to be subjected to heavy corrosion, are to be of heavy gauge construction, or be made from suitable corrosion resistant materials.

4.13 Liquid level indicators

4.13.1 Where liquid level indicators of the 'see-through' variety are used they are to be of the flat plate type incorporating glass (or equivalent material) of heat resistant grade.

4.13.2 All level indicators are to be provided with automatic shut-off devices and isolating valves. Plate-type sight glasses which form an integral part of the component in which they are mounted (e.g., compressor crankcases, pressure vessels) are exempt from this requirement.

4.13.3 All level indicators are to be suitable for the system maximum working pressure and tested accordingly.

4.14 Automatic expansion valves

4.14.1 Refrigerating systems with automatic expansion valves are also to be provided with efficient hand expansion valves and the arrangement is to be such that the automatic expansion valves can be by-passed and isolated.

4.14.2 As an alternative, duplicate automatic expansion valves may be fitted, each valve to be capable of the required duty and operable with the other out of action.

4.15 Overpressure protection devices

4.15.1 Refrigeration systems are to be provided with relief devices, but it is important to avoid circumstances which would bring about an inadvertent discharge of refrigerant to the atmosphere. The system is to be so designed that pressure due to fire conditions will be safely relieved.

4.15.2 Pressure relief devices are to be mounted in such a way that it is not possible to isolate them from the part of the system which they are protecting except that, where duplicated, a changeover valve may be fitted which will allow either device to be isolated for maintenance purposes without it being possible to shut off the other device at the same time.

4.15.3 Relief discharge is to be led to a safe place above deck away from personnel accesses and air intakes. Discharge piping should be designed to preclude ingress of water, dirt or debris which may cause the equipment to malfunction.

4.15.4 For ammonia systems, discharge from relief valves is to be led through water before venting to the atmosphere. Vapour detectors are to be provided in the discharge pipes to activate audible and visual alarms in the event of a leakage of ammonia.

4.15.5 A pressure relief valve and/or bursting disc is to be fitted between each positive displacement compressor and its gas delivery stop valve, the discharge being led to the suction side of the compressor. The flow capacity of the valve or disc is to exceed the full load compressor capacity on the particular refrigerant at the maximum potential suction pressure. For these internal relief valves, servo-operated valves will be accepted. Where the motive power for the compressor does not exceed 10 kW, the pressure relief valve and/or bursting disc may be omitted.

4.15.6 Compressors protected by bursting discs are to be provided with automatic shut-down in the event of high discharge temperatures.

4.15.7 Each compressor is to be provided with automatic shut-down in the event of high discharge pressure. For refrigeration systems where the maximum working pressure is less than or equal to 40 bar g the automatic shut-down is to operate at a pressure in excess of normal operating pressure but no greater than 0,9 of the maximum working pressure. For refrigeration systems where the maximum working pressure is greater than 40 bar g the automatic shut-down is to operate at a pressure in excess of normal operating pressure but no greater than 0,95 of the maximum working pressure.

4.15.8 Each pressure vessel which may contain liquid refrigerant and which is capable of being isolated by means of stop or automatic control or check valves is to be protected by two pressure relief valves or two bursting discs, or one of each, controlled by a changeover device.

4.15.9 Pressure vessels which are interconnected by pipework without valves, so that they cannot be isolated from each other, may be regarded as a single pressure vessel for this purpose, provided that the interconnecting pipework does not prevent effective venting of any vessel.

4.15.10 Omission of one of the specified relief devices and the changeover device, as required by 4.15.8, will be allowed where:

- vessels are of less than 300 litres internal gross volume; or
- vessels discharge into the low pressure side by means of a relief valve; or
- vessels operating using only cargo gas and, which can be independently isolated and gas freed during normal cargo operations provided that a shelf spare is carried.

4.15.11 Sections of systems and components which could become full of liquid between closed valves are to be provided with pressure relief devices relieving to a suitable point in the refrigerant circuit.

4.15.12 Refrigerant pumps are to be provided with pressure relief valves on the discharge side, which may relieve to the suction side, or to another suitable location.

4.15.13 Suitable spring-loaded safety valves are to be provided on the cooling liquid side of condensers and the brine side of evaporators where the pressure from any pump or expansion of the liquid in the circuit could exceed the design pressure of the system or any component forming part of the cooling system.

4.15.14 Relief valves are to be adjusted and bursting discs so selected that they relieve at a pressure not greater than the design pressure of the system, as defined in 2.5.

4.15.15 When satisfactorily adjusted, relief valves are to be protected against tampering or interference by a wire with a lead seal or similar arrangement.

4.15.16 Valves which are arranged to discharge to the low pressure side of the system are to be substantially independent of back pressure and are to be of a type which has been approved by LR.

4.15.17 The minimum required discharge capacity related to air of the pressure relief device for each pressure vessel is to be determined as follows:

$$C = D\,L\,f$$

where

C = minimum required discharge capacity related to air of each relief device, in kg/s
D = outside diameter of the vessel, in metres
L = length of the vessel, in metres
f = factor which is dependent on the refrigerant:

R-717 (Ammonia)	0,041
R-22, R-134a, R-407C	0,131
R290 (Propane), R-600a (Isobutane)	0,082
R-410A, R-404A, R-507A	0,203
R-744 (Carbon dioxide) (when used on the low side of a cascade system)	0,082.

4.15.18 The rated discharge capacity of the pressure relief valves expressed in kg/s of air may also be determined in accordance with an appropriate recognised National or International Standard such as *ISO 5149 Mechanical Refrigeration Systems used for Cooling and Heating – Safety Requirements.*

4.15.19 The rated discharge capacity of a bursting disc discharging to atmosphere under critical flow conditions is to be determined by the following formula:

$$d = 85{,}75\sqrt{\frac{C}{P}}\ \text{mm}$$

where

d = minimum diameter of free aperture of bursting disc, in mm
C = minimum required air equivalent discharge capacity, in kg/s, *see* 4.15.17
P = 1,1 x maximum working pressure, *see* 2.5.

4.15.20 The bore of the discharge pipe shall be at least the same bore as the relieving device outlet. The size of a common discharge line serving two or more pressure relieving devices which may discharge simultaneously shall be based on the sum of their outlet areas. Where discharge lines are long or where the outlets of two or more pressure relieving devices are connected into a common line, the discharge piping shall be sized such that the back pressure at full relief rate does not exceed 10 per cent of the relief valve set pressure.

4.15.21 Due account is to be taken of the reaction force on a relief valve or on discharge piping during discharge and adequate support provided.

4.15.22 As carbon dioxide can form a solid powder at atmospheric pressure, there is a possibility that relief devices will choke if vented directly to atmosphere. The method used to guard against the formation of powder is to be submitted for consideration.

4.15.23 In carbon dioxide systems, overpressure protection is to be fitted to pipelines or components which can be isolated in a liquid full condition. Pressure relief devices are to be arranged such as to vent vapour at all times.

4.15.24 In cascade systems where carbon dioxide is used in combination with ammonia, the effects of carbon dioxide leaking into the ammonia side are to be considered. It may be desirable to design the ammonia system to either withstand the design pressure on the carbon dioxide side or have relief arrangements to safely deal with the additional vapour produced if a leak occurs.

4.16 Filters, driers and moisture indicators

4.16.1 Suitable filters are to be provided in the refrigerant gas lines to compressors and in the liquid lines to refrigerant flow controls. Wire gauze used in filters is to be sufficiently robust and well-supported. A filter may be combined with the oil separator required by 4.7.1. Stop valves are to be provided to allow for servicing of filters. After first commissioning of the system, the filters should be examined to confirm that elements remain intact and not collapsed.

4.16.2 Refrigerant filters, driers and moisture indicators are to be fitted in halocarbon refrigerant systems, and the arrangement is to be such that filters and driers can be by-passed, isolated and opened up without interrupting plant operations.

4.17 Purging devices

4.17.1 Where the operating pressure of the low pressure system may be below atmospheric, a purging device is to be provided, the discharge from which is to be led to a safe place above deck.

4.18 Piping in way of refrigerated spaces

4.18.1 All sounding pipes, whether for compartments or tanks, which pass through refrigerated spaces or the insulation thereof, in which the temperatures contemplated are 0°C or below, are to be not less than 65 mm bore. The pipework is to be in accordance with the requirements of Pt 5, Ch 12 and Pt 5, Ch 13,2.9.

4.18.2 Sounding pipes to oil compartments are not to terminate within refrigerated spaces or in their air cooler spaces, nor are these pipes to terminate in enclosed spaces from which access is provided to refrigerated spaces or their air cooler spaces.

4.18.3 All pipes, including scupper pipes, air pipes and sounding pipes that pass through refrigerated spaces are to be insulated.

4.18.4 Where the pipes referred to in 4.18.3 pass through chambers intended for temperatures of 0°C or below, they are also to be insulated from the steel structure, except in positions where the temperature of the structure is mainly controlled by the external temperature and will normally be above freezing point. Pipes passing through a deck plate within the ship side insulation, where the deck is fully insulated below and has an insulation ribband on top, are to be attached to the deck plating. In the case of pipes adjacent to the shell plating, metallic contact between the pipes and the shell plating or frames is to be avoided so far as practicable.

4.18.5 The air refreshing pipes to and from refrigerated spaces need not, however, be insulated from the steelwork.

4.19 Drainage from refrigerated spaces

4.19.1 Provision is to be made for the continuous drainage of the inside of all refrigerated spaces and cooler trays. The pipework is to be in accordance with the requirements of Pt 5, Ch 12 and Pt 5, Ch 13,3.2.

4.19.2 All drain pipes from the refrigerated spaces and cooler trays are to be fitted with liquid sealed traps, which are to be of adequate depth and readily accessible for cleaning and refilling with brine. The pipes from lower spaces situated on the tank tops are also to be fitted with bilge non-return valves.

4.19.3 Where drains from separate refrigerated spaces join a common main, the branch pipes are each to be provided with a liquid sealed trap.

4.19.4 Sluices, scuppers or drain pipes which would permit drainage from compartments outside the refrigerated spaces into the bilges of the latter are not to be fitted.

4.19.5 Screwed plugs or other means for blanking off scuppers, draining chambers and cooler trays are not to be fitted. If, however, it is specially desired to provide means for temporarily closing these scuppers, they may be fitted with shut-off valves.

4.20 Corrosion protection of metal fixtures

4.20.1 All steel bolts, nuts, hangers, brackets and fixtures which support or secure cooling appliances, piping insulation, meat rails, linings and prefabricated insulated panels, etc., are to be suitably protected against corrosion.

4.21 Pressure testing at manufacturers' works

4.21.1 Components intended for use with a primary refrigerant are to be subject to strength and leak pressure tests as detailed in Table 3.4.2.

Table 3.4.2 Test pressure

Component	Test pressure, bar g	
	Strength test	Leakage test
1. Pressure vessels	*See* Pt 5, Ch 11	1,0p
2. Compressor cylinders/ crankcase/casing	1,5p	1,0p
3. Valves and fittings	2,0p	1,0p
4. Pressure piping, fabricated headers, air coolers, etc.	1,5p	1,0p

NOTE
p is the design pressure as defined in 2.5.

4.21.2 Component strength pressure tests are to be hydraulic or where suitable safety measures are taken, may be pneumatic. The latter is to be carried out with a suitable dry inert gas.

4.21.3 Component leakage pressure tests are to be carried out only after completion of satisfactory strength pressure tests. Pneumatic pressure is to be applied using a suitable dry inert gas.

4.21.4 Components for use with a secondary refrigerant or cooling water are to be hydraulically tested to 1,5 times the design pressure, but in no case less than 3,5 bar g.

4.22 Pressure test after installation on board ship

4.22.1 For primary refrigerant piping welded in place, strength pressure tests of the welds are to be carried out at a test pressure of 1,5*p*. This will normally take the form of a pneumatic test since hydraulic testing media such as water are not acceptable due to their incompatibility with the primary refrigerants and the difficulty of removing all traces from a completed system.

4.22.2 Pneumatic pressure tests are to be carried out using a suitable inert gas. All pneumatic tests are potentially dangerous and due precautions are to be observed.

4.22.3 Where pneumatic tests are prohibited by relevant authorities, the tests required by 4.22.2 may be omitted provided non-destructive tests by ultrasonic or radiographic methods are carried out with satisfactory results on the entire circumference of all butt welds not tested in accordance with 4.11.3. Where ultrasonic tests have been carried out, the manufacturer is to provide the Surveyor with a signed statement confirming that ultrasonic examination has been carried out by an approved operator and that there were no indications of defects which could be expected to have a prejudicial effect on the service performance of the piping.

4.22.4 After completion of the test required by 4.22.1, 4.22.2 or 4.22.3, a leak pressure test is to be carried out using a suitable inert gas at a pressure equal to the design pressure, in the presence of the Surveyor.

4.22.5 Secondary refrigerant piping welded in place is to be hydraulically tested to 1,5 times the design pressure, but in no case less than 3,5 bar g.

■ *Section 5* Refrigerant detection systems

5.1 General

5.1.1 A fixed refrigerant detection system is to be provided in the refrigerating machinery compartment or space, the discharge pipes from pressure relief valves, ventilation outlet ducts, and the cargo chambers, where appropriate.

5.1.2 The alarm system is to comply with the requirements of Chapter 1 and, as a minimum requirement, the system is to activate at a low-level concentration to give warning of refrigerant leaks, and a high-level concentration corresponding to the refrigerant's safe occupational level.

5.1.3 Detection equipment is to be so designed that it may be readily tested and calibrated, and failure of the equipment is to initiate an alarm.

5.1.4 The location of the detectors is to be determined relative to the layouts of the individual compartments and machinery spaces and are to be indicated on the plan submission.

5.1.5 For carbon dioxide systems, spaces such as machinery rooms, storage compartments, production areas on fishing vessels and valve stations, where leakage may occur, are to be fitted with detectors. Welded pipelines passing through passageways or access ducts are not considered possible leakage areas.

5.1.6 Audible and visual alarms are to be activated, located both inside and outside the affected space. The alarms are to be readily identifiable and be visible and audible in all locations within the space housing the refrigeration equipment.

5.2 Ammonia vapour detection and alarm equipment

5.2.1 A fixed detector system for ammonia is to comply with the requirements contained in 5.1.2.

5.2.2 The location of the detectors is to be determined relative to the layouts of the individual spaces and are to be indicated on the plan submission required by 1.2.

5.2.3 Ammonia vapour detectors are to be provided in the refrigeration machinery compartment, associated access ways, the exhaust ducts, the ammonia store room and the discharge pipes from pressure relief valves.

5.2.4 Sufficient detectors are to be provided to monitor the total areas of the above spaces.

5.2.5 For vapour detection in relief valve discharge pipes, *see* 4.15.4.

5.2.6 Details of the refrigerant detector set points and operational philosophy are to be submitted for consideration.

■ *Section 6* Electrical installation

6.1 General

6.1.1 Where the refrigerating machinery is to be electrically driven, the requirements of Ch 2,2 are to be complied with, as applicable.

6.1.2 The generating capacity available for the refrigerated installation is to be sufficient to supply power to the installation during cooling down of a complete cargo to, and maintenance of, the notation temperature conditions in all refrigerated spaces at the Rule maximum ambient and seawater temperatures.

6.1.3 Electrical equipment is not to be installed in spaces in which ammonia refrigerant is used or stored unless it is essential for operational purposes. Where electrical equipment is installed in such spaces the requirements of 6.2 are to be complied with.

6.2 Electrical equipment for use in explosive gas atmospheres

6.2.1 Lighting fittings are to be of a certified safe-type and be arranged on at least two independent final branch circuits. Switches and protective devices are to interrupt all lines or phases and are to be located outside the space.

6.2.2 Where electric motors driving ventilation fans are located within the spaces, within ventilation ducts, or within three metres of ventilation openings, they are to be of a certified safe-type.

6.2.3 Monitoring control and alarm systems which are required to operate under conditions of ammonia leakage are to be of a certified safe-type.

6.2.4 Electrical equipment which is not of a certified safe-type is to de-energise automatically if the ammonia concentration within the space exceeds 1,0 per cent by volume.

■ *Section 7* Instrumentation, control, alarm, safety and monitoring systems

7.1 Instrumentation

7.1.1 All compressors are to be provided with the following instrumentation and automatic shut-downs:

- Indication of suction pressure (saturated temperature), including intermediate stage, when applicable.
- Indication of discharge pressure (saturated temperature), including intermediate stage, when applicable.
- Indication of lubricating oil pressure.
- Indication of cumulative running hours (screw compressors).
- Automatic shut-down in the event of low lubricating oil pressure.
- Automatic shut-down in the event of high discharge pressure, *see also* 4.15.7.
- Automatic shut-down in the event of low suction pressure.

7.1.2 The automatic safety equipment is to be designed to fail safe and the arrangements are to be such that the compressors can be operated manually with the equipment out of action, in accordance with the relevant requirements of Chapter 1.

7.1.3 For installations greater than 25 kW the following instrumentation, additional to that required by 7.1.1, is to be provided:

- Indication of lubricating oil temperature.
- Indication of cooling water outlet temperature.
- Indication of cumulative running hours (reciprocating compressors).
- Indication of suction and discharge temperatures.

7.2 Control, alarm and safety systems

7.2.1 Where the refrigerating system is fitted with automatic or remote controls, so that under normal operating conditions no manual intervention by the operators is required, it is to be provided with the alarms required by 7.2.2 and 7.2.3 in accordance with the relevant requirements of Chapter 1.

7.2.2 Alarms are to be initiated in the event of the following compressor fault conditions:

- High discharge pressure.
- Low suction pressure.
- Low oil pressure.
- High discharge temperature.
- High oil temperature.
- Motor shut-down.

7.2.3 Alarms are also to be initiated in the event of the following fault conditions:

- Failure of condenser cooling water pumps.
- High condenser cooling water outlet temperature.
- Failure of air cooler fans.
- High and low refrigerated air delivery temperatures.
- High secondary refrigerant temperatures.
- Failure of secondary refrigerant pump.
- Failure of air refreshing fans.
- Low level in secondary refrigerant header tank.

7.3 Temperature monitoring and recording

7.3.1 Temperature sensors are to be of a type which has been approved by LR. The number of sensors and their locations are to be such as to give a true measurement of the temperatures within the refrigerated spaces and of the cooler delivery and return air temperatures.

7.3.2 At least one automatic recorder is to be provided for the remote monitoring and continuous recording of air temperatures within the refrigerated spaces, and delivery and return air temperatures of individual air coolers. Where only one recorder is installed, at least one sensor in each refrigerated space or in its air distribution system is to be connected to a separate remote temperature indicating instrument.

7.3.3 Where the equipment controlling the temperature of the air delivered from the air coolers is equipped with a temperature indicator, this indicator will be given consideration as a standby instrument.

7.3.4 In the case of freezer fishing vessels, where the catch is frozen on board and stored in a refrigerated space, thermometer(s) hung within each space(s) will be accepted as the standby temperature indicator, provided the space is accessible at all times.

7.3.5 Automatic temperature recorders and temperature indicators are to be of a type which has been approved by LR and, where appropriate, are to be in accordance with the requirements of Chapter 1. Approval will be granted on the basis of compliance with 7.3.6 and 7.3.7, together with satisfactory environmental testing in accordance with the requirements of LR's Type Approval System. This is to include low temperature testing at the class notation minimum temperatures for any components which may be installed in environments subject to temperatures below ambient.

7.3.6 All temperature instrumentation is to be accurate to within ±0,15°C of the true temperature in the range minus 3°C to plus 15°C , and to ±0,3°C in other parts of the range and is to register to 0,1 of a degree Celsius.

7.3.7 Where the installation is intended for the carriage of frozen cargo only, the readings need only be accurate to within ±0,5°C of the true temperature, throughout the range.

7.3.8 A spirit-in-glass thermometer is to be carried on board for checking purposes, which is to be calibrated to a recognised National Standard.

7.3.9 Thermometer tubes with their flanges and covers are to be insulated from the deck plating, and on weather decks they are to be so arranged that water will not run down the tubes when temperatures are being taken.

7.3.10 The inside diameter of thermometer tubes is to be not less than 50 mm, and the tubes are not to be in contact with cold decks.

7.3.11 Where thermometer tubes pass through compartments other than those which they serve, they are to be efficiently insulated.

■ *Section 8*
Personnel safety equipment and systems

8.1 Personnel safety equipment

8.1.1 Access doors and hatches to the refrigerated spaces and air cooler spaces are to be provided with an external locking arrangement.

8.1.2 Access ways to the refrigerated space are to be designed to facilitate escape in emergencies, and the removal of stretcher-borne personnel.

8.1.3 Access ways and air cooler spaces are to be provided with an independent lighting system in accordance with the requirements of Ch 2,5.7.2 and Ch 2,5.7.4, with the means of locking the switches in the 'on' position.

8.1.4 Where ammonia is used in refrigerating systems, the following items of safety equipment are to be provided as a minimum, and positioned in accessible protected storage (e.g., locked glass fronted cabinets) located outside the machinery compartment:

- Two sets of ammonia protective clothing (including helmet, boots and gloves).
- Two portable battery powered hand lamps (to be of certified safe-type).
- Two sets of self-contained breathing apparatus (compressed air).
- Two full face mask respirators.
- Two fire-resistant life-lines.
- Two firemen's axes.
- Two heavy duty adjustable spanners.
- Two wheel wrenches.
- Irrigation facilities or eye wash bottles containing an eye wash solution, distilled water or non-carbonated mineral water.
- Hand or foot-operated douches providing a copious supply of clean water, located outside the compartment's doors. *See* 3.2.4.

8.2 Personnel warning systems

8.2.1 A system to monitor the well-being of crew members entering refrigerated spaces is to be provided.

8.2.2 The system is to be such that at a predetermined time, after initiation, the crew member(s) receives warning that the Surveyors must indicate their well-being by accepting the warning.

8.2.3 The system is to be designed and arranged such that only an authorised person has access for enabling and disabling it and setting the appropriate intervals, and such that it cannot be operated in an unauthorised manner.

8.2.4 It is to be possible to acknowledge the warning by means of illuminated switches situated near the access doors or hatches of each refrigerated space or chambers within the space.

8.2.5 In the event that the crew member(s) fail(s) to respond and accept the warning within an agreed specified time, the system is to immediately initiate an alarm on the bridge and in the engineers' accommodation. Manual initiation of the alarm system from the refrigerated spaces is to be possible at any time.

8.2.6 The system is to comply with the relevant requirements of Chapter 1.

Section 9
Refrigerated cargo spaces

9.1 Airtightness of refrigerated spaces

9.1.1 The envelopes of individual refrigerated spaces, enclosing each temperature zone, are to be sufficiently airtight to prevent infiltration of water vapour and cross-contaminating odours. Each envelope is to be hose-tested for tightness before the insulation is installed. Alternative proposals to test with gas or air under pressure will be considered.

9.1.2 Hatch closing appliances, access doors, side loading doors, bilge and manhole plugs forming part of an insulated envelope are to be made airtight and, where exposed to ambient conditions, are to be provided with a double seal.

9.1.3 Ventilators, ducts or pipes passing through refrigerated spaces to other compartments are to be made airtight and efficiently insulated. Particular attention is to be given to insulation linings forming surfaces of air ducts. Ventilators to refrigerated spaces, if fitted, are to be provided with airtight closing appliances.

9.1.4 Refrigeration pipes passing through bulkheads or decks of refrigerated chambers or spaces are not to be in direct contact with the steelwork. The temperature of the ship's steelwork close to low temperature refrigeration piping must not be lower than that acceptable for the steel grade, *see also* Pt 3, Ch 2,2.2. The airtightness of the bulkheads and decks is to be maintained and, where the pipes pass through watertight decks and bulkheads, the fittings and packing of the glands are to be both fire resisting and watertight.

9.2 Insulation systems

9.2.1 Steelwork and fittings are to be clean and dry, and suitably coated to prevent corrosion, before insulation is applied.

9.2.2 *In situ* insulation and insulating panels are to be of a type that has been approved by LR and accordingly, whenever practicable, be selected from the *List of Type Approved Products* published by LR. A copy of the *Procedure for LR Type Approval System* will be supplied on application. Prefabricated panels, with an organic foam core and metal or similar cladding both sides, are also to be manufactured under survey at a works approved by LR. Organic foam materials are to be certified as self-extinguishing. All materials are to be free from odour likely to cause taint.

9.2.3 The thickness of insulation over all surfaces and the manner in which it is supported are to be in accordance with the approved specification and plan.

9.2.4 The insulation is to be efficiently packed and, where it is of slab form, the joints are to be butted closely together and staggered. Where it is intended to use a foamed *in situ* type of insulation, full details of the process are to be submitted for approval before the work commences and pre-production testing on site is to be carried out to the satisfaction of the Surveyor, using a 'mock-up' representative of the system to be employed. Prefabricated panels are to be of a design such that, when erected, continuity of the insulation envelope is maintained without any gaps. Gaps between panels or insulation slabs are to be filled with insulating material to the satisfaction of the Surveyor.

9.2.5 The inner surfaces of insulation envelopes are to be clad with a suitable lining, such as marine grade aluminium or plywood, or equivalent material which is:
- impermeable;
- able to withstand wear and tear and the flexing of the ship's structure without fracture at the notation temperatures;
- non-corrosive, non-rotting; and
- free from odour likely to cause taint.

Where prefabricated panels are employed the outer surfaces are also to be clad with a suitable lining.

9.2.6 Insulation linings are to be constructed and fitted so that they are airtight and provide an effective vapour barrier. The means of joining prefabricated panels are to have sufficient mechanical strength to maintain a vapour barrier on the inner and outer faces. All joints, including corner, deck, deckhead and tank top intersections are to be sealed with a suitable flexible, water vapour resistant sealant or gasket. Special care is necessary where air ducts are embedded in the insulation, and where refrigeration pipes, air refreshing ducts, fan supports, fixtures, etc., protrude through the linings.

9.2.7 Hatch covers and plugs, access doors, manhole plugs, bilge limbers and plugs forming part of the insulated envelope are to be constructed of, or covered with, a suitable lining material.

9.2.8 Insulation linings and air screens, together with supports, are to be strong enough to withstand the loads imposed by either refrigerated or general cargo.

9.2.9 Successive coatings impervious to oil are to be applied before insulating the exposed plating of tank tops and bulkheads protecting tanks containing oil. The total thickness of the required coating will depend on the construction of the tank, the composition of the coating used and the method of application.

9.2.10 If the cargo to be loaded on the tank top insulation could cause damage to the lining, then additional protection is to be provided in way of the hatch and 0,6 m beyond. The protection may be of either a permanent or temporary nature.

9.2.11 Where the insulation is to support fork lift trucks, the strength of the lining and its supports is to be demonstrated. A sample of the insulation, approximately 4 m x 4 m, is to be prepared and tested by a fully loaded fork lift truck with a gross weight of 6,5 tons on one axle with a wheel pitch of 1450 mm, having single wheeled pneumatic tyres. The truck is to be driven and manoeuvred over the sample to the satisfaction of the Surveyors.

9.2.12 Prefabricated panel systems are to be fitted with suitable pressure equalising devices to prevent damage which may be caused by under or over pressure resulting from the defrosting of coolers, rapid changes in pressure on the inner and outer faces of the panels or rapid cooling of the chamber.

9.2.13 The pressure equalising devices are to be so designed as to allow the passage of air in either direction, but remain effectively closed until the pressure differential reaches a value of 10 mm water column. Heating is to be provided to protect the mechanism from freezing.

9.3 Access plugs and panels

9.3.1 Insulated plugs are to be provided in the insulation where required for easy access to the bilges, bilge suction strum boxes, cooler and chamber drains and tank manhole lids. Removable panels are to be provided for access to tank air and sounding pipes and drains.

9.3.2 Tank top insulation in way of manholes and bilge hats is to be provided with a liquid-tight steel coaming to prevent seepage into the insulation.

9.3.3 Manholes are not permitted in the bulkheads of fuel oil tanks which form part of the cargo space envelope.

9.4 Air circulation and distribution

9.4.1 When frozen cargo is carried, provision is to be made for the adequate circulation of air between the frozen cargo and all the insulation lining surfaces.

9.4.2 When cooled cargo is carried, of a type which may generate heat or emit gas, provision is to be made for the adequate circulation of air through all the stow.

9.4.3 There is to be adequate air flow between cargo and cooling grids, where fitted.

9.4.4 The air distribution arrangements are to be such that the required circulation rate and uniform distribution can be achieved when the space is part or fully loaded with cargo. The arrangement is also to be capable of maintaining uniform air temperature throughout the space with any one fan, or air cooler, or cooling grid circuit out of action, *see* 4.8.

9.5 Air refreshing arrangements

9.5.1 Where spaces are intended for the carriage of refrigerated cargoes requiring controlled ventilation, means are to be provided for air refreshening. The positions of the air inlets are to be carefully selected to minimise the possibility of contaminated air entering the spaces. Chambers or spaces are to be provided with separate inlet and discharge vents. Each vent is to have a positive airtight valve capable of closing onto a seat. It is recommended that a distance of at least 3 m is maintained between inlet and exhaust vents.

9.6 Heating arrangements for fruit cargoes

9.6.1 Where the class notation includes the symbol ‡ for the carriage of fruit cargoes, facilities for heating the refrigerated spaces are to be provided to maintain the carrying temperatures when the temperatures outside the spaces are lower.

■ *Section 10*
Container ships fitted with refrigerating plant to supply cooled air to insulated containers in holds

10.1 General

10.1.1 Classed installations designed to supply refrigerated air to insulated ‘porthole’ containers in holds aboard container ships are to comply with the requirements of Sections 1 to 9 and 11, so far as they are applicable, and the special requirements of this Section.

10.1.2 The classed refrigerating installation is to include the refrigerating machinery, air coolers, supply and return air ducting, and the flexible couplings between containers and the duct system. Where the arrangements are such that cell air conditioning is essential to the carriage of the containers, the air conditioning equipment and (if fitted) the insulation of the hold, deckheads, sides and tank tops are to be included in the classification.

10.2 Additional information and plans

10.2.1 In addition to those requirements detailed in Section 1 which are also applicable to refrigerated container ships, the following information is to be submitted before the work commences:

- Details of air coolers.
- Details of the design of ducting proposed, including joints, connections, insulation, vapour sealing and linings.
- Details of cell air conditioning arrangements and components.
- Details of couplings between ducting and containers, including operating arrangements.

10.3 Air coolers

10.3.1 Air ducts supplying more than ten standard 20 ft containers or five standard 40 ft containers are to have a single air cooler with multiple circuits or two independent coolers. The individual circuits or coolers are to be provided with stop valves so that each circuit or cooler may be readily isolated.

10.3.2 The refrigeration capacity of the air cooler arrangement is to be such that the temperature conditions can be maintained with any one circuit or independent cooler out of action.

10.3.3 For air ducts supplying ten standard 20 ft containers or five standard 40 ft containers or less, a single cooler with one circuit will be acceptable.

10.4 Air duct systems

10.4.1 The air ducts, together with all branches and couplings, supplying refrigerated air to insulated containers in holds, are to be made airtight. For design purposes, however, an air leakage rate of 0,5 per cent of total volume flow at the design pressure for each duct is to be taken.

10.4.2 Where air ducting is insulated on the internal surfaces, provision is to be made to prevent retention of odour which may taint subsequent cargo.

10.4.3 Couplings are to be of a type that has been approved by LR. Prototypes are to be tested under all operating conditions, witnessed by the Surveyors, to demonstrate that they extend, retract and separate satisfactorily from a ‘container end wall’ at the minimum temperature condition. When operated by means of air pressure they are to be supplied with air sufficiently dry to avoid ice formation. The air supply lines are to be strength pressure tested to 1,5 x design pressure.

10.5 Duct air leakage and distribution tests

10.5.1 Air leakage tests on at least 10 per cent of ducting, selected at random, are to be carried out to the satisfaction of the Surveyors before the insulation is applied. The Surveyors may require further testing to demonstrate airtightness of ducting. The air leakage from each duct will depend on several factors and, while complete airtightness should be the objective, the air leakage rate for design purposes is not to exceed 0,5 per cent of total volume flow at the design pressure of 250 Pa.

10.5.2 In the case of prefabricated ducts, the prototype is to be subjected to air distribution, heat leakage and air leakage tests. Each production duct is to be tested for air leakage and is not to exceed the prototype test results by more than five per cent. Additionally, one duct in 50 or part thereof is to be tested for heat leakage and the results are not to exceed the prototype test results by more than 10 per cent.

10.5.3 In all cases when prefabricated sections are assembled on board, the tests as detailed in 10.5.2, are to be carried out aboard the ship.

10.5.4 On application from the Owner, the air leakage tests on air ducts installed aboard the ship, as detailed in 10.5.1 to 10.5.3, may be omitted provided that:

- the installation is designed with at least 20 per cent surplus refrigerating capacity, or
- assignment of a temperature notation for the installation be deferred until verified by a thermal balance test to the Surveyor’s satisfaction.

10.5.5 All ducts are to be tested for air distribution to the containers, at the manufacturer’s works, by measuring the flow of air from the supply couplings while the fan is operated at full speed against the designed pressure. The air flow at each coupling is to meet the specified figure within ±5 per cent.

10.5.6 Systems comprising rigid prefabricated ducts complete with coolers and fans are to be tested for air distribution at the place of manufacture. The remaining tests are to be carried out aboard the ship.

10.6 Cell air-conditioning arrangements

10.6.1 The cell air-conditioning equipment and ducting, and/or insulation of the holds, deckheads, sides and tank tops, is to be such as to maintain a uniform temperature throughout the cell and to ensure the ship’s steelwork is maintained above the minimum temperature acceptable for the steel grade, *see also* Pt 3, Ch 2,2.2.

■ *Section 11* Acceptance trials

11.1 Tests after completion

11.1.1 On completion of construction, the acceptance tests prescribed in 11.3.1 are to be carried out to verify the correct functioning of the installation and its ability to maintain the lowest notation temperature conditions required for the assignment of the intended class notation. The proposed test schedules, which should include methods of testing and test facilities provided, are to be submitted for approval before these acceptance tests are started.

11.2 Thermographic survey

11.2.1 The insulated envelope of refrigerated cargo ships and, where applicable, fish factory ships, fishing vessels, fruit juice carriers and container ships is to be scanned using a thermal imaging camera. The main purpose of carrying out the infra-red scan is to verify the efficiency of the insulation system.

11.2.2 During the course of, or prior to, the acceptance trials all inner insulated surfaces, including tank tops, bulkheads, 'tween decks, insulated hatches, coamings and weather decks are to be subject to an infra-red scan.

11.2.3 Where internal obstructions preclude an internal scan, it is to be carried out externally.

11.2.4 The scan is to be conducted with the 'tween deck and main holds in total darkness and with air coolers/cooling grids isolated and all heat sources disconnected. The temperature difference, cargo hold to ambient air or sea-water temperature, is to be 15 K or more.

11.2.5 Any deficiencies or abnormalities revealed are to be investigated and repaired to the extent considered necessary by the Surveyor.

11.3 Acceptance tests

11.3.1 The acceptance tests (*see also* 11.3.2 and 11.3.3) are to comprise the following:

(a) Verification of control, alarm, safety and refrigerant detection systems.
(b) Test simulating failure of selected components such as compressors, fans and pumps, to verify correct functioning of alarm and systems in service.
(c) Verification of accuracy, calibration and functioning of temperature control, monitoring and recording instrumentation.
(d) Verification of air cooler fan outputs running at maximum speed, and air circulation rates and distribution arrangements in individual refrigerated spaces or chambers. The latter is to be undertaken firstly with all coolers in operation and secondly with any one cooler or fan out of action.
(e) Verification of air refreshing and heating arrangements.
(f) Verification of personnel safety devices and warning systems in refrigerated spaces.
(g) Refrigeration and thermal balance tests to demonstrate the capability of the combined refrigerating plant and insulation envelope to maintain the lowest notation temperature to be assigned.
(h) Refrigeration tests for refrigerated container ships carrying 'porthole' type insulated containers. If the prescribed thermal balance tests cannot be carried out due to the number of insulated containers available in the shipyard being inadequate, then, alternatively, the following separate tests will be accepted:
    (i) Compressor capacity test.
    (ii) Duct heat leakage test on at least 20 per cent of the insulated ducting selected at random.
    (iii) Cell heat leakage test.
(j) Thermographic scan to be carried out as required by 11.2.

11.3.2 Where a number of identical installations are constructed for the same Owner and by the same shipyard, the refrigeration and thermal balance tests required in 11.3.1(g), need only be carried out on two of the series, provided the results are satisfactory.

11.3.3 Where the cells of 'porthole' type insulated containers are not insulated, a heat leakage test will be required on the first ship of the series only.

11.4 Sea trials

11.4.1 Where the class notation includes the symbol ‡ for the carriage of fruit, or the symbol ‡ is to be assigned to a fishing vessel the following records are to be kept during the first loaded voyage:

(a) **Refrigerated cargo or container ships:**
Refrigerating machinery logs and temperature records for the refrigerated cargo spaces or containers, demonstrating the installation's capability to cool down the full cargo of fruit and maintain the notation temperature conditions.
(b) **Fishing vessels:**
Refrigerating machinery and freezing equipment logs and temperature records for the refrigerated cargo spaces, demonstrating the installation's capability to freeze the catch and maintain the notation temperature conditions.

11.5 Reporting of tests

11.5.1 On completion of the tests prescribed in 11.1, two copies of the test schedule for the refrigerated cargo installation, giving details of all recorded data and thermal heat balance results, signed by the Surveyor and Builder are to be provided. One copy is to be placed on board the ship and the other submitted to LR.

11.5.2 At the end of the first loaded voyage a copy of the logs and temperature records requested in 11.4.1(a) and (b), as applicable, signed by the ship's Chief Engineer, are to be submitted to LR.

Section

Section 1 **General**

1.1 Application

1.1.1 Cargo ships of 500 gross tons or more, all passenger ships and gas and chemical tankers on international voyages, where provision is made within International Conventions are to be provided with the fire safety measures required by the *International Convention for the Safety of Life at Sea*, 1974, as amended (SOLAS 74). Fishing vessels of 45 m freeboard length and over are to be provided with the fire safety measures required by the Torremolinos Protocol of 1993 relating to the *Torremolinos International Convention for the Safety of Fishing Vessels*, 1977 (Torremolinos Protocol).

1.1.2 Cargo ships of 500 gross tons or more, all passenger ships, and gas and chemical tankers, employed on national voyages are to comply with the fire safety measures prescribed and approved by the Government of the Flag State.

1.1.3 It is the responsibility of the Government of the Flag State to give effect to the fire protection, detection and extinction requirements of 1.1.1 and 1.1.2. However, Lloyd's Register (hereinafter referred to as 'LR') will undertake to do this in cases where:

(a) contracting Governments have authorised LR to apply the requirements of SOLAS 74 or the Torremolinos Protocol and issue the appropriate certification on their behalf; or

(b) the Government of the Flag State is not a signatory to SOLAS 74 or the Torremolinos Protocol; or

(c) the ship or fishing vessel is to be classed for restricted or special service in national waters for which the Government of the Flag State has no national requirements. In such cases, LR will apply the fire safety measures required by SOLAS 74 or the Torremolinos Protocol, as appropriate.

However, due consideration will be given to arrangements deemed to provide an equivalent level of fire safety, taking due cognisance of the circumstances of the restricted or special service.

1.1.4 Section 2 of this Chapter, which is within the spirit of the International Convention and Protocol requirements for ships of Convention size, is applicable to cargo ships of less than 500 gross tons (where not covered by International Conventions), fishing vessels of 12 m registered length and over but less than 45 m freeboard length, and ships not fitted with propelling machinery.

1.1.5 Consideration will be given to the acceptance of fire safety measures prescribed and approved by the Government of the Flag State in lieu of 1.1.4.

1.1.6 Special consideration, consistent with the fire hazard involved, will be given to construction or arrangement features not covered by this Chapter.

1.1.7 Cargo ships of less than 500 gross tons intended for the carriage of dangerous goods are to comply with SOLAS 1974 as amended II-2/G.19.

Section 2 **Fire detection, protection and extinction**

2.1 General provisions

2.1.1 The provisions of these requirements, are intended to apply to new and, as far as reasonable and practicable, or as found necessary by the relevant Administration, to existing cargo ships of less than 500 gt.

2.1.2 It should be remembered that the *International Codes for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk and Liquefied Gases in Bulk* are applicable to such ships regardless of size including those of less than 500 gt.

2.2 Definitions

2.2.1 The terms, used in these requirements are as defined in SOLAS 1974 (as amended).

2.2.2 The term Gross Tonnage (gt) is as defined in IMO Resolutions A.493 (XII), calculated in accordance with the 1969 Tonnage Convention and the interim scheme applicable to ships with keels laid up to 18 July 1994 in accordance with IMO Resolution A.494 (XII).

2.2.3 **Service area definitions**

(a) 'Unrestricted service' means a ship engaged on international voyages.

(b) 'Restricted service' is broken down into two broad categories: (a) ships operating coastal or specified operating areas (b) ships operating within protected or extended protected waters.

  (i) **Specified coastal service**. Service along a coast, the geographical limits of which are to be defined and for a distance out to sea generally not exceeding 20 nautical miles, unless some other distance is specified for 'coastal service' by the Administration with which the ship is registered, or by the Administration of the coast off which it is operating. A typical example might be 'Indonesian coastal service'.

  Specified operating or service areas may be service between two or more ports or other geographical features, or service within a defined geographical area such as 'Red Sea Service', 'Piraeus to Thessaloniki and Islands within the Aegean Sea'.

(ii) **Protected water service**. Service in sheltered water adjacent to sand banks, reefs, breakwaters to other coastal features, and in sheltered water between islands.
Extended protected water service. Service in protected waters and also short distances (generally less than 15 nautical miles) beyond protected waters in 'reasonable weather'.

2.3 Surveys and maintenance

2.3.1 The hull, machinery and all equipment required for safety aspects of every ship should be constructed and installed so as to be capable of being regularly maintained to ensure that they are at all times, in all respects, satisfactory for the ship's intended service.

2.3.2 A competent authority should arrange for appropriate surveys of the required equipment relating to fire safety aspects during construction and, at regular intervals after completion, generally as prescribed within Chapter I of SOLAS 1974 (as amended). Such surveys should be carried out by the Society classing the ship or the Flag State.

2.3.3 The condition of the structural fire protection and fire safety related equipment shall be maintained to conform with the provisions of the requirements to ensure that the ship, in these respects, will remain fit to proceed to sea without danger to the ship or persons on board. The hull structure and machinery do not form part of these requirements but should be similarly surveyed and maintained.

2.4 Requirements

2.4.1 Table 4.2.1 details the various minimum fire protection, detection and extinction arrangements that are required depending on the vessel's intended service area.

Table 4.2.1 General fire detection, protection and extinction requirements

Fire-fighting	Unrestricted	Restricted	Protected
1. FIRE PUMPS			
Ships greater than 150 gt			
Independently driven power pumps	1	1	1
Power pumps	1	1	—
Hand pumps	—	—	1
Ships less than 150 gt			
Independently driven power pumps	—	—	—
Power pumps	1	1	1
Hand pumps	1	1	—
2. FIRE HYDRANTS			
Sufficient number and so located that at least one powerful water jet can reach any normally accessible part of ship	X	X	X
3. FIRE HOSES (Length >15 m)			
With couplings and nozzles	≥ 3	≥ 3	≥ 2
4. FIRE NOZZLES			
Dual purpose (spray/jet) with 12 mm jet and integral shut-off	X	X	X
Jet may be reduced to 10 mm and shut-off omitted for hand pump hoses			
5. PORTABLE FIRE-EXTINGUISHERS			
Accommodation and service spaces	≥ 3	≥ 3	≥ 2
Boiler rooms, etc.	≥ 2	≥ 2	≥ 2
Machinery spaces (one extinguisher per 375 kW of internal combustion engine power)	≥ 2 ≤ 6	≥ 2 ≤ 6	≥ 2 ≤ 6
Cargo pump-rooms (capacity 9 l. fluid or equivalent)	≥ 2	≥ 2	≥ 2
6. NON-PORTABLE FIRE-EXTINGUISHERS IN MACHINERY SPACES			
Ships greater than 150 gt	1	1	—
Ships greater than 350 gt (capacity 45 l. fluid or equivalent)	—	—	1
7. FIXED FIRE-EXTINGUISHING SYSTEMS SHIPS GREATER THAN 350 gt			
Category A machinery spaces	X	X	—
Cargo pump-rooms	X	X	—
8. CARGO TANK PROTECTION			
Mobile foam appliances	X	X	X
9. FIREMAN'S OUTFIT			
Ships greater than 150 gt complete outfit	≥ 2	≥ 2	≥ 2
Ships less than 150 gt complete outfit	≥ 1	≥ 1	—
Fireman's axe	—	—	1
10. MEANS OF ESCAPE			
Accommodation and service spaces	2	2	2
Machinery spaces	≥ 1	≥ 1	≥ 1
Cargo pump-rooms	1	1	1
11. STRUCTURAL FIRE PROTECTION WHEEL HOUSE AND MACHINERY SPACES			
Separation from adjacent spaces of negligible fire risk	A-0	A-0	A-0
Separation from other adjacent spaces	A-60	A-30	A-0
Escape routes	B-0	B-0	B-0

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■ *Section 1* General requirements

1.1 General

1.1.1 The requirements of this Chapter apply to refrigerated cargo ships where a Controlled Atmosphere **(CA)** notation is requested.

1.1.2 The requirements are additional to the classification requirements for refrigerated cargo installations contained in Pt 6, Ch 3.

1.1.3 Ships provided with CA systems which are approved, installed and tested in accordance with the following requirements will be eligible for the applicable class notation specified in Pt 1, Ch 2,2.6.2.

1.1.4 An example of a typical class notation on a refrigeration installation classed with Lloyd's Register (hereinafter referred to as 'LR'), fitted with a CA system built under Special Survey, would be:

✠ **Lloyd's RMC** to maintain a temperature –29°C to +14°C with sea temperature 35°C maximum.

✠ **CA (1–12% O_2, 0–25% CO_2) RH**

1.2 Novel arrangements and design

1.2.1 Where the proposed construction of the CA system, or CA zones, is novel in design, or involves the use of unusual materials or equivalent arrangements to those specified in the following sections, special tests may be required, and a suitable descriptive note may be assigned.

1.3 Definitions

1.3.1 **CA zone** means one or more cargo chambers enclosed in an air-tight envelope.

1.3.2 **Gas** means a suitable gaseous mixture to retard the metabolic process of fresh products.

1.3.3 **Gas system** means a system which controls the levels of oxygen and/or carbon dioxide.

1.3.4 **Adjacent space** means an enclosed space adjoining a CA zone separated by watertight bulkheads or decks penetrated by pipes, cables, ducts, doors, 'tween deck, etc.

■ *Section 2* Plans and documentation

2.1 Plans of CA zones and adjacent spaces

2.1.1 The following plans and particulars of the CA zones and adjacent spaces are to be submitted in triplicate for approval before construction is commenced:

(a) Capacity plan.
(b) Location and installation of CA equipment.
(c) Arrangement of CA zones in elevation and plan view.
(d) Access arrangement.
(e) Arrangement and use of spaces adjacent to CA zones.
(f) Details of securing weather deck and 'tween deck hatch lids.
(g) Details of securing gratings in way of hatch lids.
(h) Details of weather deck and access hatch seals.
(j) Door seals, scuppers, pipes, cables and ducts penetrating the decks, bulkheads, etc., together with proposed design conditions in the CA zones.
(k) Specified leakage rate and proposals for its measurement.
(l) Location of sampling points for CA gas and/or sensors in the CA zones and adjacent spaces.
(m) Details of the gas supply piping system.
(n) Details of gas freeing arrangements, including fans, valves, ducts and any interlocks.
(o) Details of pressure/vacuum valves for protecting devices in CA zones, location of outlets from P/V valves and capacity calculations.
(p) Details of security locks provided on entry to the hatch and manhole covers, and doors leading to CA zones and adjacent spaces.
(q) Arrangements of ventilation systems for the gas generator compartment and other adjacent spaces adjoining CA zones.

2.2 Gas supply system

2.2.1 The following plans and particulars of the gas supply system, etc., are to be submitted in triplicate for approval, before construction is commenced:
(a) Schematic arrangements of the proposed gas supply systems and, where applicable, details of compressors, pressure vessels, membranes, storage tanks, gas cylinders, control and relief valves and safety arrangements, including pressure set points of alarm and safety devices.
(b) Capacities of gas supply systems at different oxygen and carbon dioxide levels, if applicable.

2.3 Humidifiers

2.3.1 Where applicable, the following plans and particulars of the humidification system, etc., are to be submitted in triplicate for approval, before construction is commenced:
(a) Specification and capacity of the system.
(b) Principles of operation and control of relative humidities under different operating conditions.
(c) Details of proposed equipment, nozzles, pads, heaters, pumps, steam generator, compressors, water tanks, etc.
(d) Layouts of the equipment and the positioning of sensors and controls.

2.4 Control equipment

2.4.1 The following plans and details of the control, alarm and safety systems for CA zones, gas supply compartment and other adjacent spaces, are to be submitted in triplicate before construction is commenced:
(a) Line diagrams of all control circuits.
(b) List of monitored, control and alarm points.
(c) Details of computer systems, if fitted.
(d) Location of control panels and consoles.
(e) Controls of all valves and dampers fitted to CA zones.
(f) Details of oxygen and carbon dioxide analysers and arrangements for calibration.
(g) Relative humidity (RH) sensors and details of calibration.
(h) Details of alarm system, including location of central control panel and audible and visual warning devices.

2.5 Electrical

2.5.1 In addition to the applicable requirements of Pt 6, Ch 2,1.2, the following information and plans specific to the installed CA system are to be submitted in triplicate for approval, before construction is commenced:
(a) Main power supply arrangement to the CA system.
(b) Single-line diagram of the CA system which is to include rating of electrical machines, insulation type, size and current loading of cables and make, type and rating of protective devices.
(c) A schedule of normal operating loads of CA system, estimated for the different operating conditions expected.

2.6 Testing

2.6.1 Details of the testing programme are to be submitted, including instrumentation to be used with range and calibration.

■ *Section 3* CA zones and adjacent spaces

3.1 Air-tightness of CA zones

3.1.1 The CA zones are to be made air-tight in accordance with the requirements in 9.3. Particular attention is to be paid to sealing of hatches, plugs and access doors in each CA zone. Double seals are to be fitted to each opening.

3.1.2 Openings for pipes, ducts, cables, sensors, sampling lines and other fittings passing through the decks and bulkheads are to be suitably sealed and made air-tight.

3.1.3 The liquid sealed traps from bilges and drains from the cooler trays are to be deep enough to withstand, when filled with liquid which will not evaporate or freeze, the design pressure in each CA zone when taking account of the ship's motion.

3.1.4 Air refreshing inlets and outlets are to be provided with isolating arrangements.

3.2 CA zone protection

3.2.1 Means are to be provided to protect CA zones against the effect of overpressure or vacuum.

3.2.2 At least two P/V valves are to be fitted in each CA zone. They are to be set for the design conditions of the CA zone.

3.2.3 Consideration will be given to the use of a single valve in combination with other suitable means of overpressure or vacuum protection.

3.2.4 The proposed P/V valves for each zone are to be of adequate size to release any excess pressure and to relieve the vacuum at maximum cooling rate.

3.2.5 P/V valve discharges are to be located at least 2 m above deck and 10 m away from any ventilation inlets. Discharge piping is to be arranged to preclude ingress of water, dirt or debris which may cause the equipment to malfunction.

3.2.6 Pressure sensors are to be installed in locations necessary to monitor pressure of all CA zones. Pressure sensors are to be installed away from fans, air inlets and outlets.

3.3 Gas freeing of CA zones

3.3.1 The arrangements for gas freeing of CA zones are to be capable of purging all parts of the zone to ensure a safe atmosphere.

3.3.2 Cargo air cooling fans and the air refreshing arrangements may be used for gas freeing operations.

3.3.3 Gas freeing outlets are to be led to a safe place in the atmosphere 2 m above the deck, away from accommodation spaces and intakes of the fans for accommodation.

3.4 Ventilation of adjacent spaces

3.4.1 Deckhouses and other adjacent spaces which require to be entered regularly are to be fitted with a positive pressure type mechanical ventilation system with a capacity of at least 10 air changes per hour capable of being controlled from outside these spaces.

3.4.2 Adjacent spaces not normally entered are to be provided with a mechanical ventilation system which can be permanent or portable to gas free the space prior to entry.

3.4.3 Ventilation inlets are to be arranged so as to minimise recycling any gas and are to be at least 10 m in the horizontal direction away from the ventilation outlets.

■ *Section 4* Gas systems

4.1 General

4.1.1 Means are to be provided to achieve and maintain the required oxygen and/or carbon dioxide levels in the CA zones. This may be accomplished by the use of stored gas, portable or fixed gas generating equipment or other equivalent arrangements. The arrangements are to be such that a single failure will not cause a complete loss of gas supply to the CA zones.

4.1.2 The gas system is to have sufficient capacity to make good any gas loss from the CA zones and to maintain a positive pressure in all CA zones.

4.1.3 The gas system is also to be able to:

(a) Deliver gas at 125 per cent of the specified flow rate with two compressors operating.

(b) Maintain the specified gas levels in all CA zones when operating 24 hours per day with one unit on stand-by.

4.1.4 Air intakes are to be located to ensure that contaminated air is not drawn into the compressors.

4.1.5 Where it is intended to supply gas by means of stored gas bottles, the arrangements are to be such that depleted bottles may be readily and safely disconnected and charged bottles readily connected.

4.2 Location

4.2.1 Fixed gas generating equipment, gas bottles or portable gas generators are to be located in a compartment reserved solely for their use. Such compartments are to be separated by a gastight bulkhead and/or deck from accommodation, service and control station spaces. Access to such compartments is to be only from the open deck.

4.2.2 Gas piping systems are not to be led through accommodation, service and machinery spaces or control stations.

4.3 Gas supply

4.3.1 The gas systems are to be designed so that the pressure which they can exert on any CA zone will not exceed the design pressure of the zone.

4.3.2 During initial operation, arrangements are to be made to vent the gas outlets from each generator to the atmosphere. All vents from gas generators are to be led to a safe location on the open deck.

4.3.3 Where gas generators use positive displacement compressors, a pressure relief device is to be provided to prevent excess pressure being developed on the discharge side of the compressor.

4.3.4 Suitable arrangements are to be provided to enable the supply main to be connected to an external supply.

4.3.5 Where it is intended that gas systems are to be operated unattended, the required CA zone environment is to be automatically controlled.

4.3.6 Means of controlling inadvertent release of nitrogen into CA zones, such as locked valves, are to be provided.

4.4 Gas supply compartment ventilation and alarm

4.4.1 The gas supply compartment is to be fitted with a mechanical extraction ventilation system providing a rate of at least 20 air changes per hour based on the total empty volume of the compartment.

4.4.2 Ventilation ducts from the gas generator/supply compartment are not to be led through accommodation, service and machinery spaces or control stations.

4.4.3 The air outlet duct is to be led to a safe place on the open deck.

4.4.4 The gas supply compartment is to be provided with a low oxygen alarm system.

Section 5 Relative humidity (RH)

5.1 Humidification

5.1.1 Where a humidification system is fitted, the following requirements are to be complied with:

(a) The supply of fresh water for humidification is to be such as to minimise the risk of corrosion and contamination of the cargo.

(b) To prevent damage or blockage in the humidification system caused by water freezing, the air, steam or water pipelines in the cargo chambers are to be installed to facilitate ease of drainage and are to be provided with suitable heating arrangements.

Section 6 Electrical installation

6.1 General

6.1.1 In addition to the requirements of Pt 6, Ch 2, the following requirements are to be complied with:

(a) The electrical power for the CA plant is to be provided from a separate feeder circuit from the main switchboard.

(b) Under sea-going conditions, the number and rating of service generators are to be sufficient to supply the cargo refrigeration machinery and CA equipment in addition to the ship's essential services, when any one generating set is out of action.

Section 7 Control instrumentation and alarms

7.1 General

7.1.1 An alarm system for monitoring the atmosphere in CA zones is to be installed which may be integral with the machinery space alarm system as required by Pt 6, Ch 1,2.3.

7.1.2 Where alarms are displayed as group alarms in the main machinery space alarm system, provision is to be made to identify individual alarms at the refrigerated cargo control station.

7.1.3 The pressure in each CA zone is to be monitored and an alarm initiated when the pressure is too high or too low.

7.1.4 Where the **RH** notation is to be assigned, humidity sensors are to be installed in each of the CA zones and are to initiate an alarm when the relative humidity (RH) falls below or exceeds the predetermined set values.

7.1.5 Gas sensors or analysers are to be provided to monitor gas content in CA zones, *see* 7.3 and 7.4.

7.1.6 Gas analysers and sensors are to be calibrated automatically once in every 24 hours. An alarm is to be initiated if accuracy is outside tolerance limits.

7.1.7 Direct readout of the gas quality within any CA zone is to be available to the operating staff on demand.

7.1.8 At least one automatic recorder is to be provided for the remote monitoring and recording of O_2 and CO_2 levels in each CA zone.

7.1.9 Alarms are to be initiated in the event of O_2 or CO_2 levels in each CA zone falling below or exceeding the predetermined set values.

7.2 Gas systems

7.2.1 Where air compressors are to be used for gas production, alarms are to be initiated for the following conditions:

- High lubricating oil temperature.
- High differential pressure across the filters.
- Electric supply failure.

The compressors are to shutdown automatically in the event of:

- High discharge air temperature.
- High discharge air pressure.
- Low lubricating oil pressure.
- High pressure in CA zone.

7.2.2 Instrumentation is to be fitted for indicating continuously:

(a) Gas pressure.
(b) Gas temperature.
(c) Gas content.
(d) Gas flow.

7.3 Gas analysers and sampling

7.3.1 Where analysers are fitted, at least two analysers for oxygen and carbon dioxide having a tolerance of ±0,1 per cent by volume are to be provided to determine the content of the circulated gas within the CA zones.

7.3.2 Two separate sampling points are to be located in each CA zone and one sampling point in each of the adjacent spaces. The arrangements are to be such as to prevent water condensing and freezing in the sampling lines under normal operating conditions. Filters are to be provided at the inlet to sampling point lines.

7.3.3 Arrangements of the gas sampling points are to be such as to facilitate representative sampling of the gas in the space.

7.3.4 Where gas is extracted from the CA zones via a sampling tube to analysers outside the space, the sample gas is to be discharged safely to the open deck.

7.3.5 Provision is to be made for gas sampling by means of portable equipment as required by 9.6.3.

7.3.6 The sampling frequency is to be at least once per hour.

7.4 Gas sensors

7.4.1 Where sensors are fitted, at least two sensors for each of O_2 and CO_2, having a tolerance of ±0,1 per cent are to be installed in each CA zone to monitor gas levels.

7.4.2 Gas sensors may be used for indication and alarm.

■ *Section 8* Safety requirements

8.1 Personnel safety

8.1.1 CA zones are to be clearly labelled with 'Caution' and 'Danger' signs to alert personnel.

8.1.2 Entry hatch and manhole covers, doors leading to the CA zones and adjacent spaces are to be fitted with acceptable security-type locks and alarms activated when covers and doors are opened. The alarms are to be placed in a manned location.

8.1.3 All doors and access hatches to CA zones which may be under pressure are to open outwards and are to be fitted with secondary catches to prevent injury or damage during opening.

8.1.4 At least two portable oxygen sensors are to be provided to sample the oxygen level in all CA zones and adjacent spaces.

8.1.5 A means of communication is to be provided between CA zones and an attended location on deck.

8.1.6 Medical first aid equipment, including at least one set of oxygen resuscitation equipment, is to be provided on board.

■ *Section 9* Inspection and testing on completion

9.1 General

9.1.1 CA system trials are to be witnessed on board by the LR Surveyor, before the system is put into service and before a certificate is issued. These trials are in addition to any tests which may have been carried out at the manufacturer's works.

9.1.2 An Operating and Safety Manual for the guidance of the ship's staff is to be provided, covering the following topics:

(a) Principal information on the use of CA.
(b) Complete description of the CA installation on board.
(c) Hazards of low oxygen atmospheres and consequential effects on human life.
(d) Countermeasures when exposed to low oxygen atmospheres.
(e) Instructions for operation, maintenance and calibration of all gas detectors.
(f) Instructions for use of portable oxygen analysers with alarm for personal protection.
(g) Prohibition of entry to spaces under CA.
(h) Loading instructions prior to injection of gas.
(j) Procedure for checking security of CA zones, doors and access hatches prior to injection of gas.
(k) Gas freeing procedure for all CA zones.
(l) Procedure for checking atmosphere of CA zones before entry.

9.2 Gas supply and sampling systems

9.2.1 The gas supply main and branches are to be pressure and leak tested. The test pressures are to be 1,5 and 1,0 times the design pressure respectively.

9.2.2 All gas sampling lines are to be leak tested using a vacuum or overpressure method.

9.3 Air-tightness of CA zones

9.3.1 Air-tightness of each CA zone is to be tested and the results entered on the certificate. The measured leakage rate of each zone is to be compared with the specified value.

9.3.2 Either a constant pressure method or a pressure decay method is to be used to determine the degree of air-tightness.

9.3.3 If the constant pressure method is used, the test is to be carried out at the design pressure of the CA zones.

9.3.4 If the pressure decay method is used, the time for the pressure to drop from 350 Pa to 150 Pa is to be measured and the leakage is to be calculated using the following formula:

$$A.L. = \frac{7{,}095 \times V}{t}$$

where

$A.L.$ = air leakage, in m^3/h
V = volume of zone, in m^3
t = time, in seconds
7,095 = constant for 200 Pa pressure decay.

During this test, adjacent zones are to be kept at atmospheric pressure.

9.4 Gas system performance

9.4.1 Capability of the gas system to supply the gas at the specified flow rate and condition is to be verified by tests.

9.4.2 If the notation conditions cannot be verified during testing, assignment of the notation is to be deferred until log book entries confirm the achievement of the specified conditions in every CA zone during a loaded passage.

9.5 Gas freeing

9.5.1 The gas freeing arrangements are to be tested to demonstrate that they are effective.

9.6 Safety, alarms and instrumentation

9.6.1 The control, alarm and safety systems are to be tested to demonstrate overall satisfactory performance of the control engineering installation. Testing is also to take account of the electrical power supply arrangements, *see also* Pt 6, Ch 1,2.3.

9.6.2 Locking arrangements of all CA zones and adjacent spaces where gas may accumulate, provision of warning notices at all entrances to such spaces, communication arrangements and operation of alarms, controls, etc., are to be examined.

9.6.3 The provision of portable gas detectors and personnel oxygen monitors are to be verified by the LR Surveyor. Suitable calibrated instruments for measuring the levels of O_2, CO_2 and humidity, gas pressure and gas flow to the CA zones, are to be provided for testing. Their accuracy is to be verified.

Section

■ *Section 1* Introduction

1.1 Scope

1.1.1 This Chapter is intended for the classification of self-propelled or non-self-propelled ships with specialised structures which have plant installed on board for the processing of chemicals, liquefied gases and related products, where permitted by the Flag Administration, and which fall into one of the following environmental categories:

1A Ships which have plants operable while navigating at sea.
1B Ships which have plants operable at sea, but only while the ship is attached to an offshore mooring facility.
2 Ships which can navigate at sea, but whose plants are intended to be operated only while the ships are in harbour or similarly protected waters.
3 Specialised ships, including pontoons, barges and similar structures which are designed as sea transportation vehicles to carry non-operative process plants, but which are specially constructed to be fully supported by the sea bed when the plants are operative.

1.1.2 Each category in 1.1.1 may include provision for the storage of the products used in the process or processes concerned.

1.2 General

1.2.1 The Rules are framed on the understanding that ships will not be operated in environmental conditions more severe than those agreed for the design basis and approval, without the prior agreement of Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 Except as indicated in this Chapter, the hull, propulsion machinery, auxiliary machinery, equipment for essential services of the ship, electrical installations and control engineering systems are to comply with the relevant Sections of Parts 3, 4, 5 and 6, the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquid Chemicals in Bulk* (hereinafter referred to as the Rules for Ships for Liquid Chemicals) and the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk* (hereinafter referred to as the Rules for Ships for Liquefied Gases), where applicable. Hulls made of reinforced or prestressed concrete will be specially considered.

1.2.3 The additional hull structural requirements for Category 3 ships to enable them to be satisfactorily grounded on prepared foundations will be specially considered. Full details of the intended foundations and the local conditions at the site are to be submitted for use in assessing the hull structural capability, etc.

1.2.4 Where the process plant is intended to operate in close proximity to bulk storage of feedstocks and/or products, further consideration may be necessary in addition to that contained in this Chapter, particularly with regard to the provision of effective separation, methods of storage, loading and discharging arrangements.

1.2.5 For ships of all categories in 1.1.1 except Category 1A, provision is to be made for purging, gas freeing, inerting or otherwise rendering safe the plant and process storage facilities before the ship proceeds to sea or changes location. The provisions to be adopted, if any, when a ship of Category 1A enters harbour will be specially considered.

1.2.6 In addition to the requirements for periodical surveys, a general examination of the ship, machinery and process plant is to be carried out by LR's Surveyors before and after a ship, of any category other than 1A, changes location. Every precaution is to be taken to ensure safety during such examination.

1.2.7 Requirements additional to those of this Chapter may be imposed by the National Authority with whom the ship is registered and/or by the Administration within whose territorial jurisdiction the process plant is intended to operate.

1.3 Classification of ship

1.3.1 A ship built in accordance with the requirements of this Chapter, or in accordance with requirements equivalent thereto, will be assigned an appropriate class in the *Register Book*, as indicated in Section 2, and will continue to be classed so long as it is found, upon examination at the prescribed surveys, to be maintained in a safe and efficient condition, *see also* 1.4.6.

1.3.2 For each category described in 1.1.1, classification covers the hull, containment systems for stored products, propulsion machinery, auxiliary machinery used for essential services, and equipment necessary to maintain a suitable environment within which the plant may safely operate.

1.3.3 In general, classification will not be extended to the process plant itself, and the classification requirements do not relate to the specialised machinery, equipment and associated piping, etc., which is solely concerned with the production operations, except where the design and/or arrangements of such equipment and piping may affect the safety of the vessel.

1.3.4 When the reliquefaction plant is installed, and the plant and equipment are in accordance with the requirements of the Rules for Ships for Liquefied Gases, consideration will be given to classing the plant in accordance with Pt 1, Ch 2,2.6.

1.4 Certification of process plant

1.4.1 Process plant will be required to be certified by LR, and a note to the effect that this has been carried out will be appended to the class notation in the *Register Book*.

1.4.2 The certificate will include a brief description of the process plant, indicating the chemical(s) processed and the end products.

1.4.3 The certificate of the plant will cease to be valid if a significant alteration is made to the plant or the arrangements on board without the written approval of LR. This provision does not exclude the direct replacement of any item by a substitute part which has been approved and tested by LR.

1.4.4 The process plant will be required to be surveyed by LR's Surveyors at intervals to be prescribed by the Committee, dependent on the process involved.

1.4.5 The class notation for the ship will, in general, state that the process plant is not classed but certificated by LR and periodically surveyed by LR's Surveyors.

1.4.6 The maintenance of the class of the ship while the plant is in operation will be dependent upon a valid certificate and the plant being found, upon examination at the prescribed surveys, to be maintained in a safe and efficient condition.

1.4.7 The plant certificate is not to be taken as a recommendation for, or an approval of, the process or processes.

■ *Section 2*
Class notations

2.1 Ship notations

2.1.1 Ships of Category 1A, which have chemical process plants designed to operate while the ship is navigating at sea, will be eligible to be classed '100A1 Chemical Process Factory', *see also* 1.4.5.

2.1.2 Ships of Category 1B, which have chemical plants designed for operation at sea while the ship is specially moored, anchored or otherwise linked to the shore, sea bed or other stationary vessel or structure, will be eligible to be classed '100A1(T) moored (oil, ammonia, etc.) processing (tanker, barge, etc.) for service at . . .', *see also* 1.4.5.

2.1.3 Ships of Category 2, which have chemical plants installed and designed for operation while the ship is in harbour, will be eligible to be classed '100A(T) chemical process plant installed – for operation only when moored in harbour', *see also* 1.4.5.

2.1.4 Specialised ships of Category 3 which have chemical plants designed to operate only while the ship is fully supported on the sea bed, will be eligible to be classed 'A chemical process plant pontoon/platform – to be operated only when grounded on prepared foundations at...', *see also* 1.4.5.

2.2 Additional notations

2.2.1 A special chemical cargoes notation may be assigned to ships where raw materials or products are stored or retained on board in bulk.

2.2.2 The Committee may append details of process, product storage, safety or other particulars to the notation as it considers necessary.

2.2.3 Ships of Category 1B or 2 which have process plants installed solely for the purposes of the physical liquefaction of impure feedstock gases at low temperatures and the storage of the purified liquefied gases (where the chemical treatment of the impurities is an incidental process) will be assigned additional notations to those stated in 2.1.2 or 2.1.3, such as 'for liquefaction and storage of methane, etc., in independent tanks Type B, etc. – maximum pressure – minimum temperature'.

2.3 Special mooring and linking arrangements

2.3.1 Where the process plant is operable only when the ship is specially moored, anchored or otherwise linked to the shore, sea bed or other stationary vessel, and the equipment and/or other linking arrangements and components have been approved by the Committee as suitable and sufficient for the intended service, an equipment character, T, will be assigned in addition, or as an alternative, to the equipment character, 1, as appropriate.

2.3.2 For the purpose of the Rules, the word 'linked' is to be taken to include spuds, retractable legs, floating or submerged pipelines connecting directly to the ship, ship to shore electrical connections, etc., which restrain the ship in its operating position, or which require such restraint to be applied and the failure of which could hazard the ship.

■ *Section 3* Plans and particulars

3.1 General

3.1.1 Before the work is commenced, plans in triplicate, together with the relevant information as detailed in this Section, are to be submitted for consideration. Any subsequent modifications are subject to approval before being put into operation.

3.1.2 Any alterations to basic design, construction, materials, manufacturing procedure, equipment, fittings or arrangements of the process are to be re-submitted for approval.

3.1.3 For Category 1 ships, the plant is to be capable of sustaining an emergency condition at full operating temperatures and pressures with the hull statically listed to an angle of $22^{1}/_{2}$° and statically trimmed to an angle of 10° beyond the maximum normal operating trim. These angles may be modified by the Committee in particular cases as it considers necessary. The stress calculations for the plant and the supporting structure are to take account of this condition. Wind loads need not be considered to be acting during this emergency condition.

3.1.4 For Category 2 ships, the plant is to be capable of sustaining an emergency condition at full operating temperatures and pressures with the hull statically listed to an angle of 15° and statically trimmed to an angle of 5° beyond the maximum normal operating trim. These angles may be modified by the Committee in particular cases as it considers necessary. The stress calculations for the plant and the supporting structure are to take account of this condition. Wind loads need not be considered to be acting during this emergency condition.

3.2 Hull construction

3.2.1 For all categories of ship, the plans and information detailed in 3.2.2 to 3.2.6 are to be submitted, in addition to those required by Pt 3, Ch 1,5, Chapter IV of the Rules for Ships for Liquid Chemicals or Chapter IV of the Rules for Ships for Liquefied Gases, as applicable.

3.2.2 Plans showing the general arrangement of the ship are to be submitted, giving the location of the following:

- Hatches and other openings to enclosed plant spaces and adjacent cofferdams.
- Doors, hatches, ventilation and other openings to crew accommodation, stations essential for operation at sea, control stations, store rooms and workshops.
- Coated tanks or tanks constructed of special material.
- Additional structure associated with the plant above the deck.
- Proposed grouping of areas within the plant for segregation purposes.

3.2.3 Plans for mooring, anchoring and linking, as applicable, together with relevant wind and sea data are to be submitted for information.

3.2.4 Plans outlining the containment arrangements in the event of an accident, together with all relevant information, are to be submitted.

3.2.5 Particulars of the marine environment and safety arrangements associated with the process plant are to be submitted, including:

- Arrangements for preventing the ingress of water into the ship or structure where the process plant and equipment protrude through the weather deck.
- Proposed emergency flooding procedures and their control.

3.2.6 Particulars of the proposed storage arrangements of hazardous and/or toxic substances, feedstocks and products in bulk, on the ship or structure, are to be submitted.

3.3 Process plant

3.3.1 A description of the expected method of operation of the process plant and a diagram showing the process flow are to be submitted.

3.3.2 General arrangement plans of the process plant showing the hazardous and safe zones and spaces are to be submitted, indicating the following:

- Spaces where toxic gases or vapours may accumulate.
- Spaces where flammable gases or vapours may accumulate.
- Areas maintained at an over-pressure to prevent the ingress of such gases or vapours.

3.3.3 Details of the flammability, toxicity, corrosivity and reactivity of the substances entering, being processed and leaving, or stored in, each compartment, together with details of any exothermic and hazardous reactions particularly with regard to sea-water and other materials normally found in the marine environment, are to be submitted.

3.3.4 Plans of the layout of the process plant indicating the hatches and other openings to enclosed plant spaces and cofferdams are to be submitted.

3.3.5 Details and arrangements of the blow-down systems, including quantities of materials and the capacity and working pressure of the containers installed for the reception of the materials to be blown down, are to be submitted.

3.3.6 Proposals for de-watering blow-down tanks in which hot oils and/or chemicals are discharged are to be submitted.

3.3.7 Proposals for the purging, gas freeing, inerting or otherwise rendering safe of the process plant and storage facilities are to be submitted.

3.3.8 Particulars of the arrangements for protecting the process plant systems and vessels against temperature, over-pressure and vacuum are to be submitted.

3.3.9 Proposals for the disposal of hazardous or toxic gases and liquid effluents during normal plant operation, including any proposed flare systems, are to be submitted.

3.3.10 Particulars of the proposals for isolating the ship or structure from the shore installation and/or lightering ships or vessels, where applicable, and from the supply of fuel to boilers, etc., in the process plant and the return flow of chemicals or process effluent, are to be submitted, including:

- Feedstock supply and product discharge, with details of the arrangements showing the location of shut-off valves and of the control and indicating stations.
- The process plant parameters and analysis of transient conditions under which emergency shutdown will be initiated and the time estimated to obtain a safe environment.
- The proposed emergency procedures for controlled shutdown of the process plant, i.e. depressurising, inerting, etc., and the arrangements for the continued operation of the essential services necessary to allow for such controlled shutdown under the emergency conditions of 3.1.3 or 3.1.4, as applicable.

3.3.11 Plans for the ventilation of process plant compartments are to be submitted, together with the following information:

- Location of hazardous and safe zones and spaces.
- Location of all possible sources of ignition.
- Location of air inlets and outlets.
- Number of complete air changes per hour.
- Estimated maximum and minimum ambient temperatures for the regions in which the plant is to operate.
- Expected heat loss of the process plant to the compartment environment.

3.3.12 Particulars of any dust or gas explosion hazard in the enclosed compartments of the process plant are to be submitted.

3.3.13 Proposals for the decontamination of the process plant compartments are to be submitted.

3.3.14 Proposals for the detection of vapour or gas and of oxygen deficiency in the process plant compartments are to be submitted.

3.4 Mechanical equipment associated with the process plant

3.4.1 A list of mechanical equipment associated with the process plant, with the exception of any boilers and other pressure vessels, to be installed in the ship or structure is to be submitted.

3.4.2 Details of safety and relief devices and their discharge arrangements are to be submitted.

3.4.3 When required, in order to facilitate inspection, plans showing the materials of construction, working pressures and temperatures, maximum power and revolutions per minute, as applicable, are to be submitted before the work is commenced.

3.4.4 Calculations of the torsional vibration characteristics of the shafting systems, where applicable, are to be submitted in accordance with the requirements of Pt 5, Ch 8.

3.5 Boilers and other pressure vessels associated with the process plant

3.5.1 Plans of the boilers and other pressure vessels, including the proposals for the support of the vessels, are to be submitted.

3.5.2 Details of the safety and relief devices and their discharge arrangements are to be submitted.

3.5.3 Stress calculations are to be submitted, taking into account the ship linear and angular accelerations, roll and pitch amplitudes, ship flexure and wind loads appropriate to any condition which may normally arise at sea. Where applicable, calculations for the emergency condition in 3.1.3 or 3.1.4 are to be submitted. Due consideration is to be given to the effects of thermal expansion and contraction on the support points of the vessels.

3.5.4 Outline plans of all types of fired equipment, ventilation arrangements with projected casing temperatures, uptake arrangements, gas and/or oil fuel burning arrangements and controls are to be submitted.

3.6 Pumping and piping systems associated with the process plant

3.6.1 Plans of the process plant piping systems, showing the materials of construction, scantlings, support and expansion arrangements, together with the calculations, are to be submitted for consideration.

3.6.2 The following diagrammatic plans for systems associated with the process plant are to be submitted, in addition to those required by Pt 5, Ch 13 and Ch 15 or Chapter V of the Rules for Ships for Liquefied Gases, as applicable:

- The Shipbuilder's plan of the general pumping arrangements, including air and sounding pipes and any cross flooding pipes and fittings.
- Pumping arrangements at the fore and aft ends, drainage of cofferdams and process spaces.
- Bilge, ballast and oil fuel pumping arrangements in the process plant machinery space, including the capacities of the pumps on bilge service.
- Arrangement of oil fuel pipes and fittings at settling and service tanks.
- Arrangement of gas and/or oil fuel piping in connection with gas and/or oil burning arrangements.
- Oil fuel overflow systems, where fitted.
- Arrangement of boiler feed system.
- Arrangement of compressed air systems for the process plant.
- Arrangements of lubricating oil and cooling water systems, oil fuel settling, service and other oil tanks not forming part of the ship's structure.

3.6.3 Plans showing the arrangement and dimensions of main steam pipes, with details of flanges, bolts and weld attachments and particulars of the materials of the pipes, flanges, bolts and welding consumables, are to be submitted for consideration.

3.6.4 Details of the safety and relief devices and their discharge arrangements are to be submitted.

3.7 Electrical equipment for the process plant

3.7.1 Details of the electrical system(s) are to be submitted, including the following:

- A statement quoting the standard or Code of Practice in accordance with which the installation has been designed.
- A statement quoting the standard of design and/or manufacture of electrical equipment, e.g., BS, NEMA, VDE, etc.,
- A schedule of the normal operational loads on the system, estimated for the different operating conditions expected.
- Expected range of ambient temperature.

3.7.2 The following line diagram plans and particulars are to be submitted:

- General arrangement plan of the process plant showing the location of the major items of electrical equipment.
- Line diagram of the installation(s) indicating the rating of the various items of rotating machinery, converters, transformers and protective devices, together with the types and sizes of cables and the makes and types of protective devices.
- Arrangement plans and circuit diagrams of the switchboards.
- Calculations of short-circuit currents at the main switchboards, sub-switchboards and the secondary side of transformers.
- General arrangement plan of the process plant showing the location of electrical equipment in hazardous zones, together with the Code of Practice on which they are based.
- A schedule of safe-type electrical equipment located in hazardous zones, giving details of the type of equipment employed, the certifying authority and the certificate number.

3.7.3 Written confirmation and Works' Test Certificates that all items of electrical equipment comply with the relevant standard or Code of Practice are to be supplied.

3.8 Control equipment for the process plant

3.8.1 Details of the control system(s) are to be submitted, together with the following line diagrams and particulars:

- Line diagrams of any control system(s) fitted.
- General arrangement plan of the process plant showing the locations of items of control equipment and the locations of hazardous zones.
- Schedule of the parameters which are monitored and controlled, including alarms and shutdown devices.

3.9 Fire protection, detection and extinction

3.9.1 Plans of fire protection, detection and extinction arrangements, together with details of the fire and explosion hazards involved, are to be submitted.

■ *Section 4* Materials

4.1 General

4.1.1 The materials used in the construction are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) and of Chapter 6 of the Rules for Ships for Liquefied Gases, as applicable. Materials for which provision is not made in those requirements may be accepted, provided that they comply with an approved specification and such tests as may be considered necessary.

4.1.2 Materials of construction are to be suitable for the intended service, having regard to the substances, process and temperatures involved. For materials unsuitable for use with certain chemicals, and for the protection of materials, *see* Chapter 6 of the Rules for Ships for Liquid Chemicals.

4.1.3 Details of the materials proposed for all types of construction are to be submitted for approval.

■ *Section 5*
Process plant characteristics

5.1 Design

5.1.1 The design and arrangements are to comply with the requirements of this Chapter and with relevant statutory regulations of the National Authority of the country in which the ship or structure is registered and/or in which it is to operate.

5.1.2 The process plant is to be designed for normal operation in accordance with recognised and agreed codes suitably modified to take into account the ship-borne environment in all its aspects. Except for emergency conditions, as detailed in 3.1.3 or 3.1.4, the total stress in any component of the plant is not to exceed the code value at the temperature concerned, unless expressly agreed otherwise by LR, whether the plant is operative or non-operative, when subjected to any possible combination of the following loads:

(a) Static and dynamic loads due to wave-induced ship motions.
(b) Loads resulting from hull flexural effects at the plant support points.
(c) Direct wind loads.
(d) Normal process weights and pressures.
(e) Thermal loads.

5.1.3 For the emergency conditions in 3.1.3 or 3.1.4, the stress levels are to be agreed with LR.

5.2 Separation from ship machinery

5.2.1 Where, during operation, process plant spaces contain or are likely to contain hazardous and/or toxic substances, they are to be kept separate and distinct from the main propulsion and auxiliary machinery and essential ship services, and also the power generating machinery for the process plant.

5.2.2 Notwithstanding the requirements of 5.2.1, this does not exclude the use of the ship's main, auxiliary and/or essential services, for process plant operation in suitable cases. Where, for reason of hazard, essential ship services have to be duplicated within the process plant space, they are to comply with the requirements of Section 9 and Parts 5 and 6, as applicable.

■ *Section 6*
Hull construction

6.1 General

6.1.1 The hull structure is to comply with the relevant requirements of Parts 3 and 4, except as stated otherwise in this Section. The containment of liquefied gas products is to comply with Chapter 4 of the Rules for Ships for Liquefied Gases.

6.1.2 All chemical product and effluent tank structures and their location relative to the ship's hull are to comply with the Rules for Ships for Liquefied Gases, or with the Rules for Ships for Liquid Chemicals, as applicable. Where necessary, the probable temperature variations during operations and the thermal stress considerations are to be stated.

6.1.3 Materials for the hull structures subjected to low temperature are to comply with Pt 3, Ch 2,2.2 relating to refrigerated spaces and adjacent structures, or with Chapter 6 of the Rules for Ships for Liquefied Gases, as applicable.

6.1.4 Subdivision and damage stability are not covered by these Rules. However, attention must be given to any relevant statutory regulations of the National Authority of the country in which the ship is to be registered or in which the plant is to be operated.

6.2 Location of accommodation, service and control spaces

6.2.1 All accommodation and other compartments not directly essential to the operation of the plant are to be arranged well clear of plant spaces, and feedstock and product tanks.

6.2.2 Service and control stations essential to the operation of the plant must be made 'gas-safe' in accordance with internationally accepted codes and standards, and should, wherever possible, be so located that access thereto is from a defined safe space. If such location is not possible, the station is to be specially ventilated.

6.3 Integrity of gastightness between compartments

6.3.1 Where integrity of gastightness is required between compartments containing the plant, this is to be maintained in way of pipe tunnels or duct keels where these traverse such compartments.

6.4 Cofferdams

6.4.1 Cofferdams are to be sited as required by the Rules for Ships for Liquefied Gases, or by the Rules for Ships for Liquid Chemicals, as applicable, segregating any spaces in which raw materials or products are stored or retained in bulk.

6.4.2 Cofferdams are to be arranged around independent tanks containing chemical products or effluents where these are separate from the ship structure, but permanently connected thereto. Such cofferdams are to be mechanically ventilated using portable or permanent systems as required by Chapter 12 of the Rules for Ships for Liquid Chemicals, and are to be of sufficient size to allow effective inspection of all the tank and ship structure in way.

6.5 Access and openings to spaces

6.5.1 Access openings, windows, side scuttles and ventilation openings to accommodation, service and control stations essential for the operation of the ship, and similar safe spaces are to be located and arranged, as required by the Rules for Ships for Liquefied Gases, or by the Rules for Ships for Liquid Chemicals, as applicable.

6.5.2 Arrangements are to be made to provide easy access to, or escape from, plant working spaces. In general, ladders are not to be arranged vertically, and intermediate platforms are to be fitted at vertical intervals of about 6 m. Ladders and platforms are to have guard rails and permanent provision made for attaching hoists for use in emergencies. The arrangements for the emergency hoists are to allow a clear, unobstructed lift to the outside deck.

6.5.3 Two separate means of access from the open deck are generally to be provided to the cofferdams required by 6.4.1.

6.6 Longitudinal strength

6.6.1 Longitudinal strength calculations are to be made in accordance with Pt 3, Ch 4 for the following conditions, and the Loading Manual required by Pt 3, Ch 4,8 is to include this information:

(a) **Sea-going conditions**:
These conditions are to take account of the weights and disposition of all ballast, plant items including any working fluids, other substances, spare gear, etc., and any special support bracing where thermal effects are considered, which will be on board during any sea-going condition of the plant appropriate to the category of ship.

(b) **Harbour condition**:
This condition is to take account of the weights and disposition of all ballast and plant items, including all working and other substances (in all intended stowage dispositions) and spare gear which will be on board during operation of the plant in harbour.

6.7 Plant support structure

6.7.1 Decks and other structure supporting the plant are, in general, to comply with the requirements of Part 3. Such structure can, however, be considered on the basis of an agreed uniformly distributed loading in association with local loads at plant support points, provided that adequate transverse strength of the ship is maintained.

6.7.2 Where the nature and dispositions of heavy plant items are such that forces on the ship and support structure due to ship motions are significant (whether underway with or without working fluids, or moored with working fluids), calculations of the loading and the structural response are to be submitted. In this respect, the guidance formulae for accelerations as given in the Rules for Ships for Liquefied Gases can be used where appropriate. Details of the mass distribution and support points of the plant items are to be submitted in all cases.

6.7.3 Where model tests or reliable direct calculation procedures are used to estimate wave-induced responses and which may indicate accelerations and motion amplitudes differing from those arising from the application of the Rules, such values will be taken into account in the approval of support structure.

6.7.4 If the vessel is intended for limited service at sea (e.g. a 'once only' voyage from port of build to service location), a reduction in the Rule accelerations and motion amplitudes may be permitted. In order to apply such a reduction, details of the intended service limitation should be submitted.

6.8 Loading due to wave-induced motions

6.8.1 In cases where the mass distribution of large columnar plant items is such that the centre of action of the dynamic force differs significantly from the centre of gravity of the item, due account of this is to be taken in the calculation of the forces and moments at the support positions.

6.9 Additional loads

6.9.1 The structure supporting the plant is also to be capable of withstanding forces arising from the following:

(a) Wind loads (in all conditions of service and all categories of ships).
(b) The angle of static heel arising from the emergency condition referred to in 3.1.3 or 3.1.4, as applicable.
(c) For a Category 1A ship, a collision force acting on the tank corresponding to one-half of the weight of the item with or without working fluids, as appropriate, to the approved sea-going conditions from forward and one-quarter of the weight of the item from aft.
(d) For all other categories of ship, a collision force from any horizontal direction of one-fifth of the weight of the item.

6.9.2 Wind loading, which is to be applied to the plant items and supporting structure protruding above the weather deck, should be considered to act simultaneously with wave-induced loading. Loadings 6.9.1(b), (c) and (d) need not be combined with wind loads or wave-induced loads.

6.10 Allowable stresses in support structure

6.10.1 The following stress levels are applicable in conjunction with the loading on the support structure:

(a) Support members above or below the weather deck which are not subject to main hull girder loading:
direct stress:
$\sigma_a + \sigma_b = 0,6\sigma_y$
shear stress:
$\tau = 0,6\tau_y$ or $0,35\sigma_y$ whichever is the smaller combined stress:
$\sigma_c = 0,75\sigma_y = \sqrt{(\sigma_a + \sigma_b)^2 + 3\tau^2}$

where

$\sigma_a + \sigma_b$ = the algebraic sum of the axial and bending stresses at the point under consideration
σ_y = specified minimum tensile yield stress or 0,2 per cent proof stress at room temperature
τ_y = shear yield stress.

(b) Support members directly connected to hull structure and subject to transference of loading therefrom:
- the maximum allowable direct, shear and combined stresses as defined in (a), but with member local loading increased by a factor of 1,30, or
- when the stresses in such structure are determined using methods which satisfactorily take into account any ship deflection and load transference in way of supports, no load factor need be applied.

(c) Primary members forming an integral ship structural and plant support system:
- in general, the allowable stresses in such a system will be especially considered on the basis of the degree of refinement employed in the load prediction, structural response and stress analysis methods. Structural response calculations should include the interaction effects of the hull and plant item.

6.10.2 In general, all seatings, platform decks, girders and pillars supporting plant items are to be arranged to align with the main hull structure, which is to be suitably reinforced, where necessary, to carry the appropriate loads. Attention should be paid to the capability of the support structure to withstand buckling.

6.11 Integrity of weather deck

6.11.1 The integrity of the weather deck is to be maintained. Where items of plant equipment penetrate the weather deck and are intended to constitute the structural barrier to prevent the ingress of water to spaces below the freeboard deck, their structural strength is to be equivalent to the Rule requirements for this purpose. Otherwise, such items are to be enclosed in superstructures or deckhouses fully complying with the Rules. Full details are to be submitted for approval.

6.12 Equipment

6.12.1 Anchors and chain cables for ships navigating at sea are to comply with the requirements of Pt 3, Ch 13,7. Special consideration will be given to the equipment required for ships of Categories 1B and 2.

6.13 Gangways and freeing arrangements

6.13.1 Gangways are to be sufficient to provide proper access to all areas necessary for ship safety while the ship is operational and while it is at sea, and are to be to the Surveyor's satisfaction.

6.13.2 Freeing ports are to be fitted in accordance with the requirements of Pt 3, Ch 8,5.3.

■ *Section 7*
Mechanical equipment for the process plant

7.1 General

7.1.1 The requirements of this Section are applicable to all types of mechanical equipment associated with the process plant, with the exception of boilers and other pressure vessels.

7.1.2 The mechanical plant and equipment are to be designed and constructed in accordance with the relevant Sections of Part 5 and Pt 6, Ch 3, as applicable, and/or with agreed codes and specifications, suitably modified where necessary to suit shipboard conditions. The design is to be capable of accommodating the forces and moments stated in 6.7, 6.8 and 6.9, as applicable, generated at the support points.

7.2 Safety precautions

7.2.1 Oil engines, air compressors and associated air starting piping, concerned with supplying services not essential to the safety of the vessel or structure, are to comply with the requirements of Pt 5, Ch 2, where applicable.

7.2.2 Air intakes for internal combustion engines are to be led from a safe space. Where internal combustion engines, other than gas turbines, are used in association with plant processing flammable substances, the air intakes are to be fitted with an automatic device to prevent overspeeding in the event of accidental ingestion of flammable gases and/or vapours.

7.2.3 Exhaust pipes from internal combustion engines are to be led well clear of hazardous areas and, where such engines are used in association with plant processing flammable substances, are to be fitted with efficient spark arresters.

7.2.4 In general, air compressors are not to be installed in hazardous areas. Where this is not practicable, alternative arrangements may be accepted, provided that the air inlets are trunked or ducted from a safe space and that such trunking/ducting is fitted with gas detectors arranged to give audible and visible alarms and to shutdown the compressor in the event of flammable and/or toxic gas or vapour entering the air inlets.

7.2.5 The gas detectors are to be capable of continuously sampling the air supply and are to be so arranged as to prevent cross-communication between hazardous and safe spaces, such as control rooms, etc.

7.3 Inspection and installation

7.3.1 The scope of the inspection to be carried out at the manufacturers' works by the Surveyors is to be agreed before the work is commenced.

7.3.2 The mechanical plant and equipment are to be installed to the Surveyor's satisfaction. Proposals to site internal combustion engines in hazardous areas will be the subject of special consideration.

■ *Section 8* Boilers and other pressure vessels for the process plant

8.1 General

8.1.1 The requirements of this Section are applicable to fired and unfired pressure vessels associated with the process plant.

8.1.2 The pressure vessels are to be made in accordance with the requirements of the relevant Sections of Pt 5, Ch 10 or Ch 11, as applicable, or with agreed codes and specifications normally used for similar plant in land installations suitably modified and/or adapted for the marine environment. The design is to be capable of accommodating the forces and moments stated in 6.7, 6.8 and 6.9, as applicable, generated at the support points.

8.1.3 Stress calculations are to take account of the emergency conditions in 3.1.3 or 3.1.4, as applicable, in addition to the normal operational loadings. Due consideration is to be given to the effects of thermal expansion and contraction on the support points of the vessels.

8.2 Construction and installation

8.2.1 The pressure vessels are to be constructed, installed and tested to the Surveyor's satisfaction.

8.2.2 Suitable access is to be provided to the vessels for inspection, including checks on the operation of mountings, fittings, controls and pressure relief devices.

8.3 Safety devices

8.3.1 Where necessary, a test rig is to be supplied to enable the pressure setting of the safety and relief devices to be checked.

8.3.2 Where required, an additional pressure relieving device, with sufficient capacity (a) to prevent pressure vessels becoming liquid-full during fire engulfment and/or (b) to discharge vapours generated under fire exposure, is to be fitted in accordance with the relevant Rules for Ships for Liquefied Gases.

8.3.3 The arrangement of safety and relief discharges is to be such that there is no possibility of hazardous reaction between the substances involved.

8.3.4 Where provision is made for the isolation of safety relief devices from vessels and/or systems for maintenance purposes, not less than two such safety devices are to be fitted.

8.3.5 The isolating or blocking valves are to be so arranged that at least one safety relief device will remain in communication with the vessel or system under all conditions.

■ *Section 9* Pumping and piping systems for the process plant

9.1 General

9.1.1 Arrangements are to be made in the process plant spaces, in order that substances which are flammable, toxic or are likely to present a hazard due to reaction when mixed are kept separate.

9.2 Process plant piping systems

9.2.1 Process plant piping systems are to be designed and constructed in accordance with agreed codes and specifications normally used for similar plants in land installations, suitably modified and/or adapted where necessary to suit the marine environment.

9.2.2 Sections of piping which may contain hazardous liquids or gases and which can be isolated are to be suitably protected, *see* 8.3.2.

9.3 Lubricating oil and oil fuel piping

9.3.1 Lubricating oil and oil fuel pipes, fittings, associated equipment, oil fuel burning arrangements and their materials of construction are to comply with the requirements of Pt 5, Ch 14, where applicable.

9.4 Gas fuel supply systems

9.4.1 The gas fuel supply systems are to comply with the requirements of the relevant Sections of the Rules for Ships for Liquefied Gases, where applicable.

9.4.2 Provision to shut off the gas is to be made in the gas firing supply lines immediately before the lines enter the compartment in which the equipment is installed. The shut-off arrangements are to be of the double block and vent type, and are to be operable at the equipment or the equipment control position and at a position in a safe area remote from the equipment.

9.5 Air and sounding pipes

9.5.1 Details of air and sounding pipes to tanks containing chemical products are to be submitted for approval.

9.6 Bilge and effluent arrangements

9.6.1 The arrangements for the storage on board ship, and the disposal of bilge and effluent from the process plant spaces, are to be submitted for consideration, and due recognition is to be given to the requirements of the appropriate National Authority.

9.6.2 Bilge and effluent pumping and piping systems in the process plant spaces are to be constructed of material suitable for the substances processed or produced or any combination of the substances which might result from accidental admixture.

9.6.3 Arrangements are to be provided for the control of the bilge and effluent pumping and piping system installed in the process plant spaces from within these spaces and also from a position outside the spaces.

9.6.4 The bilge and effluent pumping and piping systems handling hazardous materials should, wherever possible, be installed in the space associated with the particular hazard. Spaces containing pumps and piping systems that take their suction from a hazardous space may also be considered as hazardous spaces where a pipeline is not of an all-welded construction without flanges, valve glands and bolted connections, etc., and the pumps are not totally enclosed.

9.6.5 Where, during operation, process plant spaces contain or are likely to contain hazardous and/or toxic substances, they are to be kept separate and distinct from the ship's main bilge pumping and piping system. This does not, however, preclude the use of the ship's main bilge system when the process plant is shutdown, gas freed or otherwise made safe.

9.6.6 Pumping and piping systems for the ship services and process plant are to be constructed and installed to the Surveyor's satisfaction.

■ *Section 10* Firing arrangements of steam boilers, fired pressure vessels, heaters, reformers, etc.

10.1 General

10.1.1 The requirements of this Section are applicable to all types of fired equipment associated with the process plant. The equipment is to be constructed, installed and tested to the Surveyor's satisfaction.

10.2 Design and construction

10.2.1 Details of the design and construction of the fuel gas burning equipment for steam boilers, oil and gas heater furnaces, reformers, etc., are to be in accordance with the Rules for Ships for Liquefied Gases, or with agreed codes and specifications normally used for similar plants in land installations, suitably modified and/or adapted for the marine environment. Ignition of the burners is to be by means of permanently installed igniters, or properly located and interlocked pilot burners and main burners arranged for sequential ignition.

10.2.2 Gas or gas/air mixtures having relative densities compared with that of air at the same temperature greater than one are not to be used as fuels for fired pressure vessels situated below deck. Proposals to burn such mixtures above deck will be specially considered in each case.

10.2.3 Proposals for the furnace purging arrangements prior to ignition of the burners are to be submitted. Such arrangements are to ensure that any accidental leakage of product liquid or gas into the furnace, from a liquid or gas heating element, or from the accidental ingestion of flammable gases and/or vapours, does not result in hazardous conditions.

10.2.4 Compartments containing fired pressure vessels, heaters, reformers, etc., for heating or processing hazardous substances are to be so arranged that the compartment in which the fired equipment is installed is maintained at a higher pressure than the combustion chamber of the equipment. For this purpose, induced draught fans or a closed stokehold system of forced draught may be employed. Alternatively, the fired equipment may be enclosed in a pressurised air casing.

10.2.5 The fired equipment is to be suitably lagged. The clearance spaces between the fired equipment and any tanks containing oil are to be not less than 760 mm. The compartments in which the fired equipment is installed are to be provided with an efficient ventilating system.

10.2.6 Smoke box and header box doors of fired equipment are to be well-fitting and shielded, and the uptake joints made gastight. Where it is proposed to install dampers in the uptake gas passages of fired equipment, the details are to be submitted. Dampers are to be provided with a suitable device whereby they may be securely locked in the fully open position.

10.2.7 Each item of fired equipment is to have a separate uptake to the top of the stack casing. Where it is proposed to install process fired equipment with separately fixed furnaces converging into a convection section common to two or more furnaces and/or a secondary radiant section at the confluence of the fired furnace uptake to the convection section, the proposed arrangements, together with the details of the furnace purging and combustion controls, are to be submitted.

Section 11
Electrical equipment for the process plant

11.1 Design of installation

11.1.1 Installations are to be designed in accordance with Pt 6, Ch 2, or with a recognised National or International Standard or Code of Practice.

11.1.2 Attention must be given to any relevant statutory regulations of the National Authority of the country in which the ship is to be registered or in which the process plant is to be operated.

11.2 Equipment suitability for environment

11.2.1 Electrical equipment is to be constructed so that it is suitable for use in the environmental conditions envisaged, e.g. in areas of high ambient temperature, derating may be necessary.

11.3 Hazardous zones

11.3.1 Where flammable gases and vapours are involved, the defining of hazardous zones is to be in accordance with a National or International Standard or Code of Practice.

11.4 Certified safe-type equipment

11.4.1 Where safe-type equipment is permitted in hazardous zones, e.g.:

- Intrinsically-safe (symbol i),
- Flameproof (symbol d),
- Increased safety (symbol e),
- Pressurised enclosure (symbol p),

such equipment is to be certified for the gases and vapours involved. The construction and type testing are to be in accordance with IEC 60079: *Electrical Apparatus for Explosive Gas Atmospheres*, or an equivalent National Standard.

11.5 Survey and testing

11.5.1 All electrical equipment is to be installed and tested to the Surveyor's satisfaction.

Section 12
Control engineering for the process plant

12.1 Design of installation

12.1.1 Normal good engineering practice and standards are to be employed in any control system(s) fitted.

12.1.2 Due to the wide variety of types of process plant, it is not possible to lay down precise details of control scheme(s), since any control scheme is affected by the nature of, and the operating procedures of, the process plant. A description of the expected method of operation of the process plant is to be submitted.

12.2 Equipment

12.2.1 Control equipment is to be compatible with the materials involved in the plant process.

12.2.2 Where flammable gases or vapours are involved, control equipment located in hazardous zones is to be of certified safe-type.

12.3 Survey and testing

12.3.1 Control system(s) are to be installed and tested to the Surveyor's satisfaction.

Section 13
Plant blowdown systems

13.1 General

13.1.1 Where a liquid blowdown system is provided in the process plant, the design and installation are to make adequate provision for the effects of back pressure in the system and vapour flash off when the pressures of liquids in the blowdown system are reduced.

13.1.2 Substances which will react with each other are to be provided with separate systems.

Section 14
Plant flare gas systems

14.1 General

14.1.1 Details of any flare gas stack system and proposals for installation on board the ships, including safety arrangements, are to be submitted for consideration.

14.1.2 The protection zone around the nozzle of the flare gas stack is dependent upon the limiting radiation intensity under all conditions and, also, whether suitable radiation screens are provided. The flare gas stack is to be located so that the nozzle is situated not less than the radius of the protection zone or 50 m, whichever is the greater, from equipment and manned stations, etc.

14.1.3 The arrangements are to ensure that combustion of the flare gas is complete and safe at all times.

■ *Section 15* Supply and discharge arrangements for feedstock and product

15.1 General

15.1.1 Arrangements are to be made to isolate the ship from the supply of feedstock for processing, the supply of oil fuel or gas to boilers, heaters, etc., and the return flow of product, chemicals or process effluent, blow-down or flare gas, etc.

15.1.2 The arrangements are to provide for valves installed at the shore connection, where applicable, and on board ship which are to be operable from shut-off control and indicating stations on the ship, on the shore, and at the valves.

15.2 Emergency procedures

15.2.1 Detailed instructions of the emergency shutdown and evacuation procedure are to be posted in a prominent position at the ship and shore control stations, where applicable.

■ *Section 16* Ventilation of the process plant and other spaces associated with the process plant operation

16.1 General

16.1.1 An efficient means of ventilation is to be provided for all enclosed compartments associated with the operation of the process plant.

16.1.2 The capacity of the ventilation systems is to comply with the requirements of Pt 5, Ch 15,1.7 or the Rules for Ships for Liquefied Gases, or Chapter 12 of the Rules for Ships for Liquid Chemicals, where applicable, or to an acceptable Code of Practice suitably modified and/or adapted where necessary to suit the marine environment. It is to be related to the hazard and/or environmental consideration of manned spaces during normal operation, and take into account additional requirements which may be necessary during start-up procedures.

16.2 Design and construction

16.2.1 Hazardous compartments where flammable and/or toxic substances are being processed or produced are to be arranged for underpressure ventilation, except as stated in 10.2.4.

16.2.2 Safe compartments, including control rooms, are to be arranged for overpressure ventilation.

16.2.3 The number and capacity of fans are to be such that the minimum ventilation capacity required in each compartment is maintained at all times, with one unit out of service. If internal combustion engines are proposed, their fuel supply is to be kept separate from any other system. Electric motors are to be supplied by two alternative circuits, each of which is capable of supplying all the motors which are normally connected to that circuit and which are operated simultaneously.

16.2.4 The mechanical ventilation system is to be capable of being controlled from a position outside the compartment being ventilated.

16.2.5 Reduction of ventilation capacity below the required level should be indicated in the compartment and also in the control room by an audible and visible alarm.

16.2.6 The parts of the rotating body and of the casing of each fan situated in a hazardous space are to be made of recognised spark-proof materials. If non-metallic materials are used, they are to have anti-static properties.

16.2.7 Ventilation trunking or ducting is to be suitably coated or painted, or made from material suitable for the substances processed or produced, or any combination of the substances which might result from accidental admixture.

16.3 Air inlets and discharges

16.3.1 The air inlets for the ventilation systems are to be located in a designated safe area.

16.3.2 The air inlets and discharges of the ventilation system are to be so situated that recirculation of the vented vapours does not occur.

16.3.3 The discharges from ventilation systems which may contain vapours that present a hazard due to reaction with each other are to be effectively segregated.

16.3.4 The discharges from ventilation systems which may contain hazardous vapours are to be located not less than 10 m from the nearest air intake or opening to accommodation, service and control station spaces or other safe spaces, and from all possible sources of ignition.

16.3.5 Air intakes and openings into the accommodation spaces and all service and control station spaces are to be fitted with closing devices. For toxic gases, these devices are to be operable from inside the space.

16.3.6 Where it is impracticable to locate a plant service or control station so that any access thereto is from a safe space, the service or control station is to be maintained at an overpressure of not less than 5 mm water gauge above the surrounding spaces. Details of the arrangements to ensure that this pressure differential is maintained are to be submitted.

16.3.7 Airlocks for intercompartmental access doors and emergency escape trunks are to have separate ventilation systems so arranged that an overpressure of 5 mm water gauge is maintained above the adjacent compartments. Details of the arrangements to ensure that this pressure differential is maintained are to be submitted.

16.4 Installation and inspection

16.4.1 The ventilation systems are to be installed to the Surveyor's satisfaction.

16.4.2 The Surveyors are to be satisfied that the ventilation system is capable of maintaining a safe environment during process plant operation. This may require monitoring over an extended period to prove its effectiveness.

■ *Section 17* Gas detection

17.1 General

17.1.1 An efficient gas detection system, suitable for the gases and/or vapours being processed or produced, and for the measurement of oxygen levels in the process plant compartments, is to be provided. Gas detector systems are also to comply with the requirements of Section 17 or of Chapter 13 of the Rules for Ships for Liquefied Gases, where applicable.

17.2 Design and construction

17.2.1 The equipment is to consist of a permanently fixed installation and at least two sets of portable equipment suitable for the process or products involved.

17.2.2 The position and number of fixed sampling points should be determined with due regard to the density of the gases and/or vapours of the substances processed or produced, and the dilution resulting from compartment ventilation. In each case, a sufficient number of sampling points are to be provided to give efficient selective sequential sampling to maintain a safe environment.

17.2.3 Unmanned or closed compartments, such as cofferdams, etc., associated with plant processing or producing flammable or toxic substances, are to have permanently installed sampling points suitable for use with portable detection equipment to be used before entry of the spaces by personnel and thereafter continuously while occupied by them.

17.2.4 Arrangements of the sampling point pipe runs are to be such that there is no possibility of hazardous gases and/or vapours entering a safe space. Common sampling lines to the detection equipment are not to be fitted.

17.2.5 The permanently installed gas detection system is to give audible and visible alarm, both in the control station and within the compartment, during hazardous conditions.

17.2.6 Except where continuous sampling is required (i.e. as in 7.2.5), the gas detection equipment should be capable of sampling and analysing from each sampling point at agreed intervals, which are in no case to exceed 30 minutes.

17.2.7 The gas detection equipment is to be designed so that it may be readily and regularly tested and calibrated. Suitable equipment and span gas is to be provided for this purpose. In addition, regular checking procedures with portable equipment are to be provided, particularly for closed or unmanned spaces during process plant operation.

17.2.8 Where equipment for detecting the specific flammable, toxic or asphyxiate substances which may be present in process plant spaces cannot be provided, full details are to be submitted, including personnel protection requirements and arrangements for decontaminating such spaces if necessary.

17.3 Installation

17.3.1 The gas detection system is to be installed to the Surveyor's satisfaction.

■ *Section 18* Fire protection, detection and extinction

18.1 General

18.1.1 The requirements of SOLAS Chapter II-2 and the Rules for Ships for Liquefied Gases are to be complied with, so far as they are applicable. Additional protection, consistent with the fire hazard involved, may be required for process plant control stations, and accommodation spaces. For the position of accommodation spaces relative to the process plant, *see* 6.2.

18.1.2 Where the design of the process plant is such that it may be operated only while the vessel or floating structure is specially moored, anchored or otherwise linked close to the shore, consideration will be given to a shore-based fire-fighting facility, taking account of the particular hazards involved.

18.2 Design arrangements

18.2.1 Arrangements are to be made in enclosed process plant spaces to prevent contact of dangerously interreactive substances and of flammable materials with sources of ignition. In general, compartments containing process plant are not to exceed 40 m in length, and the boundary bulkheads are to be 'A' Class divisions.

18.2.2 Where, during operation, process plant spaces or adjacent hazardous zones contain or are likely to contain flammable and/or explosive mixtures, special consideration is to be given to the exclusion of all possible sources of ignition.

18.2.3 All heated surfaces, e.g. exhaust pipes, boiler uptakes and steam pipes, are to be effectively lagged or cooled, so that the maximum temperature, °C, of the surfaces is, in general, not to exceed 70 per cent of the auto-ignition temperature, °C, of any substances which may be present in the compartment. In no case is the difference in these temperatures to be less than 50°C.

18.2.4 Compartments where a fire hazard exists and which are not continuously manned are to be provided with an approved fire detection system which shall give visible and audible warning of the location of the fire in the control station and, for plant operating at sea (Category 1A), at the navigating bridge control position.

18.2.5 The fire main is to be so arranged, and hoses and nozzles provided, that any part of the compartments or structure associated with the process plant can be reached with two powerful jets of water, one of which shall be produced by a single length of hose. The hoses are to be provided with dual-purpose nozzles capable of producing a jet or a spray. Special consideration will be given to an exemption from this requirement in respect of compartments where the use of water would in itself constitute a hazard.

18.2.6 Each compartment where the fire hazard so demands is to be provided with an approved fixed fire-extinguishing system capable of extinguishing fires involving the materials present. Operation of such a system at its required output is not to prevent the simultaneous use of the required jets of water from the fire main. Where carbon dioxide systems and Halon systems are fitted, due consideration should be given to the danger of static electricity.

18.2.7 An adequate number of portable fire extinguishers are to be provided in each compartment where a fire hazard exists. The number of such extinguishers will be decided in relation to the nature of the hazard and the layout of the compartment, but shall not be less than two, one of which is to be positioned near the entrance. The extinguishing medium is to be considered in relation to the nature of the hazard involved.

18.2.8 Means are to be provided for stopping all fans and, where practicable, closing all openings which might admit air to the compartment. Such means should be capable of being operated from a position outside the compartment and not likely to be rendered inaccessible by a fire in the compartment.

18.2.9 Means are to be provided for stopping the supply of combustible materials to the compartment in the event of fire.

18.2.10 The provision of additional fireman's outfits, each complying with the requirements of SOLAS Reg. II-2/A, 17, and the necessity for protective clothing, will be specially considered in relation to the layout of the process plant and the hazards involved.

Section 1
General

1.1 Application

1.1.1 The requirements of this Chapter apply to ships intended for fire-fighting operations and are additional to those applicable in other Parts.

1.1.2 A ship provided with fire protection and fire-fighting equipment in accordance with these Rules will be eligible for an appropriate class notation which will be recorded in the *Register Book*.

1.1.3 Requirements additional to these Rules may be imposed by the National Authority with whom the ship is registered and/or by the Administration within whose territorial jurisdiction the fire-fighting ship is intended to operate.

1.2 Classification and class notations

1.2.1 The class notations which may be assigned are:
- '**Fire-fighting ship 1** (total monitor discharge capacity in brackets)',
- '**Fire-fighting ship 2** (total monitor discharge capacity in brackets)',
- '**Fire-fighting ship 3** (total monitor discharge capacity in brackets)',
- '**Fire-fighting ship 1** (total monitor discharge capacity in brackets) **with water spray**',
- '**Fire-fighting ship 2** (total monitor discharge capacity in brackets) **with water spray**',
- '**Fire-fighting ship 3** (total monitor discharge capacity in brackets) **with water spray**'.

1.2.2 The notation **Fire-fighting ship 1**, **Fire-fighting ship 2** or **Fire-fighting ship 3** signifies that a ship complies with these Rules and is provided with the appropriate fire-fighting equipment described in Table 3.1.1, with the total discharge capacity of monitors in m^3/h shown in brackets.

1.2.3 The addition of the words '**with water spray**' to the notations referred to in 1.2.1 signifies that a ship is provided with a water spray system, which will provide an effective cooling spray of water over the vertical surfaces of the ship to enable it to approach a burning installation for fire-fighting purposes. The requirements for such a system are set out in 4.2.

Table 3.1.1 Fire-fighting equipment

Equipment	Fire-fighting ship 1	2	3
Minimum total pump capacity, m^3/h	2400	7200	10 000
Minimum number of water monitors	2	3	4
Minimum discharge rate per monitor, m^3/h	1200	1800	1800
Minimum height of trajectory of jets of monitors above sea level, metres	45	70	70
Minimum range of monitor jets, m	120	150	150
Minimum fuel capacity for monitors, hours	24	96	96
Number of hose connections each side of ship	4	8	8
Number of fireman's outfits	4	8	8

1.3 Surveys

1.3.1 The arrangements and equipment referred to in this Chapter are to be examined and tested under working conditions on completion of the installation and, subsequently, annually.

1.4 Submission of plans

1.4.1 The following plans and information are to be submitted:
- A general arrangement showing the disposition of all fire-fighting equipment required by this Chapter.
- Details of major items of fire-fighting equipment, such as pumps and monitors, including their capacity, range and trajectory of delivery.
- A general arrangement plan showing the disposition of fire divisions and their class.
- Detailed plans of the fire divisions and, where applicable, copies of the certificates of approval for the insulating materials proposed.
- A plan of the construction of the fire doors.
- Plans showing the layout and capacity of the water spray system. Where alternative arrangements to those specified in 4.2 are proposed, evidence is to be submitted to satisfactorily demonstrate that an equivalent level of protection from radiated heat is provided, including details of the environmental conditions in which the ship is intended to operate, *see* 4.2.1.
- A plan of the seating arrangements for the water monitors.
- Particulars of the means of keeping the ship in position during fire-fighting operations.
- A plan showing the fire pumps, the fire water main, the hydrants, hoses and hose nozzles and the monitors, together with particulars of their delivery capability.
- Details of the fireman's outfits provided.
- Plans of any other fire-fighting systems provided.

1.5 Definitions

1.5.1 'A-60 standard' means a fire-resisting construction of steel or other equivalent material, which is suitably stiffened and so constructed as to be capable of preventing the passage of smoke and flame for the complete period of the one-hour standard fire test. It is to be insulated with approved non-combustible materials, so that the average temperature on the unexposed side will not rise by more than 139°C above the original temperature, nor will the temperature at any one point, including any joint, rise more than 180°C above the original temperature within 60 minutes.

1.5.2 'Steel or other equivalent material'. In this context, 'equivalent material' means any material which, by itself or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the applicable standard fire test exposure period (e.g. aluminium with appropriate insulation).

1.5.3 'The standard fire test' is one in which specimens of the relevant bulkheads or decks, having a surface area of approximately 4,65 m^2 and a height of 2,44 m, resembling as closely as possible the intended construction and including, where appropriate, at least one joint, are exposed in a test furnace to heat on a time-temperature relationship, approximately as follows:

- At the end of the first 5 minutes, 538°C.
- At the end of the first 10 minutes, 704°C.
- At the end of the first 30 minutes, 843°C.
- At the end of the first 60 minutes, 927°C.

1.5.4 A 'non-combustible material' means a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750°C. Any other material is a 'combustible material'.

■ *Section 2* Construction

2.1 Hull

2.1.1 The structure of the ship is to be strengthened as necessary to withstand the forces imposed by the fire-extinguishing systems when operating at their maximum capacity.

2.2 Sea suctions

2.2.1 The sea suctions of the fire pumps are to be arranged as low as practicable in the ship's structure to avoid icing or the ingress of oil from the surface of the sea.

2.2.2 All sea inlet valves are to be provided with a low pressure steam or compressed air connection for clearing purposes.

2.3 Stability

2.3.1 Each ship is to comply with the draught and stability requirements of the National Authority and is to have on board sufficient stability data to enable the ship to be properly loaded and handled. This data is to take full account of the effect of the monitors when they are operating at their maximum output in all possible directions of use.

2.4 Manoeuvrability

2.4.1 Arrangements are to be provided to enable the ship to maintain position, so that the monitors may be effectively deployed.

2.5 Bunkering

2.5.1 The Owner should ensure that any fuel which may be required while the ship is operating on station can be safely received on board.

■ *Section 3* Fire-extinguishing

3.1 Water monitors

3.1.1 The minimum number of monitors, their discharge rate, their range and their height of trajectory above sea level are to comply with the requirements of Table 3.1.1.

3.1.2 The monitors are to be so arranged that the required direction, range and height of trajectory can be achieved separately, with the required number of monitors operating simultaneously.

3.1.3 The monitors are to be capable of adequate adjustment in the vertical and horizontal direction and are to be so positioned that the jets will be unimpeded within the required range of operation.

3.1.4 Means are to be provided for preventing the monitor jets from impinging on the ship's structure and equipment when in external fire-fighting mode. Combined systems for high pressure external fire-fighting and deck foam fire-fighting may be permitted provided consideration is given to monitor position and to the safety of operating pressures when used in deck foam mode and during changeover between modes. Changeover between modes is to be by a simple operator action. The combined system is to be capable of simple and rapid operation in either mode.

3.1.5 The monitors are to be capable of being activated and manoeuvred by remote control from a protected position providing a good view of the monitors and the operating area of the water jets.

3.1.6 The monitors are to be of robust construction and their seating arrangements are to be of adequate strength for all modes of operation, particular attention being paid to shock loading when all the monitors are activated simultaneously.

3.1.7 For the class notations **Fire-fighting ship 2** and **Fire-fighting ship 3,** an arrangement with one less monitor than required in Table 3.1.1 may be considered as an equivalent solution. In such cases the total pump capacity is to be as required in Table 3.1.1. The minimum range of monitor jets and minimum height of trajectory of jets of monitors above sea level are to be 180 m and 110 m, respectively.

3.2 Pumps

3.2.1 The pumps and their piping system which are intended for serving the monitors are not to be available for services other than fire-extinguishing and water spraying. They are to be provided with independent sea inlets.

3.2.2 Where the pumps are used for fixed water spray systems, the piping is to be independent of that supplying the monitors. The water spray systems are to be adequately protected against overpressure.

3.2.3 The minimum total pump capacities required are shown in Table 3.1.1.

3.2.4 For assignment of the notations **Fire-fighting ship 2** or **Fire-fighting ship 3**, there are to be at least two pumps serving the monitors and they should be of approximately equal capacity. For assignment of the notation **Fire-fighting ship 1**, one pump only need be provided.

3.3 Hose stations

3.3.1 Hose stations are to be provided on each side of the ship in accordance with Table 3.1.1.

3.3.2 Each hose station is to be provided with a hydrant, a hose and a nozzle capable of producing a jet or a spray and simultaneously a jet and a spray. The hoses are to be 15 m in length and not less than 38 mm nor more than 65 mm in diameter. Where hose stations are connected to the monitor supply lines, provision is to be made to reduce the water pressure at the hydrants to an amount at which each fire hose nozzle can be safely handled by one man. The water pressure shall be sufficient to produce a water jet throw of at least 12 m.

3.4 Fireman's outfits

3.4.1 The number of fireman's outfits provided, in addition to those provided in accordance with Pt 6, Ch 4,12 or SOLAS Reg. II-2/A, 17 as applicable, is to be in accordance with Table 3.1.1. They are to be stored in a safe position which is readily accessible from the open deck.

3.4.2 The composition of a fireman's outfit is to be as follows:

- Protective clothing of material to protect the skin from heat radiating from the fire and from burns and scalding by steam. The outer surface is to be water-resistant.
- Boots and gloves of rubber or other electrically non-conducting material.
- A rigid helmet providing effective protection against impact.
- An electric safety lamp (hand lantern) of an approved type with a minimum operating period of three hours.
- An axe having an insulated handle.
- A self-contained breathing apparatus, which is to be capable of functioning for a period of at least 30 minutes and having a capacity of at least 1200 litres of free air. Spare, fully charged air bottles are to be provided at the rate of at least one set per required apparatus.
- For each breathing apparatus, a fireproof lifeline of sufficient length and strength is to be provided capable of being attached by means of a snaphook to the harness of the apparatus or to a separate belt, in order to prevent the breathing apparatus becoming detached when the life-line is operated.

3.5 Recharging of equipment

3.5.1 A suitable air compressor for recharging the bottles used in the breathing apparatus of the fireman's outfits is to be provided. It is to be capable of recharging the bottles of the breathing apparatus required to be carried, in accordance with Table 3.1.1, in a time not exceeding 30 minutes.

■ *Section 4* Fire protection

4.1 General

4.1.1 In ships which are not provided with a water spray system as described in 4.2 all windows and port lights are to be provided with efficient deadlights or external steel shutters, except in the wheelhouse.

4.2 Water spray systems

4.2.1 Ships which are intended to operate in close proximity to a large fire will require protection from the heat radiated from the fire. Such protection may be afforded by a system which provides a water spray over the surface of the ship, or by a combination of insulation and a water spray system. Alternative arrangements providing an equivalent level of protection may be accepted where it can be demonstrated that such arrangements are effective for the environmental conditions in which the ship is intended to operate.

4.2.2 The water spray system is to be a fixed system which is capable of delivering a spray of water over all the exposed external vertical surfaces of the hull in the lightest sea-going condition, including the superstructures and deck-houses and over the monitor position. The water spray system will also be required to cover the areas of deck which form the crowns of machinery spaces and other spaces containing combustible materials.

4.2.3 The system is to have a capacity of 10 litres/min per m^2 of the protected area of uninsulated steel and 5 litres/min per m^2 of the protected area which is insulated internally to A-60 standard.

4.2.4 The system may be divided into sections, so that it will be possible to enable the closing down of those sections covering surfaces which are not exposed to radiant heat.

4.2.5 The nozzles are to be arranged to give an even distribution of water spray over the protected area.

4.2.6 The pumping capacity is to be sufficient to supply simultaneously at the required pressure the sections which serve the maximum area which may be exposed to radiant heat from a fire. If the main fire pumps are used for this purpose, they are to be capable of operating this system and the monitors and hose stations simultaneously at the required pressures, *see also* 3.2.2.

4.2.7 Deck scuppers and freeing ports are to be of sufficient area to ensure efficient drainage of water from decks and horizontal surfaces in all conditions when the water spray system is in operation.

■ *Section 5* **Lighting**

5.1 General

5.1.1 Two searchlights should be provided for illuminating the burning structure and facilitate the effective deployment of the water monitors at night.

5.1.2 The searchlights are to be capable of providing at a range of 250 m in clear atmospheric conditions a level of illumination of 50 lux within an area of not less than 11 m diameter. They are to be capable of being adjusted in the horizontal and vertical directions.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to ships with installed dynamic positioning systems and are additional to those applicable in other Parts of these Rules.

1.1.2 A ship provided with a dynamic positioning system in accordance with these Rules will be eligible for an appropriate class notation which will be recorded in the *Register Book*.

1.1.3 Requirements, additional to these Rules, may be imposed by the National Administration with whom the ship is registered and/or by the administration within whose territorial jurisdiction it is intended to operate. Where national legislative requirements exist, compliance with such regulations shall also be necessary.

1.1.4 For the purpose of these Rules, dynamic positioning means the provision of a hydrodynamic system with automatic and/or manual control capable of maintaining the heading and position of the ship during operation within specified limits and environmental conditions.

1.1.5 For the purpose of these Rules, the area of operation is the specified allowable position deviation from a set point, *see* 1.3.2.

1.1.6 Special consideration will be given where the dynamic positioning system is used primarily for purposes other than position keeping, e.g. track following. A descriptive note may be entered in column 6 of the *Register Book* to this effect.

1.2 Classification notations

1.2.1 Ships complying with the requirements of this Chapter will be eligible for one of the following class notations, as defined in Pt 1, Ch 2:

DP(CM) *See* Section 2.
DP(AM) *See* Section 3.
DP(AA) *See* Section 4.
DP(AAA) *See* Section 5.

1.2.2 The notations given in 1.2.1 may be supplemented with a Performance Capability Rating (PCR). This rating indicates the calculated percentage of time that a ship is capable of maintaining heading and position under a standard set of environmental conditions (North Sea), *see* Section 6.

1.2.3 Additional descriptive notes may be entered in column 6 of the *Register Book* indicating the type of position reference system, control system, etc.

1.2.4 Where a **DP** notation is not requested, dynamic positioning systems are to be installed in accordance with the requirements of Section 2 as far as is practicable.

1.3 Information and plans required to be submitted

1.3.1 The information and plans specified in 1.3.2 to 1.3.7 are to be submitted in triplicate. The Operation Manuals specified in 1.3.9 are to be submitted in a single set.

1.3.2 Details of the limits of the area of operation and heading deviations, together with proposals for redundancy and segregation provided in the machinery, electrical installations and control systems, are to be submitted. These proposals are to take account of the possible loss of performance capability should a component fail or in the event of fire or flooding, *see also* 1.3.6 and Sections 4 and 5.

1.3.3 Where a common power source is utilised for thrusters, details of the total maximum load required for dynamic positioning are to be submitted.

1.3.4 Plans of the following, together with particulars of ratings in accordance with the relevant Parts of the Rules, are to be submitted for:
(a) Prime movers, gearing, shafting, propellers and thrusters.
(b) Machinery piping systems.
(c) Electrical installations.
(d) Pressure vessels for use with dynamic positioning system.

1.3.5 Plans of control, alarm and safety systems, including the following, are to be submitted:
(a) Functional block diagrams of the control system(s).
(b) Functional block diagrams of the position reference systems and the environmental sensors.
(c) Details of the electrical supply to the control system(s), the position reference system(s) and the environmental sensors.
(d) Details of the monitoring functions of the controllers, sensors and reference systems, together with a description of the monitoring functions.
(e) List of equipment with identification of the manufacturer, type and model.

(f) Details of the control stations, e.g. control panels and consoles, including the location of the control stations.
(g) Test schedules (for both works testing and sea trials) that are to include the methods of testing and the test facilities provided.

1.3.6 For assignment of a **DP(AA)** or **DP(AAA)** notation, a Failure Mode and Effects Analysis (FMEA) is to be submitted, demonstrating that adequate segregation and redundancy of the machinery, the electrical installation and the control systems have been achieved in order to maintain position in the event of equipment failure (*see* Section 4); or fire or flooding, *see* Section 5. The FMEA is to take a formal and structured approach and is to be performed in accordance with an acceptable and relevant national or international standard, e.g. IEC 60812.

1.3.7 Where the **DP** notation is to be supplemented with a Performance Capability Rating (PCR) (*see* 1.2.2), the following information is to be submitted for assignment of a PCR:
(a) Lines plan.
(b) General arrangement.
(c) Details of thruster arrangement.
(d) Thruster powers and thrusts.

1.3.8 Details of the intended modes of operation are to be submitted. As a minimum, these are to include:
(a) a description of all the intended operating modes;
(b) details of the system configuration required for each mode of operation. When applicable, this is to include the configuration needed to meet the FMEA requirements of 1.3.6; and
(c) the procedures which are to be followed in each operating mode during normal and abnormal conditions.

1.3.9 A set of the operation and maintenance manuals is to be placed and retained on board the ship.

■ *Section 2* Class notation DP(CM)

2.1 General

2.1.1 For assignment of **DP(CM)** notation, the requirements of 2.1.2 and 2.2 to 2.5 are to be complied with.

2.1.2 Control engineering systems, electrical and piping installations and machinery items are to be designed, constructed, installed and tested in accordance with the relevant requirements of Parts 5 and 6.

2.2 Thrusters

2.2.1 Thruster installations are to be designed, constructed, installed and tested in accordance with the requirements of Pt 5, Ch 20, as applicable.

2.2.2 Thruster installations are to be designed to minimise potential interference with other thrusters, sensors, hull or other surfaces, which could be encountered in the service for which the ship is intended.

2.2.3 Thruster intakes are to be located at sufficient depth to reduce the possibility of ingesting floating debris and vortex formation.

2.2.4 The response and repeatability of thrusters to changes in propeller pitch or propeller speed/direction of rotation are to be suitable for maintaining the area of operation and heading within specified limits.

2.3 Electrical systems

2.3.1 This Section applies to the electrical generation and distribution system associated with the Dynamic Positioning System, whether this generating system is dedicated to the DP system or forms a central generating arrangement for all loads on the ship.

2.3.2 The electrical installation is to be designed, constructed and installed, in accordance with the requirements of Pt 6, Ch 2, together with the requirements of 2.3.3 to 2.3.12.

2.3.3 Where thrusters are electrically driven, the relevant requirements, including surveys, of Pt 6, Ch 2,16 are to be complied with.

2.3.4 Essential services are those defined in Pt 6, Ch 2,1.6, as applicable, together with thruster auxiliaries, computers, generator and thruster control equipment, reference systems, environmental sensors and electrically driven thrusters.

2.3.5 The number and rating of generator sets, transformers and converter equipment are to be sufficient to ensure the operation of essential services, even when one generating set, transformer or converter equipment is out of action.

2.3.6 For electrically driven thruster systems, the generator rating is to be determined by the maximum dynamic positioning load, together with the maximum ancillary load.

2.3.7 There are to be arrangements to prevent overloading of the running generator(s). The tripping of non-essential loads and the temporary reduction in the load demands of electrically driven thrusters may form part of these arrangements.

2.3.8 An alarm is to be initiated when the total electrical load exceeds a preset percentage of the running generator(s) capacity. This alarm is to be adjustable between 50 and 100 per cent of the running capacity and is to be set with regard to the number of generators in service and the effect of the loss of any one generator.

2.3.9 On loss of power due to the failure of the operating generator(s), there is to be provision for the automatic starting and connection to the switchboard of a standby set and the automatic sequential restarting of essential services. Consideration may be given to cases where arrangements for automatic re-starting of thrusters would not be practicable. Details are to be submitted in such cases to show that manual means for the immediate re-starting of thrusters would be available at the control station from where the dynamic positioning system would be operated.

2.3.10 Any loads that require an uninterrupted electrical power supply are to be provided with uninterruptible power systems (UPS) having a capacity for a minimum of 30 minutes' operation following loss of the main supply. A UPS is to be provided for each control computer system.

2.3.11 An indication of the absorbed power and the available on-line generating capacity is to be provided at the main dynamic positioning control station.

2.3.12 Essential services are to be served by individual circuits. Essential services that are duplicated are:

(a) to be supplied from independent sections of their switchboard or section board;
(b) to have their circuits separated throughout their length as widely as is practicable; and
(c) not to depend upon common feeders, transformers, converters, protective devices, control circuits or control gear assemblies to operate.

2.4 Control stations

2.4.1 Control stations from which the dynamic positioning system may be operated are to be designed in accordance with sound ergonomic principles, and are to be provided with sufficient instrumentation to provide effective control and indicate that the systems are functioning correctly. Colour schemes and screen layouts are to be selected such that necessary information is readily available and clearly displayed. *See also* Pt 6, Ch 1,2.10 for general ergonomic requirements.

2.4.2 Control station(s) are to be located such that the operator has a good view of the ship's exterior limits and surrounding area.

2.4.3 Indication of the following is to be provided at each station from which it is possible to control the dynamic positioning system:

(a) The heading and location of the ship relative to the desired reference point or course.
(b) Vectorial thrust output, individual and total.
(c) Operational status of position reference systems and environmental sensors.
(d) Environmental conditions, e.g. wind speed and direction.
(e) Availability status of standby thrusters.

2.4.4 At least one position reference system, heading reference sensor and wind sensor are to be provided to ensure that the specified area of operation and heading can be effectively maintained.

2.4.5 Position reference systems are to incorporate measurement techniques suitable for the service conditions for which the ship is intended.

2.4.6 Where necessary for the correct functioning of a position reference system, a vertical reference sensor is to be provided to correct for the pitch and roll of the ship. There are to be at least as many vertical reference units as there are associated position reference systems.

2.4.7 Alarms, in accordance with the requirements of Pt 6, Ch 1,2.3, are to be provided for the following fault conditions as applicable:

(a) When the ship deviates from the area of operation.
(b) When the heading exceeds the allowable deviation.
(c) Position reference system fault (for each reference system).
(d) Heading reference sensor fault.
(e) Vertical reference sensor fault.
(f) Wind sensor fault.
(g) Taut wire excursion limit.
(h) Automatic changeover to a standby position reference system or environmental sensor.

A permanent record of the occurrences of alarms and warnings, and of status changes is to be provided.

2.5 Control system

2.5.1 A centralised remote manual control system is to be provided such that changes in the vectorial thrust output may be readily effected by a single operator action.

2.5.2 Suitable processing and comparative techniques are to be provided to validate the control system inputs from position and other sensors. Abnormal signal errors revealed by the validity checks are to operate alarms.

2.5.3 The control system for dynamic positioning operation is to be stable throughout its operational range and is to meet the specified performance and accuracy criteria.

2.5.4 Automatic controls are to be provided to maintain the heading of the ship within specified limits.

2.5.5 The allowable deviation from the desired heading is to be adjustable, but should not exceed the specified limits, *see* 1.1.4. Arrangements are to be provided to fix and identify the set point for the desired heading.

2.5.6 Alarms, in accordance with the requirements of Pt 6, Ch 1,2.3, are to be provided for the following fault conditions:

(a) Control computer system fault.
(b) Automatic changeover to a standby control computer system, as applicable, *see* 4.1.8.

■ *Section 3* **Class notation DP(AM)**

3.1 Requirements

3.1.1 For assignment of **DP(AM)** notation, the applicable requirements of Section 2, together with 3.1.2 to 3.1.6, are to be complied with.

3.1.2 An automatic and a manual control system are to be provided and arranged to operate independently, so that failure in one system will not render the other system inoperative. Arrangements for manual control are to satisfy the requirements of Section 2 when the automatic system is inoperative.

3.1.3 At least two position reference systems suitable for the intended service conditions and incorporating different measurement techniques, are to be provided and arranged, so that a failure in one system will not render the other system inoperative. Special consideration will be given where the use of different techniques would not be practicable during DP operations.

3.1.4 At least two heading reference sensors and two wind sensors are to be provided and arranged, so that a failure of one sensor will not render the other sensor(s) inoperative.

3.1.5 In the event of a single failure of a position reference, heading reference, or wind sensor, the control systems are to continue operating on signals from the remaining sensors without manual intervention.

3.1.6 The area of operation is to be adjustable, but is not to exceed the specified limits based on a percentage of water depth, or as applicable, a defined absolute or relative surface movement. Arrangements are to be provided to fix and identify the set point for the area of operation.

■ *Section 4* **Class notation DP(AA)**

4.1 Requirements

4.1.1 For assignment of **DP(AA)** notation, the applicable requirements of Sections 2 and 3, together with 4.1.2 to 4.1.10 are to be complied with.

4.1.2 Power, control and thruster systems and other systems necessary for, or which could affect, the correct functioning of the DP system are to be provided and configured such that a fault in any active component or system will not result in a loss of position. This is to be verified by means of a FMEA, *see* 1.3.6. Such components may include, but are not restricted to, the following:

- Prime movers (e.g. auxiliary engines).
- Generators and their excitation equipment.
- Gearing.
- Pumps.
- Fans.
- Switchgear and control gear, including their assemblies.
- Thrusters.
- Valves (where power actuated).

Systems which are not part of the DP system but which, in the event of a fault, could affect the correct functioning of the DP system (for example, fire suppression systems, engine ventilation systems, shutdown systems, etc.) are to be included in the FMEA.

4.1.3 Cables, pipes and other components essential for correct functioning of the DP system are to be located and protected, where necessary, such that the risk of fire or mechanical damage is minimised.

4.1.4 The electrical generation and distribution arrangements are to be isolatable such that at least the minimum number of any duplicated, or otherwise replicated, items required to provide essential services would remain operational in the event of a single fault. Evidence to verify compliance with this requirement is to be submitted for consideration when required; for example, where it is intended to operate with the independent sections required by 2.3.12 connected together.

4.1.5 Where the independent switchboards or section boards required by 2.3.12 are to be connected together, this is to be via two multipole circuit-breakers connected in series. Where alternative arrangements are proposed, these may be accompanied by a technical justification showing compliance with 4.1.4.

4.1.6 For electrically driven thruster systems:

(a) a reduction in position keeping capability may be accepted, but this is not to result in a loss of position in the environmental conditions in which the DP system is intended to operate; and
(b) provision is to be made for the automatic starting, synchronising and load sharing of a non-running generator before the load reaches the alarm level required by 2.3.8.

4.1.7 Two automatic control systems are to be provided and arranged to operate independently, so that failure in one system will not render the other system inoperative.

4.1.8 Control systems are to be arranged such that, in the event of failure of the working control system, the standby system takes control automatically without manual intervention and without any adverse effect of the ship's station keeping performance.

4.1.9 At least three position reference systems incorporating at least two different measurement techniques are to be provided and arranged so that a failure in one system will not render the other systems inoperative.

4.1.10 At least three heading reference sensors are to be provided and arranged so that a failure of one sensor will not render the other sensors inoperative.

4.1.11 The DP system is to incorporate a computer based consequence analysis to determine whether the position of the vessel would remain within the limits set by the operator in the event of a worst case fault. An audible and visual alarm is to be initiated where the consequence analysis determines that the limits would be exceeded. Where applicable to the timescale for safely terminating operations, the consequence analysis is to allow for manual input of predicted environmental conditions.

Section 5
Class notation DP(AAA)

5.1 Requirements

5.1.1 For assignment of **DP(AAA)** notation, the applicable requirements of Sections 2, 3 and 4, together with 5.1.2 to 5.1.12 are to be complied with.

5.1.2 The DP system is to be arranged such that failure of any component or system necessary for the continuing correct functioning of the DP system, or the loss of any one compartment as a result of fire or flooding, will not result in a loss of position. This is to be verified by means of a FMEA. *See* 1.3.6.

5.1.3 Thruster units are to be installed in separate machinery compartments, separated by a watertight A–60 class division.

5.1.4 Generating sets, switchboards and associated equipment are to be located in at least two compartments separated by an A–60 class division, so that at least half of the equipment will be available following a fire or similar fault in one of the compartments. If the equipment is located below the operational waterline, the division is also to be watertight. There is to be provision to connect the switchboard sections together by means of circuit-breakers.

5.1.5 Duplicated cables and pipes for services essential for the correct functioning of the DP system are not to be routed through the same compartments. If this is not practicable, then they are to be carried in A–60 protected ducts. The termination arrangements are also to take due account of the degree of protection. Alternative arrangements will be considered.

5.1.6 Where duplicated cables and pipes for services essential for the correct functioning of the DP system are installed in adjacent compartments, A-60 rated fire protection is to be provided between the spaces. Details of alternative arrangements which demonstrate essential equipment located in an adjacent space will continue to operate satisfactorily and essential services will continue to be available in the event of a fire in the adjacent space may be submitted for consideration.

5.1.7 An additional/emergency automatic control unit is to be provided at an emergency control station, in a compartment separate from that for the main control station, and is to be arranged to operate independently from the working and standby control units required by 4.1.8.

5.1.8 Arrangements are to be provided such that, in the event of a failure of the working and standby control units, a smooth transfer of control to the emergency control unit may be effected from the emergency control station by manual means.

5.1.9 Arrangements are to be provided at the emergency control station so that changes in the resultant vectorial thrust output may be readily effected by a single operator action.

5.1.10 The control/indication unit of one of the position reference systems required by 4.1.9 is to be located at the emergency control station. A repeater control/indication unit from this system is to be located at the main control station.

5.1.11 One of the heading reference sensors required by 4.1.10 is to be located at the emergency control station.

5.1.12 One wind sensor is to directly supply the additional/emergency control unit.

5.1.13 The additional/emergency control unit is to be supplied from its own independent UPS, *see* 2.3.10.

Section 6
Performance Capability Rating (PCR)

6.1 Requirements

6.1.1 Where the **DP** notation is to be supplemented with a Performance Capability Rating (PCR) (*see* 1.2.2), the calculation will be carried out using the information specified in 1.3.7.

6.1.2 Two rating numerals are calculated:
(a) The first numeral represents the percentage of time that the ship can remain on station when subjected to a set of standard environmental conditions (North Sea fully developed) with all thrusters operating.
(b) The second numeral represents the percentage of time that the ship can remain on station when subjected to a set of standard environmental conditions (North Sea fully developed) with the most effective thruster being inoperative.

A typical rating might be (95), (70).

6.1.3 In calculating the PCR, the following parameters are considered:
(a) Thruster force vectors.
(b) Thruster/thruster, thruster/hull and thruster/current interactions.
(c) Sea current loads on the ship.
(d) Wind force on the ship.
(e) Wave drift force on the ship.

6.1.4 Where the ship has been subject to alteration or addition, which may affect the performance characteristics of the DP system, the PCR is to be recalculated.

Section 7
Testing

7.1 General

7.1.1 Control units are to be surveyed at the manufacturer's works and are to be tested in accordance with the approved test schedule to the Surveyor's satisfaction, *see* 1.3.5(g).

7.1.2 Before a new installation (or any existing installation, which has been subject to alteration or addition which may affect the performance characteristics of the system) is put into service, sea trials are to be carried out to the approved schedule and to the Surveyor's satisfaction, *see* 1.3.5(g).

7.1.3 The suitability of the dynamic positioning system is to be demonstrated during sea trials, observing the following:

(a) Response of the system to simulated failures of major items of control and mechanical equipment, including loss of electrical power, verifying the findings of the FMEA where required.

(b) Response of the system under a set of predetermined manoeuvres for changing:
   - (i) Location of area of operation.
   - (ii) Heading of the ship.

(c) Continuous operation of the system over a period of four to six hours.

7.1.4 Two copies of the dynamic positioning system sea trial test schedules, as required by 1.3.5(g), each signed by the Surveyor and Builder, are to be provided on completion of the survey. One copy is to be placed and retained on board the ship and the other submitted to LR.

7.1.5 Records and data regarding the performance capability of the dynamic positioning system are to be maintained on board the ship and are to be made available at the time of the Annual Survey, *see* Pt 1, Ch 3,2.2.23.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to ships equipped to handle, store and transport oil recovered from a spill in emergency situations.

1.1.2 For ships of less than 500 gross tons, also fishing vessels of 12 m length and over, but less than 45 m length, and ships not fitted with propelling machinery, the arrangements for fire protection and extinction are to comply with Section 6. Consideration will be given to the acceptance of the fire safety measures for oil recovery ships prescribed and approved by the Government of the Flag State.

1.1.3 For ships of 500 gross tons and over, also fishing vessels of 45 m length and over, it is the responsibility of the Government of the Flag State to give effect to the fire safety measures, *see* Pt 6, Ch 4,1.1. Where the Government of the Flag State has no National Requirements for oil recovery ships, Lloyd's Register (hereinafter referred to as 'LR') will apply the fire safety measures required by Section 6 for classification purposes.

1.1.4 Requirements additional to these Rules may be imposed by the National Authority with whom the ship is registered and/or by the Administration within whose territorial jurisdiction the ship is intended to operate.

1.2 Classification and class notations

1.2.1 A ship complying with the requirements of this Chapter will be eligible for the notation **Oil Recovery**.

1.2.2 A ship dedicated solely to oil recovery duties will be given the class notation **Oil Recovery Ship**. The scantlings will be specially considered on the basis of the requirements of Pt 4, Ch 9.

1.3 Surveys

1.3.1 The arrangements and equipment referred to in this Chapter are to be examined and tested on completion of the installation and, subsequently, annually.

1.4 Plans and supporting documentation

1.4.1 In addition to the supporting documentation required for classification as specified in other Parts of the Rules, details relevant to oil recovery operations are to be submitted.

1.4.2 Plans covering the following items are to be submitted for approval:

- Structural support in way of equipment.
- Structural arrangement of recovered oil tanks including access.
- Piping system arrangements for recovered oil including venting.
- Power supply, electrical protection and cabling for oil recovery equipment.
- Hazardous areas and spaces.
- Electrical equipment located in hazardous areas and spaces.
- Structural fire protection and extinguishing equipment.

1.4.3 The following supporting documents are to be submitted:

- General arrangement of recovery equipment, including portable items, handling facilities, access, ventilation details, arrangement of other openings to hazardous spaces and adjacent compartments, machinery exhaust outlet positions.
- Gas detection equipment specification.
- Operating Manual.

1.4.4 The following supporting calculations are to be submitted:

- Deck equipment support structure loadings.
- Schedule of loads on the electrical system for oil recovery operations.

■ *Section 2* Oil recovery

2.1 General

2.1.1 The ship is to be capable of performing the following functions at a safe distance from the source of oil spill:

(a) Removal of the oil from the surface of the sea.

(b) Handling, storage and transportation of the recovered oil.

2.2 Equipment and deck arrangement

2.2.1 The arrangements for collection, handling and transfer of recovered oil are to be such that the probability of oil spill on deck and overflow is minimised and the operation is to be performed as far away from the accommodation spaces as practicable.

2.2.2 In way of working areas, hand rails and gratings or other non-slip surfaces are to be provided.

2.2.3 Means are to be provided to keep deck spills away from the accommodation and service areas. This may be accomplished by provision of a permanent continuous coaming not less than 150 mm high.

2.2.4 At least two portable instruments are to be available on board for gas detection.

2.2.5 For engines used in oil recovery operations, *see* 4.4.

2.2.6 Masts and derricks, etc., are to comply with the appropriate Sections of Chapters 2 and 3 of LR's *Code for Lifting Appliances in a Marine Environment*.

■ *Section 3* Ship structure

3.1 Structural arrangement

3.1.1 The position of bulkheads is to comply with the requirements of Pt 3, Ch 3,4.

3.1.2 Any tanks not utilised during oil recovery operations are to be arranged so that recovered oil cannot be transferred to them inadvertently.

3.1.3 In tanks intended for recovered oil, internal obstructions are to be avoided as far as practicable to prevent the entrapment of foreign objects usually present in recovered oil. Adequate drainage openings are to be provided to ensure free flow of residues to assist in cleaning and gas freeing on completion of recovery operations.

3.1.4 Tanks used for the storage of recovered oil are to be located outside the accommodation and machinery spaces.

3.1.5 Except where permitted by 3.1.6 and 3.1.7, tanks intended for the storage of recovered oil are to be separated from accommodation and machinery spaces by cofferdams. Cofferdams are to be at least one frame spacing in length (600 mm minimum) and are to cover the whole area of the boundary under consideration.

3.1.6 A pump room, oil fuel bunker, water ballast tank or other closed space where oil recovery handling equipment is stored will be accepted in lieu of a cofferdam.

3.1.7 In the case of a ship not primarily intended for oil recovery operations, where cofferdams are impractical to arrange, tanks arranged adjacent to machinery spaces may be accepted for storage of recovered oil. Acceptance will be conditional upon the tank boundary bulkheads being readily accessible for inspection. The bulkheads are to be carried continuously through joining structure to the top of the tank, where full penetration welding is to be carried out. Such tanks will require to be pressure tested at every Periodical Survey, *see* Table 1.9.1, Ch 1, as applicable to oil tankers. Special consideration will be given to arrangements incorporating double bottom tanks in these locations.

3.1.8 All openings to tanks for recovered oil are to be located on the open deck. This includes sounding pipes, vent pipes, and hatches for the deployment of portable pumps and hoses. Suitable access hatches, not less than 600 mm x 600 mm, are to be arranged to facilitate tank cleaning and gas freeing. Dual access hatches, as widely separated as practicable, are to be provided for tanks of a cellular internal structure.

3.1.9 Where there is a risk of significant sloshing induced loads, additional strength calculations may be required, *see* Pt 3, Ch 3,5.4.

3.1.10 Where recovered oil temperatures are to be increased significantly above 65°C during transit voyages, attention is drawn to Pt 4, Ch 9,12 regarding thermal stress considerations.

3.2 Scantlings

3.2.1 The scantlings and arrangements are, in general, to be as required by Pt 4, Ch 1. If the ship is to perform the duties of a supply ship the requirements of Pt 4, Ch 4 are also to be complied with, as applicable.

■ *Section 4* Machinery arrangements

4.1 Piping arrangements

4.1.1 Piping arrangements for the recovered oil system are to be located outside machinery spaces and are to have no connections to such spaces.

4.1.2 When the ship is in oil recovery mode, means are to be provided to isolate the oil recovery system from any other system to which it may be connected.

4.1.3 Ventilation outlets from the recovered oil tanks are to have a minimum height of 2,4 m above deck and be fitted with flame screens. Temporary pipe sections may be used for this purpose. Outlets are to be located not less than 5 m measured horizontally from the nearest air intakes and openings to accommodation and enclosed spaces containing a source of ignition and from deck machinery and equipment which may constitute an ignition hazard.

4.1.4 Each recovered oil tank is to be fitted with suitable means of ascertaining the liquid level in the tank. Sounding pipes or other approved devices are acceptable for this purpose.

4.2 Pump room for recovered oil

4.2.1 Pump rooms are to be fitted with a permanent ventilation system of the mechanical extraction type.

4.2.2 The ventilation system is to be capable of being operated from outside the compartment being ventilated and a notice is to be fixed near the entrance stating that no person is to enter the space until the ventilation system has been in operation for a specified period, sufficient to achieve at least five air changes based on the gross volume of the space.

4.2.3 The ventilation system is to be capable of at least six air changes per hour, based on the gross volume of the space.

4.2.4 Protection screens of not more than 13 mm square mesh are to be fitted outside openings of ventilation ducts, and ventilation intakes are to be so arranged as to minimise the possibility of recycling hazardous vapours from any ventilation discharge opening. Vent exhausts are to be arranged to discharge to a safe place on the open deck and comply with the requirements of 4.2.5.

NOTE

If the pump room is designed to recover chemicals listed in Chapter 17 of the *International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, (IBC Code)* the vent exhausts are to be arranged to discharge upwards.

4.2.5 The vent exhausts from pump rooms are to discharge at least 3 m above deck, and from the nearest air intakes or openings to accommodation and enclosed working spaces, and from possible sources of ignition.

4.2.6 Ventilation fans to be constructed in accordance with Pt 5, Ch 15,1.8.

4.2.7 Pump rooms are to have no direct communication with machinery spaces.

4.2.8 Bilge drainage of the pump room is to be effected by pumps or bilge ejector suctions. For ships of less than 500 gross tons, the pump room bilge may be drained by a hand pump having a 50 mm bore suction.

4.3 Ventilation of machinery spaces

4.3.1 Where machinery spaces adjacent to recovered oil tanks are permitted by 3.1.7, the ventilation arrangements are to comply with 5.4.1(a) and (b).

4.4 Exhaust systems

4.4.1 The exhaust lines of diesel engines, boilers and equipment containing sources of ignition and the vents of diesel engine crank cases are to be led to a position outside any hazardous area as defined in 5.3. In addition, suitable spark arrestors are to be fitted.

4.5 Miscellaneous

4.5.1 Low sea suctions are to be provided to supply water for the machinery and all fire pumps.

4.5.2 Means are to be provided to enable heating coils in recovered oil tanks and adjacent tanks to be blanked off during recovery operations.

4.5.3 The heating medium supply and return lines are not to penetrate the recovered oil tank plating, other than at the top of the tank to reduce the possibility of the recovered oil entering the heating system in the event of a failure of the heating pipework within the tank.

4.5.4 If required to facilitate discharge operations, steam returns are to be led to an observation tank which is to be in a well-ventilated and well-lighted part of the machinery space remote from the boilers.

■ *Section 5* Electrical equipment

5.1 General

5.1.1 The electrical installation is to comply with the relevant requirements of Pt 6, Ch 2, with the specific exceptions of 14.1, 14.2, 14.5, 14.7, 14.8 and 14.10, which are replaced by 5.3 to 5.6 of this Chapter.

5.2 Systems of supply and distribution

5.2.1 Only the systems of generation and distribution, listed under Pt 6, Ch 2,5.1.2, are acceptable.

5.3 Hazardous zones and spaces

5.3.1 The following zones or spaces are regarded as hazardous during and on completion of oil recovery operations, until proven gas-safe:

(a) The interiors of tanks intended for the storage of recovered oil.

(b) The interiors of piping systems intended for the handling of recovered oil.

(c) Spaces separated by a single bulkhead, deck or other tank boundary, from the interior of a tank intended for recovered oil, or having a bulkhead immediately above or below and in line with a bulkhead of a tank intended for recovered oil, unless protected by a diagonal plate in accordance with Pt 4, Ch 9,1.2.7 or the arrangements comply with the requirements of 3.1.7.
(d) Spaces housing piping systems or other equipment containing or contaminated with recovered oil and having flanged joints or glands or other openings from which leakage of fluid may occur under normal operating conditions.
(e) Zones on open deck within a 3 m radius of the ventilation outlets, or inspection hatches permitted to be opened under normal operating conditions, of tanks intended for recovered oil.
(f) Zones on open deck within a 1,5 m radius of any sampling or sounding point of a tank intended for recovered oil.
(g) Zones on open deck within a 1,5 m radius of any flanged joints, glands or other parts of any equipment containing or contaminated with recovered oil from which leakage may occur under normal operating conditions.
(h) Zones on open deck within the confines of, and extending 1,5 m beyond, any bund or barrier intended to contain a spillage of recovered oil, up to a height of 1,5 m.
(j) Zones on open deck within a 1,5 m radius of any opening into a space described by (c) or (d).
(k) Zones on open deck over all tanks intended for recovered oil, where the tops of the tanks are exposed to the weather, to the full width of the ship plus 3 m fore and aft of the forwardmost and aftmost tank bulkhead, up to a height of 0,45 m above the deck or to the height of any bulwarks.
(l) Zones on open deck extending 1,5 m beyond those defined by 5.3.1(e) to (j).
(m) Any enclosed or semi-enclosed space having a direct opening into a hazardous zone or space identified above, unless the space is protected by pressurisation in accordance with 5.5.1 or 5.5.2, or the opening is a ventilation outlet arranged in compliance with 5.4.2.

5.4 Ventilation

5.4.1 The extent of any hazardous zone within an enclosed or semi-enclosed space may be limited to that defined for an equivalent situation on open deck, provided that the ventilation arrangements fulfil all the following conditions:
(a) Mechanical ventilation is provided, with the air intake and outlet located outside any hazardous area defined by 5.3.1, ensuring at least 12 air changes per hour, and leaving no region of stagnant air.
(b) Ventilation air flow is continuously monitored and so arranged that, in the event of failure of ventilation, an alarm is given at an attended station.

5.4.2 An enclosed or semi-enclosed space having a ventilation outlet situated in a hazardous zone, as defined under 5.3.1(k) or (l), may be regarded as non-hazardous if fulfilling all the following conditions:
(a) The space has mechanical ventilation with the air intake located outside any hazardous area defined by 5.3.1.
(b) The ventilation outlet is equipped with a self-closing flap or other suitable means of closure operating automatically on loss of ventilation airflow.
(c) The space contains no equipment of a type described in 5.3.1(d), or vent from or opening into any hazardous space or zone defined by 5.3.1, other than the ventilation outlet under consideration.
(d) The space is separated by at least two gastight bulkheads from the interior of any tank intended for recovered oil.

5.5 Pressurisation

5.5.1 A space having access to a hazardous space or zone, as defined under 5.3.1(c) to (j), may be regarded as non-hazardous if it fulfils all of the following conditions:
(a) Access is by means of an air-lock, having gastight doors, the inner of which, as a minimum, is self-closing without any hold-back arrangement.
(b) It is maintained at an overpressure of at least 50 Pa relative to the external hazardous area by ventilation from a non-hazardous area.
(c) The relative air pressure within the space is continuously monitored and so arranged that, in the event of loss of overpressure, an alarm is given at an attended station.
(d) It contains no piping system or equipment of a type described in 5.3.1(d), and no vent from or opening into any hazardous space or zone defined by 5.3.1, other than the access under consideration.
(e) It is separated by at least two gastight bulkheads from the interior of any tank intended for recovered oil.

5.5.2 A space having access to a hazardous zone, as defined under 5.3.1(k) or (l), may be regarded as non-hazardous if it fulfils all of the following conditions:
(a) Access is by means of a gastight self-closing door without any hold back arrangement.
(b) It is maintained at an overpressure in accordance with 5.5.1(b).
(c) The air pressure within the space is monitored in accordance with 5.5.1(c).
(d) It contains no piping system or equipment of a type described in 5.3.1(d), and no vent from or opening into any hazardous space or zone defined by 5.3.1, other than the access under consideration.
(e) It is separated from the interior of any tank intended for recovered oil in accordance with 5.5.1(e).

5.5.3 A space having access to a hazardous space or zone, as defined under 5.3.1(c) to (j), and fulfilling the conditions given under 5.5.2(a) to (e) may be regarded, for the purposes of selection of electrical equipment, as equivalent to an open-deck hazardous area, such as defined under 5.3.1(k).

5.6 Selection of electrical equipment for installation in hazardous areas

5.6.1 The installation of electrical equipment in hazardous areas is to be minimised as far as is consistent with operational necessity and the provision of lighting, monitoring, alarm or control facilities enhancing the overall safety of the ship.

5.6.2 When electrical equipment is to be installed in hazardous areas, unless permitted otherwise by 5.6.3 or 5.6.4, it is to be of a 'safe type', as listed below, certified or approved by a competent authority for Group IIA, temperature class T3. The construction and type testing is to be in accordance with IEC 60079: *Electrical Equipment for Explosive Gas Atmospheres*, or an acceptable and relevant National Standard.

- Intrinsically safe Ex 'i'
- Increased safety Ex 'e'
- Flameproof Ex 'd'
- Pressurised enclosure Ex 'p'
- Powder filled Ex 'q'
- Encapsulated Ex 'm'

5.6.3 Consideration may additionally be given to the use of equipment of the following types:

(a) Equipment such as control panels, protected by purging and pressurisation and capable of being verified by inspection as meeting the requirements of IEC 60079-2.
(b) Simple non-energy-storing apparatus having negligible surface temperature rise in normal operation, such as limit switches, strain gauges, etc., incorporated in intrinsically-safe circuits.
(c) Submersible pumps, having at least two independent methods of shutting down automatically in the event of low liquid level.
(d) Radio aerials having robust construction, meeting the relevant requirements of IEC 60079-15. Additionally, in the case of transmitter aerials, it is to be shown, by detailed study or measurement, or by limiting the peak radiated power and field strength to 1 W and 30 V/m, respectively, that they present negligible risk of inducing incendive sparking in adjacent structures or equipment.
(e) Electrical apparatus having a special type of protection (Ex's'), certified or approved by a competent authority.
(f) Electrical apparatus having the type of protection Ex'n' (or Ex'N'), that, in normal operation, is not capable of igniting a surrounding explosive gas atmosphere, and in which a fault capable of causing ignition is not likely to occur.

5.6.4 Equipment not meeting the requirements of 5.6.5 to 5.6.14 may be installed in hazardous zones or spaces, or locations rendered non-hazardous by ventilation or pressurisation, if not required to be energised during oil recovery operations, and not essential for the safety of the ship or crew. Such equipment is to be controlled by multi-pole switches or circuit breakers situated outside any hazardous area. Provision is to be made for the complete isolation of these circuits and locking the means of control in the off position.

5.6.5 In tanks and piping systems defined by 5.3.1(a) and (b), only the following electrical equipment will be permitted:

(a) Intrinsically-safe apparatus of category 'ia'.
(b) Simple apparatus, as defined under 5.6.3(b), incorporated in an intrinsically-safe circuit of category 'ia'.
(c) Submersible pumps, as defined under 5.6.3(c).
(d) Ex's' apparatus, certified for use in Zone 0, as defined by IEC 60079-10.
(e) Cable required for the operation of the equipment installed.

5.6.6 In spaces adjacent to tanks, as defined by 5.3.1(c), with no mechanical ventilation, only the following electrical equipment will be permitted:

(a) That described in 5.6.5(a), (b), (d) and (e).
(b) Ex'd' lighting fittings.
(c) Ex'p' lighting fittings of either the air-driven type, or pressurised from an external source of protective gas and arranged to be de-energised automatically on loss of pressurisation.
(d) Gas detector heads having sinter-type flametrap protection, included within an intrinsically-safe circuit, all of which is to be certified as a system.
(e) Ex'd' alarm sounders, without internal sparking contacts.
(f) Cables for impressed current cathodic protection systems (for external hull protection only) installed in heavy gauge steel pipes with gastight joints up to the upper deck; the arrangements are to comply with Pt 3, Ch 2,3.5.3.
(g) Through runs of cables, installed in heavy gauge steel pipes with gastight joints.

The electrical equipment described in (b), (c) and (e) will be permitted only where personnel are required to have access to the space during oil recovery operations.

5.6.7 In spaces adjacent to tanks, as defined by 5.3.1(c) having mechanical ventilation, and in spaces and zones containing piping systems, equipment, etc., or close to vents, flanges, etc., and other zones as defined by 5.3.1(d) to (j), only the following electrical equipment will be permitted:

(a) That described in 5.6.6.
(b) Intrinsically-safe apparatus of category 'ib'.
(c) Simple apparatus, as defined under 5.6.3(b), incorporated in an intrinsically-safe circuit of category 'ib'.
(d) Other apparatus certified as Ex'e', Ex'd', Ex'q', Ex'm' or Ex's'.
(e) Pressurised equipment, certified Ex'p', or as described in 5.6.3(a), arranged to be de-energised automatically on loss of pressurisation.
(f) Through runs of cable in spaces and zones described in 5.3.1(d) to (j) only.

5.6.8 In zones defined by 5.3.1(k) and (l), only the following electrical equipment will be permitted:

(a) That described in 5.6.7.
(b) Pressurised equipment, certified Ex'p', or as described in 5.6.3(b), arranged to give an audible and visual alarm at a manned station in the event of loss of pressurisation.
(c) Equipment as described in 5.6.3(d) and (f).

5.6.9 Electrical installations in enclosed or semi-enclosed spaces, as described in 5.3.1(m), are to comply with the requirements for the space or zone into which the opening leads, unless ventilated in accordance with 5.4.1 or 5.4.2.

5.6.10 Electrical installations in enclosed or semi-enclosed spaces, ventilated as described in 5.4.1, are to comply with the requirements for hazardous zones, as described in5.3.1(e) to (l), within the radii or distances from adjacent sources of hazard or sources within the space specified by these paragraphs. Equipment within a radius of 3 m from any ventilation outlet of such a space is to be of a type described in 5.6.8. Equipment not of a type described in 5.6.7 is to be provided with a means of disconnection capable of being controlled from an attended station in the event of ventilation failure. Where the means of disconnection is located within the space, then it is to be of a 'safe type'.

5.6.11 Electrical installations in machinery spaces adjacent to recovered oil tanks, where permitted by 3.1.7, are to comply with the requirements of 5.6.10, and the additional requirement that equipment within 0,45 m of the tank bulkhead or the bottom of the space is to be of a type described in 5.6.8.

5.6.12 In pressurised spaces defined by 5.5.1, electrical equipment not of a type described in 5.6.8 is to be automatically disconnected in the event of loss of overpressure. Other equipment is to be provided with a means of disconnection capable of being controlled from an attended station in the event of loss of overpressure. Where the means of disconnection is located within the space, it is to be of a 'safe type'. Emergency lighting, pressure monitoring equipment and any alarm sounders or lights are to be of types described in 5.6.6.

5.6.13 In pressurised spaces defined by 5.5.2, any equipment not of a type described in 5.6.8 is to be provided with a means of disconnection capable of being controlled from an attended station in the event of loss of overpressure.

5.6.14 In pressurised spaces defined by 5.5.3, only electrical equipment as described in 5.6.8 may be permitted. Any equipment that is not of a type described in 5.6.7 is to be provided with a means of disconnection capable of being controlled from an attended station in the event of loss of overpressure. Emergency lighting, pressure monitoring equipment and any alarm sounders or lights are to be of types described in 5.6.6.

■ *Section 6* Fire protection and extinction

6.1 Structural fire protection

6.1.1 Exterior boundaries of superstructures and deckhouses enclosing accommodation and service spaces, including any overhanging decks which support such accommodation and service spaces, are to be insulated to 'A-60' standard for all parts which face deck areas where there are arrangements for collection, handling and transfer of recovered oil and for a distance 3 m aft or forward thereof.

6.1.2 Windows and side scuttles in the exterior boundaries, referred to in 6.1.1, are to be provided with permanently installed inside covers of steel. Aluminium alloy components are not to be used in the construction of the windows and side scuttles.

6.1.3 As an alternative to compliance with 6.1.1 and 6.1.2, a fixed water spraying system may be accepted. The system is to be capable of delivering water at a rate of 10 litres/m^2/min. on all boundaries, windows and side scuttles, that would otherwise be required to comply with 6.1.1 and 6.1.2.

6.2 Fire-extinguishing arrangements

6.2.1 Deck areas, where there are arrangements for the collection, handling and transfer of recovered oil, are to be provided with the following fire-extinguishing equipment:

(a) Two dry powder fire-extinguishers, each at least 50 kg capacity.
(b) At least one portable low expansion foam applicator.

6.2.2 The fire-extinguishers are to be located near the working deck identified in 6.2.1 and are to be fitted with discharge hoses.

6.2.3 The foam installation is to be capable of applying foam to any part of the working deck. The capacity of any applicator is to be not less than 400 litres/min. of foam solution and the applicator throw in still air conditions is to be not less than 15 m. Sufficient foam concentrate is to be provided for at least 0,4 litres/m^2 of the working deck area with a minimum quantity of 200 litres.

6.3 Fireman's outfits

6.3.1 At least two fireman's outfits, additional to those required by Pt 6, Ch 4,12 or SOLAS Reg II-2/A, 17.3 as applicable, are to be provided.

■ *Section 7*
Operating Manual

7.1 General

7.1.1 Information regarding the safe use of the ship with respect to the oil recovery and subsequent operations is to be prepared.

7.1.2 The Operating Manual is, in general, to contain information regarding procedures for:

(a) establishing and maintaining a safe atmosphere in any space(s) liable to become hazardous during oil recovery and subsequent operations;
(b) isolation, where necessary, of electrical equipment in zones or spaces considered hazardous during oil recovery and subsequent operations, and in spaces described in 7.1.2(a) prior to carrying out, or on failure of, the measures required to establish and maintain a safe atmosphere;
(c) fire-fighting;
(d) gas measurements;
(e) recovery and storage of oil;
(f) ballasting;
(g) transfer of recovered oil;
(h) tank cleaning;
(j) gas freeing; and
(k) contacts in the event of an emergency.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to tankers equipped with bow/stern loading arrangements to facilitate the transfer of cargo oil from offshore loading terminals, such as loading platforms, loading buoys, FPSOs and FSUs, and are additional to those applicable in other Parts of the Rules. These requirements also apply to submerged turret loading systems where applicable.

1.1.2 Requirements additional to these Rules may be imposed by the National Authority with whom the ship is registered and/or by the Administration within whose territorial jurisdiction the ship is intended to operate.

1.1.3 The materials used are to be suitable for the intended service conditions.

1.2 Class notations

1.2.1 Ships complying with the requirements of this Chapter will be eligible to have one of the following special features notations included in the class notation:
(a) Ships fitted with a bow loading system, **BLS**.
(b) Ships fitted with a stern loading system, **SLS**.
(c) Ships fitted with submerged turret loading systems, **TLS**.

1.3 Surveys

1.3.1 The survey of these items is to be arranged to coincide with hull and machinery surveys, *see* Pt 1, Ch 3.

1.4 Submission of plans and documentation

1.4.1 In addition to the plans and information required by other relevant Sections of the Rules, the plans and information detailed below are to be submitted:

(a) **Bow/stern loading**:
Detail drawing(s) showing:
- Cargo loading equipment.
- Manifold position and pipeline connections.
- Mooring equipment layout, including design loads and supporting structure.
- Fire safety arrangements.
- Control station(s).

(b) **Systems and arrangements**:
General arrangement. Plans showing the general arrangement of all areas where the piping systems are located, together with ventilation arrangements and details of openings for any enclosed spaces at the fore and/or aft part of the ship.
Diagrammatic arrangement. Plans indicating all piping systems arrangements associated with loading systems between cargo tank area and manifold. The plans are to include details of means of isolation, manifold arrangement, means of draining, inerting, cleaning and gas freeing of the cargo piping. Also details of manifold drip tray arrangements with means of drainage, together with any stripping line arrangements, are to be submitted. If the ship is to be installed with a vapour emission control system, plans showing details of piping arrangements are also to be submitted.
Piping system specification. Piping design information which includes the materials specifications, design pressure, maximum allowable transfer rate, corrosion allowance, and design ambient weather conditions. Also the design forces and moments for which the presentation manifold, together with the terminal flange and associated supporting arrangements, have been designed are to be submitted.
Operating Manuals. Operating Manuals are to be submitted for approval and provided on board. The Manuals are to include the following information:
- Particulars of piping arrangements and control systems.
- Operating criteria.
- Procedures for connecting/disconnecting the cargo hose, isolation arrangements, inerting, cleaning, gas freeing of the pipe line and drainage of the drip tray.
- Procedures to be followed during cargo handling operations. These are to include guidance on procedures to be followed in the event of sudden closure of the terminal valve.
- Detailed communication sequence concerning pre-mooring, mooring, pre-loading, loading and tanker departure phases.

Where the ship is fitted with dynamic positioning and/or a positional mooring system(s), the information required by Ch 4,1.3.7 and Ch 8,1.5.6 is also to be submitted as applicable.

(c) **Submerged turret loading**:
Detail drawing(s) showing:
- Arrangement of turret room, including receiving structure, locking mechanism and traction winch equipment with associated supporting structure and design loadings.
- Turret hatch and operating equipment, including hydraulic power pack and control systems, and cargo loading equipment.
- Turret room fire safety arrangements.

- Turret room electrical installations.
- Piping arrangements for all systems associated with the turret loading.

Section 2 Arrangements

2.1 Mooring arrangements

2.1.1 The ship is to be provided with sufficient mooring arrangements, which may be combined with the ship's manoeuvring system, to ensure adequate alignment and security during bow, stern or submerged turret loading operations.

2.1.2 The mooring/positioning system is to be arranged to prevent mooring forces being transmitted to the loading line connector.

2.1.3 Suitable single point mooring arrangements are indicated in Pt 3, Ch 13,9.

2.1.4 Particular attention is to be given to operational requirements and conditions in the design and mounting of securing devices and fittings. Seatings for equipment are to be designed to avoid the formation of pockets or recesses which may lead to excessive corrosion in service.

2.2 Materials for mooring fittings

2.2.1 Where mooring fittings are used as part of a positional mooring system, they are to comply with the requirements of Chapter 8.

2.3 Strength of mooring fittings

2.3.1 The strength of the mooring arrangements associated with the bow/stern loading system is to be considered on the basis of Pt 3, Ch 13,9, and Chapter 8 as applicable.

2.4 Enclosed spaces adjacent to manifold connection

2.4.1 In addition to the arrangements required by Section 4, the following are to be complied with:

(a) Spaces where an explosive gas atmosphere may be present are to be suitably ventilated prior to entry.
(b) Spaces required to be entered during normal operations are to be provided with permanent ventilation arrangements capable of being operated from outside the compartment.

2.4.2 The ventilation arrangements are to provide a minimum of eight air changes per hour, *see* Pt 6, Ch 2,14.

Section 3 Positioning, monitoring and control arrangements

3.1 General

3.1.1 The requirements of this Section are additional to those given in Pt 6, Ch 1, and Chapter 4 and Chapter 8.

3.1.2 If the ship is fitted with a dynamic positioning system, it is at least to comply with the DP(AM) requirements, *see* Chapter 4.

3.2 Control station

3.2.1 A control station for offshore loading may be arranged within the bow area or on the navigation bridge. All operations concerning positioning of the ship and monitoring of mooring and loading parameters are to be capable of being performed from this station.

3.3 Instrumentation

3.3.1 Bow/stern mooring instrumentation is to monitor:

(a) Mooring line traction.
(b) Chain stopper.
(c) Data logger system for recording of mooring and load parameters.

3.3.2 The mooring system is to be provided with a tension meter capable of continuously indicating the tension during the bow loading operation. Consideration may be given to waiving this requirement for ships fitted with a dynamic positioning system.

3.3.3 Bow/stern/submerged turret loading instrumentation is to be provided as follows:

(a) Indicator for loading connector coupling position.
(b) Cargo valve position indicators.
(c) Cargo tank level indicators and high level alarm.
(d) A system for automatic transfer of signals from the control and safety system, to enable personnel on the offshore terminal to effect control of cargo transfer pump(s) and closing of valve(s) on the terminal.

3.4 Emergency disconnect arrangements for pipeline and mooring

3.4.1 In addition to any automatic disconnection systems, a manually operated backup emergency disconnection system is to be provided. This system is to make possible individual operation of the chain stopper and coupling by-pass locks located in the bow control station.

3.4.2 Where an emergency quick-release system is fitted for the mooring system, an equivalent arrangement is to be provided to release the cargo loading hose outboard of the ship.

3.5 Communication

3.5.1 Main and emergency means of communication are to be provided between the bow control station and the offshore loading terminal. The communication equipment is to be intrinsically-safe.

3.5.2 Continuous communication is to be maintained between the control station and the offshore terminal at all times.

■ *Section 4*
Fire protection, detection and extinction

4.1 General

4.1.1 The fire protection and extinction arrangements are to comply with the requirements of the *International Convention for the Safety of Life at Sea, 1974*, as amended, or as required by the National Authority.

4.1.2 When Lloyd's Register (hereinafter referred to as 'LR') is authorised to act on behalf of the National Authority in giving effect to the fire safety measures on non-convention tankers or the application of SOLAS for convention ships, LR will also apply the *Guidelines for bow and stern loading and unloading arrangements on oil tankers* as given in IMO MSC/Circ.474, dated 19 June 1987.

4.1.3 Tankers of less than 500 gross tons will be specially considered.

■ *Section 5*
Piping systems

5.1 Materials

5.1.1 All materials used in the piping systems are to be suitable for use with the intended cargoes and ambient weather conditions, and are to comply with the relevant requirements of Pt 5, Ch 12 and the applicable requirements of the *Rules for the Manufacture, Testing and Certification of Materials*.

5.2 Piping system design

5.2.1 All piping, valves and fittings are to be suitable for the design operating and environmental conditions.

5.2.2 The piping is to comply with the requirements for manufacture, testing and certification of Class II piping systems.

5.2.3 The pipelines and associated piping systems and equipment forward and/or aft of the cargo area are to have only full penetration butt welded joints, except at the loading station where valve connections may be flanged. The pipes are not to pass through enclosed spaces and are to be, as far as possible, self-draining.

5.2.4 Means of mechanical isolation are to be provided in the cargo area, where any pipes used for cargo handling are branched off from the cargo system. Such isolation is to be as near as possible to the boundary of the aftmost, in the case of stern loading, or forwardmost, in the case of bow loading, cargo tank bulkhead and within the cargo area.

5.2.5 A manually operated shut-off terminal valve is to be provided at the manifold. In addition, a blank flange, or equivalent arrangement, is to be provided at the bow and/or stern pipe line end connection.

5.2.6 The terminal pipe, valves and other fittings to which the cargo hose is directly connected are to be of steel or other approved ductile material. They are to be of robust construction, adequately supported and suitable for the stated design conditions. Attention is drawn to the *Recommendations for Oil Tanker Manifolds and Associated Equipment*, published by OCIMF.

5.2.7 Means of emptying, cleaning, inerting and gas-freeing the pipe lines used for cargo handling are to be provided. The venting arrangements are to be located in the cargo deck area. Isolation similar to that described in 5.2.4 is also to be provided.

5.2.8 A drip tray of adequate size, together with means of drainage, are to be provided at the manifold. Suitable spray shields are to be fitted in way of the terminal manifolds where leakage may occur at valves and pipe joints.

5.2.9 Zones on open deck within 3 m of loading manifolds or pipe joints, and within 3 m of the spillage drip tray, are to be regarded as hazardous with regard to machinery or other equipment which could constitute a possible source of ignition, *see also* Pt 6, Ch 2,14.5 and 14.10.

5.2.10 Air vent pipes to the tanks and enclosed spaces, and mechanical ventilation outlets are to be located as far as possible, but in no case less than 3 m, from the terminal manifold or the nearest barrier of the spillage drip tray, whichever is closer.

5.3 Piping system testing and non-destructive examination

5.3.1 Testing and non-destructive examination of the piping system is to comply with the relevant requirements for Class II piping.

Section 6
Trials and testing

6.1 General

6.1.1 The arrangements and equipment referred to in this Chapter are to be examined and tested on completion of the installation, including calibration of coupling equipment.

6.1.2 Examination and testing is to include witnessing of the initial hook-up trials and the implementation of operational procedures for the range of actions covered by the Operating Manual.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to ships using coal as a primary source of heat for the generation of steam for main and essential auxiliary services.

1.1.2 The relevant requirements of the Rules and those of the National Authority with whom the ship is registered, together with any special requirements of the Administration within whose territorial jurisdiction the ship is intended to operate, are to be complied with. Attention is drawn to the statutory requirements concerning intact and damaged stability of the ship.

1.1.3 For the purpose of these requirements, it is assumed that no manual handling of coal for the transportation from bunkers to boiler, or for actual firing of the boiler, will be employed. The emphasis has been placed on the presumption that the boiler firing will be by some form of moving grate. Special consideration will be given to other forms of firing, such as pulverised fuel, slurries of coal-oil-water mixtures or fluidised bed firing, if submitted.

1.1.4 For single main boiler installation, *see* Pt 5, Ch 3,5.3.

1.2 Submission of plans

1.2.1 The plans and information required by 1.2.2 to 1.2.4 are to be submitted in triplicate for consideration.

1.2.2 General arrangement plans and specification of the storing, handling and burning equipment and ash handling plant.

1.2.3 Structural plans showing details and arrangements in way of coal bunkers, and support arrangements for coal handling and ash disposal plants.

1.2.4 A general arrangement plan showing details of construction, fire protection and extinction for coal bunkers and coal handling systems, supplemented as necessary, by detailed plans and calculations for fire-extinguishing, explosion suppression, temperature monitoring and carbon monoxide detection systems.

1.3 Surveys

1.3.1 Coal bunkering, coal handling, burning and ash disposal plants are to be built, installed, and tested under operating conditions to the Surveyors' satisfaction and subsequently at each Boiler Survey. Fire-extinguishing, explosion suppression, temperature monitoring and carbon monoxide detection systems are to be installed and tested to the Surveyors' satisfaction and subsequently examined annually as required by Pt 1, Ch 3,2.2.

1.4 Additional bilge drainage

1.4.1 It should be noted that, under the provision of SOLAS 1974, additional bilge drainage is required for passenger ships burning coal, as detailed in 1.4.2 and 1.4.3.

1.4.2 In passenger ships there shall be provided in the boiler room, in addition to the other suctions required by the Rules, a flexible suction hose of suitable diameter and sufficient length capable of being connected to the suction side of an independent power pump.

1.4.3 In passenger ships where there is no watertight bulkhead between the engine and the boiler spaces, a direct discharge overboard or, alternatively, a by-pass shall be fitted from any circulating pump discharge used for emergency bilge pumping duties.

■ *Section 2* Coal storage, handling, ash collection and disposal arrangements

2.1 Coal storage

2.1.1 The arrangements for coal bunkers, including hatchways, ventilation, monitoring and their design characteristics regarding intact and damaged stability are to comply with the requirements detailed in Sections 4 and 7, as applicable.

2.1.2 Coal is to be stored in not less than two bunkers. Vessels on restricted routes having a voyage time less than the capacity of the daily service hoppers, or where the boiler has the alternative means of firing, or where alternative means of propulsion are fitted, may be provided with only one bunker.

2.1.3 The clearance spaces between the boilers, other heated surfaces and the coal bunkers are to be adequate for the free circulation of air necessary to avoid transmission of heat to the coal.

2.1.4 A daily service storage hopper is to be provided for each coal-fired boiler.

2.1.5 Coal bunkers and daily service storage hoppers are to be designed to avoid dead spots and areas where coal can accumulate and impede the normal flow or can provide the conditions to promote spontaneous combustion.

2.1.6 Bunker and daily service storage hopper outlet gravity-fed discharges are to be provided with shut-off devices. Stopping the transfer device will be acceptable in lieu where a bunker delivers to transfer arrangements and stopping the transfer device effectively prevents flow from the bunker, *see* 2.2.4.

2.1.7 Shut-off devices on the coal bunker and daily service storage hopper outlets are to be capable of being operated locally and also from an accessible position outside the compartment in which they are situated.

2.1.8 The arrangements for loading coal into bunkers or during transfer into daily service storage hoppers should, in general, avoid the tendency of the coal to segregate. For this purpose, multiple loading points should be used if necessary.

2.2 Coal handling

2.2.1 Each daily service storage hopper is to be provided with a separate system for transferring coal from the bunker(s). In the case of a single boiler installation, more than one transfer system from the bunker(s) to the daily service storage hopper are to be provided, unless alternative means of firing the boiler is available.

2.2.2 Adequate access facilities are to be provided in the coal feeder systems to permit maintenance and removal of blockages.

2.2.3 Where coal screens or crushers are necessary for the efficient operation of the coal burning equipment, they are to be provided in each boiler coal feed arrangement.

2.2.4 The coal handling plant is to be capable of being stopped locally and from an accessible position outside the compartment in which it is situated, *see* 2.1.6.

2.2.5 The use of milling systems for the production of pulverised fuel will be specially considered.

2.3 Ash collection and disposal arrangements

2.3.1 Each coal fired boiler is to be provided with a bottom ash and fly ash collecting and disposal arrangement.

2.3.2 Where both bottom ash and fly ash collecting and disposal arrangements are operated by either pneumatic or water systems, then these may be made common.

2.3.3 Two independent means of supplying the operating medium for ash collection and disposal systems are to be provided.

2.3.4 Heated ash storage and transfer systems are to be efficiently lagged to minimise risk of fire and to prevent damage by heat.

2.3.5 Where wet ash water transfer systems are used, consideration is to be given to the effects of corrosion and erosion on the collection, transfer and storage equipment.

2.3.6 Ash transfer systems employing water separation arrangements are to be such that water will drain naturally back to the de-watering bins or into a collection tank. Such drainage facilities should not, in general, be led directly to bilge wells.

2.3.7 Where a dry ash collection system is proposed, the arrangement of conveyors, pipes and chutes should avoid condensation due to excessive cooling to prevent solidification of the ash.

2.3.8 Adequate ash storage capacity, with access facilities to permit maintenance and removal of blockages, is to be provided for systems using boilers which have no alternative means of firing. Certain National Authorities or local Administrations prohibit the direct discharge of ash overboard.

■ *Section 3* Coal burning equipment

3.1 Operating conditions

3.1.1 The design and arrangements for coal burning equipment are to be such that it can be manually controlled from a suitable position local to the boiler fronts.

3.1.2 Burning arrangements for solid fuel firing:

(a) The arrangements should permit a sufficient level of control of coal feed to the grates or bed to avoid uneven firing conditions likely to cause damage to the grate or bed, due to excessive heat or coal build-up, under all operating conditions.

(b) In addition to the adequate supplies of air for efficient combustion, sufficient capacity and means of control of the combustion air supply below the grates or beds are to be provided to ensure cooling of the grate or bed under all conditions of coal or alternative means of firing.

(c) When the coal bed is not fully incandescent, i.e. during low steaming conditions when coal-fired beds are banked or reduced in output, sufficient purging sequences to sweep the furnace volumes are to be provided before any alternative means of firing is attempted.

3.1.3 Where it is proposed to provide means of firing the boiler simultaneously on coal and oil, details of the arrangements for furnace purging and ignition of oil burners are to be submitted and will be the subject of special consideration.

3.2 Forced and induced draught air fans

3.2.1 In boilers fitted with forced and induced draught fans, suitable bias is to be maintained to avoid gas leakage into the boiler room.

3.2.2 In the event of induced draught fan failure, the forced draught fan should be arranged to stop automatically. Alternative arrangements which will permit the forced draught fan to be controlled to reduce the supply of air may be considered.

3.3 Fuel characteristics and specification

3.3.1 In general, the coal burning equipment is to be designed to utilise the various grades of coal likely to be encountered.

3.4 Alternative means of firing

3.4.1 Where it is proposed to use an alternative means of firing, such as oil or coal/oil slurry mixtures, the arrangements are to be in accordance with the requirements for oil burning, *see* Pt 5, Ch 14.

3.4.2 Particular attention is drawn to the requirements concerning arrangements for securely locking up-take dampers in the fully open position when burning oil fuel.

3.4.3 Where it is proposed to use oil fuel burners for lighting up coal fires, details are to be submitted of the pre-purging sequences of the boiler before lighting-up burners are introduced into the furnace.

3.4.4 Where it is proposed to employ lighting-up burners using diesel oil or similar marine distillate fuels, they are to be provided with their own combustion air supply.

3.4.5 Where it is proposed to use steam purging or steam atomising oil burners with coal-fired boilers, particular attention is to be given to furnace purging arrangements. Details of the purging sequences are to be submitted.

3.4.6 The arrangements for purging the oil burners are to be such that the minimum practicable volume of oil will be introduced into the boiler furnace.

■ *Section 4* Ship structure

4.1 General

4.1.1 The requirements of this Section are additional to those given in other parts of these Rules and in separate Rules for specific ship types.

4.1.2 Other than as permitted in 4.3.2, separation between coal bunkers and adjacent spaces is to be gastight. In oil or chemical tankers, coal bunkers are to be separated from cargo tanks by means of cofferdams.

4.1.3 Boiler room access doors are to comply with Pt 3, Ch 11,6.4, as applicable.

4.1.4 Coaling ports on the side shell are to comply with parts of Pt 3, Ch 11,8 as applicable.

4.1.5 No side scuttles are to be fitted in spaces appropriated exclusively for the carriage of coal.

4.1.6 All openings from coal bunkers are to be located clear of the defined hazardous area for the particular ship type.

4.2 Coal bunker hatchways

4.2.1 Coal bunker hatchways are to be provided with gasketed steel covers and coamings, complying with Pt 3, Ch 11, as applicable.

4.2.2 Coal bunker hatchways are to be located clear of the defined hazardous area for the particular ship type.

4.3 Coal bunker bulkheads

4.3.1 The scantlings of main coal bunker boundary bulkheads which are counted towards the number of bulkheads required by Pt 3, Ch 3,4, or which form the boundary of deep tanks, are to satisfy the requirements of Pt 4, Ch 1,9. Other boundaries are to satisfy the requirements of Pt 4, Ch 1,9, but the load head may be taken to the top of the bunker. The scantlings of cofferdam bulkheads not forming the boundaries of a cargo tank in oil or chemical tankers are to satisfy the requirements of Pt 4, Ch 9,7. In all cases when flooding is envisaged as a means of fire-extinction, the moduli of stiffening members on bunker bulkhead boundaries are to be increased by 25 per cent.

4.3.2 Where the coal bunker is situated immediately forward of the engine room, the aft coal bunker bulkhead may be non-watertight. The scantlings for this bulkhead are to be as required for watertight bulkheads (Pt 4, Ch 1,9) but the load head may be taken to the top of the tank. With this arrangement, the forward end of the coal bunker may, if appropriate, be regarded as the engine room forward bulkhead.

4.3.3 The thickness of the plating in way of the bulkhead knuckles in the region of the hoppers and the plating of the hopper apexes is to be increased by 1,5 mm over that derived from 4.3.1 and 4.3.2. However, the minimum thickness of the lowest strake in the coal hopper is to be not less than 9 mm. Where solid stainless steel is employed, the plate thickness may be reduced by 10 per cent or 1 mm, whichever is the lesser.

4.3.4 Non-watertight coal bunker bulkhead scantlings are to be as required by Table 1.4.8 in Pt 4, Ch 1, but the thickness of the lowest strake is to be not less than 9 mm.

4.3.5 The scantlings of the boundaries of compartments intended for the storage of ash in liquid or slurry form will be specially considered.

4.3.6 Watertight doors may be fitted in watertight bulkheads between permanent and reserve bunkers, and may be of the sliding, hinged or equivalent type. They are to be accessible at all times, *see also* Pt 3, Ch 11,9.

4.3.7 Arrangements are to be made by means of screens or otherwise to prevent the coal from interfering with the closing of watertight doors.

4.4 Longitudinal strength

4.4.1 For the purpose of longitudinal strength, the requirements for the relevant ship types are to be applied.

4.4.2 The calculation of still-water shear forces and bending moments are to cover both departure and arrival conditions, and any special mid-voyage conditions caused by variation in coal bunkering and ballast distribution. Details of typical coal stowage rates are to be submitted, as well as trim and stability data for these conditions.

4.4.3 Where local reduction of double bottom depth is proposed to accommodate coal handling equipment, the strength of the double bottom and scarfing arrangements will require special consideration. Adequate scarfing of longitudinal material in way of double bottom and hopper tanks should be arranged.

4.5 Ventilation

4.5.1 Ventilators serving coal bunkers or boiler rooms are to comply with Pt 3, Ch 12,2 as applicable. In addition, the atmosphere in the bunkers is to be sampled by means of fixed or portable monitors as follows:

(a) prior to entering the space – for oxygen deficiency,
(b) prior to opening the hatchways – for accumulation of flammable gases.

4.5.2 Ventilator exits from main coal bunkers and coal processing spaces are to discharge clear of the defined hazardous area for the particular ship type and not less than 3 m from the nearest intake or opening to accommodation and enclosed working spaces, and from possible source of ignition.

■ *Section 5*
Electrical equipment

5.1 General

5.1.1 All electrical equipment should be situated in positions where it is not exposed to concentration of coal dust. Where this is not practicable, the enclosure of the equipment should be designed and installed such that:

(a) Dust cannot enter the interior of the enclosure. An ingress protection rating of at least I.P. 55 in accordance with IEC 60529, if not of a safe-type, is considered to be acceptable.
(b) Dust will not collect on the surface of the enclosure to such an extent that proper cooling is prevented, thus causing a dangerous rise in temperature.
(c) The maximum surface temperature of the enclosure is not capable of igniting the dust, and should be limited to 165°C for equipment not subjected to overloading and 120°C for equipment such as motors, that may be overloaded.

5.2 Arrangements in coal bunkers

5.2.1 Electrical equipment located within the coal bunkers is to be of a safe-type certified for Group II A atmospheres and temperatures Class T1 in accordance with IEC 60079, *Electrical Apparatus for Explosive Atmospheres*, or an equivalent National Standard.

5.2.2 The switches and protective devices for such equipment are to interrupt all lines or phases and are to be located outside the coal bunker spaces. Provision is to be made for the complete isolation of these circuits and locking the means of control in the off position.

■ *Section 6*
Control engineering systems

6.1 General

6.1.1 The requirements of Pt 6, Ch 1 are applicable. The additional requirements for boilers which are coal grate-fired and under normal operation are remotely controlled or are automatic in operation, are given in Table 7.6.1.

6.1.2 In general, ships complying with the relevant requirements of Pt 6, Ch 1,4 or Ch 1,5 will be eligible for the notations **UMS** (unattended machinery space) or **CCS** (centralised control station) respectively.

Table 7.6.1 Coal burning: Alarms and safeguards

Item	Alarm	Note
Drum water level	Low	Combustion air; coal spreaders and/or any alternative fuel supply to be shut-off automatically
Daily service hopper level	High/Low	—
Coal feed plant	Failure	—
Primary combustion air system	Failure	Coal spreaders to be stopped automatically
Secondary combustion air system	Failure	—
Coal supply controller (if separate from spreader)	Failure	Per controller
Spreader drive	Failure/ Overload	Per drive. *See also* primary combustion air system failure
Grate drive	Failure/ Overload	Per drive
Localised overheating of the grate	Excessive	—
Induced draught fan	Failure	Coal spreaders to be stopped automatically, *see also* 3.2.2
Ash disposal system	Failure	—

NOTE
Interlocks are to be provided to prevent the burning of oil fuel, unless dampers in the gas passages of uptakes have been securely locked in the fully-open position, *see also* 3.4.2.

■ *Section 7*
Fire protection and extinction

7.1 Fire protection

7.1.1 In general, the coal bunkers are to be separated from adjacent spaces by 'AO' divisions, but where such spaces are intended to contain highly flammable substances, such as the cargo tanks of an oil tanker, they are to be separated from the coal bunkers by a cofferdam or equivalent space.

7.1.2 The spaces above the coal in the coal bunkers and coal processing spaces are to be adequately ventilated to prevent the accumulation of flammable gases. The ventilators are to be provided with means of closure which are readily accessible at all times. Where mechanical ventilation is provided, means are to be provided for stopping the fans from a position which will be readily accessible at all times.

7.2 Fire-extinction

7.2.1 A fixed fire-extinguishing system should be provided in the coal bunkers. This system should discharge CO_2, but alternative arrangements such as water flooding will be considered, *see also* 4.3.

7.2.2 Where, due to operating conditions, it is considered likely that coal dust in significant quantities will be present in the coal crushing and conveying system, an explosion suppression system is to be provided in the coal crushing and conveying system. Activation of the explosion suppression system is to operate an audible and visual alarm.

7.2.3 A fixed fire-extinguishing system should be provided in the ready-use coal hopper and this should be extended to the boiler room, if there is any danger of the spread of fire to that space. The system should depend on $C0_2$, but alternative extinguishing media will be considered. Where it can be shown that the residence time, of the coal in the hopper, is of sufficiently short duration that a fire in the hopper is unlikely to be sustained, consideration will be given to dispensing with this requirement.

Section

Section 1 General

1.1 Application

1.1.1 The requirements of this Chapter apply to Lloyd's Register (hereinafter referred to as 'LR') classed ships with positional mooring systems or thruster-assisted positional mooring systems and are additional to those applicable in other Parts of the Rules. The Rules are not intended to apply to vessels which have station-keeping capabilities, but which are not required to remain on station in adverse weather conditions. This normally precludes the Rules being applicable to small ships.

1.1.2 Compliance with this Chapter is not mandatory, but ships provided with a positional mooring system or thruster-assisted positional mooring system which do comply will be eligible for an appropriate class notation which will be recorded in the *Register Book* at the specific request of an Owner.

1.1.3 The mooring system will be considered for classification with LR on the basis of operating constraints and procedures specified by the Owner and recorded in the Operations Manual.

1.1.4 Requirements additional to these Rules may be imposed by the National Authority with whom the ship is registered and/or by the administration within whose territorial jurisdiction it is intended to operate.

1.2 Classification notations

1.2.1 Ships provided with a positional mooring system which complies with the requirements of this Chapter will be eligible to have included in the class notation one of the following special features notations:

(a) For ships fitted with a positional mooring system:
PM (Positional mooring system), or
PMC (Positional mooring system for mooring in close proximity to other ships or installations. This notation will apply in particular to any ship operating in conjunction with a fixed installation, e.g. crane barge, accommodation unit, maintenance vessel, etc.)

(b) For ships fitted with a thruster-assisted positional mooring system:
PM T1 [or T2 or T3]
or
PMC T1 [or T2 or T3]
The numeral in the circled supplementary notation, T1, etc., defines the thruster allowance which may be permitted in the design of the positional mooring system, and is determined by the capacity/redundancy of the thrust/machinery installation, *see* Table 8.3.2.

1.2.2 Additional descriptive notes may be given and entered in column 6 of the *Register Book* indicating the type of positional mooring system, reference system, control system, limiting environmental criteria, etc.

1.3 Surveys

1.3.1 The positional mooring and thruster-assisted positional mooring systems and their associated equipment are to be examined and tested during construction and under working conditions on completion of the installation. The Periodical Survey of these items is to be arranged to coincide with Hull and Machinery Surveys as required by other Parts of these Rules.

1.4 Definitions

1.4.1 Positional mooring is a method of station keeping by means of multiple anchor lines laid out in catenary array. Each positional mooring system is to consist of the following:
(a) Anchors or anchor piles.
(b) Anchor lines.
(c) Anchor line fittings (shackles, connecting links, wire rope terminations, quick release devices, etc.).
(d) Fairleads.
(e) Winches or windlasses.
(f) Chain or wire rope stoppers.
Where applicable, the structural or mechanical connection of these items to the ship is also considered to be part of the positional mooring system.

1.4.2 'Thruster-assisted Mooring' is the use of thrusters and main propulsion, if so designed, to supplement the ship's anchoring system.

1.5 Plans and data submission

1.5.1 The information and plans specified in 1.5.2 to 1.5.5 are to be submitted in triplicate. One copy of the Operations Manual referred to in 1.5.6 is to be forwarded for information.

1.5.2 Plans and data dealing with positional mooring arrangements and the associated equipment are to be submitted, including the following:

(a) Mooring arrangements with details of mooring patterns, anchor lines and fittings, etc.
(b) Mooring equipment with details of anchors, fairleads and cable stoppers.
(c) Winches or windlasses with details of gearing shafting, brake systems, ratchet and pawl, drum/cable lifter and frame.

1.5.3 For thruster-assisted positional mooring systems, plans of the following, together with particulars of ratings, in accordance with the relevant Parts of these Rules are to be submitted for the following:

(a) Prime movers, gearing, shafting, propellers and thrust units, *see also* Pt 5, Ch 8.
(b) Machinery piping systems.
(c) Electrical installations.

In addition, details of proposals for the redundancy provided in machinery, electrical installations and control systems are to be submitted. These proposals are to take account of the possible loss of performance capability should a component fail. Where a common power source is utilised for thrusters, details of the total maximum load required for thruster-assist are to be submitted.

1.5.4 Plans of control, alarm and safety systems, including the following, are to be submitted:

(a) Functional block diagrams of the control system(s).
(b) Functional block diagrams of the position reference systems and the environmental sensors.
(c) Details of the electrical supply to the control system(s), the position reference system(s) and the environmental sensors.
(d) Details of the monitoring functions of the controllers, sensors and reference system, together with a description of the monitoring functions.
(e) List of equipment with identification of the manufacturer, type and model.
(f) Details of the overall alarm system linking the centralised control station, subsidiary control stations, relevant machinery spaces and operating areas.
(g) Details of the control stations, e.g. control panels and consoles, including the location of the control stations.
(h) Test schedules which are to include the methods of testing and the test facilities provided.

1.5.5 The following supporting plans, data, calculations or documents are to be submitted:

(a) General arrangement showing plan views, side elevations and sections of the ship.
(b) Design criteria showing operating and survival environment, water depth range and required station keeping limits.
(c) Environmental forces on ship showing wind, current and wave drift. These forces are to be verified by direct calculation, model test reports, or full-scale data, etc.
(d) Ship motions showing first order wave motions, surge, sway and yaw. Tank test data or equivalent to be provided.
(e) Mooring analysis, including computer printout where relevant.
(f) Strength calculations for anchors, fairleads, winches/windlasses, cable stoppers and special fittings.
(g) Thruster arrangements for thruster-assist systems, including powers, thrusts and interactions between thrusters, thruster and hull, thruster and current.

1.5.6 An Operations Manual for the system is to be placed on board the ship. This Manual is to contain all necessary information and instructions regarding positional mooring and, where relevant, thruster-assisted positional mooring. It would normally also contain descriptions of the following:

- Mooring systems.
- Laying the mooring system.
- Anchor pre-loading.
- Pre-tensioning anchor lines.
- Tension adjustment.
- Winch performance.
- Winch operation.
- Procedure in event of failure or emergency.
- Procedure for operating thrusters.
- Fault-finding procedures for thruster-assist system.

■ *Section 2*
Environmental criteria – Forces and motions

2.1 Limiting environmental criteria

2.1.1 Limiting criteria in the form of maximum operating and survival environmental conditions are to be specified by the Owner or Designer.

2.1.2 The limiting criteria are to be defined in terms of wind and current speeds, wave heights and periods, and water depth range.

2.1.3 As water depth will have a large influence on a ship's mooring capability, the limiting environmental criteria may be varied according to water depth.

2.1.4 **Maximum operating conditions** will be those in which the ship is able to carry out its primary operational activities, while anchor line tensions remain within designated operating limits. *See* 3.2 for required factors of safety in operating conditions.

2.1.5 **Survival conditions** are to be based on an average recurrence period of not less than 50 years. The mooring system is to be such that maximum line tensions will be limited in these conditions to designated survival levels. *See* 3.2 for required factors of safety.

2.2 Design environmental criteria

2.2.1 **Wind**. The design wind speed for wind force determination can normally be taken as the one-hour mean value referenced to 10 m above sea level. Account is to be taken of the variation of wind speed with height above sea level. The wind velocity gradient can be calculated from the following:

$$V_H = V_{10}\left(\frac{H}{10}\right)^{0,125}$$

where

V_H = wind velocity at H height above sea level

V_{10} = 1 hour mean wind speed referenced to 10 m above sea level.

2.2.2 **Current**. The design current speed is to be taken as the sum of wind-induced and tidal current velocities. For calculation purposes, tidal current velocity can be assumed constant over water depth, and wind-induced current velocity can be taken to reduce linearly from its maximum value at the surface to zero at 50 m below sea level.

2.2.3 **Wave**. The significant wave height and period range is to be defined for each relevant design case.

2.3 Environmental forces

2.3.1 In determining environmental forces, it is to be assumed that the defined limiting environment of wind, waves and current will act concurrently. For fixed azimuth mooring systems, these forces are considered to act in the same direction.

2.3.2 Environmental loading on the ship (and the corresponding catenary system motions analysis to determine anchor loads and line tensions, etc.) will require to be investigated for a sufficient number of directions to establish the critical cases.

2.3.3 It is generally to be assumed that the maximum specified environmental conditions can come from any direction relative to the ship's heading. However, in cases where a ship is to be restricted to specific defined locations, consideration will be given to the acceptance of an environmental rosette (allowing the ship to be headed in the most favourable direction with respect to mooring loads).

2.3.4 Where quasi-static methods of analysis are adopted (*see* 3.1.2), at least the wind, current, and mean wave drift forces acting on the ship in the various relevant design conditions are to be calculated or determined. In addition, any significant yawing moments induced by these effects are to be taken into account when carrying out the mooring system motions analysis.

2.3.5 Environmental forces and moments can be determined by suitable methods of direct calculation or by model testing. In either case, account must be taken of all significant load generating structural elements or equipment. In the case of wind force and moment determination, all deck structures, fittings, cranes, towers, superstructures, etc., are to be considered, and for current force, account is to be taken of thrusters, nozzles, propellers, etc.

2.3.6 First order wave motions – the oscillatory motions of the ship – are to be determined. Surge and sway are the most relevant motions in terms of quasi-static mooring analysis, *see* 3.1.2 and Fig. 8.3.1.

2.3.7 The first order wave motions of the ship are to be determined from appropriate wave spectra, either by use of tank testing or by suitable direct calculation methods.

2.3.8 Account is to be taken of the effects of shallow water on the ship's first order wave motions.

■ *Section 3* Mooring system – Design and analysis

3.1 General

3.1.1 The positional mooring system is to be designed to meet the specified limiting environmental criteria (*see* 2.1), and any associated operational constraints (restricted offset of ship, etc.) as contained in the Operations Manual.

3.1.2 This Section in general, and the anchor line factors of safety in particular, relate principally to the quasi-static approach to mooring analysis. This method of analysis takes wind, current and wave drift forces to be steady effects which will displace the moored ship from its original equilibrium position to a new mean position where the mooring system will have developed sufficient restoring force to 'balance' the steady applied force. Wave-induced oscillatory vessel motions take place about this new mean position. In quasi-static analysis, maximum anchor line tensions are taken to occur at the extremity of vessel offset, *see also* Fig. 8.3.1.

3.1.3 Consideration will be given to the adoption of alternative methods of design for the mooring system, including the use of part-dynamic or full-dynamic analysis techniques. In such cases, factors of safety, etc., will be specially considered.

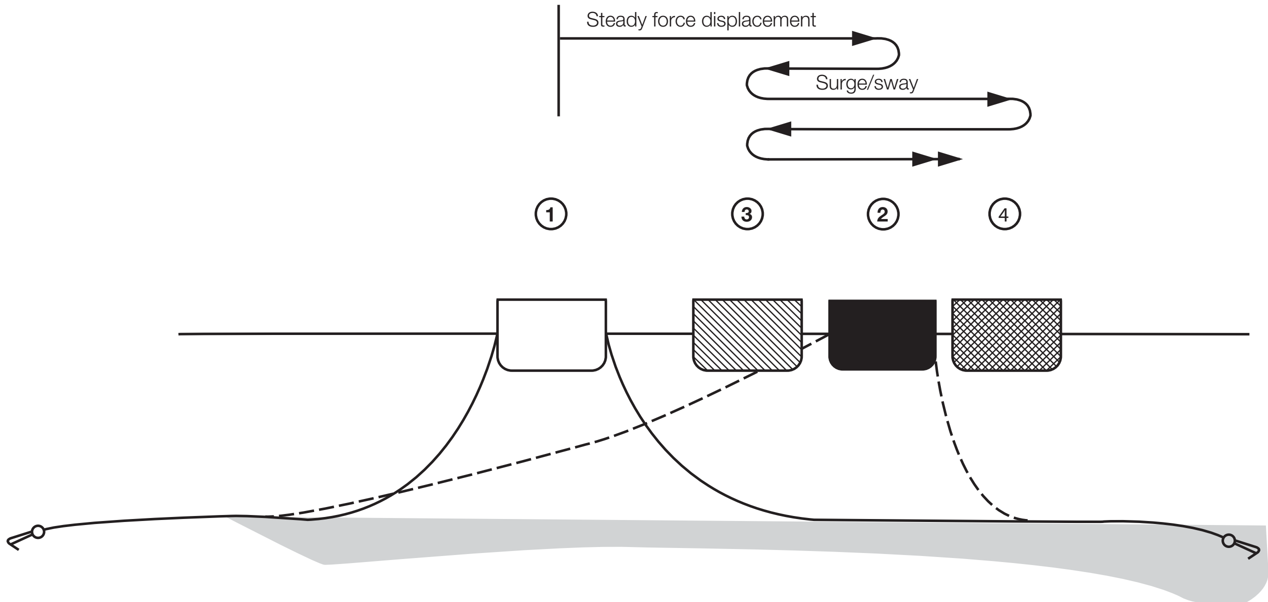
3.1.4 For ships which intend to utilise thruster assistance, as an aid to position-keeping or as a means of reducing anchor line tensions, the extent of thruster allowance which is permitted in calculations is given in Table 8.3.2.

3.1.5 Anchor line length is to be sufficient to avoid uplift forces occurring at the anchors in the worst damaged survival condition.

3.1.6 Account is to be taken in the mooring analysis of the elastic stretch of anchor lines.

3.2 Design cases and factors of safety

3.2.1 The design cases which require to be considered, and the associated minimum anchor line factors of safety are given in Table 8.3.1.



Position 1: Zero environmental force on ship. Anchor lines under pre-tension only.

Position 2: New mean position taken up by ship under the action of steady forces – wind, current and wave drift.

Positions 3 & 4: The inner and outer limits of vessel motion at wave frequency. Maximum quasi-static anchor line tension occurs at position 4.

NOTE

Mooring lines and anchor lines omitted in position 3 and position 4 for clarity.

Fig. 8.3.1 Quasi-static analysis

Table 8.3.1 Minimum anchor line factors of safety

Design case	Description	Factor of safety – Class notation: **PM**, **PM** T1 etc.	Factor of safety – Class notation: **PMC**, **PMC** T1 etc.
1	Operating – Intact The ship in an operating mode with its mooring system intact, subject to specified operating constraints (limiting environment and permissible offset of the ship).	2,7	3,0
2	Survival – Intact The ship in survival mode with mooring system intact, subject to maximum (survival) environmental conditions.	1,8	2,0
3	Operating – Damaged As Case 1, but with loss of restraint of any one anchor line, *see also* Note 3.	1,8	2,0
4	Survival – Damaged As Case 2, but with loss of restraint of any one anchor line.	1,25	2,0/1,4 (*See* Note 5)

NOTES
1. In the context of this Chapter, Cases 1 and 2 ('Intact' Cases) refer to the mooring system with all anchor lines intact. Cases 3 and 4 ('Damaged' Cases) refer to the mooring system with the loss of any one anchor line.
2. $\text{Anchor line factor of safety} = \dfrac{\text{Minimum rated break strength}}{\text{Maximum line tension}}$
3. The factors of safety given in Table 8.3.1 are to be based on maximum line tensions resulting from steady force offset of the ship, plus maximum first order wave motion. In Design Cases 3 and 4, the factors relate to the ship in its post-damage settled position, following the loss of restraint from an anchor line, (i.e. neglecting transient effects, but *see* Note 4).
4. In addition to the 'static' considerations in Design Cases 3 and 4 (*see* Note 3), account is also to be taken of transient vessel motions following anchor or line failure. The motion path taken by the vessel in moving to a new static equilibrium position is to be determined for each line breakage case to ensure that:
   (a) The ship maintains adequate clearance from any adjacent installation (applicable where **PMC** or **PMC** T1 etc. notation is to be assigned). A minimum dimensional clearance of 10 m will normally be required.
   (b) The ship remains within its required operational excursion limits.
   (c) Successive line failures will not occur. In calculating factors of safety, the maximum anchor line tensions in this case are to be those resulting from the extreme point of transient motion, with the ship subject to steady force and significant wave motion.
5. The factor of safety of 2,0 applies to critical lines maintaining separation between the moored ship and an adjacent installation.

Table 8.3.2 Thruster allowance

Case	Thruster allowance: T1	Thruster allowance: T2	Thruster allowance: T3
Operating (Intact)	None	70% of all thrusters, less one	All thrusters, less one
Survival (Intact)	70% of all thrusters	All thrusters	All thrusters
Operating (Damaged)	None	70% of all thrusters, less one	All thrusters, less one
Survival (Damaged)	70% of all thrusters	All thrusters	All thrusters

NOTES
1. The conditions for assignment of supplementary notations T1, T2 and T3 are defined in Section 8.
2. Where all thrusters are permitted, the net effect of all thrusters can be included in calculations.
3. Where all thrusters except one are permitted, the net effect of all thrusters, less the single most effective one, can be included in calculations.

■ *Section 4* Mooring equipment

4.1 Anchors

4.1.1 Anchors for positional mooring are to be sufficient in number and holding power, and are to have adequate structural strength, for the intended service. It is the Owners'/ Operators' responsibility to ensure adequate anchor holding power for each location or holding ground.

4.1.2 The anchors are to be of an approved type. Supporting calculations to verify the structural strength of the anchor under proof test loading are to be submitted.

4.1.3 The anchors are to be manufactured in accordance with the requirements of Chapter 10 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

4.1.4 The anchors are to be proof tested in the manner laid down in Chapter 10 of the Rules for Materials. The level of proof test loading for positional mooring anchors is to be the greater of the following:
(a) 50 per cent of the minimum rated break strength of the intended anchor line; or
(b) the value given in Table 10.1.1 in Chapter 10 of the Rules for Materials.

4.2 Fairleads

4.2.1 Fairleads are to be designed to permit free movement of the anchor line in all mooring configurations. Fig. 8.4.1 shows the minimum operating range of the fairlead to be considered in conjunction with the design load.

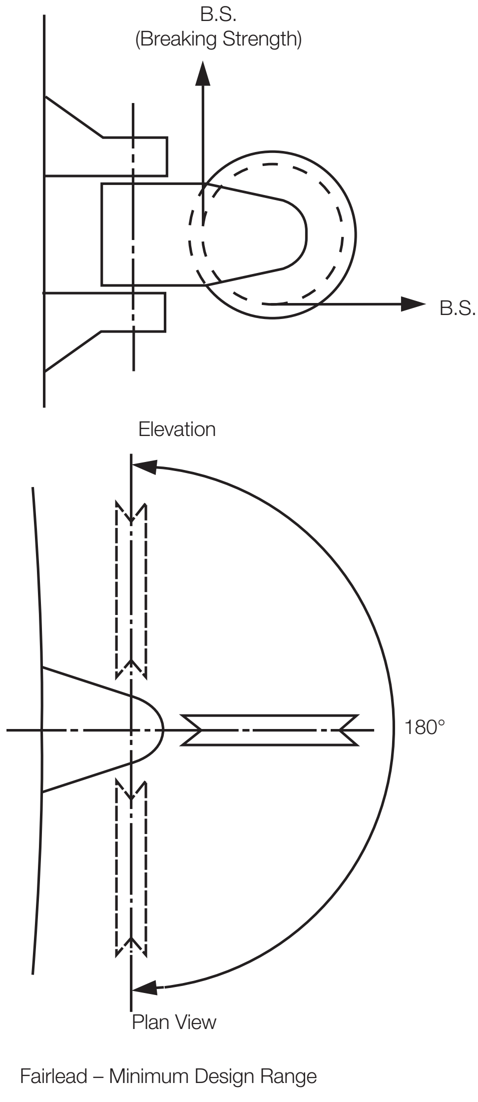


Fig. 8.4.1
Minimum operating range and design loading of fairlead

4.2.2 Fairleads and their supporting structures are to be designed for a load equivalent to the rated minimum break strength of the anchor line.

4.2.3 Maximum allowable stresses for the design criteria given in 4.2.1 and 4.2.2 are to be based on the following factors of safety:

Shear	1,89	Factors relate to tensile yield stress
Tension, compression or bending	1,25	
Combined	1,11	

$$\left(\text{combined stress} = \sqrt{\sigma_X^2 + \sigma_Y^2 - \sigma_X\sigma_Y + 3\tau^2}\right)$$

Where σ_X and σ_Y are the combined axial and bending stresses in the X and Y directions respectively and τ is the combined shear stress due to torsion and/or bending in the X-Y plane.

4.2.4 Materials and steel grades are generally to comply with the requirements given in 5.2 for Type P components.

4.2.5 Chain cable fairleads are to have a minimum of five pockets.

4.2.6 Wire rope fairleads are generally to have a minimum diameter of 20 times the wire rope diameter.

4.3 Stoppers

4.3.1 Stoppers may require to be provided depending on the winch arrangements, *see* Section 5.

4.3.2 Where stoppers are fitted, they are to comply with Section 5 in respect to mechanical and strength aspects, and Section 6 for release arrangements.

4.4 Anchor lines

4.4.1 Anchor lines are generally to be of stud link chain cable, steel wire rope or a combination of both. Special consideration will be given to proposals for the use of alternative materials.

4.4.2 Stud link chain cable is to be either of unified grade (U2 or U3) meeting the requirements of Chapter 10 of the Rules for Materials, or an approved special grade.

4.4.3 Wire rope for anchor lines is to have a suitable construction for its purpose (6 x 37 construction with independent wire rope core is generally acceptable).

4.4.4 Steel wire ropes are generally to comply with Ch 10,5 of the Rules for Materials, or with an equivalent recognised National or International Standard.

4.4.5 Wire rope terminal fittings are to comply with an acceptable code or standard. The strength of terminations, connecting fittings, shackles or links is not to be less than that of the anchor line.

■ *Section 5*
Anchor winches and windlasses

5.1 General

5.1.1 Machinery items are to be constructed, installed and tested in accordance with the relevant requirements of Part 5. For electrical and control equipment, *see* Section 6.

5.2 Materials

5.2.1 Materials are generally to comply with the requirements of Pt 5, Ch 1,2.2.

5.2.2 Components have been categorised in this Section as Type P (Primary) and Type S (Secondary) for material selection purposes:

(a) **Type P**: Components where failure would result in the loss of a primary function of the winch or windlass, e.g.:
Winch drum.
Windlass cable lifter.
Reduction gears.
Shafts.
Brakes.
Pawl stoppers.
Bedplates.

NOTE
Consideration will be given to designating any of the above components as Type S (*see* below), provided adequate redundancy of operation exists.

(b) **Type S**: Secondary, stressed items, not categorised as Type P, and where failure would not result in the loss of a primary winch function.

5.2.3 Steel materials for Type P or Type S components are generally to comply with the following Chapters and Sections of the Rules for Materials:

(a) Plates and bars: Chapter 3, Sections 1 and 2, 3 or 6, as appropriate.
(b) Castings: Chapter 4, Sections 1 and 7.
(c) Forgings: Chapter 5, Sections 1 and 8.

Consideration will be given to the acceptance of suitable equivalent National Standards.

5.2.4 Material grades are to be selected to provide the necessary notch toughness. *See* Table 8.5.1 for suitable Grades.

5.2.5 The requirements of 5.2.3 and 5.2.4 apply where the minimum design air temperature is within the range 0°C to minus 15°C. Requirements for design temperatures outside this range will be subject to special consideration.

Table 8.5.1 Material grades

Component type	Thickness (mm)	Grade					
		Plate		Castings		Forgings	
		AW (*see* Note 1)	PWHT (*see* Note 2)	AW	PWHT	AW	PWHT
P	$t \leq 25$	D, DH32, DH36	AH, B	C-Mn	C-Mn	LT20	LT0
	$25 < t \leq 50$	E, EH32, EH36	DH32, DH36	C-Mn	C-Mn	LT40	LT20
	$50 < t \leq 60$	E, EH32, EH36	E, EH32, EH36* *(*See* Note 5)	C-Mn	C-Mn	LT40	LT40 (*See* Note 5)
	$60 < t \leq 80$	LT60 (*See* Note 3)	E, EH32, EH36	$2\frac{1}{4}$ Ni (*See* Note 3)	C-Mn	LT60 (*See* Note 3)	LT40
	$80 \leq t \leq 100$	LT60	LT60 (*See* Note 3)	$2\frac{1}{4}$ Ni	$2\frac{1}{4}$ Ni (*See* Note 3)	LT60	LT60 (*See* Note 3)
	$100 < t \leq 130$	(*See* Note 4)	LT60	$3\frac{1}{2}$ Ni	$2\frac{1}{4}$ Ni	(*See* Note 4)	LT60
	$130 < t \leq 160$	$1\frac{1}{2}$ Ni	(*See* Note 4)	(*See* Note 7)	(*See* Note 7)	$1\frac{1}{2}$ Ni	(*See* Note 4)
S	$t \leq 60$	DH32, EH36	Not normally applied (*See* Note 6)				
	$60 < t \leq 80$	E, EH32, EH36* *(*See* Note 5)					
	$80 < t \leq 100$	E, EH32, EH36					
	$100 < t \leq 130$	LT60 (*See* Note 3)					
	$130 < t \leq 160$	LT60					

NOTES
1. AW. Without post-weld heat treatment.
2. PWHT. With post-weld heat treatment or not welded.
3. Impact test temperature may be raised to –50°C.
4. Use either $\frac{1}{2}$ Ni or $1\frac{1}{2}$ Ni with impact test at –70°C.
5. Impact test temperature may be raised to –30°C.
6. If PWHT is used, grades will be specially considered.
7. To be specially considered.

5.2.6 For components such as gears, shafts and boltings made from rolled or forged bar materials not subject to welding, the material composition and heat treatment, etc. may be submitted for approval as an alternative to the requirements of Table 8.5.1.

5.2.7 Non-ductile materials are not to be used for torque transmitting items or for those elements subject to tensile/bending stresses.

5.2.8 Spheroid graphite iron castings are to comply with Ch 7,3 of the Rules for Materials, Grades 370/17 or 400/12, or to an equivalent National Standard.

5.2.9 The use of grey iron castings will be subject to special consideration. Where approved, they are to comply with the requirements of Ch 7,2 of the Rules for Materials. This material is not to be used for gear components.

5.2.10 Brake lining materials are to be compatible with operating environmental conditions.

5.3 Brakes

5.3.1 Each anchor winch or windlass is required to have one primary braking system and one secondary braking system. The two systems are to operate independently.

5.3.2 The braking action of the motor unit may be used for secondary braking purposes where the design is suitable.

5.3.3 A residual braking force of at least 50 per cent of the maximum braking force required by 5.5.1 is to be immediately available and automatically applied in the event of a power failure.

5.4 Stoppers

5.4.1 If the winch motor is to be used as a secondary brake, then a stopper is to be provided to take the anchor line load during maintenance of the primary brake.

5.4.2 The stopper may be one of two different types – a pawl stopper fitted at the cable lifter/drum shaft, or a stopper acting directly on the anchor line.

5.4.3 Where the stopper acts directly on the cable, its design is to be such that the cable will not be damaged by the stopper at a load equivalent to the rated breaking strength of the cable.

5.4.4 *See also* 6.2.1 and 6.2.2 for stopper control station requirements, and 6.4.5 for emergency release of stoppers.

5.5 Winch/Windlass performance

5.5.1 The primary brake is required to hold a static load equal to the minimum break strength of the anchor line (at the intended outer working layer of wire rope on storage drum winches). The static load capacity of the primary brake can be reduced to 80 per cent of that value when a stopper capable of holding 100 per cent of the breaking strength of the line is fitted.

5.5.2 The secondary brake is required to hold a static load equal to 50 per cent of the minimum breaking strength of the anchor line.

5.5.3 The anchor winch or windlass is to have adequate dynamic braking capability. The two brake systems in joint operation are to be capable of fully controlling, without overheating, the anchor lines during:

(a) all anchor handling operations;

(b) adjustment of anchor line tensions. (This is particularly relevant where the mooring system has been designed and sized, on the basis of active adjustment of anchor lines in extreme conditions, to minimise line tensions).

5.5.4 *See also* 6.2 for control of winches, windlasses, stoppers and pawls, and 6.4 for brake fail safe requirements and standby power for operation of brakes and release of stoppers in the event of a failure of normal power supply.

5.5.5 The pulling force of the winches or windlasses is to be sufficient to carry out anchor pre-loading on location, to the necessary level. A minimum low-speed pull equal to 40 per cent of the anchor line breaking strength is recommended.

5.6 Strength

5.6.1 Design load cases for the winch or windlass assembly and the stopper when fitted are given in Table 8.5.2. The associated maximum allowable stresses are to be based on the factors of safety given in Table 8.5.3.

Table 8.5.2 Design load cases

Load case	Condition	Anchor line load percentage of break strength
1	Winch braked	100% (*See* Note)
2	Stopper engaged	100%
3	Winch pulling	40% or specified duty pull if greater

NOTE
Where stopper is fitted, anchor line load in Case 1 can be taken as brake slipping load, but is not to be less than 80 per cent break strength.

Table 8.5.3 Safety factors for design load cases

Stress	Load case	
	1 & 2	3
	Factor of safety	
Shear	1,89	2,5
Tension, compression, bending	1,25	1,67
Combined	1,11	1,43

NOTES
1. Factors of safety relate to tensile yield stress.
2. Combined stress = $\sqrt{\sigma_X^2 + \sigma_Y^2 - \sigma_X\sigma_Y + 3\tau^2}$

   Where σ_X and σ_Y are the combined axial and bending stresses in the X and Y directions respectively and τ is the combined shear stress due to torsion and/or bending in the X-Y plane.

5.7 Testing

5.7.1 Works tests are to be carried out in the presence of the Surveyor, on at least one of the winch or windlass units out of the total outfit for the vessel. The tests to be carried out are given in Table 8.5.4. Alternatively, where a prototype winch has been suitably tested, consideration will be given to the acceptance of these results.

Table 8.5.4 Works test

Test	Test load
Static brake – Primary	100% Anchor line break strength (or 80% where stopper fitted. *See* 5.5.1)
Static brake – Secondary	50% Anchor line break strength
Stopper (where fitted)	100% Anchor line break strength
Motor stall test	Specified stall load

5.7.2 The residual braking capability (*see* 5.5.4) is to be verified.

5.7.3 Each winch or windlass is to be tested on board the vessel, in the presence of the Surveyor, to demonstrate that all main aspects, including dynamic brakes, function satisfactorily. The proposed test programme is to be submitted.

5.8 Type approval

5.8.1 Winches or windlasses may be type approved in accordance with LR's Type Approval Scheme. Where this type approval is obtained, the requirements of 5.7.1 may not be applicable.

■ *Section 6*
Electrical and control equipment

6.1 General

6.1.1 The electrical installation is to be designed, constructed and installed in accordance with the relevant requirements of Pt 6, Ch 2.

6.1.2 Control, alarm and safety systems are to be designed, constructed and installed, in accordance with the relevant requirements of Pt 6, Ch 1, together with the requirements of 6.2 to 6.4.

6.2 Control stations

6.2.1 The operation of winches, windlasses and associated brakes, chainstoppers and pawls is to be controlled locally from weather-protected control stations which provide good visibility of the equipment and associated anchor handling operations.

6.2.2 A central control station, which may be located on the bridge or a separate manned control room, is to be provided from which brakes, chainstoppers and pawls can be remotely released.

6.2.3 For each anchor winch, the respective local control station is to be provided with a means of indicating the following:
(a) Line tension.
(b) Length of line paid out.
(c) Line speed.

6.2.4 The indication required by 6.2.3(a) and (b) is to be repeated to the central control station and, in addition, a means of indicating the following is to be provided at this position:
(a) Mooring patterns and anchor line catenaries.
(b) Status of winch operation.
(c) Position and heading, *see also* 6.4.6.
(d) Gangway angle and extension, when applicable.
(e) Riser angle, when applicable.
(f) Wind speed and direction, *see also* 6.4.9.

6.2.5 Means of voice communication are to be provided between the central control station, each local control station and anchor handling vessels, when applicable.

6.3 Alarms

6.3.1 Alarms are to be provided at the local and central control stations for the following fault conditions:
(a) Excessive line tension.
(b) Loss of line tension.
(c) Excessive gangway angle and extension, when applicable.
(d) Excessive riser angle, when applicable.

6.3.2 Alarms are to be provided adjacent to the winches and windlasses to warn personnel prior to and during any remote operation.

6.3.3 Alarms are to be provided at the central control station for the following fault conditions:

(a) When the ship deviates from its predetermined area of operation.

(b) When the ship deviates from its predetermined heading limits.

These alarms are to be adjustable, but should not exceed specified limits. Arrangements are to be provided to fix and identify their set points.

6.4 Controls

6.4.1 Adequate controls are to be provided at the local control station for satisfactory operation of the winch(es).

6.4.2 The braking system is to be arranged so that the brakes, when applied, are not released in the event of a failure of the normal power supply.

6.4.3 Standby power is to be provided to enable winch brakes to be released within 15 seconds in an emergency. The release arrangements are to be operable locally at each winch and from the central control position, and are to be such that the entire anchor line can be lowered in a controlled manner.

6.4.4 The standby power is to be such that, during lowering of the anchor line, it is possible to apply the brakes once and then release them again in a controlled manner.

6.4.5 Standby power is to be provided, so that any anchor line stoppers or pawl mechanisms may be released from either the local or central control stations up to a line tension equal to the minimum rated break strength of the anchor line. These mechanisms are to be capable of release at the maximum angles of heel and trim under the damage stability and flooding conditions for which the ship is designed.

6.4.6 At least one position reference system and one gyrocompass or equivalent is to be provided, when applicable, to ensure the specified area of operation and heading deviation can be effectively monitored.

6.4.7 Position reference systems are to incorporate suitable position measurement techniques which may be by means of acoustic devices, radio, radar, taut wire, riser angle, gangway extension and angle or other acceptable means depending on the service conditions for which the ship is intended.

6.4.8 A vertical reference sensor is to be provided, if applicable, to measure the pitch and roll of the ship.

6.4.9 Means are to be provided to ascertain the wind speed and direction acting on the ship.

■ *Section 7*
Thruster-assisted positional mooring

7.1 General

7.1.1 When the positional mooring system is supplemented by thrusters, the requirements of Pt 7, Ch 4, are to be generally complied with in respect of the machinery, electrical and control engineering arrangements. In applying these requirements, the arrangements for the notations **DP(CM)**, **DP(AM)** and **DP(AA)** may be regarded as equivalent to those for supplementary notations T1, T2 and T3 respectively, unless otherwise stated in this Chapter.

7.2 Control systems

7.2.1 Suitable processing and comparative techniques are to be provided at the central control station to validate the control system inputs, thereby ensuring optimum performance of the thruster-assisted mooring system.

7.2.2 Abnormal signal errors revealed by the validity checks required by 7.2.1 are to initiate alarms.

7.2.3 The control system is to be stable throughout its operational range and is to meet the specified performance and accuracy criteria.

7.2.4 An alarm is to be provided for a control computer system fault.

7.2.5 Sufficient instrumentation is to be fitted at the central control station to ensure effective control and indicate that the system is functioning correctly, *see also* 6.2.

7.2.6 The deviation from the desired heading and/or position is to be adjustable, but should not exceed the specified limits. Arrangements are to be provided to fix and identify the set points for the desired heading and/or position.

■ *Section 8*
Thruster-assisted mooring – Classification notation requirements

8.1 Notation T1

8.1.1 For assignment of notation T1, the applicable requirements of Sections 6 and 7, together with 8.1.2, are to be complied with.

8.1.2 Centralised automated manual control of the thrusters is to be provided to supplement the position mooring system. The manual control system is to provide output signals to the thrusters, via the manual controller, to change the speed, pitch and azimuth angle, as applicable, thereby optimising line tension, as indicated at the central control station, *see* 6.2.4.

8.2 Notation (T2)

8.2.1 For assignment of notation (T2), the applicable requirements of Sections 6 and 7, together with 8.2.2 to 8.2.5, are to be complied with.

8.2.2 Automatic and manual control systems are to be provided to supplement the positional mooring systems and arranged to operate independently, so that failure in one system will not render the other system inoperative. *See also* 8.1.2 for manual control.

8.2.3 The automatic control system is to utilise automatic input(s) from the position reference system, the environmental sensors and line tensions, and automatically provide output signals to the thrusters to change the speed, pitch and azimuth angle, as applicable, thereby optimising line tension.

8.2.4 In the event of line failure or failure of the most effective thruster, the ship is to be capable of maintaining its predetermined area of operation and desired heading in the environmental conditions for which the ship is designed and/or classed.

8.2.5 Control, alarm and safety systems are to incorporate a computer-based consequence analysis, which may be continuous or at predetermined intervals, and is to analyse the consequence of predetermined failures to verify that the anchor line tensions and position/heading deviations remain within acceptable limits. In the event of a possible hazardous condition, arising as a result of the consequence analysis, an alarm is to be initiated at the central control station.

8.3 Notation (T3)

8.3.1 For assignment of notation (T3), the applicable requirements of Sections 6 and 7, together with 8.2.3 to 8.2.5 and 8.3.2 to 8.3.5, are to be complied with.

8.3.2 Two automatic control systems are to be provided and arranged to operate independently, so that failure in one system will not render the other system inoperative.

8.3.3 In the event of failure of the working system, the standby automatic control system is to be arranged to changeover automatically without manual intervention and without any adverse effect on the ship's station keeping capability. The automatic changeover is to initiate an alarm.

8.3.4 At least two position reference systems, as defined by 6.4.7, are to be provided.

8.3.5 At least two of each of the environmental sensors, as required by 6.4.8 and 6.4.9, are to be provided.

■ *Section 9* **Trials**

9.1 General

9.1.1 Before a new installation (or any alteration or addition to an existing installation) is put into service, trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturers' works and are to be based on the approved test schedules list as required by 1.5.4(h).

9.1.2 The suitability of the positional mooring and/or thruster-assisted positional mooring system is to be demonstrated during sea trials, observing the following:

(a) Response of the system to simulated failures of major items of control and mechanical equipment, including loss of electrical power.
(b) Response of the system under a set of predetermined manoeuvres for changing:
  (i) Location of area of operation.
  (ii) Heading of the ship.
(c) Automatic thruster control and line tension optimisation.
(d) Monitoring and consequence analyses.
(e) Simulation of line breakage and damping.
(f) Continuous operation of the thruster-assisted positional mooring system over a period of four to six hours.

9.1.3 Two copies of the test schedules, as required by 1.5.4(h), signed by the Surveyor and Builder, are to be provided on completion of the survey. One copy is to be placed on board the ship and the other submitted to LR.

Section

Section 1 General requirements

1.1 General

1.1.1 The requirements of this Chapter apply to ships where an optional class notation for optimising environment on the bridge for navigational tasks, including periodic operation of the ship under the supervision of a single watch-keeper on the bridge and/or integrated bridge systems, is requested, and are additional to those applicable in other Parts of the Rules.

1.1.2 The requirements of this Chapter are based on the understanding that the *International Regulations for Preventing Collisions at Sea* and all other relevant Regulations relating to Radio Communications and Safety of Navigation required by Chapters IV and V respectively of SOLAS are complied with.

1.1.3 Requirements additional to those in this Chapter may be imposed by the National Authority with whom the ship is registered and/or by the Administration within whose territorial jurisdiction it is intended to operate.

1.1.4 The requirements of this Chapter are framed on the understanding that contingency plans for emergencies are specified and the conditions under which one man watch is permitted are clearly defined in an operations manual which is acceptable to the Administration with which the ship is registered.

1.1.5 In general, ships complying with the requirements of Sections 1 to 4 of this Chapter will be eligible for the notation **NAV1**.

1.1.6 Section 5 of this Chapter states additional requirements which apply where the navigational functions are integrated. In general, ships complying with the requirements of Section 5 will be eligible for the notation **IBS**, *see* Pt 1, Ch 2,2.4. In addition to the assessment of the navigational function integration, the assignment of the notation **IBS** requires that the layout of the bridge and the equipment located on the bridge is to the satisfaction of Lloyd's Register (hereinafter referred to as LR), *see* 5.2.1.

1.2 Information and plans required to be submitted

1.2.1 The following information and plans are to be submitted in triplicate:

- For programmable electronic systems, the plans required by Pt 6, Ch 1,1.2.6.
- Details of the intended area of operation of the ship.
- List of navigational equipment detailing manufacturer, and model and National Authority approval (where applicable).
- Functional block diagrams and descriptions of the navigational equipment, internal communications systems and watch safety system indicating their relationship to each other.
- Details of the electrical power supplies to the navigational equipment, internal communications systems, watch safety system, and clear view arrangements.
- A general arrangement of the ship showing the fields of vision from the bridge.
- A general arrangement of the bridge and wheelhouse showing the positions of consoles, panels, handrails, seating, windows and clear view arrangements.
- A profile view of the wheelhouse detailing the inclination of windows, heights of upper and lower edges of windows, and dimensions of consoles.
- Detailed arrangements of consoles and panels showing the layout of equipment.
- Test schedules which should include methods of testing and test facilities provided.
- A schedule of the electrical and electronic equipment referred to in 2.2.10 giving details of:
  - equipment description;
  - manufacturer;
  - type and/or model; and
  - evidence of electromagnetic compatibility.

1.3 Definitions

1.3.1 The following definitions are applicable to these Rules:

(a) **Workstation:**
A position at which one or several tasks, constituting a particular activity, is carried out.

(b) **Navigation workstation:**
A workstation at which the navigator may carry out all tasks relevant for deciding, executing and maintaining course and speed in relation to waters and traffic. The instrumentation and controls at the navigation workstation should allow the navigator to:
  - analyse the traffic situation;
  - monitor position, course, track, speed, time, propeller revolutions and pitch, rudder angle, depth of water, rate of turn, and wind speed and direction;
  - alter course and speed;
  - effect internal and external communications;
  - give and receive sound signals;
  - control navigational lights;
  - monitor and acknowledge navigational alarms and warnings;
  - confirm his well-being and watch-keeping awareness; and
  - record navigational data.

(c) **Main steering position:**
That part of the navigation workstation where those controls and instrumentation relevant to controlling the ship's course are located.

(d) **Conning position:**
A place on the bridge which is used by navigators when commanding, manoeuvring and controlling a ship.

(e) **Voyage planning workstation:**
A workstation at which the navigator may carry out the following tasks without affecting the actual navigation of the vessel:
- examine and update charts and other relevant documentation;
- plan a voyage as a series of waypoints, courses, speeds and turns;
- calculate an estimated time of arrival at various points on the voyage; and
- determine and plot the ship's position.

■ *Section 2* Physical conditions

2.1 Bridge and wheelhouse arrangement

2.1.1 The bridge configuration, arrangement of consoles and equipment location are to be such as to enable the officer of the watch to perform navigational tasks and other functions allocated to the bridge, as well as maintain an effective lookout. The following tasks are to be supported:
- navigation and manoeuvring;
- monitoring;
- manual steering;
- docking;
- planning;
- safety;
- communications; and
- conning.

2.1.2 Equipment and associated displays and indicators are to be sited at clearly defined workstations.

2.1.3 Consoles, including the chart table, are to be positioned, so that the instrumentation they contain is mounted in such a manner as to face a person looking forward. As far as practicable, operating surfaces are to be normal to the operator's line of sight.

2.1.4 From other workstations within the wheelhouse it is to be possible to monitor the navigation workstation and to maintain an effective lookout.

2.1.5 The main access to the bridge is to be by means of an internal stairway. Secondary external access is also to be provided.

2.1.6 Clear passage of at least 700 mm width is to be available to allow movement around the bridge with a minimum of inconvenience. Particular attention is to be paid to the following routes which are to be as direct as possible:

(a) From bridge wing to bridge wing, a clear passage of at least 1200 mm in width.
(b) Between the internal entrance to the bridge and the route in (a) a clear passage of at least 700 mm in width is to be provided.
(c) Between adjacent workstations, a clear passage of at least 700 mm is to be provided.
(d) Between the bridge front bulkhead or any consoles and installations placed against the front bulkhead, to any consoles or installations placed away from the bridge front, a clear passage of at least 800 mm is to be provided.

Space necessary for operating at a workstation is to be considered as part of the workstation and is not to be part of the passageway.

2.1.7 The clear height between the wheelhouse deck surface covering and the underside of the deckhead is to be at least 2250 mm. The lower edge of deckhead mounted equipment is to be at least 2100 mm in open areas, passageways and at standing workstations.

2.1.8 Toilet facilities are to be provided on the bridge or adjacent to the bridge on the bridge deck.

2.2 Environment

2.2.1 The bridge is to be free of physical hazards to personnel. There are to be no sharp edges or protuberances and wheelhouse, bridge wing and upper bridge decks are to be free of trip hazards and have non-slip surfaces whether wet or dry.

2.2.2 Sufficient hand-rails or equivalent are to be fitted inside the wheelhouse and around workstations to enable personnel to move or stand safely in bad weather. Protection of stairway openings is to be given special consideration.

2.2.3 Provision for seating is to be made in the wheelhouse. Means for securing the seating are to be provided having regard to storm conditions.

2.2.4 Glare and reflections from surfaces are to be minimised. In this respect, walls, ceilings, consoles, chart tables and other major fittings are to be provided with a suitable low reflective finish. Arrangements are to be provided to prevent the obscuration of information presented on visual display units and instruments which are fitted with transparent covers.

2.2.5 Entrance doors to the wheelhouse are to be securable from the inside, and operable with one hand. Bridge wing doors are not to be self-closing, and are to be provided with means to hold them open. For ships required to comply with the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk*, the sealing mechanism of each door is to be such that a rapid and efficient gas and vapour tightening can be ensured.

2.2.6 An adequate air conditioning or mechanical ventilation system, together with sufficient heating according to climatic conditions, is to be provided in order to maintain the temperature of the wheelhouse within the range of 14°C to 30°C and the humidity within the range 20 per cent to 60 per cent. The discharge of hot or cold air is not to be directed towards bridge personnel. Control of this system is to be provided in the wheelhouse.

2.2.7 The noise level on the bridge is not to interfere with verbal communication, mask audible alarm signals, or be uncomfortable to bridge personnel. In this respect, the ambient noise level in the wheelhouse in good weather is not to exceed 65 dB(A).

2.2.8 A sound reception system or alternative means is to allow external sound signals to be heard and their direction determined within the wheelhouse.

2.2.9 Permanently installed electrical and electronic equipment is to be installed so that electromagnetic interference does not affect the proper function of the navigational systems and equipment. Installation of the equipment in accordance with the guidelines and recommendations included in IEC 60533: *Electrical and electronic installations in ships – Electromagnetic compatibility*, or an acceptable equivalent Standard, would generally be considered to meet the requirement.

2.2.10 Permanently installed electrical and electronic equipment, on the bridge and in the vicinity of the bridge, that is not subject to the approval required by 3.1.13, is to have undergone electromagnetic compatibility testing that demonstrates the equipment satisfies the conducted and radiated emission requirements of:

- IEC 60533: *Electrical and electronic installations in ships – Electromagnetic compatibility; or*
- IEC 60945: *Maritime navigation and radio communication equipment and systems – General requirements – Methods of testing and required test results.*

Testing in accordance with other appropriate standards is subject to consideration and details are to be submitted.

2.2.11 To demonstrate compliance with 2.2.10, a schedule of applicable equipment is to be compiled, *see* 1.2.1. Where it is proposed to add to or modify the equipment referred to in 2.2.10 the schedule is to be maintained accordingly, *see also* 6.1.1. A copy of the schedule documentation is to be placed on board the vessel and a copy is to be made available to the LR Surveyor on request.

2.2.12 Passive electromagnetic equipment, considered not liable to cause or be susceptible to electromagnetic disturbances, may be provided with an exemption statement in place of evidence of electromagnetic compatibility for the purposes of 2.2.11. Examples of passive electromagnetic equipment include cables, purely resistive loads and batteries.

2.3 Lighting

2.3.1 The level of lighting is to enable bridge personnel to perform all bridge tasks, including maintenance and chart and office work, by day and night. Controls, indicators, instruments, keyboards, etc., on the bridge are to be capable of being seen in the dark, either by means of internal lighting within the equipment or the wheelhouse lighting system. A satisfactory level of flexibility within the lighting system is to be available to enable the bridge personnel to adjust the lighting in brightness and direction as required in different areas of the bridge and by the needs of individual instruments and controls.

2.3.2 All illumination and lighting of instruments, keyboards and controls are to be adjustable down to zero, except the lighting of alarm and warning indicators and the controls of dimmers which are to remain readable.

2.3.3 Two separate circuits are to be provided for wheelhouse lighting, such that failure of any one of the circuits does not leave the space in darkness, *see* Pt 6, Ch 2,5.7.

2.3.4 Emergency lighting is to be provided for the wheelhouse, stairways and exits, *see* Pt 6, Ch 2,3.

2.3.5 Lighting used in areas and at items of equipment requiring illumination, whilst the ship is navigating, is to be such that night vision is not impaired, e.g. red lighting. Such lighting is to be arranged, so that it cannot be mistaken for a navigation light by another ship, and to prevent glare and stray image reflections.

2.3.6 In order to avoid possible confusion in colour discrimination, red lighting is not to be fitted over chart tables.

2.3.7 To avoid unnecessary light sources in the front area of the bridge, only instruments necessary for the safe navigation and manoeuvring of the ship are to be located in this area.

2.3.8 Means are to be provided to prevent the sudden flooding of light onto the bridge from alleyways, accommodation areas and the chart table area.

2.3.9 Deck and superstructure lights which may impair safe navigation are to be controlled from the bridge.

2.3.10 Each navigation light is to be provided with an audible and visual alarm to indicate failure of the light, *see* Pt 6, Ch 2,15.6.

2.3.11 Means are to be provided to test alarm and other indicator lamps.

2.4 Windows

2.4.1 All wheelhouse windows are to be constructed of shatterproof toughened glass having a strength commensurate with the degree of exposure of the bridge to storm conditions and complying with a recognised National or International Standard, e.g. ISO 21005, *Ships and marine technology – Thermally toughened safety-glass panes for windows and side scuttles.*

2.4.2 Windows are to be as wide as possible and divisions between them are to be kept to a minimum. No division is to be positioned immediately forward of any work-station or on the ship's centreline.

2.4.3 To reduce reflections from internal lighting, etc., the bridge windows are to be inclined from the vertical plane top out, at an angle of not less than 10° and not more than 25°. Alternative arrangements will be specially considered.

2.4.4 The height of the lower edge of the front windows is to allow a forward view over the bow for a person at the navigation workstation and is not to obstruct any of the required fields of vision, *see* 2.5. In this respect, the height of the lower edge of the front windows above the deck is to be kept as low as possible and, as far as practicable, is not to be more than 1000 mm above the deck surface.

2.4.5 The upper edge of the front windows is to allow a forward view of the horizon for a person with an eyeheight of 1800 mm at the conning position when the ship is pitching in heavy seas and, as far as practicable, is not to be less than 2000 mm above the deck surface.

2.4.6 Clear views through the windows in front of the conning position, navigation workstation, and, where applica-ble, bridge wings are to be provided at all times regardless of weather conditions. At least two windows are to provide such a view.

2.4.7 To ensure a clear view in bright sunshine, sun-screens with minimum colour distortion are to be provided. Such screens are to be readily removable and not permanently installed. Polarised and tinted windows are not to be fitted.

2.4.8 Heavy duty wipers, preferably provided with an interval function and a fresh water wash, are to be fitted.

2.4.9 Efficient cleaning, de-icing and de-misting systems are to be fitted.

2.4.10 Suitable safe external access arrangements fitted under the bridge windows are to be provided to enable cleaning in the event of failure of the above systems.

2.5 Fields of vision

2.5.1 It is to be possible to observe all objects necessary for navigation, including other traffic and navigation marks, in any direction from inside the wheelhouse. In this respect, there is to be a field of view around the ship of 360° obtained by an observer moving within the confines of the wheelhouse.

2.5.2 The view of the sea surface from the conning position and the navigation workstation is not to be obscured by more than two ship lengths, or 500 m, whichever is less, forward of the bow to 10° on either side, irrespective of the ship's draught, trim and deck cargo, *see* Fig. 9.2.1.

2.5.3 Blind sectors caused by cargo, cargo gear and other obstructions outside of the wheelhouse forward of the beam obstructing the view of the sea surface as seen from the conning position and the navigation workstation are not to exceed 10° each. The total arc of blind sectors is not to exceed 20° and the clear sector between blind sectors shall be at least 5°. However, in the view described in the preceding paragraph, each individual blind sector is not to exceed 5°.

2.5.4 The horizontal field of vision from the conning position and the navigation workstation is to extend over an arc from more than 22,5° abaft the beam on one side, through forward, to more than 22,5° abaft the beam on the other side, *see* Fig. 9.2.2.

2.5.5 From the main steering position, the field of vision is to extend over an arc from dead ahead to at least 60° on each side, *see* Fig. 9.2.3.

2.5.6 From each bridge wing, the field of vision is to extend over an arc from at least 45° on the opposite bow through dead ahead and then aft to 180° from dead ahead, *see* Fig. 9.2.4.

2.5.7 There is to be a line of sight from the port wing to the starboard wing through the wheelhouse.

2.5.8 The ship's side is to be visible from the bridge wing.

2.5.9 From workstations for functions other than navigation, the field of vision is to enable an effective lookout to be maintained and, in this respect, is to extend at least over an arc from 90° on the port bow, through forward, to 22,5° abaft the beam on the starboard side, *see* Fig. 9.2.5.

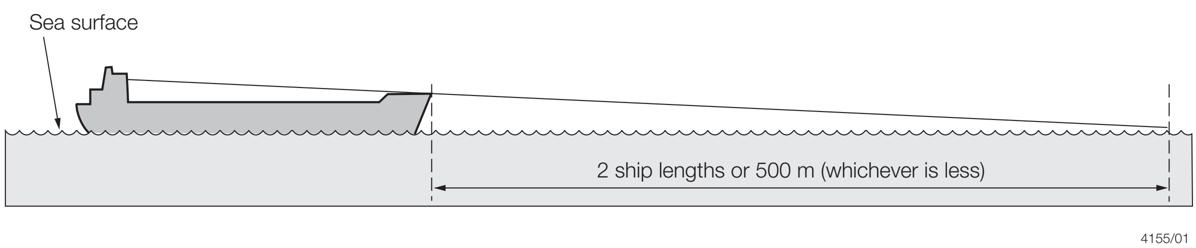


Fig. 9.2.1 View of sea surface from conning position and navigation workstation

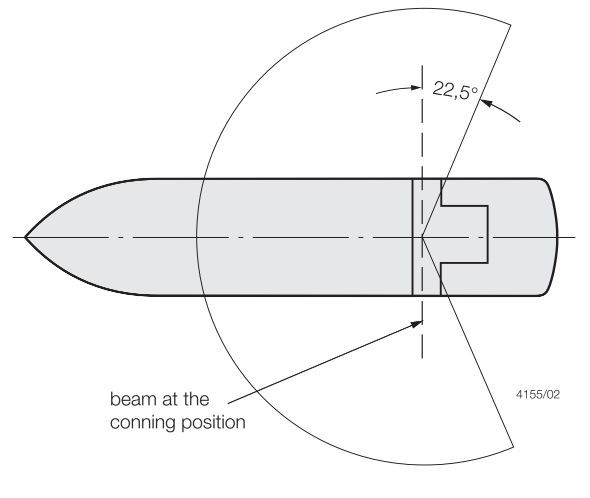


Fig. 9.2.2
Horizontal field of view from conning position and navigation workstation

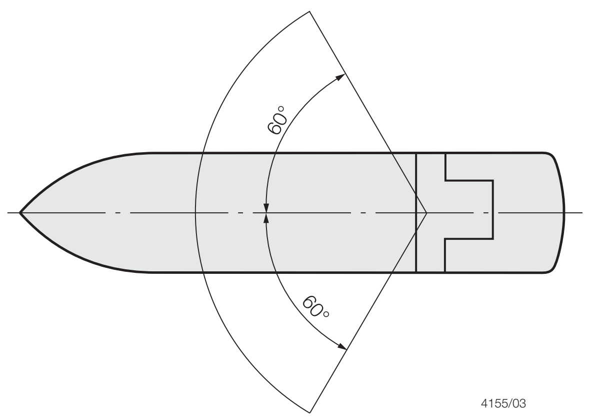


Fig. 9.2.3 Field of view from main steering position

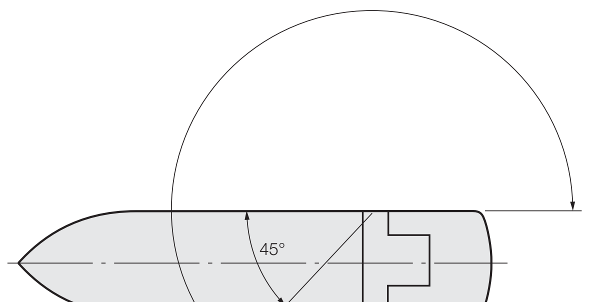


Fig. 9.2.4 Field of view from starboard bridge wing

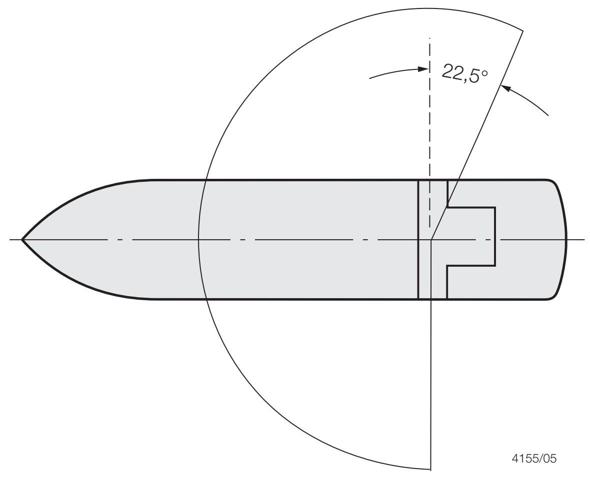


Fig. 9.2.5
Field of view from workstation other than for navigation

2.5.10 The height of consoles is not to interfere with the fields of vision defined above and is not to exceed 1350 mm.

■ *Section 3* Workstations

3.1 Navigation workstation

3.1.1 A workstation for navigation is to be arranged to enable efficient operation by one person under normal operating conditions. The workstation area is to be sufficient to allow at least two operators to use the equipment simultaneously. The arrangement of instruments and controls is to allow the use of all instruments and controls necessary for navigating and manoeuvring in any normal working position.

3.1.2 An adequate conning position is to be provided close to the forward centre window. If the view in the centreline is obstructed by large masts, cranes, etc., two additional conning positions giving a clear view ahead are to be provided, one on the port side and one on the starboard side of the centreline, no more than 5 m apart. In addition to the conning position, a second position with a view of the area immediately in front of the bridge superstructure is to be provided close to a forward window or, alternatively, the conning position is to be wide enough to accommodate two persons.

3.1.3 The main steering position is to be located on the ship's centreline, unless the view ahead is obstructed by large masts, cranes, etc. In this case, the steering position is to be located a distance to starboard of the centreline sufficient to obtain a clear view ahead and special steering references for use by day and night are to be provided, e.g. sighting marks forward.

3.1.4 The following facilities are to be provided at the navigation workstation:

- Radar and radar plotting facilities, *see* 3.1.5.
- Position-fixing system displays, *see* 3.1.6.
- Echo sounder display.
- Speed and distance indications, *see* 3.1.11 and 3.1.12.
- Gyrocompass displays, *see* 3.1.7.
- Magnetic compass display.
- Wind speed and direction indication.
- Steering controls and indication, *see* Pt 5, Ch 19,5.
- Rate of turn indication.
- Course/track controls and indications, *see* 3.1.8 to 3.1.10.
- Main propulsion and thruster controls and indication, *see* Pt 6, Ch 1,2.6 and Pt 5, Ch 7,5.3.
- Watch safety system acknowledge.
- Watch safety system manual initiation.
- Internal communications system.
- VHF radiotelephone.
- Time indication.
- Window clear view controls.
- Navigation lights controls.
- Whistle control.
- Morse light keys.
- Wheelhouse/equipment lighting controls.
- Automatic ship identification system (AIS) information.
- Sound reception system where fitted, *see* 2.2.8.
- Means to cease the distribution of long-range identification and tracking information, where required by SOLAS Ch V, Reg.19-1,7.

3.1.5 Two functionally independent radars or alternative means are to be provided to determine and display the range and bearing of radar transponders and other surface craft, obstructions, buoys, shorelines and navigational marks. One of the radars is to operate in the X-band (9 GHz) and the other is to operate in the S-band (3 GHz).

3.1.6 At least two different automatic position-fixing systems giving a continuous display of latitude and longitude are to be provided in the interests of redundancy and diversity. One of these is to be GPS or equivalent. The other is to be a system providing similar global coverage such as GLONASS, where available. When a second GPS receiver is installed to satisfy this requirement, at least one of the receivers is to be provided with differential correction functionality (DGPS) and the receivers are to be arranged to operate independently as far as is practicable.

3.1.7 A gyrocompass or alternative means for determining, displaying and transmitting the ship's heading by shipborne, non-magnetic means, is to be provided and is to be clearly readable by the helmsman at the main steering position. The heading information is to be used directly by the radars, radar plotting aids and automatic identification system, *see* 3.1.5 and 3.1.13. The gyrocompass is to be provided with a gyrocompass heading repeater located at the emergency steering position in the steering gear compartment and a gyrocompass bearing repeater allowing bearings to be taken over 360°.

3.1.8 An autopilot, track control system or alternative means of automatically maintaining the ship's heading or a straight track is to be provided. At any time, it is to be possible to immediately restore manual control.

3.1.9 Heading monitoring is to be provided to monitor the actual heading information by independent heading sources. An off-course warning is to be given if the actual heading of the ship deviates from the set track course beyond a pre-set value. The pre-set off-course warning limit is to be large enough to prevent unnecessary alarms.

3.1.10 Where automatic track following is provided, sufficient warning is to be given of the approach of a waypoint, so that, in the event of no acknowledgement from the officer of the watch, there is adequate time for the backup navigator to reach the bridge and accept the change of course.

3.1.11 A speed log or alternative means of indicating the ship's speed and distance through water is to be provided. The speed through water measurement is to be used directly by the ARPA as an aid to collision avoidance.

3.1.12 A speed log or alternative means of indicating the ship's speed and distance over ground is to be provided, which is to be separate from the device required by 3.1.11. Speed over ground is to be indicated in both the fore-aft and athwartships directions.

3.1.13 Navigational systems and equipment are to be of a type approved by the national administration and in conformity with appropriate performance standards not inferior to those adopted by IMO from time to time. Documentary evidence to this effect is to be submitted. *See* SOLAS 1974 as amended, Ch V, Reg. 18.

3.1.14 Where alternative means of fulfilling the navigational requirements are permitted, the means are to be approved by the national administration and in conformity with appropriate performance standards.

3.2 Voyage planning workstation

3.2.1 A voyage planning workstation is to be provided at which the following facilities are available:

- Chart display and information facilities.
- Position-fixing systems.
- Time indication.

3.2.2 Time indication at the voyage planning workstation is to be derived from the same system as used at the navigation workstation.

3.2.3 An Electronic Chart Display and Information System (ECDIS) is to be provided. Chart tables for paper charts, where provided, are to be large enough to accommodate all chart sizes normally used internationally for maritime traffic and are to have facilities for illuminating the chart, *see also* 2.3.8.

Section 4
Systems

4.1 Alarm and warning systems

4.1.1 Alarms associated with navigation equipment are to be both audible and visual and are to be centralized for efficient identification. Repeater displays may be fitted on the bridge wings and at other appropriate positions on the bridge where necessary.

4.1.2 The following alarms are to be provided:

- Closest point of approach.
- Shallow depth.
- Waypoint approaching (where automatic track following is provided).
- Off-course.
- Off-track (where automatic track following is provided).
- Steering alarms, *see* Table 19.5.1 in Pt 5, Ch 19 or Table 20.4.1 in Pt 5, Ch 20, as applicable.
- Navigation light failure alarms, *see* Pt 6, Ch 2, 15.6, including 15.6.8 for grouping.
- Gyrocompass failure.
- Watch safety system failure.
- Failure of any power supply to the distribution panels referred to in 4.4.1.

4.1.3 Audible signals are to be designed not to startle operators. Suitable types are shown in Table 9.4.1.

Table 9.4.1 Suitable audible signals

Type	Typical characteristics	Considerations
Buzzer	Low intensity and frequencies	Good alerting in quiet environment without startling
Bell	Moderate intensity and frequencies	Penetrates low frequency noise well, abrupt onset has a high alert value
Chime	Moderate intensity and frequencies	Good in quiet environment, non-startling
Tone	Moderate intensity and limited frequency range	Convenient for intercom transmission, high alert value if intermittent

4.1.4 In the event that any alarm initiated by navigation equipment on the navigating bridge has not been acknowledged on the bridge within a period of 30 seconds, a visual and audible alarm is to be initiated immediately to warn the appointed back-up navigator and/or the Master.

4.1.5 In the event that the alarm required by 4.1.4 is not acknowledged, the system is to initiate an alarm at the locations of further crew members capable of taking corrective actions following a time delay sufficient to allow the Master or back-up navigator to reach the bridge. The time interval is to be adjustable between 90 seconds up to a maximum of 3 minutes. In ships, other than passenger ships, the alarm to warn the further crew members may be initiated at the same time as the alarm to warn the Master and back-up navigator.

4.1.6 The functionality specified in 4.1.4 and 4.1.5 may be incorporated in the watch safety system required by 4.2, or in another fixed system.

4.2 Watch safety system

4.2.1 A watch safety system satisfying the requirements of the IMO Resolution MSC.128(75), *Performance standards for a bridge navigational watch alarm system* (BNWAS), and approved by the national administration is to be provided to monitor the well-being and awareness of the watchkeeper.

4.2.2 If, depending upon the shipboard work organisation, the backup navigator may attend locations not connected to the alarm transfer system, a wireless portable device is to be provided enabling both the transfer of alarms and two-way speech communication with the bridge. An audible warning from the portable device is to be provided in the event of loss of the wireless link with the bridge. Alternative arrangements will be considered.

4.2.3 Acknowledgement of any alarm is to automatically reset the time interval between warnings. Manual adjustment of controls may also be used for this purpose. Manual adjustment of controls and navigation equipment (*see also* 5.3.14) is to automatically reset the watch safety interval timer. Reset arrangements based on the detection of movement in the bridge are not considered to satisfy this requirement or to confirm well-being and watch-keeping awareness.

4.3 Communications

4.3.1 A telephone system is to be provided to enable two-way speech communication between the wheelhouse and at least the following locations:

- machinery control station space, *see* Pt 6, Ch 1,2.6.7;
- emergency steering position in the steering gear compartment;
- Master's and Navigating Officers' cabins, offices, mess and public rooms.

4.3.2 The bridge is to have priority over the system.

4.3.3 A list of extension numbers is to be clearly displayed adjacent to each telephone.

4.4 Power supplies

4.4.1 Local distribution panels are to be provided for all items of electrically operated navigational equipment, the telephone system, the watch safety system and the clear view systems. These panels are to be supplied by two exclusive circuits, one fed from the main source of electrical power and one fed from an emergency source of electrical power. Each item of equipment is to be individually connected to its distribution panel. The power supplies to the distribution panels are to be arranged with automatic changeover facilities between the two sources, *see also* Pt 6, Ch 2,15.7. Failure of any power supply to the distribution panels is to initiate an audible and visual alarm. This alarm should be included in the ship's alarm system, as required by Pt 6, Ch 1,4.2, where applicable.

4.4.2 The watch safety system and the telephone system are to remain operational during blackout conditions.

4.4.3 Following a loss of power which has lasted for 45 seconds or less, all navigation functions are to be readily re-instated. In this respect, all navigational equipment is to recover within five minutes, with minimum operator intervention, by virtue of the emergency source and, where necessary, an uninterruptible power source.

■ *Section 5* Integrated Bridge Navigation System – IBS notation

5.1 General

5.1.1 Where it is proposed that the bridge navigation functions are so arranged as to form an integrated bridge system, the requirements of 5.2 to 5.6 are to be complied with.

5.2 General requirements

5.2.1 For assignment of the notation **IBS**, in addition to satisfying the other requirements of this Section:

(a) the layout of the bridge and the equipment located on the bridge is to satisfy the requirements of a relevant international or national ergonomic or human-centred design Standard or an acceptable equivalent; or

(b) the notation **NAV1** is also to be assigned and the layout of the bridge and the equipment on the bridge are to satisfy the requirements Sections 1 to 4; or

(c) where the bridge is not intended to operate a periodic one man watch, the layout of the bridge and the equipment on the bridge are to satisfy the requirements of Sections 1 to 4, with the exception that the requirements of 4.3 may be relaxed.

5.2.2 Where 5.2.1(a) is applicable, the submissions required by 1.2.1 are to include evidence demonstrating satisfaction of the requirements of an identified relevant Standard.

5.2.3 To satisfy 5.2.2, the evidence submitted is to:

(a) be submitted to LR for assessment, including identification of testing necessary to verify compliance in the submitted test schedules; or

(b) include relevant statutory documentation demonstrating compliance with the relevant identified standard to the satisfaction of the National Administration. Such documentation is to be submitted prior to the assignment of the **IBS** notation. This may necessitate co-ordination of classification and statutory Surveys, particularly for new construction, before the **IBS** notation may be assigned.

5.2.4 Where 5.2.1(c) is applicable, the submissions required by 1.2.1 are to include plans and information for the consideration of LR which demonstrate that the applicable requirements of Sections 1 to 4 have been satisfied.

5.2.5 The design features for computer hardware, local area networks and software required by Pt 6, Ch 1,2.10, 2.11, 2.13 and 2.14 respectively are to be complied with. Alarms and warnings associated with hardware and data communication are to be incorporated in the centralised alarm system required by 4.1.

5.2.6 Failure of a part of the integrated bridge navigation system is not to affect other parts except for those that directly depend upon the information from the defective part. Following such a failure, it is to be possible to operate each other part of the system separately.

5.3 Equipment

5.3.1 Two independent gyrocompasses are to be available to provide heading information to the system. The heading signal from each gyrocompass is to be continuously available for display and for providing input to all relevant items of navigational equipment.

5.3.2 Only one gyrocompass is to be used by the integrated bridge system at any time for main display and control purposes. The navigating officer is to be able to switch between compasses at any time. The non-selected compass is to be used automatically as the independent heading source for the off-course warning required by 3.1.9.

5.3.3 It is to be possible to compare readings from each gyrocompass via the navigation workstation displays.

5.3.4 Automatic comparison between the gyrocompasses is to be provided and an alarm given if the difference between heading signals exceeds a pre-set value.

5.3.5 The capability to receive and utilise differential GPS corrections (or an equivalent) is to be included in the integrated bridge system.

5.3.6 As a minimum, the following information is to be displayed at the navigation workstation via visual display units:

- Steering mode.
- Gyro heading.
- Course to steer.
- Rate of turn.
- Rate of turn order.
- Speed and distance (from log and from GPS).
- Speed order.
- Waypoint bearing, distance and ETA.
- Water depth and alarm setpoint.
- Position fix from each available system.
- Main propulsion and thruster indication, *see* Pt 6, Ch 1,2.6 and Pt 5, Ch 7,5.3.
- Steering indication, *see* Pt 5, Ch 19,5.
- Wind speed and direction.
- Time, *see* 3.2.2.

5.3.7 Additional information such as machinery monitoring, fire detection, cargo control, etc., may also be provided via additional pages on the visual display units.

5.3.8 The centralised alarm system and the watch safety system required by 4.1 and 4.2 respectively are to be incorporated as functions of the integrated bridge system and are to be presented to the navigating officer via the conning display. The presentation and display of alarms and warnings is not to mask, obscure or degrade essential information displayed to aid navigational functions and maintain awareness of the navigational information, *see also* 5.5.

5.3.9 A route planning capability is to be provided by the integrated bridge system. This is to allow a voyage to be pre-planned as a series of waypoints and turn radii. It is to be possible to edit a voyage plan at any time without affecting route control and monitoring.

5.3.10 An automatic track following capability is to be provided in conjunction with the pre-planned route. The position fix used by the system is to be based at least upon GPS or equivalent, and is to be cross-checked by dead-reckoning, based upon speed over ground provided by the ship's log. In areas where differential corrections are available, it is to be possible to utilise these in the track following system.

5.3.11 In the event of failure of the track following capability, the current heading or rate of turn is to be maintained until manually altered by the navigating officer. The quality of position fix input to the system is to be monitored, *see also* 3.1.10 and 4.1.2.

5.3.12 The integrated bridge system is to incorporate a display, which combines simultaneously the ECDIS high resolution colour representation of a nautical chart with a continuously updated record of own ship's position, pre-planned track, and radar targets in the vicinity. The entire tactical situation is to be displayed for the navigating officer in such a way that any risk from approaching, overtaking or crossing vessels may be assessed. Factors affecting the vessel's freedom to manoeuvre, such as water depths, channel boundaries, separation zones and other traffic are to be shown on the display.

5.3.13 The following alarms are to be provided and included in the centralised alarm system specified by 4.1.1:

- Off-track.
- Waypoint approaching, *see* 3.1.10.
- Position fix inaccurate/lost.
- Loss of heading input.
- Loss of log input.
- Equipment or sub-system failure.
- Gyro mis-match.

5.3.14 Manual adjustment of any of the facilities of the integrated bridge system is to reset automatically the watch safety interval timer.

5.4 Operator interface

5.4.1 Integrated display and control functions are to adopt a consistent man-machine interface philosophy and strategy. Particular consideration is to be paid to symbols, colours, controls, and information priorities.

5.4.2 The size, colour and density of text and graphic information displayed on a visual display unit is to be such that it may be read easily from the normal operator position under all operational lighting conditions.

5.4.3 Means are to be provided for the manual adjustment of the brightness of each visual display unit.

5.4.4 All information is to be presented on a background of high contrast, emitting as little light as possible by night.

5.4.5 Paged displays are to be presented in a way which allows the operator to find quickly the information needed. An overview page is to be easily available to remind the operator of the paging system.

5.4.6 Pages are to have a standardised format. Particular types of information and functional areas should be presented in a consistent manner, e.g. in the same position on different pages.

5.4.7 Each page is to have a unique identifying label on the screen.

5.4.8 Keyboards are to be divided logically into areas enabling rapid access to a desired function. Alphanumeric, paging and specific system keys are to be grouped separately and grouping is to be identical at all operator interfaces.

5.4.9 Soft keys may be used for display control and operation of systems non-critical to the safe operation of the vessel, otherwise dedicated controls are to be used.

5.4.10 Functions requested by the operator are to be acknowledged and confirmed by the system on completion.

5.4.11 Interfaces are to incorporate the capability for operators readily to decline or override automatic ship control functions critical to safe operation. *See* Pt 6, Ch 1,1.2.2 regarding submission of information on safety functions and overrides.

5.4.12 Default values, where applicable, are to be indicated by the system when requesting operator input.

5.4.13 If an input error is detected by the system, it is to allow the operator to correct the error immediately.

5.4.14 The system is to require confirmation from the operator for critical actions, e.g. they should not rely on single keystrokes.

5.4.15 Input error messages are to guide the correct responses, e.g.:

use Invalid entry: re-enter set point between 0 and 10

not Invalid entry.

5.4.16 All functions of the integrated bridge system are to remain available in the event of a single failure of an operator interface. This is to be achieved through redundancy in the integrated bridge system interfaces.

5.5 Alarm management

5.5.1 All alarms provided on the bridge are to be included in the centralised alarm system required by 4.1.1.

5.5.2 In general, the alarm system is to be in accordance with Pt 6, Ch 1,2.3, *A.1021(26) Code on Alerts and Indicators, 2009* and MSC.302(87) *Performance Standards for Bridge Alert Management*.

5.5.3 Alarm management on priority and functional levels is to be provided within the integrated bridge system. Alarms and other alerts are to be prioritised according to the urgency and type of response required by the bridge team, as follows:

(a) **Emergency alarms** – alarms which indicate that immediate danger to human life, or to the ship and its machinery exists and that immediate action must be taken.

(b) **Alarms** – conditions requiring immediate attention and action by the bridge team:
- to avoid any kind of hazardous situation and to maintain the safe operation of the ship, including escalation of unacknowledged warnings; or
- alerts which indicate that a caller is in distress or has an urgent message to transmit.

(c) **Warnings** – conditions or situations which require immediate attention for precautionary reasons, to make the bridge team aware of conditions which are not immediately hazardous, but may become so.

(d) **Cautions** – awareness of a condition which still requires attention out of the ordinary consideration of the situation or of given information.

5.5.4 Appropriate alarm management is to be provided. This includes prioritisation, distribution and recording of alarms and other alerts as required.

5.5.5 Within each priority, alerts are to be arranged in groups, in order to reduce the quantity of information presented to the operator. More detailed information on the group alarm is to be readily available from the integrated bridge system on request.

5.5.6 Group alarms may be arranged on the bridge to indicate machinery faults, but alarms associated with faults requiring speed or power reduction or the automatic shutdown of propulsion machinery are to be identified by separate group alarms or by individual alarm parameters.

5.5.7 The following alarms are not to be grouped:
- Emergency alarms.
- Separate group alarms associated with faults requiring speed or power reduction or the automatic shutdown of propulsion machinery.
- Steering gear alarms.
- Navigation light power supply failure alarms, *see* Pt 6, Ch 2,15.6.8.

5.5.8 Alerts are to be displayed in order of priority. Within the priorities, alerts are to be displayed in the order in which they occur. The visual display units are to provide immediate display of new information, regardless of the information display page currently selected. This may be achieved by provision of a dedicated alert monitor, a dedicated area of screen for alerts or other suitable means.

5.5.9 Unacknowledged alarms are to be distinguished by either flashing text or a flashing marker adjacent to the text, and not merely by a change of colour. Acknowledged alarms are to be distinguished by either steady illuminated text or a steady illuminated marker adjacent to the text.

5.5.10 The centralised alarm system is to be capable of displaying at least 20 items simultaneously. There is to be a clear and unambiguous indication that there are additional items requiring attention when the display does not show all active alerts simultaneously, and it is to be possible to display the additional messages and to return to the display containing the highest priority items by single operator actions.

5.5.11 Alerts are to be acknowledged individually. It is to be possible temporarily to silence all audible signals with a single operator action.

5.5.12 The characteristics of audible warning and, where provided, caution signals are to be such that it is possible to differentiate these from audible alarm signals.

5.6 Power supplies

5.6.1 All equipment forming part of the integrated bridge navigation system is to be regarded as navigational equipment and, as such, is to have power supplies in accordance with 4.4.

■ *Section 6* Trials

6.1 General

6.1.1 Before a new installation (or any alteration or addition to an existing installation) is put into service, tests are to be carried out to ensure satisfactory operation of the navigational equipment. These tests are in addition to any acceptance tests which may have been carried out at the manufacturers' works and are based on the approved test schedule as required by 1.2.1.

6.1.2 For **IBS** Notation, testing at the manufacturer's works and trials on board are to be carried out that cover the individual components and their interaction; and the bridge functions and their integration to form the Integrated Bridge System.

6.1.3 Two copies of the test schedule, signed by the Surveyor and Builder, are to be provided on completion of the survey. One copy is to be placed on board the ship and the other submitted to LR.

6.1.4 Acceptance tests and trials for Programmable Electronic Systems are to include verification of software lifecycle activities appropriate to the stage in the system's lifecycle at the time of system examination.

Section

■ *Section 1* General requirements

1.1 General

1.1.1 The requirements of this Chapter apply to ships where the class notation **CRC** 'carriage of refrigerated containers' is requested.

1.1.2 This notation may be applied to any ship which has the ability to carry refrigerated containers. The requirements of this Chapter cover refrigerated containers stowed on deck as well as in a hold space. A descriptive notation may be assigned in addition to the **CRC** notation giving details of electrical power and type of cargo.

1.1.3 The requirements are additional to the classification requirements for ships contained in other applicable parts of the Rules.

1.1.4 Ships which comply with the requirements of this Chapter will be eligible for the applicable class notation specified in Pt 1, Ch 2,2.6.

1.1.5 An example of a typical class notation for a container ship classed with LR, fitted with a ventilation system built under Special Survey and fitted with electrical plug-in points for deck stowed refrigerated containers, would be:

✠ **CRC 230/140** to maintain 230 hold-stowed and 140 deck-stowed refrigerated containers operating at their design condition with a 24 hour average external ambient air temperature of 35°C.

1.1.6 An example of a typical class notation for a reefer ship classed with LR, fitted with electrical plug-in points for deck stowed refrigerated containers, would be:

✠ **CRC -/110** to maintain 110 deck-stowed refrigerated containers operating at their design condition with a 24 hour average external ambient air temperature of 35°C.

1.1.7 In addition to any class notation, an appropriate descriptive notation may be assigned to provide additional information about the ship's ability to carry refrigerated containers.

1.1.8 An example of a typical descriptive notation, which may be assigned in addition to the class notation, would be:

crc 2,800 kW provided with a power generating capacity of 2,800 kW dedicated to supplying the container plug-in points.

crc 60%/40% stowage ratio of 60% deep frozen and 40% chilled cargoes

1.1.9 These Rules do not cover any requirements for alarm and monitoring systems that may be fitted to container refrigeration units.

1.2 Novel arrangement and designs

1.2.1 Where the proposed ventilation arrangement is novel in design, or the ventilation system involves the use of an arrangement different from that specified in the following sections, special tests may be required and a suitable descriptive note may be assigned.

1.2.2 The carriage of refrigerated containers in the hold spaces of ships other than dedicated container ships will be given special consideration. The **CRC** and descriptive notations will be assigned provided that the ventilation system is approved, installed and tested in accordance with the requirements of this Chapter.

1.2.3 Where a dedicated fresh water circulation system is installed to supply cooling water to containers fitted with an optional water cooled condenser, the fresh water system will also need to comply with the relevant Sections of Pt 5, Ch 12 of the Rules.

1.3 Definitions

1.3.1 **Balanced ventilation system** means a ventilation system consisting of a combination of forced draught and induced or natural draught, to produce a pressure condition in the hold space approximately equal to atmospheric pressure.

1.3.2 **Blackout** means that the main and auxiliary machinery installations, including the main power supply, are out of operation but the services for bringing them into operation (e.g. compressed air, starting current from batteries, etc.) are available.

1.3.3 **Container cell** means the position of an individual container. This is usually within a set of vertical cell guides and is normally enclosed by transverse stringers located above and below the container.

1.3.4 **Container electrical power supply** means the generated power supply which is dedicated to supplying the total number of refrigerated containers and the hold ventilation system fan motors.

1.3.5 **Container plug-in point** means an electrical socket located at each applicable container location on deck and each cell location below deck being in accordance with Annex L of ISO 1496-2: 1996.

1.3.6 **Design conditions** means the lowest design internal container temperature and the design maximum hold space temperature.

1.3.7 **Hold space** means an enclosed space containing refrigerated containers. The containers are usually restrained within cell guides. For hatch coverless ships, hold space means the space below the hatch coamings.

1.3.8 **Independent ventilation system** means a ventilation system that is in no way connected to another ventilation system and there is no provision available to allow connection to another ventilation system.

1.3.9 **Refrigerated container** means a standard container with a self-contained refrigeration system, located within the outer dimensions of the container, which can be driven by electrical power fed from an external power supply. The refrigeration system may be either a 'clip-on' or an integral type of cooling unit.

1.3.10 **Stack factor** means the ratio of the actual heat flowing into the containers forming the stack, to the heat which would flow into the same containers if all their surfaces were completely exposed to the hold temperature.

1.3.11 **Standard container** means a forty-foot equivalent unit (FEU) standard production container constructed in compliance with LR's *Container Certification Scheme*, or another recognised Container Certification Scheme in accordance with ISO 1492/2 requirements. The container may be of the normal or 'high-cube' type.

1.3.12 **Stowage ratio** means the proportion of deep-frozen cargo in relation to banana or chilled cargoes. Unless specifically stated, the stowage ratio will be deemed to be 50 per cent deep-frozen and 50 per cent chilled cargo.

1.3.13 **Ventilation system** means a forced ventilation arrangement using mechanical fans to supply and/or extract air from the hold space.

■ *Section 2* **Plans and documentation**

2.1 General

2.1.1 The following plans and information regarding the hold ventilation systems and the electrical supplies to container plug-in points are to be submitted in triplicate for appraisal before construction is commenced:

(a) **Plans of ventilation arrangements**:
- Location and installation details of each hold space ventilation system showing duct arrangement and sizes.
- Details of all mechanical ventilation fans including locations, number, duty at design conditions and power consumption.
- Details of air inlets including number, type, size and locations.
- Details of air outlets including number, type, size and locations.
- Details and locations of dampers and flaps, if applicable.

(b) **Plans of hold spaces**:
- Refrigerated container stowage plans, including sectional elevation and plan views.
- Design pressure or vacuum in each hold space.
- Details of hatch cover sealing arrangements.
- Personnel access arrangements.
- Details and locations of hold temperature measurement sensors.
- Details of any pressure/vacuum safety valves if applicable.

(c) **Ventilation throughput**:
- Specified air throughput rate and proposed method of measurement.
- Design temperature rise in the hold space and corresponding diurnal external ambient air temperature and relative humidity.
- Schematic arrangement of the ventilation system showing proposed air volume and velocity at junctions.

(d) **Plans of deck-stowed containers**:
- Refrigerated container stowage plans, including sectional elevation and plan views.
- Details of access arrangements for maintenance and monitoring of refrigeration units fitted to deck-stowed containers.

(e) **Hull structure**:
- Details of associated openings through the hull structure are to be submitted.

(f) **Electrical**. In addition to the applicable requirements of Pt 6, Ch 2,1.2, the following information and plans specific to the container plug-in points and ventilation system are to be submitted:
- Power supply arrangements to the deck stowed refrigerated containers.
- Power supply arrangements to the hold space stowed refrigerated containers.
- Power supply arrangements to the ventilation system.
- Single-line diagram of the ventilation system. This is to include rating of motors, insulation type, size and current loading of cables and make, type and rating of protective devices.

- A schedule of normal operating loads of the ventilation system estimated for the design conditions expected.

(g) **Control equipment**. In addition to the applicable requirements of Pt 6, Ch 1,1.2, the following information and plans specific to the ventilation system are to be submitted:
- Line diagram of control circuits.
- List of monitored, control and alarm points.
- Locations of control panels and consoles.
- Details of alarm system, including location of control panel and audible and visual warning devices.

(h) **Testing**:
- Details of the testing and commissioning programme, including instrumentation to be used, are to be submitted.

■ *Section 3* Ventilation and hold temperature

3.1 Ventilation system

3.1.1 Means are to be provided to maintain the hold space at an acceptable temperature. This can be achieved by either; the direct removal of the waste heat from the refrigerant equipment of each container, or by the dissipation of the waste heat using large quantities of external ambient air. In each case the system is to be arranged in such a way as to minimise its effect on the hold space temperature. This may be accomplished by the use of a ventilation system of a mechanical supply and/or extract type.

3.1.2 The selection of a maximum allowable hold temperature is to be agreed between the designer and Operator/Owner. Whilst the recommendations given in these Rules do not stipulate a maximum allowable hold temperature, generally it should not exceed 45°C dry bulb. Guidance should be sought from container manufacturers on the maximum allowable ambient air temperature. When determining the maximum allowable hold temperature, the maximum number of refrigerated containers within the hold space, operating at their design condition, is to be taken into consideration.

3.1.3 The ventilation system is to have sufficient capacity to remove or dissipate the heat from each designated refrigerated container cell and maintain the hold temperature at or below the maximum allowable hold temperature.

3.1.4 The volume of air to be supplied or exhausted from a hold space per refrigerated container is at the discretion of the ventilation system designer. For guidance purposes, an indication of the amount of air required for a standard FEU having an air cooled condenser operating at the example notation as stated in 1.1.5 is as follows:

Simple supply only system	90 m^3/min
Supply and exhaust duct system	75 m^3/min
Sealed exhaust system	37 m^3/min

3.1.5 The design of the hold space is to be compatible with the type of ventilation system proposed. For example, for supply and ducted exhaust systems, the semi enclosure of each stringer level may be beneficial. For a simple supply only system the provision of multiple gratings in each stringer level would benefit the free circulation and removal of warm air.

3.1.6 Only container cells served by the ventilation system are to be used for the transportation of refrigerated containers.

3.1.7 The design heat rejection for each container cell and the total hold space heat rejection, including any heat imparted from the ventilation system fans, if applicable, are to be stated. Guidance on heat rejection values which may be used is given below.

3.1.8 The minimum quantity of air supplied or extracted for each container cell and for each hold space is dependent on the type of system proposed and to be stated.

3.1.9 The ventilation system designer is to stipulate the maximum allowable back pressure occurring within the hold space. Due regard needs to be given to this value when selecting the ventilation fans and their ability to operate efficiently again the proposed maximum back pressure. The lower the back pressure, the more efficient the system and, hence, the lower the electrical power requirement to drive the fan motors for a given air throughput.

3.1.10 For supply air systems, the air outlet at each container location is to be such as to provide a flow of air towards the container's integral refrigeration system. Consideration should be given to the use of movable spigot outlets or ducting to allow both standard and high-cube containers to be stowed in any location.

3.1.11 The positions of supply air inlets and exhaust air outlets are to be such as to reduce the possibility of short-cycling. An adequate distance is to be maintained between inlet and outlet vents on the open deck.

3.1.12 The effect of warm exhaust air on deck-stowed refrigerated containers is to be taken into consideration. Similarly, the effect of warm exhaust air from deck-stowed refrigerated containers on the inlet air to the hold is to be considered.

3.1.13 Arrangements are to be provided to permit a rapid shutdown and effective closure of the ventilation system in each hold space in case of fire.

3.1.14 Ventilation ducts which penetrate the deck and/or hatch coaming, including dampers and/or closures, are to be made of steel and their arrangement is to be to the satisfaction of the relevant Administration. The use of non-metallic flexible ducts, local to each container location, will be acceptable provided the material demonstrates suitable low flame spread characteristics.

3.2 Heat balance

3.2.1 The amount of heat absorbed from the hold space by each container, which is used to determine the design air change rate, is to be stated.

3.2.2 The heat gain or loss from all adjacent spaces, such as fuel oil tanks, ballast tanks, engine room, etc., is to be stated.

3.2.3 The heat rejection from the refrigeration unit of a standard TEU or FEU container when working at low temperature (minus 18°C), chill temperature (2°C) and banana carriage temperature (13°C), used to determine the design air change rate, is to be stated. The following FEU values may be used for guidance purposes:

Frozen cargo (minus 18°C/38°C)	7,0 kW
Chill cargo (2°C/38°C)	10,0 kW
Banana cargo (13°C/38°C)	13,0 kW.

3.2.4 The above heat rejection values are for the container during normal operation after the cooling down period of a non-precooled cargo.

3.2.5 The stowage ratio, for the carriage of containers at different internal temperatures, which is used to determine the design air change rate, is to be stated.

3.2.6 When an extraction ventilation system is proposed, a stack factor of 0,9 may be used in the heat balance calculations. If a ventilation system using supply air only is proposed, then no stack factor can be allowed.

3.3 Fan redundancy

3.3.1 A single supply or exhaust fan is not to be used for multiple container stack locations.

3.3.2 Individual container cells may be fed by a system having a single mechanical fan or fans to supply and/or extract air.

3.3.3 Installed standby fans are not required. However, a minimum of one replacement fan, or fan blade assembly and motor, of each size is to be carried onboard. Fans are to be arranged to enable each to be replaced whilst the remaining systems remain in operation.

3.4 Hull structures

3.4.1 Special consideration will be given to installations using hull spaces for air distribution, rather than dedicated ductwork.

3.4.2 Consideration is to be given to measures to prevent ingress of water into air inlets and exhaust outlets, where applicable.

■ *Section 4* Electrical, including container plug-in sockets

4.1 General

4.1.1 In addition to the requirements of Pt 6, Ch 2, the following are to be complied with:

(a) Electrical power for the ventilation system is to be provided by one or more separate feeder circuit(s) from the main switchboard.

(b) Under sea-going conditions, the number and rating of service generators are to be sufficient to supply all container plug-in socket outlets and the hold space ventilation system in addition to the ship's essential services, when any one generating set is out of action.

4.1.2 The choice between a low (440 V) or high (6,600 V) distribution system serving the container plug-in point is considered a purely commercial decision. Consideration needs to be given to the fault level of the generating equipment selected and the total generating capacity of the ship. Independent of the system voltage, only the dedicated plug-in socket outlet kW value will be stated in the notation.

4.1.3 Where a distribution system exceeding 1000 V a.c. is employed, the plug-in socket outlets for each hold space may be fed from a local transformer and the following are to be complied with:

(a) Transformers are to be fed from individual circuits divided between different sections of the main switchboard.

(b) The electrical power for the ventilation system may be fed locally from each transformer.

4.1.4 Container plug-in socket outlets are to comply with the requirements of Pt 6, Ch 2,13.6.

4.2 Plug-in socket outlet supply transformers

4.2.1 A standby transformer serving the container plug-in socket outlets is to be provided. However, if the CRC notation is not assigned, then there is no specific requirement covering the installation of a standby power supply.

4.2.2 If a standby transformer is to be provided, then the exact requirements are open to interpretation and consideration should be given to the contents of IACS Unified Interpretation SC 83 with regard to the equipment provided.

4.3 Container plug-in socket outlets

4.3.1 The distribution and sub-circuit cabling for the container plug-in socket outlets is to be rated at the full load capacity (maximum rated capacity).

4.3.2 Groups of container plug-in socket outlets may be fed from a number of independent sub circuits.

4.3.3 Sub circuits are to be able to be individually switched, thus allowing a sequential start up after a prolonged (12 hours) blackout. A suitable procedure is to be proposed and approved that takes into consideration the requirements of 4.4 in addition to the requirements of Pt 6, Ch 2.

4.4 Generated power for plug-in socket outlets

4.4.1 When determining the dedicated generating power for the plug-in socket outlets, the electrical power drawn by the refrigeration unit of a standard TEU and FEU refrigerated container when working at both low temperature (minus 18°C) and chill temperature (2°C), is to be stated.

4.4.2 The following values for various cargoes operating at normal design conditions may be used for guidance purposes:

4.4.3 Twenty foot equivalent unit (TEU):

Frozen cargo (minus 18°C/38°C)	5,5 kW
Chill cargo (2°C/38°C)	7,5 kW
Banana cargo (13°C/38°C)	*see* 4.4.5

4.4.4 Forty foot equivalent unit (FEU) including high-cube containers:

Frozen cargo (minus 18°C/38°C)	8,5 kW
Chill cargo (2°C/38°C)	11,0 kW
Banana cargo (13°C/38°C)	*see* 4.4.5

4.4.5 If the Owner, charterer or operator has operational data indicating that, for the ship's specific trade (for example banana only cargoes), the power provision for the refrigerated containers requirements exceeds those stated above, then these higher values should be substituted and submitted for consideration.

4.4.6 The above values are for the container during normal operation after the cooling-down period of a non-pre-cooled cargo.

4.4.7 An overall diversity factor may be applied to the container's total power requirement. Consideration is to be given to Pt 6, Ch 2,5.6. This diversity factor is to be applied to all refrigerated container cell locations. For guidance purposes, the diversity factor is not generally to be less than 0,75.

■ *Section 5* Instrumentation, control and alarm systems

5.1 General

5.1.1 The alarm system is to indicate failure of each independent ventilation system in each hold space. If a balanced ventilation system is proposed, indication of failure for each individual part is to be given. The alarm system may be integral with the machinery space alarm system or, if fitted, the refrigerated container monitoring system.

5.1.2 Alarms are to be initiated in a manned location. Where alarms are displayed as group alarms in the main machinery space alarm system, provision is to be made to identify individual alarms at a separate control panel.

5.1.3 Alarms are to give both an audible and visual warning.

5.2 Hold space temperature monitoring

5.2.1 A minimum of two temperature sensors are to be provided in each hold space carrying refrigerated containers. The sensors are to be positioned to give an indication of the mean air temperature occurring in the hold space used for the carriage of refrigerated containers. Sensors are to be positioned so as not to be directly affected by warm air from the condensers.

5.2.2 The hold temperature is to be continually monitored. Temperatures are to be recorded, either automatically or manually as a hold temperature log. If temperatures are to be logged manually, then the mean temperature in each hold space is to be recorded.

5.2.3 If the mean hold space temperature rises above the design maximum, then an alarm is to be initiated.

5.3 Container refrigeration system alarms

5.3.1 These Rules do not cover any requirements for alarm and monitoring systems fitted to containers. It is acceptable to utilise the container power supply cables to transmit signals to a suitable receiver or data logger.

■ *Section 6* Hold access and maintenance access arrangements

6.1 Hold pressure/vacuum

6.1.1 The maximum permitted pressure or vacuum that may occur in the hold space is to be stated. It is proposed that a value, in accordance with the contents of Pt 3, Ch 1,9.6.4, may be considered as a maximum value. An over-pressure of 0,15 bar may be used for guidance purposes. If the ventilation system is capable of producing a positive pressure or vacuum in excess of the design allowable figure, then means are to be provided to protect the hold space against the effect of over pressure or vacuum. If axial supply fans are proposed, even if aerofoil fan blades are fitted, it is unlikely that the fans will be able to produce a pressure above 0,025 bar (250 mm water gauge).

6.1.2 If required, consideration is to be given to the use of a pressure or vacuum relief device or other arrangement set to operate below the maximum allowable hold pressure or vacuum.

6.1.3 The proposed pressure or vacuum relief device for each hold space is to be of adequate size.

6.2 Hold access arrangements

6.2.1 Suitable means are to be provided to allow personnel safe access to each hold space when the ventilation system is in operation. Consideration is to be given to the possible over pressure or partial vacuum that may occur in the hold space. The use of an airlock arrangement may need to be considered.

6.3 Maintenance access arrangements

6.3.1 Free access to each applicable container cell and hold space is to be provided to allow replacement of refrigeration equipment in the event of failure or malfunction.

6.3.2 Adequate access is to be provided to allow plugging in, data recording or retrieval and general maintenance of all deck- and hold-stowed refrigerated containers. Suitable means are to be provided to allow the removal of the compressor and electric motor from each refrigerated container.

6.3.3 Suitable safe access is to be provided to each tier of deck-stowed refrigerated containers to allow electrical connection, monitoring and maintenance. The use of fixed platforms, such as lashing bridges, should be proposed where possible.

■ *Section 7* Water cooler refrigeration units

7.1 Cooling water system

7.1.1 A minimum of two independently operated circulation pumps are to be installed. One of the pumps may be used for other services, such as a general service pump.

7.1.2 The capacity of each pump should be sufficient to supply each container at the required flow rate with an excess capacity of at least 10 per cent. This required flow rate should be obtained from the container manufacturer.

7.1.3 The fresh water system is to provide sufficient flow and even distribution to each container location. This is to be achieved using all possible combinations of fresh water pumps and dedicated refrigerated container cells.

7.1.4 The temperature of the cooling water is to be maintained in accordance with the container manufacturer's recommendations.

7.1.5 Flexible hoses are to be utilised for connecting the water supply and return pipes. The connectors on the ends of the flexible hoses are to be of a type that self-closes on disconnection. Adequate valves are to be provided to allow isolation of each cargo hold sub-circuit in the event of a leak or pipe fracture.

7.1.6 A minimum of two fresh-water to sea-water heat exchangers are to be provided. Each is to be rated at 100 per cent of the required cooling duty at the notation conditions. The second heat exchanger may be a standby or part of a common central system such as that used for main engine cooling duties. The heat exchangers are to be supplied by a minimum of two separate sea-water pumps.

7.1.7 If metal pipes are used, the contents of Pt 5, Ch 12,10.8 are to be given due consideration.

■ *Section 8* Deck-stowed refrigerated containers

8.1 General

8.1.1 Consideration is to be given to the effect of the warm air discharged from the condenser of each deck-stowed refrigerated container. When refrigerated containers are stowed on only two tiers high, it is considered that the warm air from each condenser is dissipated without any undue effect on adjacent containers.

8.1.2 If containers are to be carried three or more tiers high, then consideration is to be given to limiting the effect of short-cycling warm discharge air within the central section of the stack. The proposed method or methods for dealing with this effect are to be stated. Possible options would include reserving the central cells of each stack for non-refrigerated containers, to reduce the block effect or providing fans and ductwork to supply ambient temperature air to the bottom of each vertical stack. Trials of any proposed system are to be undertaken.

8.1.3 Any adverse effect that the warm air discharged from the hold space ventilation system has on the deck stowed refrigerated containers is to be minimised. Similarly, the warm air discharged from the deck stowed refrigerated containers is to be shielded from entering the hold space ventilating system.

Section 9 Inspection and testing on completion

9.1 General

9.1.1 On completion of construction and all appropriate safety checks, the acceptance tests prescribed in 9.2 are to be carried out. Their purpose is to verify the correct functioning of the installation and its ability to maintain the air throughput required for the assignment of the intended class notation.

9.1.2 The proposed test schedules, including methods of testing and details of the test equipment to be provided are to be submitted to LR before the tests commence. The proposed test methods are to be appropriate for the design of the system installed and are to include such acceptance criteria as:

(a) Volume of air to be supplied and/or exhausted at each container cell location.
(b) Maximum allowable deviation from this air volume.
(c) Maximum allowable pressure within the hold space when the system is under normal operating conditions.

9.1.3 Trials of the air distribution system within the hold spaces are to be witnessed by LR surveyors before the ship is put into service and prior to the **CRC** notation certificate being issued. These trials are to be in addition to any tests which may have been carried out whilst commissioning the system.

9.2 Acceptance tests

9.2.1 The acceptance tests (*see also* 9.2.2 and 9.2.3) are to comprise the following:

(a) Control and alarm systems are to be tested to demonstrate that they operate correctly, *see also* Pt 6, Ch 1,2.3.
(b) The accuracy, calibration and functioning of all instrumentation is to be verified.
(c) For supply air systems: Verification of each supply fan's output when running at maximum speed. Verification of the air discharge rate and operation of any distribution arrangements at each individual container cell location. During the test, all supply fans serving the hold space are to be operated simultaneously, thus replicating normal operating conditions. If a common or multiple supply fan distribution system is fitted, then the arrangements are to be verified; firstly, with all supply fans in operation and, secondly, with any one fan out of action.
(d) For exhaust air systems: Verification of each exhaust fan's output when running at maximum speed. The volume of air being extracted from each individual container cell location is to be verified with each exhaust fan running at maximum speed. All exhaust fans serving the same hold space are to be operated simultaneously thus replicating normal operating conditions.
(e) For combined supply and exhaust air systems: Verification of each supply and exhaust fan's output when both are running at maximum speed. The volume of air being supplied and extracted from each individual container cell location is to be verified. All fans serving the same hold space are to be operated simultaneously thus replicating normal operating conditions.
(f) If the supply and/or exhaust ductwork is prefabricated and installed in one piece testing at the manufacturer's works may be accepted provided the following are considered:
    - Any change in the supply and/or exhaust fan(s) output due to differences in electricity supply.
    - Any de-rating of the fan throughput due to a back pressure or partial vacuum occurring within the hold space during normal operating conditions.
    - Verification of the test results is to be undertaken in a single hold space.
(g) Where the air volume required to meet the class notation cannot be verified during testing for practical reasons, assignment of the notation is to be deferred until it is demonstrated that the system is able to achieve the specified air throughput within each hold space during a loaded passage.

9.2.2 Where a number of identical fan and ductwork installations are constructed and fitted within each hold space, the acceptance trials required in 9.2.1 need only be carried out in two separate hold spaces, provided that the results are satisfactory.

9.2.3 Where the same system is installed on a number of identical sister ships for the same Owner and by the same shipyard, the testing in accordance with 9.2.1 will only be required on the first ship of the series, provided that the results are satisfactory.

9.2.4 The effect of exhausting warm hold space ventilation air on the operation of the integral air-cooled condensers of deck stowed containers is to be established under normal operational conditions. The discharge from hold space discharges is to be suitably modified if necessary.

9.3 Testing of cooling water system

9.3.1 Cooling water piping that is welded *in situ* is to be hydraulically strength tested at 1,5 times the design pressure, but in no case less than 3,5 bar g.

9.3.2 A distribution test is to be carried out to ensure that even fresh water distribution to each container as well as sufficient flow is achieved. As the fresh water system may be somewhat complicated, this test should be carried out with care, using all possible combinations of fresh water pumps installed.

9.3.3 If required, the distribution test can be carried out without containers, utilising flexible hoses for connecting the water supply and return pipes together. The return valves should be partly closed or flexible pipe may be crimped to represent the condenser pressure drop. Water flow meters are to be installed at the highest and the lowest container levels to verify equal water flow.

9.3.4 The capacity of each pump should be measured by a flow meter with an accuracy of ±3 per cent. Alternatively, this capacity could be obtained from the manufacturer's curves if the static pressure difference across a pump under test conditions is measured.

9.3.5 Sea-water pumps and heat exchangers are normally subjected to a functional test only.

■ *Section 10*
Spare gear

10.1 General

10.1.1 Adequate spares, together with the tools necessary for maintenance or repair of the ventilation systems are to be carried. The spares are to be determined by the Owner according to the design and intended service.

10.1.2 A minimum of one replacement fan, or complete fan impeller and motor assembly for each size fitted is to be carried onboard.

10.1.3 The maintenance of the spares is the responsibility of the Owner.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter contains requirements for the control of operational pollution.

1.1.2 Compliance with this Chapter is optional. An LR classed ship meeting the requirements of this Chapter will be eligible for **ECO** class notation, which will be recorded in the *Register Book*.

1.1.3 Additional requirements may be imposed by the National Administration with which the ship is registered and/or by the Authority within whose territorial jurisdiction it is intended to operate. Where such additional requirements are relevant to the ship, compliance with those Regulations is the responsibility of the Owner. If specifically requested, Lloyd's Register (hereinafter referred to as 'LR') may provide suitable certification or statement of compliance.

1.1.4 LR is to be advised of any matter that relates to the environmental performance of the ship that would affect the assignment of the **ECO** class notation.

1.2 ECO class notation: minimum requirements and additional characters

1.2.1 Section 2 states the minimum requirements to be met for assignment of the **ECO** notation.

1.2.2 Section 3 contains additional requirements. Ships complying with these requirements will be eligible for one or more of the following associated supplementary characters, as applicable:

A	Anti-fouling coatings.
BIO	Bio-fouling.
BWT	Ballast water treatment.
CRM	Cargo residue minimisation.
EEDI-1, **EEDI-2**, **EEDI-3**	Energy efficiency design index.
SEEMP, **EnMS**	Ship energy efficiency management
GW	Grey water.
IBTS	Integrated Bilge Water Treatment System
IHM	Inventory of hazardous materials.
NOx-1, **NOx-2**, **NOx-3**	Nitrogen Oxides (NO_x) exhaust emissions.
OW	Oily bilge water.
P	Protected oil tanks.
R	Refrigeration systems.
SOx, **DIST**	Sulphur Oxides (SO_x) exhaust emissions.
TC	Enhanced tank cleaning.
VECS-L, **VOC-R**	Vapour emission control systems (tankers only).

1.3 Transfer of class ships

1.3.1 A ship classed with another IACS class society that transfers to LR class will be eligible for the class notation **ECO(TOC)** if it holds the previous society's environmental class notation at the time of the transfer of class. However, ships with **ECO(TOC)** notation are not eligible for any of the supplementary characters listed in 1.2.2.

1.3.2 To maintain the **ECO(TOC)** notation a ship must implement and maintain the operational procedures listed in 1.5.4, as applicable.

1.4 Definitions

1.4.1 The following definitions are applicable:

- **Animal carcasses** means the bodies of any animals that are carried on board as cargo and that die or are euthanised during the voyage.
- **Antifouling Convention** means the International Convention on Control of Harmful Antifouling Systems on Ships. This Convention prohibits the use of organotin anti-fouling systems on ships and was adopted by the International Maritime Organization (IMO) in October 2001.
- **Ballast Water Convention** means the International Convention for the Control and Management of Ships' Ballast Water and Sediments. This international legislation was developed by the IMO to regulate discharges of ballast water and reduce the risk of introducing non-native species from ships' ballast water.
- **Cargo Residues** means the remnants of any cargo which is not covered by other Annexes to MARPOL and which remains on the deck or in holds following loading or unloading, including loading and unloading excess or spillage, whether in wet or dry conditions or entrained in wash water. This does not include cargo dust remaining on the deck after sweeping or dust on the external surfaces of the ship.
- **Cooking oil** means any type of edible oil or animal fat used or intended to be used for the preparation or cooking of food. This does not include the food that is prepared using these oils.
- **Domestic wastes** mean all types of wastes not covered by other Annexes that are generated in the accommodation spaces on board the ship. Domestic waste does not include grey water.
- **Garbage** means all kinds of food wastes, domestic wastes and operational wastes, all plastics, cargo residues, cooking oil, fishing gear, and animal carcasses generated during the normal operation of the ship and is liable to be disposed of continuously or periodically, except where those substances are defined or listed in other Annexes to MARPOL. Garbage does not include fresh fish and parts thereof which are generated as a

result of fishing activities undertaken during the voyage, or as a result of aquaculture activities which involve the transport of fish, including shellfish for placement in the aquaculture facility and the transport of harvested fish, including shellfish from such facilities to shore for processing.

- **Geometric mean** means the *n*th root of the product of *n* numbers.
- **Grey water** is drainage from dishwater, galley sink, shower, laundry, bath and washbasin drains and does not include drainage from toilets, urinals, hospitals, and animal spaces, as defined in Regulation 1.3 of MARPOL Annex IV and does not include drainage from cargo spaces.
- **Incinerator ashes** means ash and clinkers resulting from shipboard incinerators used for the incineration of garbage.
- **Leakage detection system** means a calibrated mechanical, electrical or electronic device for detecting leakage of refrigerant gases which, on detection, alerts the operator.
- **MARPOL** or **MARPOL 73/78** is the International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978.
- **Operational wastes** means all solid wastes (including slurries) not covered by other Annexes that are collected on board during normal maintenance or operations of a ship, or used for cargo stowage and handling. Operational wastes also include cleaning agents and additives contained in the cargo hold and external wash water. Operational wastes do not include grey water, bilge water, or other similar discharges essential to the operation of a ship, taking into account the guidelines developed by the Organisation.
- **Operator** means the natural or legal person exercising actual power over the technical functioning of the equipment and systems.
- **Refrigerant system log book** means a method of maintaining a record of maintenance, calibration, refrigerant charging, leak detection, recovery, etc. The log book may take the form of a stand-alone book, a series of log sheets or form part of the engine room log.
- **SEEMP** means a Ship Energy Efficiency Management Plan, and is a ship-specific manual which aims to improve the energy efficiency of ship operations.
- **Thermotolerant coliforms** is the group of coliform bacteria which produce gas from lactose in 48 hours at 44,5°C. They are also referred to as ‘faecal coliforms’; however, the term ‘thermotolerant coliforms’ is now accepted as more appropriate, since not all of these organisms are of faecal origin.
- **VECS** means vapour emission control system.
- **VOC** means volatile organic compound.

1.5 Information to be submitted

1.5.1 The following are to be submitted:

(a) One copy of every Certificate listed in 1.5.3.
(b) Two copies of the Operational Procedures listed in 1.5.4.
(c) One copy of all plans and information listed in 1.5.5.

1.5.2 For existing ships the certificates, information and plans listed in 1.5.3 to 1.5.5 are to be submitted for approval prior to the **ECO** Initial Survey for assignment of the **ECO** notation, *see* 4.1.1. For new ships, information and plans listed in 1.5.3 and 1.5.5 are to be submitted for approval prior to the **ECO** Initial Survey. However, the operational procedures listed in 1.5.4 may be submitted up to six months after the ship enters into service.

1.5.3 Certificates:

(a) MARPOL certificates or statements on behalf of the ship’s Flag State, including:
- Engine International Air Pollution Prevention (EIAPP) Certificate or Statement of Compliance with the NO_x emission requirements of MARPOL Annex VI for each engine to which Regulation 13 applies;
- International Energy Efficiency Certificate.

(b) Safety Management Certificate (SMC) and Document of Compliance (DOC) in accordance with the International Safety Management Code (ISM Code).
(c) Incinerator Type Approval Certificate or equivalent, as required by 2.9.2.
(d) TBT-free anti-fouling system certificate.
(e) Sewage system and, where fitted, sewage treatment system statement of compliance with the requirements of USCG 33 CFR 159 and/or MARPOL 73/78 Annex IV.
(f) Vapour emission control system certificate or statement of compliance with the requirements of USCG 46 CFR 39 or the IMO Standards for Vapour Emission Control Systems (MSC Circular 585) (oil tankers carrying crude oil only).
(g) VOC reducing device Type Approval Certificate or equivalent as required by (supplementary character **VOC-R**).
(h) ISO 50001 (Energy Management) Certificate, issued by an accredited organisation (supplementary character **EnMS** only).

1.5.4 Operational procedures:

(a) Procedures to be adopted to ensure that the ship’s NO_x certification is maintained.
(b) Oil fuel management for the control of SO_x emissions.
(c) Refrigerant management including adding and recovering refrigerant charge, leak detection and sample log book.
(d) Retention and disposal of spilled or spent foam, chemical or liquid based fire-fighting media, as applicable.
(e) Oil pollution prevention measures.
(f) Garbage management.
(g) Sewage treatment and discharge control.
(h) Precautionary measures to minimise the transfer of non-native organisms in ballast water.
(j) Ballast Water Management Plan (all ships).
(k) Ship Energy Efficiency Management Plan.
(l) Vapour management plan (tankers carrying crude oil only).
(m) Grey water treatment or holding and discharge (supplementary character **GW** only).
(n) Procedures for maintaining the inventory of hazardous materials (supplementary character **IHM** only).

1.5.5 Information and plans:

(a) SERS registration number or statement of membership of alternative scheme from IACS Member service provider.
(b) Details of engine make and model, rated power, rated speed and duty cycle for all installed engines falling within the scope of MARPOL Annex VI, Regulation 13.
(c) Description of the method(s) by which the NO_x certified value has been achieved. The supplementary characters (**NOx-1** and **NOx-2**) and NO_x Technical File for the engine plus NO_x reducing device (**NOx-3** supplementary character). .
(d) Details and location of each permanently installed refrigeration system (including those used for cargo temperature control, air conditioning, provision rooms and chiller units).
(e) Mass of refrigerant charge in each system and the refrigerant designation (e.g., R-134a) in accordance with ISO 817.
(f) Refrigerant plant general arrangement drawing showing number and locations of the refrigerant leak detectors.
(g) Details of fire-extinguishing media to be used in fixed fire-fighting systems and portable extinguishers.
(h) Bilge holding, waste oil and sludge tank capacities and piping arrangements.
(j) Arrangements of non-cargo oil loading and discharge connections together with associated drip trays and drainage systems.
(k) Oil fuel storage, settling and service tank high level alarms/overflow systems.
(l) Cargo and ballast tank arrangements (tankers only).
(m) Cargo and ballast piping system plans, including cargo tank overfill prevention arrangements (tankers only).
(n) Arrangements of tanker cargo manifolds together with associated drip trays and drainage systems.
(o) Details of sewage treatment and handling systems.
(p) Capacity of sewage holding and/or treatment system.
(q) Maximum numbers of crew and passengers.
(r) Details of incinerator arrangements, as applicable, associated piping systems, control and monitoring equipment.
(s) Hull coating system.
(t) Ballast water treatment arrangements, as applicable (for supplementary **BWT** character only).
(u) Energy Efficiency Design Index Statement of Compliance or certificate (supplementary characters **EEDI-1**, **EEDI-2** and **EEDI-3** only).
(v) Details of grey water treatment plant and effluent quality (for supplementary **GW** character only).
(w) Inventory of Hazardous Materials Statement of Compliance.
(x) Arrangements for protected oil tanks (for supplementary **P** character only).
(y) Shadow area diagrams (supplementary character **TC** only).
(z) Details of self-contained vapour recovery systems, where fitted, required for **VOC-R** character; for tankers carrying crude oil as applicable (*see* 2.13.2); and for **VECS-L** character as applicable (*see* 3.16.3).
(aa) LR Statement of SEEMP conformance and associated documentation (supplementary character **SEEMP** only).
(ab) Any information relating to the environmental performance of the ship, which may influence the assignment of the **ECO** notation.

1.6 Alterations and additions

1.6.1 When an alteration, amendment, deletion or addition to the approved arrangements and procedures is proposed, appropriate details are to be submitted for approval.

■ *Section 2*
Minimum requirements

2.1 General

2.1.1 It is a prerequisite for assignment of the **ECO** notation that the ship:

(a) complies with the Anti-fouling Convention, the Ballast Water Convention, except as modified by 2.12.4, and all Annexes to MARPOL 73/78, as amended, applicable to the ship;
(b) has a valid Safety Management Certificate (SMC), in accordance with the ISM Code issued by the Flag State Administration with which the ship is registered or a duly authorised organisation complying with Resolution A.739(18) and authorised by the National Authority with which the ship is registered; and
(c) is enrolled in LR's Ship Emergency Response Service (SERS) or the equivalent scheme of another IACS Member.

2.1.2 Where a ship, by virtue of its gross tonnage, is not required by the MARPOL Convention to have MARPOL Certification, the following are to be maintained:

(a) An Oil Record Book in accordance with MARPOL Annex I.
(b) A garbage management plan and record book in accordance with MARPOL Revised Annex V.

2.1.3 Where a ship, by virtue of its gross tonnage, is not required by the Antifouling Convention to have certification, an antifouling system (AFS) declaration in the format shown in Appendix 2 of Annex 4 to the Convention is to be maintained onboard.

2.1.4 Where a ship, by virtue of its gross tonnage is not required to have a SMC, it is exempt from 2.1.1(b).

2.1.5 High speed craft, as defined in LR's *Rules and Regulations for the Classification of Special Service Craft,* will be the subject of special consideration.

2.1.6 Offshore supply vessels that are less than 100 m in length, as per MSC 235(82), are exempt from the requirement to be enrolled in LR's Ship Emergency Response Service (SERS) or the equivalent scheme of another IACS member.

2.2 Nitrogen oxides (NO_x)

2.2.1 These requirements apply to all installed diesel engines with an individual output power greater than 130 kW, other than those used solely for emergency purposes on the ship on which the engine is installed. There are no specific requirements relating to NO_x emissions from boilers, incinerators or gas turbine installations.

2.2.2 All engines falling within the scope of MARPOL Annex VI, Regulation 13 are to comply with its provisions and meet the NO_x emission limits applicable to the date of constr uction of the ship or, where relevant, the engine installation date.

2.2.3 **EIAPP** certification or Statement of Compliance is to be issued by, or on behalf of, the Flag State.

2.2.4 Alternative arrangements providing an equivalent level of environmental protection will be considered.

2.3 Sulphur oxides (SO_x)

2.3.1 Emissions of SO_x are to be controlled by limiting the sulphur content of oil fuels used on board.

2.3.2 The maximum sulphur content of oil fuel to be used on board is not to exceed 3,00 per cent m/m.

2.3.3 Where the grade of fuel normally used cannot be obtained with the appropriate fuel sulphur level, then a better grade of fuel meeting this requirement will need to be purchased.

2.3.4 An oil fuel management system is to detail the maximum sulphur content to be specified when ordering oil fuels and the means adopted to verify that the sulphur content of oil fuels supplied meets that requirement. This management system is to include the practices to be adopted to ensure that appropriate low sulphur oil fuels are used when the ship is within IMO designated 'Emission Control Areas established for SO_x and particulate matter control' and/or the jurisdiction of other local, national or regional 'SO_x Emission Control regimes' as applicable.

2.3.5 Where testing to determine the sulphur content of fuel received on board is to be carried out, a representative sample is to be drawn at the time of delivery from the ship's bunker manifold using the manual or automatic sampling methods defined in ISO 3170 or 3171, or their national respective equivalents. Fuel sulphur content is to be subsequently determined using the laboratory test method ISO 8754-2003: *Determination of sulphur content – Energy-dispersive X-ray fluorescence spectrometry*.

2.3.6 Alternative arrangements providing an equivalent level of environmental protection will be considered. If an exhaust gas cleaning system is fitted, it is to be certified to MPEC.184(59).

2.4 Energy management

2.4.1 A Ship Energy Efficiency Management Plan (SEEMP) is to be retained on board according to the provisions of Regulation 22 of MARPOL Annex VI and subsequently be reviewed by LR.

2.4.2 The SEEMP is to be developed in accordance with MEPC.213(63) *Guidelines for the Development of a Ship Energy Efficiency Management Plan (SEEMP)*.

2.5 Refrigeration systems

2.5.1 These requirements apply to all permanently installed refrigeration and air conditioning installations on board. These requirements do not apply to stand-alone refrigerators, freezers and ice makers used in galleys, pantries, bars and crew accommodation.

2.5.2 The use of chlorofluorocarbons (CFCs) in existing, and hydrochlorofluorocarbons (HCFCs) in new, refrigeration or air conditioning installations is prohibited.

2.5.3 If halocarbon refrigerants are used, they are to have an Ozone Depleting Potential (ODP) rating of zero and a Global Warming Potential (GWP) of less than 1950, based on a 100-year time horizon.

2.5.4 Systems are to be arranged with suitable means of isolation so that maintenance, servicing or repair work may be undertaken without releasing the refrigerant charge into the atmosphere. Unavoidable minimal releases are acceptable when using recovery units.

2.5.5 For the purposes of refrigerant recovery, the compressors are to be capable of evacuating a system charge into a liquid receiver. Additionally, recovery units are to be provided to evacuate a system either into the existing liquid receiver or into cylinders dedicated for this purpose. The number of cylinders is to be sufficient to contain the complete charge between points of isolation in the system.

2.5.6 Where different refrigerants are in use they are not to be mixed during evacuation of systems.

2.5.7 Refrigerant leakage is to be minimised by leak prevention and periodic leak detection procedures. The frequency of leak detection and the maximum allowable annual leakage rate is dependent on the charge of each system and is specified in Table 11.2.1.

Table 11.2.1 Refrigerant leak testing – maximum periodicity

Charge size	Periodicity	Leakage
under 3 kg	6 months	10%
3–30 kg	3 months	10%
30–300 kg	Monthly	5%
Over 300 kg	Monthly	<3%

2.5.8 Records are to be maintained demonstrating that leak testing is carried out in accordance with the periodicity specified in Table 11.2.1 by qualified personnel holding relevant certification, using either direct or indirect measuring methods and calibrated instruments where applicable.

2.5.9 A leak detection system appropriate to the refrigerant is to be provided to monitor continuously the spaces into which the refrigerant could leak. An alarm is to be activated to give warning in a permanently manned location when the concentration of refrigerant in the space exceeds a predetermined limit, (25 ppm for ammonia; 300 ppm for halogenated fluorocarbons). Remedial measures to repair the leakage are to be implemented as soon as practicable after an alarm is activated. Each leak detection system is to be checked at least once every 12 months to ensure proper functionality. The system is to be maintained and calibrated in accordance with the manufacturer's recommendations and recorded in the log book.

2.5.10 Procedures for refrigerant management including adding and recovering refrigerant charge, leak detection and the means adopted to control the loss and leakage of refrigerants are to be established and implemented.

2.5.11 Refrigerant inventory and log book records are to be maintained covering:
(a) Refrigerant added to each system.
(b) Refrigerant leaks, including remedial actions.
(c) Refrigerant recovered and storage location.
(d) Refrigerant disposal including quantity and location.
(e) Details of personnel suitably experienced or with an applicable qualification for maintenance of the onboard refrigerant system(s), including relevant certification.

2.5.12 After a leak has been identified, repaired and recorded it is to be rechecked prior to the system entering normal service. All applications, independent of charge size, are to be checked for leakage within one month after a leak has been repaired to ensure that the repair remains effective.

2.5.13 Records demonstrating the implementation of the operational procedures specified in 2.5.10, as applicable, are to be maintained. These records are to be kept on board for a minimum period of three years, in a readily accessible form, and are to be available for inspection by LR Surveyors, as required.

2.5.14 A refrigerant log book is to be maintained for the lifetime of the system. It must record the quantity and type of refrigerant installed and the quantities added and recovered during servicing, maintenance and final disposal.

2.5.15 All personnel involved in the following activities must be suitably experienced or possess an applicable qualification:
(a) installation, servicing or maintenance of the refrigeration equipment covered by the **ECO** Notation;
(b) checking such equipment for any leakages of refrigerant gases; or
(c) repairing, or carrying out work to prevent, such leakages.

2.6 Fire-fighting systems

2.6.1 The use of halon or halo-carbons as the fire-extinguishing medium in fixed fire-fighting systems or portable extinguishers is not permitted.

2.6.2 Where foam concentrates or other chemical or liquid based fire-fighting media with the potential to cause environmental pollution are used, instructions and procedures are to be provided for the safe containment and disposal of spilled media and other contaminated products during routine maintenance and, where practicable, following emergency use.

2.7 Oil pollution prevention

2.7.1 All ships are to comply with the requirements of 2.7.2 to 2.7.12. In addition, tankers are to comply with the requirements of 2.8.

2.7.2 Drainage from machinery space bilges is to be discharged to sea in accordance with the requirements of MARPOL 73/78, Annex I or retained onboard for discharge ashore.

2.7.3 The oil-in-water content of the water discharged is to be less than 15 ppm. Oily bilge water is to be discharged through approved oil filtering equipment and a 15 ppm alarm combined with a device for automatically stopping any discharge to sea when the oil content in the discharge exceeds 15 ppm. Full records of all discharges are to be kept.

2.7.4 The loading or discharge connections and vent pipes/overflows associated with oil fuels, lubricating oils, hydraulic oils and other oils are to be fitted with drip trays. Drip trays fitted to loading or discharge connections are to be fitted with closed drainage systems except on tankers where alternative arrangements will be considered.

2.7.5 Oil fuel storage, settling and service tanks are to be fitted with high level alarms and/or acceptable overflow systems.

2.7.6 The tank arrangement and engine room management procedures are to ensure that any leakages and waste oil from machinery and equipment are collected prior to disposal ashore or incineration. At all times, there is to be sufficient capacity to store a complete lubricating oil charge from the largest engine used for propulsion or electrical generating purposes. The tank arrangement is to allow the lubricating oil charge subsequently to be renovated or to be discharged ashore.

2.7.7 For those ships which only operate on distillate fuel, the tank arrangements in 2.7.6 and sludge tanks may be combined to form a single tank. Where such a combined tank is fitted, the total capacity is to be equal to or greater than the aggregated total of the required individual tank capacities.

2.7.8 The bilge holding tank, the tank arrangements in 2.7.6 and the sludge tank are to be arranged to facilitate the periodic removal of accumulated sediments and other material.

2.7.9 Discharge piping systems to deck from the bilge holding tank, and the tank arrangements in 2.7.6, are to be separate from the oil fuel loading and transfer systems. Their piping systems are to be terminated with the standard discharge connections specified in MARPOL Annex I, Regulation 13.

2.7.10 Means are to be provided for the collection and recovery of any oil spilled on decks.

2.7.11 For ships delivered after 1 August 2010, fuel oil tanks with a capacity of greater than 60 m^3, except overflow tanks, are to be located in a protected location away from the ship's side or bottom shell plating. Tanks are to be located in accordance with the requirements relating to fuel oil tank protection given in MARPOL Annex I, Regulation 12A.

2.7.12 Procedures covering the handling of all oils and oily wastes are to be established and implemented. As a minimum, these are to cover:

(a) loading, storage and transfer of oil fuels, lubricants, hydraulic oil, thermal heating oil and drummed oil products;
(b) storage, transfer, discharge and disposal of oily mixtures contained in the ship's sludge, bilge holding and waste oil tanks and machinery space bilges;
(c) recovery of any oil spilled on decks.

2.8 Arrangements on ships carrying oil cargoes in bulk

2.8.1 The constructional requirements of MARPOL Annex I, Regulations 19 and 20 as applicable, are to apply to all oil tankers greater than 600 tonnes deadweight.

2.8.2 Cargo tanks are to be fitted with high level alarms and/or acceptable overflow systems.

2.8.3 The cargo area is to have arrangements to collect accidental outflow of oil under overfilling conditions. Accidental oil spills are to be discharged to a slop tank or collecting tank. These tanks are not be located in the double hull space.

2.8.4 Cargo tank ballasting arrangements and segregated ballast systems are to be connected to separate and distinct sea chests.

2.8.5 A non-return valve is to be provided to isolate the cargo piping system from the sea connections.

2.8.6 Cargo manifold connections are to be fitted with drip trays with closed drainage systems.

2.8.7 Cargo manifold terminal pieces are to be designed, where practicable, in accordance with the relevant Oil Companies International Marine Forum (OCIMF) Recommendations for tanker manifolds and associated equipment.

2.8.8 Procedures covering ship to ship transfer of bulk liquid cargoes are to be established for ships engaged in the transfer of oil cargo at sea (STS Operations as defined in MARPOL Annex 1 Ch 8 Regulations 40, 41 and 42). These are to be agreed with LR, and implemented.

2.9 Garbage handling and disposal

2.9.1 A garbage management plan, developed in accordance with IMO Resolution MEPC 201(62), is to be available and implemented. This plan, *inter alia*, shall include:

(a) identification of the sources of garbage;
(b) means of minimising garbage production;
(c) procedures for the safe and hygienic collection, segregation, storing, processing and disposal of garbage, including the use of the equipment (compactors, comminuters, incinerators or other devices) on board. These procedures are to cover all garbage generated during the normal operation of the ship. The disposal of the following materials is to be specifically covered:
    - Cargo residues.
    - Cargo associated wastes.
    - Waste oil.
    - Paint and painting materials.
    - Medical wastes.
    - Large metal objects such as oil drums and machinery components.
    - Ropes: metal, synthetic or natural fibre.
    - Rust/scale debris.
    - Ballast tank sediments.
    - Equipment containing refrigerants.
    - Plastic.
    - Food waste.
    - Cooking oil.
    - Domestic waste.
    - Fishing gear.
    - Operational waste.
    - Incinerator ashes.
    - Animal carcasses.

2.9.2 Where fitted, incinerators are to be designed and constructed in accordance with the requirements of IMO Resolution MEPC 76(40). A type approval certificate issued by LR, another IACS Member or the relevant Flag State Administration is to be provided. As an alternative, a Declaration of Conformity issued under the EU Marine Equipment Directive is acceptable.

2.9.3 Where incineration is to be carried out, procedures are to be developed and implemented, covering:

(a) operation, documentation and training in accordance with the requirements of MARPOL Annex VI, Regulation 16, irrespective of ship construction or incinerator installation date; and
(b) prevention of incineration within areas where incineration is prohibited by the Coastal State Administration.

2.9.4 Cargo residues are included in the definition of garbage within the meaning of revised Annex V, Regulation 1.9 and may be discharged in accordance with Regulations 4.1.3 and 6.1.2. However, cargo material contained in the cargo hold bilge water should not be treated as cargo residues if the cargo material is not harmful to the marine environment and the bilge water is discharged from a loaded hold through the ship's fixed piping bilge drainage system.

2.9.5 The discharge of cargo residues is to be based on the physical, chemical and biological properties of the substances and may require special handling not normally provided by reception facilities, although ports receiving such cargoes should have adequate reception facilities for all relevant residues, including when entrained in wash water.

2.10 Sewage treatment

2.10.1 Where fitted, the sewage treatment system is to be approved in accordance with MEPC Resolution 159(55). As an alternative, a Declaration of Conformity issued under the EU Marine Equipment Directive is acceptable.

2.10.2 The capacity of the sewage treatment system, is to be sufficient for the maximum number of persons on board. Where 'black water' only is treated, the minimum capacity is to be 115 litres/person/day for a conventional flushing system or 15 litres/person/day for a vacuum system. Where both 'black water' and 'grey water' are treated, an additional allowance of 300 litres per person, per day (made up from 85 litres of galley grey water, 40 litres of laundry grey water and 175 litres of cabin and domestic grey water) is to be made.

2.10.3 Procedures for the operation of a sewage treatment system, including the certification of performance, are to be established and implemented. Records are to be maintained of maintenance, repair, remedial work and disinfectant dosing rates.

2.10.4 The manufacturer's restriction on materials, which may be disposed of through the sewage treatment system, are to be clearly displayed at each input point.

2.10.5 The disinfectant dosing points of the sewage treatment system are to be readily accessible. Ready access is also to be provided for the taking of samples.

2.10.6 As an alternative to treatment, sewage and/or grey water may be retained on board. The sewage holding tank(s) and grey water holding tank(s) are to be of adequate capacity, taking into account the operation of the ship, the number of persons on board and other relevant factors (*see* guidance figures in 2.10.2). The tank is to be fitted with a visual contents gauge and a high level alarm.

2.10.7 Means are to be provided to aerate holding tanks to prevent the development of anaerobic conditions, taking into account MSC Circular 648.

2.10.8 Records are to be maintained detailing discharges from the holding tank. These are to include:

(a) the date, location and quantity of sewage discharged from the holding tank either ashore or at sea in accordance with MEPC Resolution.157(55);
(b) rate of discharge of raw sewage;
(c) distance from land and ship's speed, when sewage is discharged to sea.

2.10.9 Ventilation pipes from the sewage system are to be independent of other vent systems.

2.10.10 A suitable piping system from the sewage treatment system or holding tank is to be provided to allow discharge from the system/tank to shore reception facilities. The systems discharge pipe is to terminate with a standard discharge connection complying with the requirements of MARPOL Annex IV, Regulation 10.

2.10.11 Procedures for the cleaning and safe entry of sewage treatment systems and holding tanks, including the use of suitable personal protective equipment, are to be provided and implemented.

2.11 Hull anti-fouling systems

2.11.1 The application of anti-fouling systems containing TBT above the level specified in the Antifouling Convention is prohibited.

2.12 Ballast water

2.12.1 All ships carrying ballast water, to which the Ballast Water Convention applies, are to have on board, and to implement, a ballast water management plan approved by LR or by another IACS member.

2.12.2 The ballast water management plan is to meet the requirements of Regulation B-1 of the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 and encompass the recommendations in IMO Resolution MEPC 127(53).

2.12.3 For new ships intending to undertake ballast water exchange, the guidance on ballast water exchange design and construction standards within IMO Resolution MEPC 149(55) is to be taken account of, as far as practicable.

2.12.4 A ship should carry out ballast water exchange in accordance with the convention; however, a ballast water treatment system is not required to be installed and used until such time as required by Regulation B-3 of the Convention and the Convention has entered into force.

2.12.5 A ballast water record book is to be kept on board and is to be used to record all ballast water operations.

2.13 VOC management

2.13.1 Tankers carrying crude oil are required to develop and implement a VOC Management Plan in accordance with IMO Guidelines for the Development of a Volatile Organic Compound (VOC) Management Plan for tankers carrying crude oil (Resolution MEPC.185(59)) that has been approved by LR or by, or on behalf of, the ship's Flag State.

2.13.2 For all tankers carrying crude oil, a Vapour Emission Control System is to be fitted which has been designed and constructed in accordance with the requirements of USCG 46, CFR 39 or the IMO Standards for Vapour Emission Control Systems (MSC Circular 585). A Certificate or Statement of Compliance issued by LR or a competent Authority recognised by LR is to be provided. As an alternative, a self-contained Vapour Recovery System, which is of a type approved by LR and which achieves equivalent performance to the systems above, may be fitted.

■ *Section 3*
Supplementary characters

3.1 Hull anti-fouling systems – A character

3.1.1 For assignment of the **A** character, the anti-fouling system applied to the ship's hull is to be listed as biocide-free in the Lloyd's Register List of Approved Products.

3.2 Bio-fouling – BIO character

3.2.1 For the assignment of the **BIO** character, the ship is to have in place bio-fouling management plans, developed in accordance with IMO Resolution MEPC.207(62): 2011 *Guidelines for the Control and Management of Ship's Biofouling to Minimise the Transfer of Invasive Aquatic Species*. In addition, the Bio-fouling Management Plan is to be reviewed by LR for conformance with MEPC.207(62).

3.2.2 The ship is also to have on board a Bio-fouling Record Book in the format shown in Appendix 32 of MEPC.207(62) that contains at least the following:

- Details of the anti-fouling systems and operational practices used (where appropriate, as recorded in the Anti-fouling System Certificate), where and when it was installed, areas of the ship that are coated, its maintenance and, where applicable, its operation; dates and location of dry-dockings/slippings, including the date the ship was refloated, and any measures taken to remove bio-fouling or to renew or repair the anti-fouling system;
- The date and location of in-water inspections, the results of those inspections and any corrective action taken to deal with observed bio-fouling;
- The dates and details of inspection and maintenance of internal sea-water cooling systems, the results of those inspections, and any corrective action taken to deal with observed bio-fouling and any reported blockages; and
- Details of when the ship has been operating outside its normal operating profile, including any details of when the ship was laid-up or inactive for extended periods of time.

3.3 Ballast water treatment – BWT characters

3.3.1 Where a ballast water treatment system is installed, the character **BWT** will be assigned, provided that the treatment system is installed, utilised and approved in accordance with MEPC 174(58) or MEPC.125(53).

3.3.2 As an alternative to a system approved in accordance with MEPC.174(58) or MEPC.125(53), a system meeting the requirements of Regulation D-4 *Prototype Ballast Water Treatment Technologies* of the BWM Convention will be accepted.

3.3.3 A ballast water record book for the purpose of recording all ballast water operations and use of the treatment system is to be available on board and maintained.

3.3.4 New ships are to take account of the guidance on design and construction to facilitate sediment control within IMO Resolutions MEPC 150(55) and MEPC 206(62), as far as is practicable.

3.4 Cargo residue minimisation – CRM character

3.4.1 For assignment of the **CRM** character, cargo residue is to be minimised.

3.4.2 In accordance with MARPOL Annex II, Resolution 12.3, individual cargo tanks are not to retain more than 60 litres of residue in the tank and associated piping.

3.4.3 A performance test is to be conducted in accordance with appendix 5 of MARPOL Annex II and a record of the test results retained on board.

3.5 Energy Efficiency Design Index – EEDI-1, EEDI-2, EEDI-3 characters

3.5.1 For assignment of the **EEDI-1**, **EEDI-2** and **EEDI-3** characters, the 'attained' EEDI must be equal to or less than the applicable reference line.

3.5.2 The 'attained' Energy Efficiency Design Index is to be established in accordance with the 2012 Guidelines on the method of calculation of attained EEDI for new ships (MEPC.203(62)) and verified in accordance with LR's procedure for verifying EEDI values.

3.5.3 For ships constructed before 1 January 2015, the **EEDI-1** character will be assigned when the 'attained' EEDI is less than or equal to the EEDI Phase 1 requirement (i.e., 10 per cent less than the applicable reference line).

3.5.4 For ships constructed before 1 January 2020, the **EEDI-2** character will be assigned when the 'attained' EEDI is less than or equal to the EEDI Phase 2 requirement (i.e., 15 per cent less than the applicable reference line for general cargo ships and refrigerated cargo ships or 20 per cent less than the applicable reference line for other ship types).

3.5.5 For ships constructed before 1 January 2025, the **EEDI-3** character will be assigned when the 'attained' EEDI is less than or equal to the EEDI Phase 3 requirement (i.e., 30 per cent less than the applicable reference line).

3.6 Energy management – SEEMP and EnMS characters

3.6.1 For assignment of the **SEEMP** character, and in addition to the requirements specified in 2.4, a SEEMP is to be reviewed by LR to check that it is in alignment with the IMO *Guidelines for the Development of a Ship Energy Efficiency Management Plan (SEEMP)* (MEPC.213(63) and reflects industry guidelines as applicable. This is to be demonstrated by the LR SEEMP Statement of Conformance and associated documentation.

3.6.2 For the assignment of the **EnMS** character, certification under ISO 50001 (Energy Management) is to be issued by an accredited organisation and is to be applicable to the management and operation of the ship.

3.7 Integrated bilge water treatment system – IBTS character

3.7.1 These requirements apply to ships with an integrated bilge water system.

3.7.2 For assignment of the **IBTS** character, the ship is to have an integrated bilge water system designed and installed to meet the requirements of the *Revised Guidelines for Systems for Handling Oily Wastes in Machinery Spaces of Ships* and incorporating *Guidance Notes for an Integrated Bilge Water Treatment System (IBTS)* – (12 November 2008) contained in MEPC.1/Circ.642 & 643 as amended by MEPC.1/Circ. 676 & 760.

3.7.3 Ships are to have on board a Statement of Fact on Installation of an Integrated Bilge Water Treatment System (IBTS), issued by LR.

3.8 Grey water – GW character

3.8.1 For assignment of the **GW** character where a plant for the treatment of grey water is installed, the plant discharge effluent is to meet the standards specified in 3.8.2 or 3.8.3, as applicable. The **GW** character will also be assigned where grey water is retained onboard in dedicated holding tank(s) for discharge ashore, subject to the requirements specified in 3.8.4 to 3.8.9 being met.

3.8.2 Where it is not intended that the effluent is recycled or re-used for any purpose, the effluent of the grey water treatment plant is to meet the following standards:

(a) Thermotolerant coliforms:
The geometric mean of the thermotolerant coliform count of samples of effluent taken during a test period is not to exceed 100 thermotolerant coliforms/100 ml as determined by membrane filter, multiple tube fermentation or an equivalent analytical procedure.

(b) Total suspended solids:
- Where the equipment is tested onshore, the geometric mean of the total suspended solids content of the samples of effluent taken during the test period is not to exceed 35 mg/l.
- Where the equipment is tested onboard the ship, the geometric mean of the total suspended solids content of the samples of effluent taken during the test period is not to exceed the suspended solids content of the ambient (flushing) water used onboard plus 35 mg/l.
- The method of testing is to be as given in Resolution MEPC.159(55).

(c) Biochemical Oxygen Demand (BOD_5) and chemical oxygen demand (COD):
- The geometric mean of a 5-day Biochemical Oxygen Demand (BOD_5) is not to exceed 25 mg/l. The chemical oxygen demand (COD) is not to exceed 125 mg/l. Test methods are to be ISO 15705:2002 for COD and ISO 5815-1:2003 for carbonaceous BOD_5 or other internationally accepted equivalent test standards.

(d) pH: The pH of the samples of effluent taken during the test period is to be between 6 and 8,5.

(e) Zero or non-detected values: For thermotolerant coliforms, zero values are to be replaced with a value of 1 thermotolerant coliform/100 ml to allow the calculation of the geometric mean. For total suspended solids, BOD_5 and COD values below the limit of detection are to be replaced with one half the limit of detection to allow the calculation of the geometric mean.

3.8.3 Where it is intended that the effluent of the grey water treatment plant is to be re-used or recycled for any purpose, the effluent is to meet the potable water quality standards of the Flag or Port State Administration, as appropriate.

3.8.4 As an alternative to treatment, where grey water is retained onboard in dedicated holding tank(s) for discharge ashore the holding tank(s) is to be of adequate capacity taking into account the operation of the ship, the number of persons on board and other relevant factors. Each tank is to be fitted with a means to open the tank, means to verify visually the contents of the tank and a high level alarm. *See* 2.11.2.

3.8.5 Means are to be provided to aerate the tanks to prevent the development of anaerobic conditions, taking into account IMO MSC/Circ.648 *Guidelines for the Operation, Inspection and Maintenance of Ship Sewage Systems*.

3.8.6 Ventilation pipes from the grey water treatment system and, where provided, from holding tank(s) are to be independent of other ventilation systems.

3.8.7 A suitable piping system from the grey water treatment system or holding tank(s) is to be provided to allow discharge to shore reception facilities. The discharge pipe is to terminate with a standard discharge connection complying with the requirements of MARPOL Annex IV, Regulation 10. Any connection from the grey water system to the sewage discharge is to be via a screw down non-return valve.

3.8.8 Records of grey water treatment and/or discharge are to be maintained. A single record book may be utilised for both grey water and sewage records. Records detailing discharges from the holding tank(s) are to include:

(a) the date, location and quantity of grey water discharged from the holding tank(s) either ashore or at sea;
(b) rate of discharge of untreated grey water;
(c) distance from land and ship's speed, when untreated grey water is discharged to sea.

3.8.9 Procedures for the cleaning and safe entry of grey water treatment systems and holding tanks, including the use of suitable personal protective equipment, are to be provided and implemented.

3.9 Inventory of hazardous materials – IHM character

3.9.1 For assignment of the IHM character, the ship is to possess an inventory of hazardous materials in compliance with Regulation 5 of the *Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships*.

3.9.2 The inventory is to be independently verified by LR.

3.9.3 Procedures covering maintenance of the inventory of hazardous materials throughout the ship's life are to be established and implemented. The procedures are to address, *inter alia*, new installations containing hazardous materials specified in appendices 1 and 2 of the *Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships* and relevant changes in the ship's structure and equipment.

3.10 Nitrogen oxides – NOx-1, NOx-2, NOx-3 characters

3.10.1 For assignment of the **NOx-1** or **NOx-2** character, the total weighted value of NO_x emissions from all installed diesel engines defined within 2.2.1 is not to exceed 80 per cent of the total weighted NO_x emission limits specified in MARPOL Annex VI, Regulation 13.

3.10.2 The total weighted emission value for the ship (*WV*) is to be calculated as follows:

$$WV_{[ship]} = \frac{WAEV_{[cert]}}{WAEV_{[IMO]}}$$

where

$$WAEV_{[cert]} = \frac{\sum_{n=1}^{n} (NO_{x[cert]}.P}{\sum_{n=1}^{n} (P)}$$

$$WAEV_{[IMO]} = \frac{\sum_{n=1}^{n} (NO_{x[IMO]}.P}{\sum_{n=1}^{n} (P)}$$

n = the number of individual engines on board the ship
P = the rated power, in kW, of each individual installed engine
$NO_{x[cert]}$ = the certified NO_x emission value, in g/kWh, for each individual engine
$NO_{x[IMO]}$ = the NO_x emission limit value of each individual engine, in g/kWh, applicable at the date of construction of the ship, or installation date of the engine, as applicable, as specified in Regulation 13 of Annex VI to MARPOL.

3.10.3 For ships constructed before 1 January 2011, the **NOx-1** character will be assigned when:

$$\frac{WAEV_{[cert]}}{WAEV_{[IMO]}} \leq 0{,}80$$

For ships constructed on or after 1 January 2011, the **NOx-2** character will be assigned when:

$$\frac{WAEV_{[cert]}}{WAEV_{[IMO]}} \leq 0{,}80$$

3.10.4 For assignment of the **NOx-3** character, engines, as defined in 2.2.1, and any associated NO_x emission abatement systems are to be certified as meeting the Tier 3 NO_x emission limits specified in MARPOL Annex VI, Regulation 13.5.1.1.

3.10.5 Equipment and systems used to control NO_x emission levels are to:

(a) be arranged so that failure will not prevent continued safe operation of the engine;
(b) be operated in accordance with manufacturer's instructions;
(c) be designed, constructed and installed to ensure structure integrity and freedom from significant vibration;
(d) be designed to include adequate hatches for inspection and maintenance purposes; and
(e) be instrumented to record operation. Records of operation and the degree of control are to be maintained.

Alternative control arrangements will be given special consideration.

3.10.6 Procedures covering the use and maintenance of the equipment and systems used to control NO_x are to be established and implemented. Records are to be maintained which demonstrate the operation of the equipment and systems and the resultant level of NO_x emissions to the atmosphere.

3.10.7 Where engines constructed before 1 January 2000 are not certified in accordance with MARPOL Annex VI, the test procedure and measurement method are to be in accordance with either the Simplified Measurement Method or Direct Measurement and Monitoring Method given in Chapter 6 of the IMO NO_x Technical Code 2008.

3.10.8 Where engines are constructed on or after 1 January 2000, the NO_x emission value is to be established in accordance with the NO_x Technical Code 2000.

3.10.9 In the case where the individual engines are 'family' or 'group' engines, as defined in the NO_x Technical Code, the respective certified emission value is to be taken as that of the relevant Parent Engine.

3.11 Oily bilge water – OW character

3.11.1 For assignment of the **OW** character, all drainage from machinery space bilges is to be discharged ashore, except under exceptional circumstances.

3.11.2 Adequate capacity for storage of oily bilge water between discharges ashore is to be provided.

3.11.3 Alternatively, discharge to sea is permitted where it can be demonstrated that the oil-in-water content of the water discharged is less than 5 ppm.

3.11.4 The bilge alarm, set at 5 ppm, is to be recalibrated or retested every five years by the manufacturer or other acceptable alternative and full records of the recalibration or retesting are to be kept on board.

3.11.5 Full records of all discharges are to be kept.

3.12 Protected oil tanks – P character

3.12.1 For assignment of the **P** character, in addition to compliance with the requirements of 2.8.11, all oil fuel, lubricating oil and hydraulic oil tanks are to be located in a protected location away from the ship's side or bottom shell plating.

3.12.2 Oil fuel, lubricating oil and hydraulic oil tanks are to be located in accordance with the requirements relating to fuel oil tank protection given in MARPOL Annex I, Regulation 12A, paragraphs 6, 7 and 8. The performance standard specified in paragraph 11 of Regulation 12A will not be accepted.

3.12.3 Main engine lubricating oil drain tanks and fuel overflow tanks are excluded.

3.12.4 Arrangements providing equivalent protection will be given special consideration.

3.12.5 Suction wells may protrude below oil fuel tanks provided they are as small as possible and the distance between the tank bottom and the ship's bottom shell plating is not reduced by more than 50 per cent.

3.13 Refrigeration systems – R character

3.13.1 For assignment of the **R** character, natural substances are to be used as the refrigerants in all main refrigeration systems such as cargo systems, provision rooms and air conditioning.

3.13.2 Small factory-built refrigeration system(s) that use fluorinated refrigerants, having a Global Warming Potential (GWP) of less than 1950 are allowable.

3.13.3 The GWP value is based on the 100-year time horizon.

3.14 Sulphur oxides – DIST and SOx character

3.14.1 For assignment of the **DIST** character, ships must meet the requirements of LR's Descriptive Note **DIST(M, AB, I, IG)**, as applicable.

3.14.2 For assignment of the **SOx** character, all fuel used on board is to be:
(a) distillate with a sulphur content not exceeding 0,10 per cent m/m; or
(b) an alternative fuel or a hybrid fuel management solution which has a resulting sulphur content which is not to exceed 0,10 per cent m/m.

3.14.3 The sampling, fuel sulphur analysis methods and verification requirements stipulated in 2.3.4 and 2.3.5 are to be complied with.

3.14.4 Alternative arrangements providing an equivalent level of environmental protection will be considered for the assignment of the **SOx** character. If an Exhaust Gas Cleaning System is fitted, it is to be certified to MEPC.184(59).

3.15 Enhanced tank cleaning – TC character

3.15.1 For the assignment of the **TC** character, oil and chemical tankers are to be provided with tank washing equipment meeting the standards specified in 3.15.2 to 3.15.8.

3.15.2 Cargo tanks are to be served by individual pumps.

3.15.3 Permanent tank washing machines shall be type approved in accordance with the revised IMO Resolution A.446(XI) - *Revised Specifications for the Design, Operation and Control of Crude Oil Washing Systems*, and their method of support is to be acceptable to LR.

3.15.4 At the design stage the following minimum procedures are to be used to determine the area of the tank surface covered by direct impingement (longitudinals, brackets, stiffeners, ladders, pipework, corrugations on corrugated bulkheads and face plates can be ignored):
(a) using suitable structural plans, lines are set out from the tips of each machine to those parts of the tank within the range of the jets; or
(b) a pinpoint of light simulating the tip of the tank washing machine in a scale model of the tank are to be used.
Alternative methods of measurement will be considered.

3.15.5 Additional tank washing equipment, which may be portable, is also to be provided to enable washing of the shadow areas without the necessity to enter the tanks. The use of portable machines to wash the shadow areas is not to be undertaken where the last cargo in the tank has toxic or low ignition properties, reacts with water or has other properties specified in chapter 15 of the *International Bulk Chemical Code* which would prevent water washing or opening of the tank to allow the use of portable washing machines.

3.15.6 A back-up system to provide cleaning capability in the event of failure of one tank washing machine is to be provided.

3.15.7 Heating equipment is to be provided for a tank washing medium which achieves a minimum temperature of 85°C at the connection to the tank washing machine.

3.15.8 The effectiveness of the tank washing system is to be confirmed by tank inspections or other means as required by LR. The confirmation is to be carried out when the ship is in service. For ships fitted with crude oil washing system(s) the confirmation will be carried out as part of the MARPOL Annex **I** survey and need not be carried out separately.

3.16 Vapour emission control systems – VECS-L and VOC-R characters

3.16.1 Tankers carrying crude oil, petroleum products or chemicals having a flash point not exceeding 60ºC (closed-cup test) will be assigned the **VECS-L**, **VOC-R** character(s), provided the requirements of 3.16.2 and/or 3.16.3 respectively are complied with, as applicable.

3.16.2 For assignment of the **VECS-L** character, a vapour emission control system is to be fitted, which, in addition to 3.15.2, has been designed and constructed to meet the requirements for vapour balancing in accordance with USCG 46, CFR 39.40 for service vessels.

3.16.3 For assignment of the **VOC-R** character, a self-contained system capable of preventing vapour emission formation during loading is to be fitted. This vapour emission prevention system is to be of a type approved by LR and is to reduce vapour emission formation by at least 75 per cent (v/v) as compared to an equivalent ship to which no vapour emissions prevention system has been fitted.

■ *Section 4* Survey requirements

4.1 Initial Survey and Audit

4.1.1 Following satisfactory review of the plans and other information submitted, (*see* 1.5), an **ECO** Initial Survey is to be undertaken for ships under construction or in service.

4.1.2 At the **ECO** Initial Survey, the Surveyor is to be satisfied that the requirements of these Rules, including those relating to any requested supplementary characters, are complied with. The Surveyor is to verify that the hull and machinery arrangements are in accordance with the approved documentation. The installed equipment, together with associated control and alarm systems, is to be demonstrated under working conditions.

4.1.3 Following the successful completion of the Initial Survey, the **ECO** notation may be assigned to a ship. The **ECO** notation will be valid, in the first instance, until the first **ECO** Annual Survey. At the first Annual Survey, an audit of the operational procedures as required by these Rules is to be undertaken. Prior to the LR audit, the operational procedures must have been fully implemented and audited by the Operator and the applicable record books must contain in-service records for a period of at least 3 months.

4.1.4 Audits are to confirm by direct observation, examination of internal audit reports and scrutiny of records that each of the procedures has been implemented over the preceding period. It is also to be verified that:

(a) the required resources and equipment have been provided; and
(b) the ship's staff are aware of their duties and responsibilities, and can perform the assigned tasks.

4.2 Periodical Surveys and Audits

4.2.1 **ECO** Annual Surveys and Audits are to be held on all ships to which the **ECO** notation applies within three months of each anniversary of assignment of the full **ECO** notation.

4.2.2 At the **ECO** Annual Survey and Audit, the Surveyor is to be satisfied that the arrangements and equipment comply with these Rules and operating procedures have been implemented. As far as possible, the installed equipment, together with associated control and alarm systems, are to be demonstrated under working conditions. Additionally:
(a) where changes to arrangements or equipment fitted to meet the requirements of these Rules have been made, it is to be verified that these changes are in accordance with approved documentation; and
(b) records for the preceding 12 months are to be reviewed.

4.2.3 **ECO** Audits are to be undertaken in accordance with the requirements given in 4.1.4.

4.2.4 Where the periodical surveys and audits are not completed in accordance with 4.2.1, the **ECO** Notation will be suspended. Re-instatement will be subject to surveys being held appropriate to the age of the ship and the circumstances of the case.

4.2.5 Where the periodical surveys and audits identify non-conformances, the **ECO** notation will be suspended. Re-instatement will be as directed by the Classification Committee, appropriate to the circumstances of the case.

4.3 Change of company

4.3.1 Where the company (as defined in the ISM Code) changes, the **ECO** notation will be suspended.

4.3.2 The new company may adopt the previously approved procedures as required by these Rules or may compile new procedures.

4.3.3 Following implementation of the approved procedures, an audit, in accordance with the requirements in 4.1.3 and 4.1.4, is to be undertaken.

4.3.4 The **ECO** notation will be re-assigned following successful completion of the audit provided that the ship has a valid Safety Management Certificate (SMC) and the general requirements given in 2.1.1 are complied with.

Section

■ *Section 1* General requirements

1.1 Scope

1.1.1 These Rules set down the criteria for the assessment of the noise and vibration on ships and are applied in addition to the other relevant requirements of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

1.1.2 The requirements of this Chapter may be applied where no other statutory requirements exist.

1.1.3 These Rules provide for two alternatives:
(a) **Class Notations** which indicate that the ship has been assessed and complies with noise and vibration criteria in these Rules and that a periodic survey regime has been established for the lifetime of the ship.
(b) **Certificate of Compliance** which provides evidence that the ship has been assessed and found to comply with the noise and vibration criteria in these Rules.

1.1.4 Spaces that comply with the noise level limits specified in Table 12.2.4 and under Acceptance Numeral 3 in Tables 12.2.1 and 12.2.3, will meet the requirements of section 4 of IMO Resolution MSC.337(91), when measured in accordance with the requirements of Chapters 2 and 3 of that Resolution.

1.1.5 Spaces that comply with the noise level limits specified under Acceptance Numerals 1 and 2 in Tables 12.2.1 and 12.2.3, will achieve enhanced levels of passenger and crew comfort as applicable, when measured in accordance with the requirements of Chapters 2 and 3 of IMO Resolution MSC.337(91). All vessels can apply for *Acceptance Numerals 1 and 2.*

1.1.6 These Rules recognise existing National and International Standards and specify levels of noise and vibration currently achievable using good engineering practice. Compliance with these requirements will be assessed by review of procedures, inspection and measurement of the relevant parameters and pre-survey reviews. Inspections and measurements are to be conducted, witnessed or assessed by LR's Surveyors unless otherwise agreed by Lloyd's Register (hereinafter referred to as LR).

1.1.7 Accommodation comfort is a function of ship type and layout. These Rules address two types of ship:
(a) Passenger (e.g., cruise ships, ro-ro ferries).
(b) Cargo (e.g., container ships, tankers).

1.1.8 These Rules include levels of noise and vibration which should be verified by measurements following completion of the ship. It is recommended that the Builders undertake calculations of noise and vibration characteristics so that any potential problem areas can be identified and control measures implemented.

1.1.9 The sound pressure levels for audible alarms and public address systems fitted in accordance with other sections of the Rules are to satisfy IMO Resolution A.1021(26) *Code on Alerts and Indicators, 2009*.

1.2 Definitions

1.2.1 **Passenger spaces** are defined as all areas intended for passenger use, and include the following:
(a) Passenger cabins.
(b) Public spaces (e.g., restaurants, hospital, lounges, reading and games rooms, gymnasiums, corridors, shops).
(c) Open deck recreation areas.

1.2.2 **Crew spaces** are defined as all areas intended for crew use only, and include the following:
(a) Accommodation spaces (e.g., cabins, offices, mess rooms, recreation rooms).
(b) Work spaces.
(c) Navigation spaces.

1.2.3 **Noise level** is defined as the A-weighted sound pressure level measured in accordance with ISO 2923.

1.2.4 **Vibration level** is defined by the application of ISO 6954:2000:
The vibration level is defined as the overall frequency weighted r.m.s. value of vibration during a period of steady-state operation over the frequency range 1 to 80 Hz.

1.3 Class notations

1.3.1 The class notations described in 1.3.2 to 1.3.6 provide standards for noise and vibration levels in different spaces at the time of delivery and during the ships life if substantial changes to the machinery installation or interior arrangements are made.

1.3.2 The **PAC** (Passenger Accommodation Comfort), **CAC** (Crew Accommodation Comfort) and **PCAC** (Passenger and Crew Accommodation Comfort) notations are optional and are primarily intended to apply to passenger ships. If requested, however, any ship can be assessed for compliance, using these requirements as the basis for the assessment and a LR Certificate of Compliance issued (*see* 1.1.3(b) and 1.4).

1.3.3 The **PAC** notation indicates that the passenger accommodation meets the acceptance criteria whilst the **CAC** notation indicates that the crew accommodation and work areas meet the acceptance criteria. The **PCAC** notation indicates that the passenger and crew spaces both meet the acceptance criteria.

1.3.4 For ships which achieve the noise and vibration comfort standards specified in these Rules, the notation **PAC**, **CAC** or **PCAC** will be assigned.

1.3.5 Following the **PAC** or **CAC** notation, numerals **1**, **2** or **3** will indicate the acceptance criteria to which the noise and vibration levels have been assessed. In the case of the **PCAC** notation, two numerals will be assigned. The first will indicate the acceptance criteria for passenger accommodation, whilst the second will indicate the crew comfort criteria.

1.3.6 For particular vessels, impact insulation and transient noise in accordance with 2.5 and 2.6 together with any additional or more stringent noise and vibration criteria may be assessed within the scope of the notations where agreed between the Owner, Builder and LR.

1.4 Certificate of Compliance

1.4.1 A Certificate of Compliance records that a ship has been designed and constructed to satisfy the noise and vibration criteria contained in these Rules. This is to be confirmed by measurements and reporting in accordance with Sections 4 and 5.

1.4.2 A Certificate of Compliance is optional and if requested, any ship can be assessed for compliance using the Rule requirements as basis for assessment.

1.4.3 Where noise and vibration levels are at variance with those prescribed by these Rules, these will be added to the certificate for information purposes.

1.4.4 A Certificate of Compliance will be issued after the initial survey required by Section 6.

■ *Section 2*
Noise

2.1 Assessment criteria

2.1.1 Where a space is occupied by both passengers and crew, the more stringent of the relevant requirements apply unless agreed between the Builder and Owner and advised to LR.

2.2 Passenger accommodation and public spaces

2.2.1 Under test conditions specified in 4.2, the applicable noise levels specified in Table 12.2.1 should not generally be exceeded. *See* 2.2.3.

Table 12.2.1 Passenger ships – Maximum noise levels in dB(A)

Location		Acceptance Numeral 1	2	3
Passenger cabins:	Standard Superior	49 45	52 47	55 50
Public spaces:	Excluding shops Shops	55 60	58 62	62 65
Medical centre:		50	55	60
Theatre/auditorium		50	55	60
Open deck recreation areas (excluding swimming pools and similar)		67	72	72
Swimming pools and similar		70	75	75

NOTES
1. The levels may be exceeded by 5dB(A) within 3 m of a ventilation inlet/outlet or machinery intake/uptake on open decks.
2 The levels may be exceeded by 3dB(A) in accommodation above the propellers for three decks above the mooring deck.
3. The levels for open deck recreation areas refer to ship generated noise only. On open deck spaces the noise generated from the effects of wind and waves can be considered separately to limits agreed between the Builder and Owner and advised to LR for the trial conditions.

2.2.2 For cabins bordering discotheques and similar entertainment areas, the deck and bulkhead sound insulation is to be sufficient to ensure that the maximum cabin noise levels are not exceeded even when high external noise levels prevail.

2.2.3 Acceptance of noise levels greater than those specified in Table 12.2.1 may be considered where agreed between the Owner and Builder. Not more than 20 per cent of the passenger cabins, 30 per cent of the public spaces and 20 per cent of the crew cabins should exceed the relevant noise criteria by more than 3 dB(A).

2.2.4 Acoustic insulation of bulkheads and decks between passenger spaces is to be generally in accordance with the values of the weighted apparent sound reduction index R_w as given in Table 12.2.2, calculated using ISO 717/1. *See also* 2.2.6.

2.2.5 For the purpose of selecting acoustic sound insulation, the following sound noise levels may be used with the agreement of the Owner and Builder:

(a) Cabins – 80 dB(A).
(b) Dining Rooms – 85 dB(A).
(c) Corridors – 90 dB(A).
(d) Discotheques, Theatres, Entertainment Areas – 105 dB(A).

2.2.6 Acceptance of bulkhead and deck acoustic insulation values less than those specified in Table 12.2.2 may be considered where agreed between the Owner and Builder. Not more than 20 per cent of the interfaces tested should have airborne sound insulation indices, R_w, more than 3 dB(A) lower than the minimum specified values.

Table 12.2.2 Minimum air-borne sound insulation indices, R_w

Location		Acceptance Numeral		
		1	2	3
Passenger cabins:	Standard Superior	40 45	38 42	37 40
Cabin to corridor:	Standard Superior	38 42	36 40	34 37
Cabin to stairway:	Standard Superior	47 50	45 47	43 45
Cabin to public space (excluding corridors/stairwells and discotheques):	Standard Superior	52 55	48 50	48 50
Discotheques to cabins		60	60	60
Discotheques to stairwells and public spaces		52	52	52
Cabin to machinery rooms and engine casing		55	53	50

2.3 Crew accommodation and work areas

2.3.1 Under the applicable test conditions specified in 4.2, the noise levels specified in Tables 12.2.3 and 12.2.4 are not to be exceeded.

Table 12.2.3 Crew accommodation – Maximum noise levels in dB(A)

Location	Acceptance Numeral			
	1	2	3	
			Ships <10,000 grt	Ships ≥10,000 grt
Sleeping cabins, hospitals	50	53	60	55
Offices, conference rooms and day cabins	55	58	65	60
Mess rooms, lounges, reception areas and recreation rooms within accommodation	55	58	65	60
Recreation areas on open deck	67	72	75	75
Alleyways, changing rooms, bathrooms, lockers	70	75	75	75
NOTE The levels may be exceeded by 5dB(A) within 3 m of a ventilation inlet/outlet or machinery intake/uptake on open decks.				

Table 12.2.4 Crew work areas – maximum noise levels in dB(A)

Location	dB(A) level
Machinery space(continuously manned) e.g. stores	90
Machinery space(not continuously manned) e.g. pump, refrigeration, thrusters or fan rooms	110
Workshops and non-specified work spaces	85
Machinery control rooms	75
Wheelhouse	65
Look-out posts e.g., at bridge wing or window Additional limits: • 250 Hz band • 500 Hz band (measured according to IMO A.343(IX))	70 68 63
Radio room	60
Galleys and pantries: • Equipment not working • Individual items at 1 metre	 75 80
Normally unoccupied spaces (e.g. holds, decks)	90
Ship's whistle, on bridge or forecastle	110

2.3.2 Crew space insulation is to comply with the requirements of IMO Resolution MSC.337(91).

2.4 Maximum noise levels

2.4.1 Where the measured noise level exceeds the specified criterion by 3 dB(A), or contains subjectively annoying low frequency or tonal components, the noise rating (NR) number is to be established in accordance with the graph shown in Fig. 12.2.1. This is achieved by plotting the linear octave band levels on the graph; the NR number is that NR curve to which the highest plotted octave band level is anywhere tangent. The specified criterion may be considered satisfied if the NR number does not exceed the specified A-weighted value minus 5 dB(A).

2.4.2 Guidance on maximum acceptable sound pressure levels and noise exposure limits for crew spaces is given in IMO Resolution MSC.337(91).

2.5 Impact insulation

2.5.1 Where agreed between the Owner, Builder and LR, enhanced criteria for noise levels recognising the effects of impact sound pressures may be applied in accordance with 2.5.2 to 2.5.5.

2.5.2 For passenger and crew cabins located below or adjacent to dance floors, stages, aerobics and gymnasium areas, jogging tracks or other areas where impact noise is generated, the normalised impact sound pressure level measured within the cabins is not to exceed 45 dB.

2.5.3 For public rooms under dance floors, stages, aerobics and gymnasium areas, jogging tracks or other areas where impact noise is generated, the normalised impact sound pressure level within the space is not to exceed 55 dB.

2.5.4 For passenger cabins, the normalised impact sound pressure level, $L_{n,w}$, calculated using ISO 717/2, is to be generally in accordance with the values stated in Table 12.2.5. *See also* 2.5.5.

Table 12.2.5 Passenger cabins normalised impact maximum sound pressure level $L_{n,w}$

Location	dB
Below decks covered with carpet and soft materials	50
Below decks covered in hard materials (such as wood, marble or similar)	60
Below dance floors, theatre or sports rooms	45

2.5.5 Acceptance of normalised impact sound pressure levels greater than those specified in Table 12.2.5 may be considered for assignment of the applicable class notation where agreed between the Owner, Builder and LR. No more than 20 per cent of the passenger cabins tested should exceed the levels specified by more than 3 dB.

2.6 Transient noise

2.6.1 Where agreed between the Owner, Builder and LR, enhanced criteria for transient noise levels may be applied in accordance with 2.6.2.

2.6.2 The maximum sound pressure level (L_{max}) emanating from any machinery or system caused by a single event that produces a noise 'spike' compared to the reference condition sound level (such as vacuum systems or valve operations) is not to cause an increase in noise in comparison with the reference condition as below:

(a) Passenger cabins and public areas: +2 dB(A)
(b) Officer cabins: +2 dB(A)
(c) Crew cabins and public areas: +3 dB(A)

A tolerance of +1 dB(A) may be applied to 5 per cent of cabins and public areas in each fire zone on each deck. This criterion is generally applicable to the specified maximum noise levels for the space concerned.

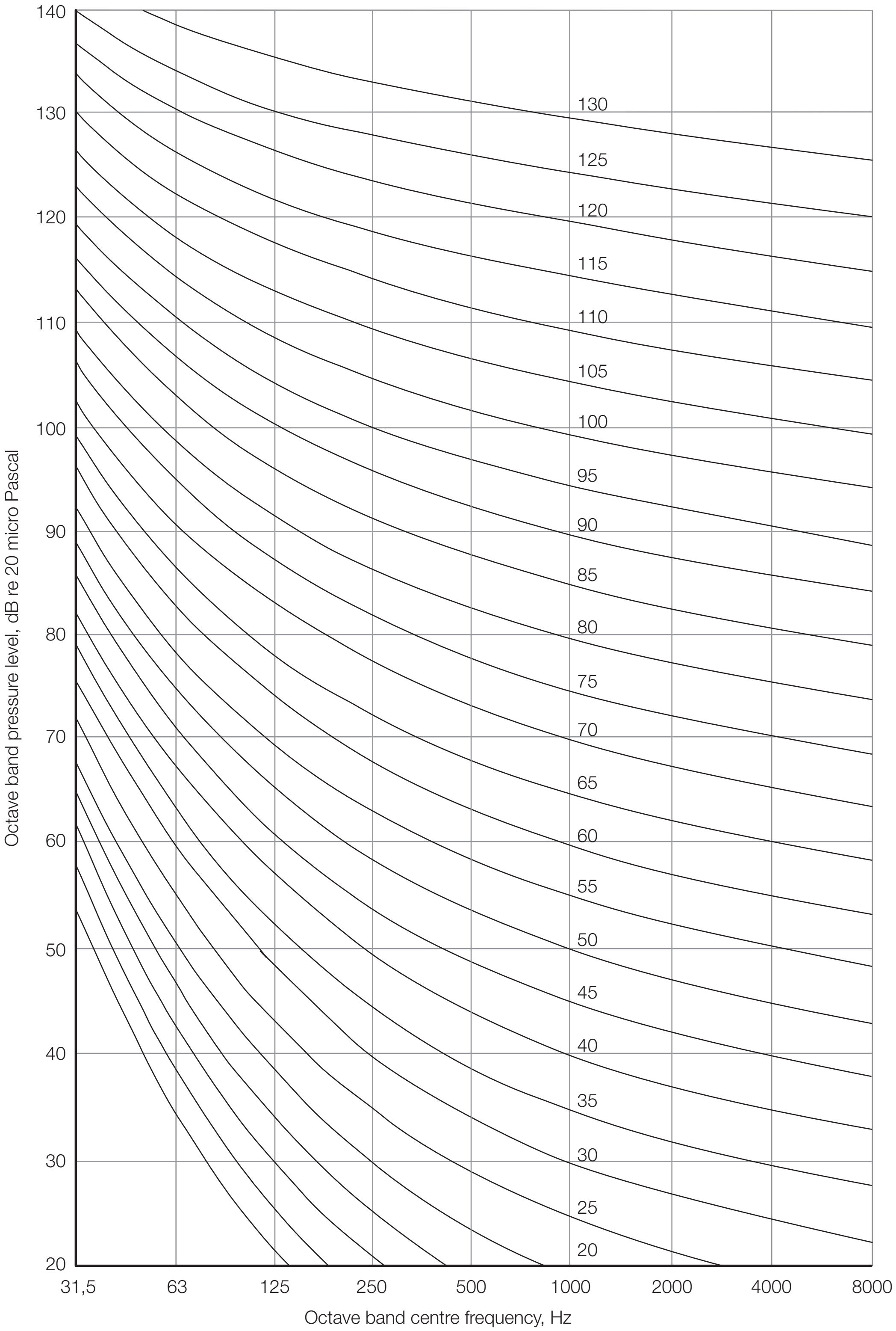


Fig. 12.2.1 Noise rating curves

Section 3 **Vibration**

3.1 Assessment criteria

3.1.1 Where a space is occupied by both passengers and crew, the more stringent of the relevant requirements apply unless agreed between the Builder and Owner and this agreement advised to LR.

3.1.2 The limits apply to vertical, fore and aft and athwartship vibrations which are to be assessed separately.

3.1.3 Under test conditions specified in 4.2, the applicable vibration levels specified in Tables 12.3.1 and 12.3.2 should not be exceeded.

Table 12.3.1 Passenger ship – Maximum vibration levels

Standard	ISO 6954:2000		
Units:	Peak velocity (1–80 Hz) velocity mm/s rms		
	Acceptance Numeral		
Location	1	2	3
Passenger cabin Luxury	1,5	1,8	2,1
Passenger cabin Standard	1,8	2,1	2,4
Public spaces	2,0	2,5	3,0
Open recreation decks	2,5	3,0	3,5
NOTE The vibration level may be exceeded by 0,3 mm/s in the ship's aft body directly above the propellers.			

Table 12.3.2 Crew spaces – Maximum vibration levels

Standard:	ISO 6954:2000
Units:	Frequency weighted (1-80 Hz) velocity mm/s rms
Location	
Accommodation and navigation spaces	3,5
Work spaces	5,0

3.1.4 Acceptance of vibration levels greater than those specified in Tables 12.3.1 and 12.3.2 may be considered for assignment of the applicable class notation where agreed between the Owner, Builder and LR.

3.2 Passenger accommodation and public spaces

3.2.1 Passenger spaces are to comply with the overall vibration levels specified in Tables 12.3.1 and 12.3.2.

3.2.2 No more than 20 per cent of all passenger spaces/areas and public spaces should exceed the relevant vibration criteria specified in Tables 12.3.1 and 12.3.2 by more than 0,3 mm/s.

3.3 Crew accommodation and work spaces

3.3.1 Crew spaces are to comply with the overall vibration levels specified in Table 12.3.2.

Section 4 **Testing**

4.1 Measurement procedures

4.1.1 These requirements take precedence where quoted standards may differ.

4.1.2 The trial measurements may be undertaken by an approved technical organisation as defined in 4.7 or by LR. In the former case, the measurements are to be witnessed by a LR Surveyor.

4.1.3 Subject to agreement by LR and the Owner/ Operator, the measurements may be undertaken by the Builder. In this case, the measurements are to be witnessed by a LR Surveyor.

4.2 Test conditions

4.2.1 Test conditions for the surveys are to be in accordance with those detailed in ISO 2923 and ISO 6954:2000 as applicable.

4.2.2 The intended operating and loading conditions of the ship during assessment surveys are to be submitted to LR for agreement, prior to commencement of surveys.

4.2.3 Surveys are to be conducted when the ship is fully outfitted and all systems contributing to noise and vibration levels are operational.
NOTE
All systems operational are to include those systems that may operate simultaneously with others during normal ship operation.

4.2.4 The test conditions required for the vibration and noise measurements are to be in accordance with the following conditions:

(a) For passenger ships, prior to measurement surveys being carried out, the ship operating condition where the worst conditions are experienced between 0 and 85 per cent maximum continuous rating of the propulsion machinery is to be determined. To establish this condition, four measurement positions are to be defined with the agreement of LR and measurements taken of the parameters of interest at ship speeds corresponding to percentages of the maximum continuous rating of the propulsion machinery increasing up to 40 per cent MCR in 10 per cent intervals and from 40 per cent in 5 per cent intervals up to the 85 per cent maximum continuous rating of the propulsion machinery. If the 85 per cent maximum continuous rating condition is found to be the worst condition, then this will form the trial operating conditions. However, if a lower speed condition is found to be worse than the 85 per cent maximum continuous rating condition then both that condition and the 85 per cent maximum continuous rating condition will form the trial operating conditions. Where unavoidable any barred range within the values required for the trial operating condition may be excluded on agreement between Owner and Builder subject to approval by LR.

(b) The power absorbed by the propeller(s) is to be that defined in 4.2.4(a). Alternatively, by special agreement, some lesser power could be accepted if it can be demonstrated by the Owner that this would correspond to a more representative normal service condition.

(c) Auxiliary machinery essential for the ship's operating conditions together with HVAC systems are to be running at their normal rated capacity during the noise and vibration trials. Combinations of auxiliary machinery operation may be necessary. In addition, the following equipment is to be running if appropriate: stabilisers, waste treatment equipment, swimming pool and jacuzzi equipment.

(d) For sea-going ships, measurements are to be taken with the ship proceeding ahead, at a constant speed and course, in a depth of water not less than five times the draught of the ship. For other ships, an appropriate water depth is to be agreed with LR prior to the trials.

(e) Trials are to be conducted in sea conditions not greater than sea state 3 on the WMO sea state code. In addition, noise measurements should not be taken when the wind force exceeds 4 on the Beaufort scale.

(f) The ship is to be at a displacement and trim representative of an operating condition.

(g) Rudder angle variations are to be limited to ±2° of the midship position and rudder movements are to be kept to a minimum throughout the measurement periods.

(h) In addition, for ships which are designed to spend a considerable period of time in harbour, the noise and vibration, are to be measured for this condition, with the auxiliary machinery and HVAC systems running at their normal rated capacity.

(j) For passenger ships, intermittently run equipment such as transverse propulsion units are to be operated at 60 per cent of their rated power for additional measurements in surrounding ship areas.

4.2.5 Prior to survey, a test programme is to be submitted for approval by LR. This programme is to contain details of the following:

(a) Measurement locations indicated on a general arrangement of the ship.

(b) The ship's loading condition during survey.

(c) The machinery operating condition, including HVAC system, during survey.

(d) Noise and vibration measuring equipment.

4.3 Noise measurements

4.3.1 Noise measurements are to be conducted in accordance with ISO 2923 and IMO Resolution MSC.337(91). Measurements of noise levels are to be carried out using precision grade sound level meters conforming to IEC 60651, Type 1 or 2. Subject to demonstration, equivalent standards are acceptable.

4.3.2 Where the measured noise level exceeds the relevant criterion by 3 dB(A), or contains subjectively annoying low frequency noise or obvious tonal components, octave band readings are to be taken, with centre frequencies from 31,5 Hz to 8 kHz.

4.3.3 When outfitting is complete, and all soft furnishings are in place, sound insulation indices for passenger spaces are to be determined in accordance with ISO 140. Cabin to cabin indices are to be determined from a minimum of three locations within the passenger accommodation, the number of test locations being agreed with LR.

4.3.4 If required, impact sound measurements are to be carried out in accordance with ISO 140/7 and presented in accordance with ISO 717/2. *See* 4.4.4.

4.4 Noise measurement locations

4.4.1 Measurement locations are to be chosen so that the assessment represents the overall noise environment on board the ship. In addition to the requirements of IMO Resolution MSC.337(91) for crew spaces, all public spaces and at least 50 per cent of passenger cabins in the after third of the ship, and 25 per cent elsewhere, are to be surveyed. Distribution of the measurement locations is to be agreed by LR.

4.4.2 During measurement trials, recognised noise sources are to be operated at their normal level of noise output (e.g. machinery at design rating).

4.4.3 In larger sized spaces, where noise levels may vary considerably, such as restaurants, lounges, atria and open deck recreation areas, measurements are to be taken at locations not greater than 7 m apart.

4.4.4 The number of and locations for impact noise measurements are to be agreed between the Builder, Owner and LR. The measurements are to be carried out when the ship is in harbour. The number and location of measurements are to take account of all different combinations of construction, areas of application, types of cabin and spaces below.

4.5 Vibration measurements

4.5.1 Vibration measurements are to be conducted in accordance with ISO 6954:2000.

4.5.2 Measurements are to be made with instrumentation meeting the requirements of ISO 8041.

4.5.3 Vibration levels are to be given in terms of the velocity measurement appropriate to the version of the standard being used and should be measured over a period of not less than one minute.

4.6 Vibration measurement locations

4.6.1 Measurement locations are to be chosen so that the assessment represents the overall vibration environment onboard the ship. To minimise survey times, readings may be taken at the locations previously defined for the noise assessment part of the survey.

4.6.2 In cabins, vibration readings are to be taken in the centre of the floor area. The measurements are to indicate the vibration of the deck structure. In large spaces, such as restaurants, sufficient measurements are required to define the vibration profile.

4.6.3 Where deck coverings make transducer attachment impracticable, use of a small steel plate having a mass of at least 1 kg, with spikes as appropriate, is permissible.

4.6.4 At all locations, vibrations in the vertical direction are to be assessed. Sufficient measurements in the athwartships and fore and aft directions are to be taken to define global deck vibrations.

4.7 Approved technical organisation

4.7.1 An approved technical organisation for the purposes of these Rules is one that is acceptable to the Owner and LR with proven capability in noise and vibration measurement and satisfies all the criteria set out below:

(a) Have instrumentation whose calibration, both before and after the measurements, can be traced back to National Standards and, hence, back to International Standards.
(b) Have analysis procedures capable of data reduction to the requirements and standards set out in these Rules.
(c) Be able to provide a written report in English with contents as defined by Section 5.

■ *Section 5* Noise and vibration survey reporting

5.1 General

5.1.1 Prior to survey, a noise and vibration measurement plan is to be agreed by the Owner, Builder and LR.

5.1.2 The survey report is to comprise the data and analysis for both noise and vibration and is to be submitted to LR for consideration.

5.1.3 The survey report is to be prepared by the organisation undertaking the trial measurements, which may be an approved technical organisation or LR.

5.1.4 The survey report is to be submitted to LR's London Office (MCS/TID) for evaluation and confirmation that the results are in accordance with the noise and vibration levels specified in these Rules and/or agreed between the Owner and Builder. The assignment of a Class Notation or the issue of a Statement of Compliance will be subject to confirmation by LR MCS/TID.

5.2 Noise

5.2.1 The reporting of results is to comply with ISO 2923 and IMO Resolution MSC.337(91), and is to include:

(a) Measurement locations indicated on a general arrangement plan including, where possible, the measured dB(A) level.
(b) Tabulated dB(A) noise levels, together with octave band analysis for positions where the level exceeds the specified criterion by 3 dB(A), or where subjectively annoying low frequency or tonal components were present. The Noise Rating number is also to be given where octave band analyses have been conducted.
(c) Ship and machinery details.
(d) Trial details:
    - Loading condition.
    - Machinery operating condition.
    - Speed.
    - Average water depth under keel.
    - Weather conditions.
    - Sea state.
(e) Details of measuring and analysis equipment (e.g. manufacturer, type and serial numbers), including frequency analysis parameters (e.g., resolution, averaging time, window function).
(f) Copies of the relevant instrument calibration certificates, together with the results of field calibration checks

5.3 Vibration

5.3.1 The report is to contain the following information:

(a) Measurement positions indicated on a general arrangement plan.
(b) Where ISO 6964:2000 is used, the frequency-weighted overall r.m.s. vibration levels tabulated for all measurement locations calculated using the weighting functions and methodology stated in the standard.
(c) Ship and machinery details.
(d) Trial details:
- Loading condition.
- Machinery operating condition.
- Speed.
- Average water depth under keel.
- Weather conditions.
- Sea state.

(e) Frequency analysis parameters (e.g. resolution, averaging time and window function), if the analysis is done in the frequency domain.
(f) Copies of the relevant instrument calibration certificates, together with the results of field calibration.

■ *Section 6* Non-periodical survey requirements

6.1 Class notation assignment

6.1.1 Where the assignment of a Class Notation or a Statement of Compliance is requested, an Initial Survey is to comprise sea trial or initial in-service testing, reporting and assessment against the criteria set out in these Rules.

6.1.2 The sea trial or initial in-service testing requirements are set out in Section 4, and are to be reported in accordance with Section 5 and evaluated against the requirements of Sections 2 and 3.

6.2 Maintenance of class notation through-life and following modifications

6.2.1 Where an Owner has requested assignment of a Class Notation, arrangements are to be agreed between LR and the Owner to record observations/complaints of excessive noise and vibration that have been such as to disturb the comfort of passengers and crew. The records of the observations are to be made available to the attending LR Surveyor at each Annual Survey.

6.2.2 Where the observations indicate that the noise and/or vibration levels may exceed the criteria relating to the Class Notation requirements and those measured at the Initial Survey, a measurement programme is to be agreed between the Owner and LR and measurements taken in accordance with these Rules.

6.2.3 A Renewal Survey may be required following modifications, alterations or repairs including replacement of major machinery items. It is the responsibility of the Owner to advise LR of such modifications.

■ *Section 7* Referenced standards

7.1 Noise

7.1.1 The following National and International Standards for noise are referred to in these Rules:

- ISO 2923, *Acoustics – Measurement of noise on board vessels*.
- ISO 717/1, *Acoustics – Rating of sound insulation in buildings and of building elements; Part 1: Airborne sound insulation*.
- ISO 717/2, *Acoustics – Rating of sound insulation in buildings and of building elements; Part 2: Impact sound insulation*.
- IMO Resolution MSC.337(91), *Adoption of the code of noise levels on board ships*.
- IEC Publication 651, *Sound level meters*.
- ISO140/4, *Acoustics – Measurement of sound insulation in buildings and of building elements; Part 4: Field measurements of airborne sound insulation between rooms*.
- ISO 140/7, *Acoustics – Measurement of sound insulation in buildings and of building elements; Part 7: Field measurements of impact sound insulation of floors*.

7.2 Vibration

7.2.1 The following National and International Standards for vibration are referred to in these Rules:

- ISO 6954:2000, *Mechanical vibration and shock – Guidelines for the measurement, reporting and evaluation of vibration with regard to habitability on passenger and merchant ships*.
- ISO 8041, *Human response to vibration. Measuring instrumentation*.

■ *Section 1* General

1.1 General

1.1.1 These optional requirements apply to the safety, reliability and availability of shipboard machinery, electrical and control engineering arrangements installed to permit continued operation of services by connection to an external electrical power supply in port. These requirements are additional to those applicable in other Parts of the Rules. Regular operation of ship's services from an external electrical power supply is often referred to as On-shore Power Supply, Cold Ironing, High Voltage Shore Connection or Alternative Marine Power.

1.1.2 These requirements are intended for application to the shipboard elements of designs where the connection(s) with external power supply arrangements are achieved by either extending ship cables from the ship to the external power supply connection points or by bringing external cables on board to connect to shipboard connection points. However, external equipment and machinery (including shore based transformers, circuit breakers, gantries, cables, connectors and control engineering arrangements) are not covered by classification or these requirements.

1.1.3 Compliance with these requirements is intended to assess the suitability of shipboard arrangements for the documented intended application and only addresses compatibility with external power supply arrangements that are suitable for connection to the installed ship arrangements.

1.1.4 Assessment of the overall compatibility and suitability of an external electrical power supply (including combined electrical and control engineering assessments, compliance with applicable regulations, operating practices and risk assessment, etc., as applicable) is necessary before connection and is the responsibility of the Owner. Elements of the overall assessment of compatibility will be required to be completed in advance to prepare for a ship visit to a port where it is intended to connect to an external power supply due to the need to involve competent and responsible parties.

1.2 Authorities and administrations

1.2.1 Additional requirements and/or restrictions may be imposed by the National Authority with which the ship is registered and/or by the appropriate Administration or Authorities within whose jurisdiction the ship is intended to operate and/or by the Owners or Authorities responsible for an external electrical power supply. Where such additional requirements are relevant, compliance is the responsibility of the Owner. If specifically requested, Lloyd's Register (hereinafter referred to as 'LR') may be able to provide a suitable statement of compliance.

1.2.2 Where additional requirements imposed by an Authority or Administration would result in a departure from the requirements of this Chapter, details demonstrating that safety, availability and reliability will not be adversely affected are to be submitted to LR for consideration.

1.3 Class notations

1.3.1 **OPS** machinery class notation may be assigned where machinery, electrical and control engineering arrangements installed onboard to permit continued operation of services by connection to an external electrical power supply are assessed and found to comply with the requirements of this Chapter.

1.4 Plans and information

1.4.1 Three copies of the plans and particulars in 1.4.2 to 1.4.9 are to be submitted for consideration.

1.4.2 Operating Manuals that describe the intended methods of connection together with operating and monitoring instructions. Assessments of the external supplies that are to be connected to the ship together with the mooring and environmental conditions are to be included. Details of equipment and arrangements necessary to ensure safety when connecting, disconnecting, transferring electrical load, testing and operating are to be incorporated.

1.4.3 A Design Statement which details the Defined Operations. This statement is to include a description of the operating capability, functionality, limits and restrictions; in terms of:

- Connection Equipment, *see* 1.6.2;
- Connection Equipment routes;
- mooring arrangements;
- environmental conditions including tidal and weather and, where applicable, electromagnetic conditions required to ensure compatibility or prevent damage caused by heating or sparking;
- Connection Equipment suitability for hazardous areas, *see* 2.1.4 and Pt 6, Ch 2,1.2.6
- arrangements for an external connection cable to be brought on board, where provided;
- Separation details, *see* 3.2.7;
- the rating of the arrangements;
- ratings and requirements for external power supplies, *see* 3.1.10; and
- the services to be supplied.

1.4.4 Arrangement plans of equipment, control stations, locations, routes to and from connections, openings and accesses and flexible or movable arrangements.

1.4.5 Operational and construction details of Connection Equipment, including any flexible or adjusting arrangements, including plugs and socket-outlets, *see* 3.3.8.

1.4.6 Plans for control and electrical engineering arrangements required by Pt 6, Ch 1 and 2, as applicable.

1.4.7 Details of type tests for Connection cables, plugs and socket-outlets required by 3.3.6.

1.4.8 Details of supplementary arrangements required to protect equipment from exposure to moisture, condensation or temperatures outside their rating.

1.4.9 Schedule of testing at manufacturers' works, initial surveys and trials. The test schedules are to address the defined operations and are to include normal operations and failure conditions.

1.5 Additions and alterations

1.5.1 When an alteration or addition to the approved arrangements is proposed, including changes to the defined service profile, details are to be submitted for consideration.

1.6 Definitions

1.6.1 'Defined Operations' include the application, connection, electrical load transfer, in-service operation, failure response, disconnection and stowage of the connection to an external power supply.

1.6.2 'Connection Equipment' is the ship equipment used to connect permanently installed ship equipment with external electrical power supply connection points in accordance with the Design Statement. This includes, as applicable, flexible cables, plugs and socket-outlets, slip rings or other power conductors or control connections, and support and management measures for these connections. For the purposes of this Chapter, 'Connection Equipment' does not include external equipment, *see* 1.1.

■ *Section 2*
Essential features

2.1 General requirements

2.1.1 Connection equipment is to be designed to be compatible with ship mooring arrangements and the limits of acceptable forces, moments and deflections on correctly applied Connection Equipment resulting from the movement of the moored ship under normal operational circumstances is to be defined in the Design Statement.

2.1.2 Electrical and control engineering arrangements for operation with external electrical power supplies are to be in accordance with the requirements of Pt 6, Ch 1 and 2, as applicable.

2.1.3 Connection to an external electrical power supply is not to adversely affect the availability of main, auxiliary or emergency machinery, including ship sources of electrical power to allow ship power to be restored. Details of arrangements provided to maintain availability (for example, pre-heating and lubrication and availability of starting, fuel, lubrication, air and auxiliary systems) are to be included in the Design Statement, *see also* 4.5 and 5.1.9.

2.1.4 The permanent or temporary installation of electrical equipment in areas containing flammable gas or vapour and/or combustible dust, is to be minimised as far as is consistent with operational necessity and the provision of facilities enhancing the overall safety of the ship and connection to an external power supply. Where it is necessary to install electrical equipment in these areas, the arrangements are to be in accordance with the requirements of Pt 6, Ch 2,14. The suitability of electrical Connection Equipment for operation in areas containing flammable gas and/or vapour and/or combustible dust while in port is to be defined in the Design Statement and should, additionally, address the implications for Connection Equipment extended ashore, where applicable, and the suitability for operation in berths requiring extended, hazardous areas.

2.1.5 As far as practicable, Connection Equipment is to be located outside of areas where it could be damaged by in-port activities under normal operational circumstances.

2.1.6 Consideration may be given to arrangements that are considered by LR to provide an equivalent level of safety. Evidence demonstrating compliance with IEC/ISO/IEEE 80005-1: *Electrical installations in ships – Special features: High-voltage shore connection systems*, or a relevant National Standard, may be submitted for consideration of acceptability by LR.

■ *Section 3*
Electrical connection

3.1 General

3.1.1 A connection cubicle is to be provided at a convenient location for the reception or extension of connection cable(s) for connection to the external electrical power supply connection points. The connection cubicle is to contain terminals for the connection cable(s) that can be isolated.

3.1.2 Power connections with external electrical power supply arrangements may be made with either suitable connections or by using socket-outlets and plugs in accordance with 3.3.

3.1.3 Suitable cables, permanently fixed, are to be provided from the connection cubicle to the Connection Circuit-Breaker switchboard, with on-board overcurrent protection situated at or as close as is practicable to the connection cubicle. Connection Equipment to this overcurrent protection is to be installed in a manner such as to minimise the risk of short-circuit.

3.1.4 Where shipboard connection cables are extended to the external electrical power supply connection points, the connection cubicle is to be situated as close as practicable on board to the point where they are extended from the ship.

3.1.5 Means are to be provided to permit the quality of insulation between Connection Equipment conductors, and between the conductors and earth to be measured to verify suitability prior to the connection of an external power supply. The means of verifying satisfactory insulation quality of Connection Equipment in hazardous areas is to be addressed in the Operating Manuals, *see* 1.4.2.

3.1.6 An earth connection is to be provided for connecting the hull to an earth appropriate for the external electrical power supply which is being connected.

3.1.7 For high voltage connections, means are to be provided, as applicable to the design, to either:
(a) permit termination of circuits used by external power supply equipment to monitor the continuity of the earth connection referred to in 3.1.6; or
(b) monitor the continuity of the earth connection referred to in 3.1.6, *see* 5.3.8.

3.1.8 Means are to be provided for checking the phase sequence of the incoming supply.

3.1.9 An indicator is to be provided at the Connection Circuit-Breaker switchboard, and at the connection cubicle if in a different location, in order to show when connections are energised.

3.1.10 Requirements for an external electrical power supply to be connected are to be defined in the Design Statement and this is to detail the following:
- connections, including control, alarm and safety systems and data communication links;
- emergency Shut-Down requirements, *see* 5.3;
- nominal voltage(s) or voltage range;
- nominal frequency or frequency range;
- number of phases and system of supply;
- rated current or apparent power;
- quality of power supply;
- reference to protection system design, including protection characteristics for the Connection Circuit-Breaker;
- maximum permitted prospective fault level;
- minimum supply apparent power or current capacity;
- earth fault limiting requirements for earthed high voltage connections;
- isolation and earthing; and
- supply requirements for lightning and surge protection, galvanic isolation of supply circuit from other ships, etc.

Required electrical characteristics are to address steady state, transient and fault conditions, as necessary.

3.1.11 A notice is to be provided at the connection cubicle referencing the Operating Manuals and Design Statement and advising of the requirement to ensure that external electrical power supplies satisfy the requirements of 3.1.10 prior to connection. *See* 1.1.4 for the conducting of the assessment of overall compatibility.

3.2 Connection Equipment

3.2.1 Connection Equipment support and management arrangements, including those for control engineering arrangements, are to be arranged not to apply damaging forces or tension to correctly applied equipment. Support arrangements are to ensure that the weight of connected cable is not borne by cable end terminations or connections, including those in plugs or socket-outlets.

3.2.2 Connection Equipment arrangements are to be such as not to coil or twist correctly applied equipment in a manner that would result in heating or physical tension beyond its rating during Defined Operations.

3.2.3 Where Connection Equipment passes through support or management arrangements or structural openings or is placed against structures, it is to be suitably protected against damage having regard to the Defined Operations.

3.2.4 Connection Equipment routes are not to reduce the effectiveness of openings required for the safety of the ship, for instance bulkhead or deck penetrations, watertight or fire doors.

3.2.5 Connection Equipment support and management arrangements are to be able to operate satisfactorily without damage during the Defined Operations.

3.2.6 Means are to be provided for Connection Equipment to be readily and safely adjusted in response to tidal changes, and other movements that could lead to damage or failure of connections, during the Defined Operations.

3.2.7 Connections with external electrical power supply arrangements are to be designed to prevent damage to the ship structure or Connection Equipment cable reels, cranes and/or gantries as a result of the connections separating in the event of the ship leaving a berth inadvertently or as a result of high cable tension for other reasons. Evidence of compliance with this requirement is to be included in the submission required by 1.4.3 and is to identify Connection Equipment (weak points) that will be damaged, if any, in the event of separation. Damage to connection cables, plugs and socket-outlets or other identified equipment may be considered.

3.2.8 Connection Equipment cable reels, cranes and/or gantries used to manage, handle or adjust connection cables, plugs and/or socket-outlets, are to be designed and manufactured in accordance with applicable LR Rules or a marine standard acceptable to LR. A manufacturer's certificate verifying suitability for safe and effective operation for the Defined Operations and service profile is to be submitted.

3.2.9 The manufacturer's certificate referred to in 3.2.8 is to be in the English language and include the following information:

(a) Design and manufacturing standard(s) used.
(b) Materials used for construction of key components and their sources.
(c) Details of the quality control system applied during design, manufacture and testing.
(d) Details of any existing type approval or type testing.
(e) Details of installation and testing recommendations.

The manufacturer is to have a recognised quality management system certified by an IACS member or a Notified Body.

3.2.10 Connection cubicle and connection equipment locations are to have warning notices placed in prominent positions to indicate the presence of moving equipment, electricity and high voltage as applicable.

3.2.11 Effective means are to be provided to prevent the accumulation of moisture and condensation within equipment enclosures. Failure of heaters and/or ventilation fans provided to satisfy this requirement is to activate an alarm at a machinery control station that is attended while connected to an external power supply. The installation of open deck enclosures for high voltage connections is to be minimised to that required for the Defined Operations; a technical justification, including proposed degree of protection ratings, is to be included in the submission required by 1.4.8.

3.2.12 Connection Equipment support and management arrangements are to ensure that the correctly applied equipment is kept clear of areas where they may be exposed to moisture or temperatures outside their rating.

3.2.13 Arrangements are to be provided for stowage of on-board equipment when not in use such that equipment:

- will not be exposed to environmental conditions outside its rating;
- can be stowed, stored and removed without damage; and
- does not present a hazard during normal ship operation.

Adapters, extensions and parts dismantled after use are also to be provided with stowage arrangements.

3.3 Connection cables, plugs and socket-outlets

3.3.1 Plugs and socket-outlets for external electrical power supply connection points, including those for external control engineering arrangements, are to be designed, constructed and tested in accordance with IEC 62613-1: *Plugs, socket-outlets and ship couplers for high-voltage shore connection systems (HVSC Systems) – Part 1: General requirements* or a relevant National Standard.

3.3.2 Plugs are to conform to applicable requirements that ensure compatibility with the intended socket-outlet type. Compatible plugs and socket-outlets are to be in accordance with IEC 62613-2: *Plugs, socket-outlets and ship couplers for high-voltage shore connection systems (HVSC-Systems) – Part 2: Dimensional compatibility and interchangeability requirements for accessories to be used by various types of ships* or a relevant National Standard.

3.3.3 Type tests are to be carried out on power connection plug and socket-outlets and cables, in accordance with IEC 62613-1: *Plugs, socket-outlets and ship couplers for high-voltage shore connection systems (HVSC Systems) – Part 1: General requirements* and Annex A.3 of the IEC/ISO/IEEE 80005-1:2012: *Electrical installations in ships – Special features: High-voltage shore connection systems* respectively or a relevant National Standard, to verify design suitability for the intended application described in the Design Statement. Type test reports are to be submitted that include details of the standards, the tests conducted and their order and the acceptance criteria. Alternative proposals may be submitted for consideration.

3.3.4 Power connection plugs and socket-outlets are to be assigned with ratings based on testing in accordance with IEC 62613-1: *Plugs, socket-outlets and ship couplers for high-voltage shore connection systems (HVSC Systems) – Part 1: General requirements* or a relevant National Standard. Details are to be provided in the submission required by 1.4.5.

3.3.5 Power connection plugs and socket-outlets are to be located to minimise the potential of arc flash hazards and suitable warning notices are to be provided at locations along Connection Equipment routes, including power connection plugs and socket-outlets operational locations.

3.3.6 Connection Equipment power cables are to be Type Approved in accordance with LR's *Type Approval System Test Specification Number 3* or, alternatively, surveyed by the Surveyors during manufacture and testing to assess compliance with 3.3.3 and application of an acceptable quality management system. Connection equipment cables are to be installed so as to minimise the risk of short-circuit when correctly applied.

3.4 Containers

3.4.1 Connection Equipment installed in removable containers is to satisfy the additional requirements of this sub-Section.

3.4.2 Containers are to be for the ship's exclusive use and are to be provided with a permanent notice indicating the ship name and IMO Ship Number.

3.4.3 Container locations are to be designated and identified in the plans required by 1.4.4 and provided with fixings that are suitable for the Defined Operations. Procedures for container fixing, use and movement are to be included in the Operating Manuals.

3.4.4 The container type is to be a steel, closed type, weatherproof construction sufficient to prevent damage during expected use, for example during loading and unloading.

3.4.5 Measures necessary to prevent movement of the container when the container has electrical cables connected are to be provided.

3.4.6 Suitable protection is to be provided to prevent damage to Connection Equipment at the container entry points.

3.4.7 Suitable safe access is to be provided to the container for the Defined Operations, inspection and maintenance.

3.4.8 Container entry points are to be provided with suitable sealing arrangements to prevent the ingress of water into the container.

3.4.9 Containers are to be provided with effective means of ventilation. Where a container ventilation fan is provided, alarms are to be provided in accordance with 3.2.11.

3.5 High voltage in the presence of personnel

3.5.1 The Defined Operations are, as far as is practical, not to require personnel to be in the vicinity of high voltage equipment when it is energised.

3.5.2 For high voltage:
(a) switchgear and control gear assemblies;
(b) cable reels, cranes and gantries; and
(c) mounting enclosures for socket-outlets used to connect flexible cables to fixed connections;

arrangements are to be made to protect personnel in the event of gases, arc flash or vapours escaping under pressure as the result of arcing due to an internal fault. Where the Defined Operations require personnel to be in the vicinity of such equipment when it is energised, this may be achieved by an assembly that has been tested in accordance with Annex A of IEC 62271-200 and qualified for classification IAC (internal arc classification), or equivalent.

■ *Section 4* Electrical system

4.1 Electrical load transfer

4.1.1 'Dead transfer' arrangements are to be provided that permit transfer between operation using ship sources of electrical power and an external electrical power supply by disconnecting one from the ship distribution system and then connecting the other to the dead system.

4.1.2 Additional arrangements for connecting ship sources of electrical power and an external electrical power supply in parallel temporarily to transfer load from one to the other only are permitted, provided these are in accordance with 4.1.3 to 4.1.9.

4.1.3 Means to automatically synchronise a ship source of electrical power with an external electrical power supply and connect them in parallel for load transfer when requested by operating staff are to be provided.

4.1.4 Means to automatically transfer load between a ship source of electrical power and an external electrical power supply following their connection in parallel, are to be provided. The load transfer is to be completed in as short a time as practicable without causing machinery or equipment failure or operation of protective devices and this time is to be used as the basis for defining the Transfer Time Limit required by 4.1.5.

4.1.5 When transferring of load between ship sources of electrical power and an external electrical power supply exceeds a defined Transfer Time Limit then, arrangements are to be such that:
- the transfer is aborted;
- load is removed from the ship sources of electrical power or external electrical power supply that was intended to take the load; and then
- the Connection Circuit-Breaker is opened.

An alarm is to be provided at a machinery control station that is attended when connected to an external electrical power supply when the Transfer Time Limit is exceeded and is to indicate the return to previous operating conditions.

4.1.6 The Transfer Time Limit referred to in 4.1.5 may be adjustable to match the ability of an external electrical power supply to accept and shed load. Setting of the Transfer Time Limit is to be demonstrated to the attending Surveyor at Surveys and Trials, *see* 6.1.

4.1.7 An external power supply may only be connected in parallel with a single ship source of electrical power. Arrangements are to be provided to ensure that this requirement is satisfied before and during parallel connection. Details of alternative proposals may be submitted for consideration.

4.1.8 Arrangements provided to adjust ship sources of electrical power to allow connection in parallel and transfer of load are not to cause machinery or equipment failure, operation of protective devices or damage under normal conditions or in the event of a failure.

4.1.9 Where load reductions are required to transfer load they are not to result in loss of essential services or the loss of availability of emergency services. Means are to be provided to readily make necessary load reductions and re-instate supplies following transfer.

4.2 Capacity

4.2.1 Arrangements for operating from external supplies are to be sufficiently rated to supply the following:
- essential services normally required in port;
- emergency services;
- services required to ensure ready availability of non-operating main and auxiliary machinery;
- services required to prevent damage to cargo or stores; and
- the services required for the Defined Operations.

The schedule of loads required by Pt 6, Ch 2,1.3.3 is to incorporate operation when connected to an external electrical power supply.

4.2.2 The maximum electrical step load switched on or off is not to cause the power supply quality to exceed the parameters given in Pt 6, Ch 2,1.8 or failure when connected to an external electrical power supply in accordance with the defined requirements, *see* 3.1.10.

4.2.3 Consideration is to be given to providing means to inhibit automatically the connection of large motors, or the connection of other large loads, that the arrangements are not rated to supply when connected to an external electrical power supply having the defined minimum apparent power or current capacity, *see* 3.1.10 and Pt 6, Ch 2,6.9.4.

4.3 Protection

4.3.1 Where an external electrical power supply is not arranged to operate in parallel with ship sources of electrical power, the connection to the external electrical power supply is to be provided with a Connection Circuit-Breaker arranged to open simultaneously, in the event of short-circuit, overload or undervoltage, all insulated poles.

4.3.2 Where an external electrical power supply is arranged to operate in parallel with ship sources of electrical power during load transfer, the connection to the external electrical power supply is to be provided with a Connection Circuit-Breaker arranged to open simultaneously, in the event of a short-circuit, an overload or an undervoltage, all insulated poles. This circuit-breaker is to be provided with reverse power protection with time delay, selected or set within the limits of 2 per cent to 15 per cent of full load to a value fixed in accordance with the rating defined in the Design Statement; a fall of 50 per cent in the applied voltage is not to render the reverse power mechanism inoperative, although it may alter the amount of reverse power required to open the circuit breaker.

4.3.3 The electrical system, including short-circuit protective device rating, is to be suitable for the highest prospective fault level at the point of installation. The short-circuit current calculations required by Pt 6, Ch 2,1.2.6 are to identify the system state that would result in the highest prospective fault level. The highest prospective fault level may occur during parallel connection with an external power supply and the resulting combination of:

(a) ship sources of electrical power, taking into account 4.1.7; and

(b) an external electrical power supply having the defined maximum permitted prospective fault level, *see* 3.1.10.

Details of alternative proposals may be submitted for consideration.

4.3.4 The connection circuit is to be arranged such that contamination due to the products of arcing as a result of a fault in the Connection Circuit-Breaker enclosure on the external power supply side will not result in essential or emergency services not being available when supplied by ship sources of electrical power.

4.3.5 Initial connection of an external electrical power supply to the ship switchboards or converter equipment to connect to ship loads is to be arranged to be made by closing of the Connection Circuit-Breaker only.

4.3.6 Converter equipment used to connect an external electrical power supply to the ship electrical system is to ensure that a supply that would result in damage is not applied to the connected ship electrical systems in the event of a failure.

4.3.7 The voltage and time delay settings of the Connection Circuit-Breaker undervoltage release mechanism(s) are to be selected to ensure that the discriminative action required by Pt 6, Ch 2,6.1.1(a) is maintained.

4.3.8 Means are to be provided to prevent closure of the Connection Circuit-Breaker when a connected external electrical power supply has a different phase rotation or has a voltage or frequency that does not match the ship electrical system rating within the tolerances defined by Pt 6, Ch 2,1.8.2 or 1.8.4. Signals are to be provided, where necessary, to allow comparison with ship electrical system characteristics.

4.3.9 Connection power circuits are to be provided with protection against earth faults in accordance with Pt 6, Ch 2,6.4.

4.4 Interlocking and synchronising arrangements

4.4.1 External electrical power supply connections are to be provided with instruments and devices on board equivalent to those required for alternating current generators by Pt 6, Ch 2,7.11.1 where synchronising is not provided, or by Pt 6, Ch 2,7.11.2 to 7.11.3 where synchronising for load transfer is provided. *See also* Pt 6, Ch 2,7.11 and 7.12.

4.4.2 Means are to be provided to ensure that a source of electrical power or electrical power supply can only be connected to other live parts when synchronised. *See also* 4.1.2 for temporary parallel connection for load transfer.

4.4.3 The arrangements are to prevent Connection Equipment power conductors being made live by connecting to the ship electrical system.

4.4.4 The simultaneous connection of a ship source of electrical power and external electrical power supply to the same dead part of the electrical system is to be prevented.

4.4.5 For high-voltage connections, suitable means are to be provided to earth the connection power circuit so that it is discharged and so maintained that it is safe to touch.

4.4.6 Means provided to connect a connection power circuit to earth are to be arranged such that the circuit may only be earthed when it is isolated.

4.4.7 Interlocking arrangements are to be provided to prevent the connection of a high-voltage external power supply to a switchboard connected to earth using the means required by Pt 6, Ch 2,7.8.

4.5 Ship power restoration

4.5.1 When the ship main source of electrical power is shut-down and failure of the connected external electrical power supply occurs, the Connection Circuit-Breaker is to be arranged to automatically open followed by:

(a) connection of the emergency source of electrical power to emergency services in accordance with Pt 6, Ch 2,3.2.8(a)(ii), 3.2.8(b)(ii) to (iii), 3.3.8(a)(ii) or 3.3.8(b)(ii) to (iii) as applicable; and
(b) automatic connection of the transitional source of electrical power to emergency services in accordance with Pt 6, Ch 2,3.2.7 or 3.3.7 as applicable; and
(c) automatic starting and connecting to the main switchboard of the main source of electrical power and automatic sequential restarting of essential services, in as short a time as is practicable. *See also* 2.1.3 and Pt 6, Ch 2,2.2.3.

Failures include loss of power, disconnection, phase failure and quality of supply outside the tolerances given in Pt 6, Ch 2,1.8.2 or 1.8.4.

4.5.2 An alarm is to be provided at a machinery control station that is attended when connected to an external electrical power supply to indicate activation of the automatic power supply failure response required by 4.5.1. The alarm is to indicate the failure that caused the activation.

4.5.3 The automatic power supply failure response required by 4.5.1 is to be inhibited during the 'dead transfer' required by 4.1.1 but arrangements are to permit personnel to readily revert to operation from ship sources of electrical power if the 'dead transfer' to the external electrical power supply is not completed.

■ *Section 5* Control and monitoring

5.1 General

5.1.1 Control engineering arrangements are to be in accordance with Pt 6, Ch 1, as applicable. The connection of, and the electrical load transfer to and from, an external electrical power supply are only to be controlled on board using shipboard arrangements.

5.1.2 External control of ship equipment may only be provided when in accordance with 5.1.5. Otherwise, external arrangements may be used to send requests for action to ship personnel for consideration.

5.1.3 Integration or connection with external, control, alarm and safety systems is to be 'fail-safe'.

5.1.4 The effects of failure of control, alarm and safety system and data communication link connections are to be documented along with resulting failure responses in the submission required by 1.4.6.

5.1.5 Details of proposals that would involve external control of ship equipment to respond to potentially hazardous situations detected externally are to be submitted for consideration. Provided that the arrangements are considered to be in accordance with the provisions of an acceptable and relevant standard, the following external control functions may be permitted:

- initiation of load reductions;
- initiation of electrical load transfer to ship sources of electrical power; and
- initiation of Emergency Shut-Down.

5.1.6 The connection power circuit is to be isolated, and for high-voltage connections connected to earth so that it is discharged and so maintained that it is safe to touch, until the connections necessary for safe and effective operation are correctly established, including control, alarm and safety system and data communication link connections.

5.1.7 Following the correct establishment of the necessary connections in accordance with 5.1.6:

- where applicable, the connection power circuit may be disconnected from earth; and arranged such that only then
- may the request to make the external power supply connection points live described in 5.1.8 be sent.

5.1.8 Ship control system arrangements are to be provided to request the external electrical power supply conductors to be:

- where applicable, disconnected from earth; and then
- made live up to the connection points.

5.1.9 An alarm is to be provided at a machinery control station that is attended when connected to an external electrical power supply upon failure of arrangements required to maintain ready availability in accordance with 2.1.3 (for example pre-heating).

5.1.10 Additional alarms with their associated safeguards are indicated in Table 13.5.1. These are in addition to those required by other Parts of the Rules.

5.1.11 Means are to be provided to allow testing of control, alarm and safety system connections with external arrangements, including operation of Emergency Shut-Down facilities, before electrical connection to an external power supply.

5.1.12 If, depending upon the in-port shipboard work organisation, no machinery control stations are continuously attended while connected to an external power supply, then alarm transfer arrangements that activate an audible indication to warn relevant duty personnel of alarm initiation may be accepted. An audible warning from any portable devices is to be provided in the event of loss of the wireless link.

Table 13.5.1 Additional alarms and associated safeguards

<table>
<tr><th>Item</th><th>Alarm</th><th>Note</th></tr>
<tr><td>Presence of voltage on connections</td><td></td><td>Indicators in accordance with 3.1.9.</td></tr>
<tr><td>Transfer of load</td><td>Time limit exceeded</td><td>Return to previous operating state to be indicated, see 4.1.5.</td></tr>
<tr><td>Ship power restoration</td><td>Activation</td><td>See 4.5.2.</td></tr>
<tr><td>Arrangements to ensure main and auxiliary machinery availability</td><td>Failure</td><td>When shut-down. See 5.1.9.</td></tr>
<tr><td>Applied connection equipment status</td><td>Changed</td><td>Indication to be provided also. See 5.2.4 and 5.2.5.</td></tr>
<tr><td>Connection equipment</td><td>Close proximity to water level</td><td>See 5.2.6.</td></tr>
<tr><td>Heaters and/or ventilation fans</td><td>Failure</td><td>See 3.2.11 and 3.4.9</td></tr>
<tr><td>Connection equipment tension</td><td>High</td><td rowspan="6">Emergency Shut-Down to be activated. See 5.3.11.</td></tr>
<tr><td>Plug connectors</td><td>Withdrawal</td></tr>
<tr><td>Earth connection, if required. See 5.3.9</td><td>Loss of continuity</td></tr>
<tr><td>Manual disconnection</td><td>Activation</td></tr>
<tr><td>Plug and socket-outlet, if required. See 5.3.6</td><td>Not in locked position</td></tr>
<tr><td>Switchgear enclosure mounted socket-outlets</td><td>Arc fault detection</td></tr>
</table>

5.2 Connection Equipment control and monitoring

5.2.1 Connection Equipment is to be capable of unattended operation under normal operating conditions after correct application of the connection. Remote indication of active ship equipment faults at a machinery control station that is attended when connected to an external electrical power supply is to be provided. Details of arrangements that involve periodic attendance to inspect and adjust Connection Equipment may be submitted for consideration.

5.2.2 A control station is to be provided locally to Connection Equipment cable reel, cranes and gantries that permits identification of faults and permits safe and effective supervision and control of this equipment in the foreseeable environmental conditions.

5.2.3 A fixed means of two-way voice communication with a machinery control station that is attended when connected to an external electrical power supply is to be provided at the control station required by 5.2.2.

5.2.4 The control station required by 5.2.2 is to be provided with a means for operators to:
- select manual control; or
- lock equipment in position; or
- where provided, select automatic adjustment.

This status is to be indicated remotely at a machinery control station that is attended when connected to an external electrical power supply.

5.2.5 When the equipment status selection referred to in 5.2.4 is changed whilst an external electrical power supply is connected, an alarm is to be activated at a machinery control station that is attended when connected to an external electrical power supply.

5.2.6 Where correctly applied connection equipment is not protected from submersion in the water between the ship and shore (e.g. submersible equipment, equipment routing or slack cable prevention by torque control), an alarm is to be provided at a machinery control station that is attended when connected to an external electrical power supply when Connection Equipment approaches a situation where it may be submerged in the water between the ship and shore, for instance due to tidal changes. The time between alarm initiation and possible exposure to this water is to be sufficient to allow the equipment to be attended and adjusted prior to exposure to water.

5.3 Emergency Shut-Down

5.3.1 The requirements of this sub-Section apply to arrangements for the emergency disconnection of live electrical power from the connection to an external electrical power supply.

5.3.2 Emergency Shut-Down facilities are to be provided that, when activated, will instantaneously:
- isolate the connection from ship electrical power supplies; and
- request isolation of the external electrical power supply connection points.

5.3.3 High-voltage Connection Equipment is to be either:
(a) provided with permanent arrangements for manual discharging and routed to prevent personnel access to live connection cables and connection points by barriers and/or adequate distance(s) under expected operating conditions; or
(b) automatically discharged so that it is safe to touch with immediate initiation of switching device closure following the isolation from ship and shore electrical power supplies required by 5.3.2.

5.3.4 For ships that are intended to connect in ports where Connection Equipment may move into a hazardous area associated with the terminal or port area as a result of the ship inadvertently leaving the berthed position (slipping/breaking of moorings, etc.), this condition is to be included in the Design Statement. The arrangements are to comply with 5.3.3(b) and, additionally, other electrically powered connection equipment that is not intrinsically safe is to be arranged for automatic isolation.

5.3.5 Means are to be provided to detect or predict tension in the external electrical power supply connection cable that activate the Emergency Shut-Down facilities described in 5.3.2 before damage occurs. Where alternative arrangements to tension detection are proposed (automatic break-away release, connectors with shear bolts and pilot lines, connection with ship/shore Emergency Shut-Down system, etc.), details are to be submitted for consideration.

5.3.6 To detect and react to the withdrawal of plugs from socket-outlets while power supply connections are live, the Emergency Shut-Down facilities described in 5.3.2 are to be activated before the necessary degree of protection is no longer achieved or power connections are broken by the removal of a plug from a connected socket-outlet, including in-line connections.

5.3.7 For high-voltage connection points on board where the means of locking together plugs and socket-outlets required by 3.3.4 are not interlocked to prevent removal from the locked position when the Connection Equipment power connections are not discharged so that they are safe to touch, the Emergency Shut-Down facilities described in 5.3.2 are to be activated when connected plugs are moved from the locked position. Consideration may be given to relaxing this requirement when evidence is submitted which demonstrates that appropriate controls and procedures acceptable to LR are in place to control personnel access plugs and socket-outlets.

5.3.8 Where connection power plugs are connected to socket-outlets mounted on a switchgear enclosure, arrangements are to be provided to activate the Emergency Shut-Down facilities described in 5.3.2 in as short a time as practicable in the event of an arc occurring in the enclosure at the rear of the socket-outlets.

5.3.9 Where 3.1.7(b) applies, the Emergency Shut-Down facilities described in 5.3.2 are to be activated in the event of loss of earth connection continuity being detected.

5.3.10 Means to manually activate the Emergency Shut-Down facilities described in 5.3.2 are to be provided at:
- a machinery control station that is attended when connected to an external electrical power supply;
- in close proximity to the connection cubicle; and
- at the switchboard where the fixed cable from the shore connection cubicle are received.

Additional manual activation facilities may also be provided at other locations where it is considered necessary. The means of activation are to be visible and prominent, prevent inadvertent operation and require a manual action to reset.

5.3.11 An alarm to indicate activation of the Emergency Shut-Down is to be provided at a machinery control station that is attended when connected to an external electrical power supply. The alarm is to indicate the cause of the activation. For power supply restoration, *see* 4.5.1 to 4.5.3.

■ *Section 6* Testing, trials and surveys

6.1 General

6.1.1 The testing and trials required by 6.1.2 to 6.1.5 are to be successfully completed to the Surveyor's satisfaction before **OPS** notation may be assigned. Where appropriate test facilities cannot be provided, trials are likely to require the additional co-operation of a port facility with a suitable external electrical power supply and the ability to operate the defined services to be supplied during these trials and allow the testing described to be conducted.

6.1.2 Electrical and control engineering equipment is to be surveyed at manufacturer's works and undergo survey and operational trials on board in accordance with the approved test schedules and applicable testing requirements in Pt 6, Ch 1 and Ch 2.

6.1.3 In addition to 6.1.2, the following Connection Equipment, where applicable, is to be surveyed by the Surveyors during manufacture and testing:
- filters;
- converters; and
- slip ring assemblies.

6.1.4 Cable reels, cranes and/or gantry drives for Connection Equipment are to be surveyed and tested in accordance with applicable LR Rules and 3.2.9(e).

6.1.5 Trials are to be conducted when connected to a compatible external electrical power supply in accordance with 3.1.10 to demonstrate to the attending Surveyor that the Rules have been complied with in respect of:

(a) operation of connection management arrangements;
(b) trials on cable lifting appliances (for example cable reels or cranes) are to be conducted that demonstrate suitability for the maximum mechanical load and duty required by the Defined Operations within the service profile contained in the Design Statement, including connection of extensions or adapters;
(c) satisfactory performance of the connection and Connection Equipment throughout the Defined Operations, including a run with the defined services to be supplied operational;
(d) temperature of electrical joints, connections, circuit-breakers and fuses;
(e) the operation of electrical load transfer arrangements, (including Transfer Time Limit setting), electrical system protection and interlocking devices, Emergency Shut-Down arrangements and other safety devices and ship power restoration;
(f) where acceptable type-test evidence is not submitted, connection break-away, *see* 3.2.7;
(g) voltage regulation when the maximum load is suddenly thrown off and when starting the largest motor connected to the system;
(h) where more than one external power supply connection can be operated in parallel, satisfactory load sharing at loads up to normal working load; and
(j) voltage drop is to be measured, where necessary, to verify that this is not in excess of that specified in Pt 6, Ch 2,1.8.

6.1.6 Arrangements are to be:

- examined at Annual Survey; and
- examined and functionally tested whilst connected to an external electrical power supply during the Complete Surveys of machinery or, where this is not practical, within 12 months of the due date of the Complete Surveys of machinery.

This is to include examination of Connection Equipment.

Section 1 Requirements for machinery and engineering systems of unconventional design

1.1 General – Scope and objectives

1.1.1 Consistent with the aims of the IMO guidelines for Formal Safety Assessment (MSC-MEPC.2/Circ.12), the requirements of this Section aim to ensure that risks to maritime safety and the environment, stemming from the introduction of machinery or engineering systems of unconventional design, are addressed insofar as they affect the objectives of classification.

1.1.2 The requirements of this section are to be satisfied where:

(a) machinery is required to be constructed, installed and tested in accordance with Lloyds Register's (hereinafter referred to as LR) Rules and Regulations and for which the corresponding machinery class notation is to be assigned (*see* Pt 1, Ch 2,2.4); and

(b) the machinery and engineering systems are considered by LR to be of an unconventional design and which, as a result, are not directly addressed by LR's extant Rules and Regulations.

1.1.3 It is to be noted that as well as the requirements of this section, the general requirements of LR's Rules and Regulations are also to be satisfied as far as they are applicable.

1.1.4 Compliance with ISO15288 *Systems Engineering – System Life Cycle Processes* or an acceptable equivalent National Standard may be accepted as meeting the requirements of 1.3 to 1.11.

1.2 Information to be submitted

1.2.1 Information is to be submitted for assessment of compliance with the general requirements of LR's Rules and Regulations, including the general requirements for:

(a) Machinery, *see* Pt 5, Ch 1.

(b) Steam raising plant and pressure vessels, *see* Pt 5, Ch 10.

(c) Machinery and ship piping systems, *see* Pt 5, Ch 12 to Ch 14.

(d) Control engineering, *see* Pt 6, Ch 1.

(e) Electrical engineering, *see* Pt 6, Ch 2.

(f) Materials, *see Rules for the Manufacture, Testing and Certification of Materials*.

1.2.2 In addition to the information identified in 1.2.1, the information described in 1.2.3 and 1.2.4 is also to be submitted for consideration.

1.2.3 General description detailing the extent of the machinery or engineering system, the shipboard services it is to provide, its operating principles, and its functionality and capability when operating in the environment to which it is likely to be exposed under both normal and foreseeable abnormal conditions. The general description is to be supported by the following information as applicable:

(a) System block diagram.

(b) Piping and instrumentation diagrams.

(c) Description of operating modes, including:
Start-up, shut-down, automatic, reversionary, manual and emergency.

(d) Description of safety related arrangements, including:
Safeguards, automatic safety systems and interfaces with ships safety systems.

(e) Description of connections to other shipboard machinery, equipment and systems, including:
Electrical, mechanical, fluids and automation.

(f) Plans of physical arrangements, including:
Location, operational access and maintenance access.

(g) Operating manuals, including:
Instructions for start-up, operation, shut-down, instructions for maintenance, instructions for adjustments to the performance and functionality and details of risk mitigation arrangements.

(h) Maintenance manuals, including:
Instructions for routine maintenance, repair following failure, disposal of components and recommended spares inventory.

1.2.4 Project process documentation including:

(a) Project Management Plan, *see* 1.3.

(b) Requirements Definition Document, *see* 1.4.

(c) Quality Assurance Plan, *see* 1.5.

(d) Design Definition Document, *see* 1.6.

(e) Risk Management Plan, *see* 1.7.

(f) Configuration Management Plan, *see* 1.8.

(g) Verification Plan, *see* 1.9.

(h) Integration Plan, *see* 1.10.

(j) Validation Plan (certification and survey), *see* 1.11.

1.3 Project management

1.3.1 A project management procedure is to be established in order to define and manage the key project processes. The project processes are to include the processes described in 1.4 to 1.11.

1.3.2 For the entire project, and each of the processes within the project, the project management procedure is to define the following:

(a) Activities to be carried out.

(b) Required inputs and outputs.

(c) Roles of key personnel.

(d) Responsibilities of key personnel.

(e) Competence of key personnel.

(f) Schedules for the activities.

1.4 Requirements definition

1.4.1 A requirements definition procedure is to be established in order to define the functional behaviour and performance of the machinery or engineering system required by individual stakeholders, in the environments to which the machinery or engineering system is likely to be exposed under both normal and foreseeable emergency conditions.

1.4.2 The procedure is to take account of requirements resulting from key stakeholders, including:
(a) Ship's owner.
(b) Ship's operator.
(c) Ship's crew.
(d) Shipyard.
(e) Systems integrator.
(f) Designers.
(g) Maintenance personnel.
(h) Surveyors.
(j) Manufacturers and suppliers.
(k) National Administration.
(l) LR.

1.4.3 The procedure is to take account of requirements resulting from the following influences:
(a) Ship operations, including:
Underway, manoeuvring, pilotage, docking, alongside and training exercises.
(b) Ship conditions, including:
Normal operation, abnormal operation, blackout, deadship, fire in a single compartment and flooding of a single compartment.
(c) Environmental conditions, including:
Temperature, humidity, water spray, salt mist, vibration, shock, inclination, electrical fields and magnetic fields.
(d) Applicable provisions, including:
Statutory legislation, classification requirements, international standards, national standards and codes of practice.
(e) Expected users, including:
Multi-national users with a range of national languages and cultures, fatigued users, users without dedicated training, and maintenance and survey personnel.
(f) Design, construction and operational constraints, including:
Effect of particular design decisions or component choices on other aspects of design, risk and production engineering compromises, verification, integration and validation considerations, maintenance and disposal, and changes in use.

1.4.4 The procedure is to specify the functional behaviour and performance requirements and is to identify the source of the requirements.

1.5 Quality assurance

1.5.1 A quality assurance procedure is to be established in order to ensure that the quality of the machinery or engineering system is in accordance with a defined quality management system.

1.5.2 The procedure is to define the specific quality controls to be applied during the project in order to satisfy the requirements of the quality management system.

1.5.3 The quality management system is to satisfy the requirements of ISO9001:2000 *Quality management systems – Requirements*, or an equivalent acceptable National Standard.

1.6 Design definition

1.6.1 A design definition procedure is to be established in order to define the requirements for the design of machinery or an engineering system which satisfies stakeholder requirements, quality assurance requirements and complies with basic internationally recognised design requirements for safety and functionality.

1.6.2 The procedure is to ensure that the design of the machinery or engineering system satisfies:
(a) Statutory legislation.
(b) LR's requirements.
(c) International Standards and Codes of Practice where relevant.

1.6.3 The procedure is to take account of stakeholder requirements, *see* 1.4.

1.6.4 The procedure is to take account of quality assurance requirements, *see* 1.5.

1.6.5 The procedure is to ensure that the requirements for the design of major components and subsystems of the machinery or engineering system can be verified before and after integration.

1.6.6 The procedure is to specify the design requirements and is to identify the source of the requirements.

1.6.7 Any deviations from stakeholder requirements are to be identified, justified and accepted by the originating stakeholder.

1.7 Risk management

1.7.1 A risk management procedure is to be established in order to ensure that any risks stemming from the introduction of the machinery or engineering system are addressed, in particular risks affecting:
(a) The structural strength and integrity of the ship's hull.
(b) The safety of shipboard machinery and engineering systems.
(c) The safety of shipboard personnel.
(d) The reliability of essential and emergency machinery and engineering systems.
(e) The environment.

1.7.2 The procedure is to consider the hazards associated with installation, operation, maintenance and disposal, both with the machinery or engineering system functioning correctly and following any reasonably foreseeable failure.

1.7.3 The procedure is to take account of stakeholder requirements, *see* 1.4.

1.7.4 The procedure is to take account of design requirements, *see* 1.6.

1.7.5 The procedure is to ensure that hazards are identified using acceptable and recognised hazard identification techniques, and that the effects of the following influences are considered:

(a) Ship operations, including:
Underway, manoeuvring, pilotage, docking, alongside and maintenance, commissioning and trials.
(b) Ship conditions, including:
Normal operation, blackout, dead-ship, fire in a single compartment and flooding of a single compartment.
(c) Modes of operation, including:
Start-up, running, shut-down, automatic, reversionary, manual and emergency.
(d) Environmental conditions, including:
Temperature, humidity, water spray, salt mist, vibration, shock, inclination, electrical fields and magnetic fields.
(e) Dependencies, including:
Power, fuel, air, cooling, heating, data and human input.
(f) Environmental impact, including:
Emissions to air, discharges to water, noise and waste products.
(g) Failures, including:
Human error, supply failure, system, machinery, equipment and component failure, random, systematic and common cause failures.

1.7.6 The procedure is to ensure that risks are analysed using acceptable and recognised risk analysis techniques and that the following effects are considered:

(a) Local effects:
Loss of function, component damage, fire, explosion, electric shock, harmful releases and hazardous releases.
(b) End effects on:
Services essential to the safety of the ship, services essential to the safety of shipboard personnel and services essential to the protection of the environment.

1.7.7 The procedure is to ensure that risks are eliminated wherever possible. Risks which cannot be eliminated are to be mitigated as necessary.

1.7.8 Details of risks, and the means by which they are mitigated, are to be included in the operating manual, *see* 1.2.3.

1.8 Configuration management

1.8.1 A configuration management procedure is to be established in order to ensure traceability of the configuration of the machinery or engineering system, its subsystems and its components.

1.8.2 The procedure is to identify items essential for the safety or operation of the machinery or engineering system (configuration control items) which could foreseeably be changed during the lifetime of the machinery or engineering system, including:

(a) Documentation.
(b) Software.
(c) Sensors.
(d) Actuators.
(e) Instrumentation.
(f) Valves.
(g) Pumps.

1.8.3 The procedure is to take account of the design requirements, *see* 1.6.

1.8.4 The procedure is to include items used to mitigate risks, *see* 1.7.

1.8.5 The procedure is to ensure that any changes to configuration control items are:

(a) Identified.
(b) Recorded.
(c) Evaluated.
(d) Approved.
(e) Incorporated.
(f) Verified.

1.9 Verification

1.9.1 A verification procedure is to be established in order to ensure that subsystems and major components of the machinery or engineering system satisfy their design requirements.

1.9.2 The procedure is to verify design requirements, *see* 1.6.

1.9.3 The procedure is to identify the requirements to be verified, the means by which they are to be verified, and the points in the project at which verification is to be carried out.

1.9.4 The procedure is to be based on one or a combination of the following activities as appropriate:

(a) Design review.
(b) Product inspection.
(c) Process audit.
(d) Product testing.

1.10 Integration

1.10.1 An integration procedure is to be established in order to ensure that the machinery or engineering system is assembled in a sequence which allows verification of individual subsystems and major components following integration in advance of validating the entire machinery or engineering system.

1.10.2 The procedure is to take account of the verification requirements, *see* 1.9.

1.10.3 The procedure is to identify the subsystems and major components, the sequence in which they are to be integrated, the points in the project at which integration is to be carried out, and the points in the project at which verification is to be carried out.

1.11 Validation (certification and survey)

1.11.1 A validation procedure is to be established in order to ensure the functional behaviour and performance of the machinery or engineering system meets with its functional and performance requirements.

1.11.2 The procedure is to validate stakeholder requirements, *see* 1.4.

1.11.3 The procedure is to validate arrangements required to mitigate risks, *see* 1.7.

1.11.4 The procedure is to validate the traceability of the configuration control items, *see* 1.8.

1.11.5 The procedure is to identify the requirements to be validated, the means by which they are be validated and the points in the project at which validation is to be carried out, including:
(a) Factory acceptance testing.
(b) Integration testing.
(c) Commissioning.
(d) Sea trials.
(e) Survey.

Section

Section 1
General requirements

1.1 General

1.1.1 This Chapter states the requirements for ships having centralised refrigeration systems, designed to reject heat from refrigerated stores or from the air-conditioning and ventilation arrangements fitted to both passenger and crew accommodation spaces and are in addition to the relevant requirements of Parts 5 and 6.

1.1.2 The requirements, which are optional, cover arrangements, equipment, and systems necessary for provision stores and air-conditioning arrangements as defined in 1.1.3 and 1.1.4.

1.1.3 The refrigeration system is to include the refrigeration compressor(s), condenser(s), evaporator(s), direct expansion air handling and fan coil units, interconnecting primary refrigerant piping system and fittings.

NOTE

For the purpose of these Rules, the term primary refrigerant system, unless otherwise stated, applies to primary refrigerant systems and secondary refrigerant systems containing volatile refrigerants.

1.1.4 These requirements are intended to mitigate risks associated with the safety of refrigeration and air-conditioning machinery, and do not cover air distribution ductwork, chilled water systems or the calculation and verification of air flow rates and cooling loads within the air conditioned or refrigerated spaces. The method used to calculate the capacity of the air-conditioning refrigeration equipment is the responsibility of the Shipbuilder and Owner and should be in accordance with a recognised code or standard such as ISO 7547:2002 *Ships and marine technology – Air-conditioning and ventilation of accommodation spaces – Design conditions and basis of calculations* or, ASHRAE 26-1996(RA2006) *Mechanical Refrigeration and Air-Conditioning Installations Aboard Ship*.

1.1.5 Ships complying with the applicable requirements of this Chapter will be eligible for the optional machinery class notation **RPA** (Refrigeration Machinery for Provision Stores and Air-conditioning).

1.2 Plans and information

1.2.1 The following plans and particulars, as applicable, and any others which may be specially requested for the refrigerating plant and systems, are to be submitted in triplicate for approval, before construction is commenced:

(a) Schematic plans, including full particulars of piping and instrumentations, for:
   - (i) primary and secondary refrigerant systems containing a volatile fluid;
   - (ii) air cooler defrosting arrangements; and
   - (iii) condenser cooling water systems.

(b) Detailed dimensioned plans and material specifications for:
   - (i) reciprocating compressor crankshaft and crankcase, where exposed to refrigerant pressure;
   - (ii) rotary-type compressor rotors and casing;
   - (iii) condensers, both shell and tube, and plate type;
   - (iv) evaporators, both shell and tube, and plate type;
   - (v) air coolers or arrangement of air cooling pipe grids and construction method;
   - (vi) liquid receivers;
   - (vii) oil separators; and
   - (viii) any other pressure vessels or heat exchangers containing primary refrigerants, *see* Pt 5, Ch 11,6.1.

(c) General arrangement of refrigerating machinery compartments in elevation and plan, showing location and arrangement of the plant, ventilation details and location of temperature sensors and refrigerant vapour detectors.

(d) Details of automatic controls, alarms and safety systems, *see* Pt 6, Ch 1,1.

(e) Details of primary refrigerant level indicators.

(f) Capacity calculations for pressure relief valves and/or bursting discs, and inlet and discharge pipework pressure drop calculations.

(g) Programme of tests to be conducted on completion of the installation, *see* Section 7.

1.2.2 In addition to the applicable requirements detailed in 1.2.1, the following information is also to be submitted for air-conditioning refrigeration equipment:

(a) Details of direct expansion fan coil units (FCUs).

(b) Details of cooling coils, fitted to air handling units (AHUs) that contain primary refrigerant.

(c) General arrangement drawing showing the location of the air-conditioning refrigeration equipment, direct expansion FCUs and AHUs throughout the ship.

(d) Details of pressure testing procedures for the refrigeration equipment.

1.2.3 Plans showing the general arrangement of refrigeration plant compartments, together with a description of the equipment and arrangements installed for isolation and distribution of ventilation air and the electrical power supply systems. The plans are to indicate segregation and access arrangements for compartments and associated control rooms and control stations.

1.2.4 A statement of the intended design system capacity for the intended operating conditions for verification purposes at the trials required by 7.2.1

1.2.5 A schedule of testing and trials to demonstrate that systems are capable of operating as designed and as required by Section 7.

1.2.6 Operating manuals are to be submitted for information. The manuals are to include the following information:
(a) Particulars and a description of the systems.
(b) Operating instructions for the equipment and systems.
(c) Maintenance instructions for the installed arrangements.

1.2.7 Evidence that the required performance of refrigeration systems, pump and fan equipment is capable of being maintained under ambient and inclination operating conditions defined in Pt 5, Ch 1,3.5 and 3.6 is to be provided by the manufacturer.

■ *Section 2* Construction and installation

2.1 Materials

2.1.1 The selection of materials for piping systems in provision store refrigeration systems is to take account of the following:
(a) The pressures and temperatures of the refrigerant fluids.
(b) Locations of systems and equipment.
(c) Compatibility of materials.
(d) Fluid flow rates and static pressure conditions.
(e) Minimising corrosion and erosion through life of system.
(f) Refrigerant flammability and toxicity.

2.1.2 Pipes, valves and fittings are in general to be made of steel, ductile cast iron, copper, copper alloy, or other approved ductile material suitable for the intended purpose. The use of plastics materials is also acceptable subject to the restrictions in Pt 5, Ch 12,5.

2.1.3 Where applicable, the piping systems are to comply with the requirements of Pt 5, Ch 12.

2.2 Equipment – Selection and installation

2.2.1 Pressure vessels in provision store and air-conditioning refrigeration systems are to be in accordance with Pt 5, Ch 11.

2.2.2 Valves and flexible hose lengths are to comply with the relevant requirements of Pt 5, Ch 12.

2.2.3 Pipes in piping systems are to be permanent pipes made with approved pipe connections to enable ready removal of valves, pumps, fittings and equipment. The pipes are to be efficiently secured in position to prevent chafing or lateral movement.

2.2.4 Suitable means for expansion are to be made, where necessary, in each range of pipes.

2.2.5 Suitable protection is to be provided for all pipes and equipment situated where they are liable to mechanical damage.

2.2.6 All moving parts are to be provided with guards to minimise danger to personnel.

2.2.7 Primary refrigerant pipework, serving AHUs and FCUs, which pass through bulkheads and deckheads is to comply with the requirements of SOLAS Chapter II-2, Regulation 9.3.

2.3 Valves and relief devices

2.3.1 Valves are to be fitted in places where they are readily accessible at all times.

2.3.2 Relief valves are to be adjusted and bursting discs so selected that they relieve at a pressure not greater than the design pressure of the system. When satisfactorily adjusted, relief valves are to be protected against tampering or interference by a locking wire with a lead seal or similar arrangement, *see also* 2.4.4.

2.4 Refrigerant systems

2.4.1 The primary refrigerants ammonia, hydrocarbons or carbon dioxide shall not be used in direct expansion FCUs located in accommodation spaces. The use of these refrigerants in machinery spaces, such as a separate AHU compartment, may be accepted subject to suitable safety arrangements being provided to the satisfaction of Lloyd's Register (hereinafter referred to as LR).

2.4.2 Compartments containing refrigeration plant are to be provided with refrigerant gas leak detectors with an alarm. *See* Section 4.

2.4.3 The design of refrigeration systems is to permit maintenance and repair without unavoidable loss of refrigerant to atmosphere. To minimise refrigerant release to the atmosphere, refrigerant recovery units are to be provided to allow evacuation of a system prior to maintenance.

2.4.4 Refrigeration systems are to be provided with relief devices which are arranged with sufficient margins to avoid circumstances that would allow an inadvertent discharge of refrigerant to the atmosphere. The system is to be so designed that overpressure due to fire conditions can be safely relieved.

2.4.5 A pressure relief valve and/or bursting disc is to be fitted between each positive displacement compressor and its gas delivery stop valve, the discharge being led to the suction side of the compressor. The refrigerant flow capacity of the valve or disc is to exceed the full load compressor capacity for the particular refrigerant at the maximum potential suction pressure. For these internal relief valves, servo-operated valves will be accepted. Where the motive power for the compressor does not exceed 10 kW, the pressure relief valve and/or bursting disc may be omitted.

2.4.6 Each pressure vessel which may contain liquid refrigerant and which is capable of being isolated by means of a stop or automatic control or check valve is to be protected by two pressure relief valves or two bursting discs, or one of each, controlled by a changeover device. Pressure vessels that are connected by pipework without valves, so that they cannot be isolated from each other, may be regarded as a single pressure vessel for this purpose, provided that the interconnecting pipework does not prevent effective venting of any pressure vessel.

2.4.7 Omission of one of the specified relief devices and changeover device, as required by 2.4.6, will be accepted where:

(a) vessels are of less than 300 litres internal gross volume; or
(b) vessels discharge into the low pressure side of the system by means of a relief valve.

2.4.8 Sections of systems and components that could become full of liquid between closed valves are to be provided with pressure relief devices relieving to a suitable point in the refrigerant circuit.

2.4.9 Where any hermetic or semi-hermetic compressor has the electric motor cooled by the circulating refrigerant, the following arrangements are to be provided:

(a) Refrigeration circuits are to contain no more than one hermetic or semi-hermetic compressors.
(b) Each compressor motor is to be fitted with a thermal cut-out device to protect the motor against overheating.
(c) Each refrigerant circuit is to contain a suitable arrangement to allow debris or contaminants from a motor failure to be removed.
(d) The pressure envelope of any hermetic or semi-hermetic compressor exposed to the refrigerant pressure is to be designed and constructed in accordance with the requirements of Pt 5, Ch 11 and Pt 5, Ch 17 as applicable. Plans are to be submitted for consideration as required by Pt 5, Ch 11,1.6.

2.5 Air handling unit(s) (AHUs) for air-conditioning systems

2.5.1 Evaporator coils as fitted to direct expansion AHUs are to be considered for approval and plans are to be submitted, *see also* 1.2.2. All other equipment fitted to an AHU, such as air filtration, dehumidification, heating and humidification systems are outside the scope of these Rules and are the responsibility of the Shipyard and Owner.

2.5.2 Each AHU is to be provided with suitable drip trays and drainage arrangements to remove any condensate which may form.

2.5.3 The installation arrangements of AHUs are to be such as to allow sufficient space for the withdrawal and replacement of the refrigerant cooling coil.

2.6 Air coolers and cooling grids for provision store refrigeration systems

2.6.1 Air cooler fan motors are to be suitably enclosed to withstand the effects of moisture.

2.6.2 Means are to be provided for effectively defrosting air coolers. Air coolers are to be provided with trays of suitable depth arranged to collect all condensate. The trays are to be provided with drains at their lowest points to enable the condensate to be drained away when the refrigerated spaces are in service. When a store operates at temperatures at, or lower than 0°C, provision is to be made for the prevention of freezing of the condensate.

2.6.3 The installation arrangements of air coolers are to be such that when the refrigerated spaces are loaded with provisions, adequate space is provided for the inspection, servicing and renewal of controls, valves, fans and fan motors.

2.6.4 Steel air cooler circuits and cooling grids are to be suitably protected against external corrosion.

2.7 Design pressures

2.7.1 The design pressure of the system will be regarded as equal to its maximum working pressure, *see* 2.7.5.

2.7.2 The maximum working pressure is the maximum permissible pressure within the system (or part system) in operation or at rest. No pressure relief valve or other protective device is to be set to a pressure higher than the maximum working pressure.

2.7.3 The design pressure of the low pressure side of the system is to be the saturated vapour pressure of the refrigerant at plus 46°C. Due regard is to be taken of defrosting arrangements which may cause a higher pressure to be imposed on the low pressure side of the system. For carbon dioxide design pressures, *see* 2.7.6.

2.7.4 The minimum design pressure of the high pressure side of the system (P_{dh}), is to be determined from 1,11 × P_b, where P_b is an allowance for the compressor high pressure cut-out. P_b is to be not less than to 1,11 × P_a, where P_a is the condenser working pressure, when operating in tropical zones and equates to the saturation pressure of the refrigerant at plus 46°C.

2.7.5 Design pressures applicable to refrigerants are to be not less than the values given in Table 15.2.1 when condensers are sea-water cooled. The design pressure for other refrigerants and condensing arrangements is to be agreed with LR.

Table 15.2.1 Design pressure limits

Refrigerant	Pressure, (bar g)	
	High	Low
R-717	21,2	17,2
R-22	20,6	16,7
R-290	18,1	14,7
R-600a	6,4	5,2
R-134a	13,4	10,9
R-407C	23,5	19,0
R-410A	34,5	28,0
R-507A	25,3	20,5
R-404A	24,8	20,1
R-744	*See* 2.7.6	

NOTE
In view of increasing world-wide restrictive legislation and phasing out of the HCFC refrigerant R-22, it is recommended that this refrigerant should not be used in new installations.

2.7.6 The proposed design pressure for a carbon dioxide system is to be stated, taking account of the maximum working pressure and the maximum pressure at rest conditions. Where the maximum pressure at rest condition is maintained by the fitting of a supplementary refrigeration unit, condensing the vapour in a holding vessel, supporting calculation is to be provided to show that this can be undertaken with a local ambient temperature of 45°C. The holding vessel is to be thermally insulated to prevent the operation of the relief devices within a 24 hour period after stopping the supplementary refrigeration unit at an ambient temperature of 45°C and an initial pressure equal to the starting pressure of the refrigeration unit.

2.7.7 Where a carbon dioxide system is designed for hot gas defrosting, due regard is to be given to the possibility of a higher pressure being imposed on the low pressure system. The design pressure for the hot gas defrosting section of the system is to be 10 per cent greater than the maximum pressure experienced during defrosting.

2.8 Insulation materials

2.8.1 Where applicable, having regard to their location and environmental conditions, insulation arrangements are to have:

(a) materials suitably resistant to fire;
(b) insulation lining suitably resistant to flame spread;
(c) effective protection against penetration of water vapour; and
(d) adequate protection against mechanical damage.

2.8.2 The potential for smoke generation and toxicity of insulation materials is to be in accordance with SOLAS Chapter II-2, Part B, Regulation 6.

2.8.3 Where the *in situ* foam type of insulation is proposed, full details of the process are to be submitted.

2.8.4 Prefabricated panel systems are to be fitted with suitable pressure equalising devices.

2.8.5 All low temperature pipework, valves and fittings are to be provided with suitable thermal insulation. *See* Pt 6, Ch 3,4.11.10.

2.9 Manufacture and certification

2.9.1 Pressure vessels satisfying the conditions listed in Pt 5, Ch 11,1.6.1 are to be constructed in accordance with the requirements of Pt 5, Ch 11 and 17. Plans are to be submitted for consideration as required by Pt 5, Ch 11,1.6.

2.9.2 Other equipment, apart from applicable pressure vessels and heat exchangers, used for air-conditioning or provision stores refrigeration systems are not required to be constructed under survey.

2.9.3 All major items of equipment, containing refrigerant, such as compressors, condensers, AHU cooling coils and FCUs shall be supplied with a manufacturer's works certificate providing details of the design and test pressures.

■ *Section 3*
Refrigerating machinery and refrigerant storage compartment arrangements

3.1 General

3.1.1 Refrigerating machinery is to be installed in a well ventilated compartment. In general, the arrangements are to be such that all components of the refrigerating machinery can be readily opened up for inspection or replacement. Space is to be provided for the withdrawal and renewal of the tubes in 'shell-and-tube' type evaporators (secondary refrigerant coolers) and condensers. Proposals for alternative arrangements are to be submitted to LR for consideration.

3.1.2 Refrigerating machinery using toxic and/or flammable refrigerants is to be located outside the main machinery space in a separate gastight compartment.

3.1.3 Where the refrigerating machinery is located in a separate gastight compartment, outside the main machinery space, this compartment is to be equipped with effective mechanical ventilation to provide 30 air changes per hour based upon the total volume of the space. The mechanical ventilation system is to have two methods of control, one of which is to be operable from outside the compartment.

3.1.4 Openings for pipes, electrical cables and other fittings in bulkheads and decks are to be fitted with gastight seals.

3.2 Gas storage compartments

3.2.1 Portable steel cylinders containing reserve supplies of refrigerant are to be stored in a well ventilated compartment reserved solely for this purpose.

3.2.2 The storage compartment is to be provided with a mechanical ventilation system providing 10 air changes per hour.

3.2.3 The storage compartment is to be provided with a suitable vapour detection system, *see* Section 4.

3.2.4 The storage compartment is to be provided with suitable water drainage arrangements not connected with the main machinery spaces.

3.2.5 Steel storage cylinders are to be of an approved type and are to be filled to a level suitable for an ambient temperature of plus 46°C.

3.2.6 The storage compartment is to be provided with racks to facilitate secure stowage of the cylinders.

3.3 Pressure testing at manufacturers' works

3.3.1 Components intended for use with a primary refrigerant are to be subject to pressure testing procedures as detailed in Table 15.3.1.

Table 15.3.1 Test pressure

Component	Test pressure, (bar g)	
	Pressure test	Tightness test
(1) Pressure vessels	*See* Pt 5, Ch 11	1,0*p*
(2) Compressor cylinders/ crankcase/casing	1,5*p*	1,0*p*
(3) Valves and fittings	2,0*p*	1,0*p*
(4) Pressure piping, fabricated. headers, air coolers, etc.	1,5*p*	1,0*p*
NOTE *p* is the design pressure as defined in 2.7.		

3.3.2 Component pressure tests are to be hydraulic or where suitable safety measures are taken, may be pneumatic. The latter is to be carried out with a suitable dry inert gas.

3.3.3 Component tightness tests are to be carried out only after completion of satisfactory pressure tests. Pneumatic pressure is to be applied using a suitable dry inert gas.

3.3.4 Components for use with a secondary refrigerant or cooling water are to be hydraulically tested to 1,5 times the design pressure which, in no case is to be less than 3,5 bar g.

3.4 Pressure test after installation on board ship

3.4.1 For primary refrigerant piping welded in place, pressure tests of the welds are to be carried out at a test pressure of 1,5*p*. This will normally take the form of a pneumatic test (*see* 3.4.2) since hydraulic testing media such as water are not acceptable due to their incompatibility with the primary refrigerants and the difficulty of removing all traces from a completed system.

3.4.2 Pneumatic pressure tests are to be carried out using a suitable inert gas.

NOTE

Where pneumatic testing is used, adequate safety precautions recognising the hazards involved should be observed to prevent danger to personnel and to minimise risk to property.

3.4.3 Where pneumatic tests are prohibited by relevant authorities, the tests required by 3.4.1 and 3.4.2 may be omitted provided non-destructive examination has been carried out by an approved operator to the satisfaction of LR and in accordance with the requirements of Pt 5, Ch 17,6.

3.4.4 After completion of the test required by 3.4.1, 3.4.2 or 3.4.3, a tightness test is to be carried out using a suitable inert gas at a pressure equal to the design pressure, in the presence of the surveyor.

3.4.5 Secondary refrigerant piping welded in place is to be hydraulically tested to 1,5 times the design pressure which, in no case is to be less than 3,5 bar g.

■ *Section 4*
Refrigerant detection systems

4.1 General

4.1.1 A fixed refrigerant detection system is to be provided in the refrigerating machinery compartment or space and ventilation outlet ducts when the ventilation system is shared with other compartments.

4.1.2 The alarm system is to comply with the requirements of Pt 6, Ch 1 and, as a minimum requirement, the system is to activate at a low-level concentration to give warning of refrigerant leaks, and at a high-level concentration corresponding to the refrigerant's safe occupational level.

4.1.3 Detection equipment is to be so designed that it may be readily tested and calibrated; any failure of the equipment is to initiate an alarm.

4.1.4 The location of the detectors is to be determined relative to the layouts of the individual compartments and machinery spaces and are to be indicated in the plan submission.

4.1.5 Audible and visual alarms are to be activated, located both inside and outside the affected space. The alarms are to be readily identifiable and be visible and audible in all locations within the space housing the refrigeration equipment.

■ *Section 5* Control and monitoring and electrical power arrangements

5.1 General

5.1.1 Control engineering arrangements are to comply with Pt 6, Ch 1 as applicable.

5.1.2 All cooling and secondary refrigerant pumps are to be provided with an indication of discharge pressure and a low discharge pressure alarm at each control station.

5.1.3 The power to all independently driven ventilation fans is to be capable of being stopped from position(s) outside the fire boundary which will remain readily accessible in the event of fire occurring in any space, as well as from the local control panel.

5.1.4 Electrical engineering arrangements are to comply with Pt 6, Ch 2.

5.1.5 Refrigeration compressors are to be provided with the following instrumentation and automatic shutdowns:

(a) Indication of suction pressure (saturated temperature), including intermediate stage when applicable.
(b) Indication of discharge pressure (saturated temperature), including intermediate stage when applicable.
(c) Indication of lubricating oil pressure.
(d) Indication of cumulative running hours (screw compressors).
(e) Automatic shutdown in the event of low lubricating oil pressure.
(f) Automatic shutdown in the event of high discharge pressure, *see also* 5.1.13.
(g) Automatic shutdown in the event of low suction pressure.

5.1.6 For refrigeration compressors greater than 25 kW, the following instrumentation, additional to that required by 5.1.5, is to be provided:

(a) Indication of lubricating oil temperature.
(b) Indication of condenser cooling water outlet temperature.
(c) Indication of cumulative running hours (reciprocating compressors).
(d) Indication of suction and discharge temperatures.

5.1.7 Alarms are to be initiated in the event of the following fault conditions with refrigeration compressors:

(a) High discharge pressure.
(b) Low suction pressure.
(c) Low oil pressure.
(d) High discharge temperature.
(e) High oil temperature.
(f) Motor shutdown.

5.1.8 Refrigeration plants are to be provided with the following alarms as applicable:

(a) Failure of condenser cooling water pumps.
(b) High condenser cooling water outlet temperature.
(c) Failure of air cooler fans.
(d) High and low refrigerated air delivery temperatures.
(e) High secondary refrigerant temperatures.
(f) Failure of secondary refrigerant pump.
(g) Low level in secondary refrigerant header tank.

5.1.9 Where the air-conditioning/refrigerating system is fitted with automatic or remote controls, so that, under normal operating conditions, no manual intervention by the operators is required, it is to be provided with the alarms required by 5.1.6 to 5.1.8 in accordance with the relevant requirements of Pt 6, Ch 1.

5.1.10 Where more than one compressor is fitted, the control sequence is to be such as to allow one machine to stop in the event of a reduction in cooling duty. Provision is to be made to allow selection of the lead machine to equalise running hours.

5.1.11 To allow the equipment to be isolated from the power supply in the event of a failure or refrigerant leak, refrigeration compressors and AHUs are to be fitted with local emergency stop switches.

5.1.12 AHUs are to be provided with the following instrumentation as a minimum:

(a) Indication of primary refrigerant outlet pressure and temperature; and
(b) Indication of outlet air temperature.

5.1.13 Compressors are to be provided with automatic shutdown in the event of high discharge pressure. For refrigeration systems where the maximum working pressure is less than or equal to 40 bar g, the automatic shutdown is to operate at a pressure in excess of normal operating pressure but no greater than 0,9 of the maximum working pressure. For refrigeration systems where the maximum working pressure is greater than 40 bar g, the automatic shutdown is to operate at a pressure in excess of normal operating pressure but no greater than 0,95 of the maximum working pressure.

Section 6
Personnel safety equipment and systems

6.1 Personnel safety equipment

6.1.1 Access doors to the refrigerated spaces are to open outwards, alternatively sliding doors may be used where the door is external to the space.

6.1.2 Access ways to the refrigerated spaces are to be designed to facilitate escape in emergencies, and the removal of stretcher-borne personnel.

6.1.3 Access ways and refrigerated compartments are to be provided with an independent lighting system in accordance with the requirements of Pt 6, Ch 2,5.7.2 and 5.7.4, with the means of locking the switches in the 'on' position.

6.1.4 Arrangements are to be such that means are provided for both opening the room door(s) and sounding the alarm required by 6.2.2 from inside refrigerated spaces.

6.1.5 Where ammonia is used in refrigerating systems, the following items of safety equipment are to be provided as a minimum, and positioned in accessible protected storage (e.g. locked glass fronted cabinets) located outside the machinery compartment:
(a) Two sets of ammonia protective clothing (including helmet, boots and gloves).
(b) Two portable battery powered hand lamps (to be of certified safe-type).
(c) Two sets of self-contained breathing apparatus (compressed air).
(d) Two full face mask respirators.
(e) Two fire-resistant life-lines.
(f) Two firemen's axes.
(g) Two heavy duty adjustable spanners.
(h) Two wheel wrenches.
(j) Irrigation facilities or eye wash bottles containing an eye wash solution, distilled water or non-carbonated mineral water.
(k) Hand or foot-operated douches providing a copious supply of clean water, located outside the compartment's doors.

6.2 Personnel warning systems

6.2.1 A system to monitor the well-being of crew members entering refrigerated spaces is to be provided.

6.2.2 The system is to be such that at a predetermined time, after initiation, the crew member(s) receives warning that the system is to alarm and must indicate their well-being by accepting the warning.

6.2.3 The system is to be designed and arranged such that only an authorised person has access for enabling and disabling it and setting the appropriate intervals, and such that it cannot be operated in an unauthorised manner.

6.2.4 It is to be possible to acknowledge the warning by means of illuminated switches situated near the access doors or hatches of each refrigerated space or chambers within the space.

6.2.5 In the event that the crew member(s) fails to respond and accept the warning within an agreed specified time, the system is to immediately initiate an alarm on the bridge and at the main control station, or subsidiary control stations as appropriate. Manual initiation of the alarm system from the refrigerated spaces is to be possible at any time.

6.2.6 The system is to comply with the relevant requirements of Pt 6, Ch 1.

Section 7
Testing and trials

7.1 Testing

7.1.1 The requirements of the Rules relating to testing of pressure vessels, piping and related fittings including hydraulic testing are applicable. *See* Pt 5, Ch 11 and Ch 12,8.

7.1.2 On completion, tanks and reservoirs for service and storage of system fluids are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

7.1.3 After installation on board, piping systems together with associated fittings that are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

7.1.4 Testing is to cover the following items:
(a) Verification of control, alarm and safety systems.
(b) Simulation tests for failure of refrigeration equipment, to verify correct functioning of alarms and systems in service.
(c) Verification of accuracy, calibration and functioning of temperature control for refrigeration systems.

7.2 Trials

7.2.1 Acceptance trials, as stipulated in this Section, are to be conducted. It is to be demonstrated that the provision store or air-conditioning refrigerating system capacity meets the design duty. As far as is practicable, the trials are to represent the operating conditions that will be encountered in service. For example, the condenser cooling water flow should be restricted so that the compressor discharge pressure is at the design value.

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Rules and Regulations for the Classification of Ships

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Rules for Ice and Cold Operations
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Chapter Contents

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■ *Section 1* Scope

1.1 General

1.1.1 The following requirements are for ships intended for operations in ice and cold conditions.

1.1.2 Guidance on the appropriate requirements and notations is provided in Table 1.1.1.

1.1.3 At the Owner's request and in order to enhance safety and awareness on board during ship operation, the **ShipRight SEA(ICE)** *Ship Event Analysis Procedure* may be applied. This procedure may be applied to all ships where it is intended to provide a hull surveillance system for monitoring of the ship's hull girder stresses and local ice loads when the ship is navigating in ice, and warning the ship's personnel that the load levels or the frequency and magnitude of ice impacts are approaching a level where corrective action is advisable. *See* Pt 1, Ch 2,2.8.3 and Pt 3, Ch 16,5.

1.1.4 At the Owner's request and in order to enhance safety, the **ShipRight FDA ICE** *Fatigue Induced by Ice Loading Procedure* may be applied. This procedure is supplementary to the FDA procedures and is to assess fatigue damage induced by ice loads for ships navigating in ice-covered regions. The objective of the **ShipRight FDA ICE** procedure is to provide technical guidelines to assess fatigue at the end connections of stiffeners in the ice belt regions under ice loading. *See* Pt 1, Ch 2,2.3.17 and Pt 3, Ch 16,3.

Table 1.1.1 Ice and cold operations

Reference			Conditions	Description	Notation
Ice operations					
Chapter 2	Section 1		Application		
	Section 2 Section 3	Hull Machinery	General requirements	Applicable to all ice classes	
	Section 4 Section 5	Hull Machinery	Light and very light ice conditions	For ships with length less than 150 m	**Ice Class 1E**
				Hull strengthening in forward region only	**Ice Class 1D**
	Section 6 Section 7	Hull Machinery	First-year ice conditions	*Finnish-Swedish Ice Class Rules*	**Ice Class 1C FS** **Ice Class 1B FS** **Ice Class 1A FS** **Ice Class 1AS FS**
	Section 8 Section 9	Hull Machinery		*Finnish-Swedish Ice Class Rules* with enhanced engine power for icebreaking capability	**Ice Class 1C FS(+)** **Ice Class 1B FS(+)** **Ice Class 1A FS(+)** **Ice Class 1AS FS(+)**
	Section 10 Section 11	Hull Machinery	Multi-year ice conditions	IACS Polar Ship Rules	**Ice Class PC7** **Ice Class PC6** **Ice Class PC5** **Ice Class PC4** **Ice Class PC3** **Ice Class PC2** **Ice Class PC1**
Cold operations					
Provisional Rules for the Winterisation of Ships	Section 1		Application		
	Section 2	Hull materials	Low temperature operations	Hull construction materials	**Winterisation H(*T*)**
	Section 3	Equipment and systems	Low temperature operations	Short duration	**Winterisation C(*T*)**
				Seasonal duration	**Winterisation B(*T*)**
				Prolonged duration	**Winterisation A(*T*)**

■ *Section 2*

Ice environment

2.1 General

2.1.1 This Section is intended to give assistance on the selection of a suitable ice class notation for the operation of ships in ice-covered regions.

2.1.2 The Owner is to confirm which notation is most suitable for their requirements. Ultimately, the responsibility rests with the master of the ship and their assessment of the ice and temperature conditions at the time.

2.1.3 The documentation supplied to the ship is to contain the ice class notation adopted, any operation limits for the ship and guidance on the type of ice that can be navigated for the nominated ice class.

2.2 Definitions

2.2.1 The World Meteorological Organisation's, WMO, definitions for sea ice thickness are given in Table 1.2.1.

Table 1.2.1 WMO defintion of ice conditions

Ice conditions	Ice thickness
Medium first-year	1,2 m
Thin first-year, second stage	0,7 m
Thin first-year, first stage	0,5 m
Grey-white	0,3 m
Grey	0,15 m

2.2.2 Table 1.2.2 defines the ice classes in relation to the Rules and the equivalent Internationally Recognised Standards.

Table 1.2.2 Comparison of ice Standards

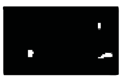
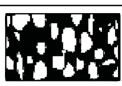
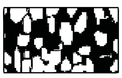
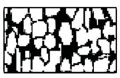
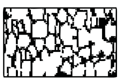
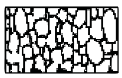
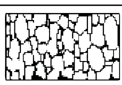
Lloyd's Register class notation	*Finnish-Swedish Ice Class*	Canadian type
Ice Class 1AS FS(+) **Ice Class IAS FS**	IA Super	A
Ice Class 1A FS(+) **Ice Class 1A FS**	IA	B
Ice Class 1B FS(+) **Ice Class 1B FS**	IB	C
Ice Class 1C FS(+) **Ice Class 1C FS**	IC	D
Ice Class 1D	—	D
Ice Class 1E	—	E

2.3 Application

2.3.1 The variable nature of ice conditions is such that the average limits of the conditions are not easily defined. However, it is possible to plot the probable limits of the ice flows and the ice edge for each season. *See* Figs. 1.2.1 to 1.2.4, and Table 1.2.3.

2.3.2 Operation with **Ice Class 1C FS** may be possible up to 150 nm inside the 7/10 region shown depending on the severity of the winter. Operation with **Ice Class 1A FS** may be possible up to 150 nm inside the medium first-year ice shown depending on the severity of the winter. Operation up to the multi-year ice is possible most years with **Ice Class 1AS FS**.

Table 1.2.3 Concentration of ice

Free ice	 0/10		
Open water	 <1/10		
Very open drift	 1/10	 2/10	 3/10
Open drift	 4/10	 5/10	 6/10
Close pack/drift	 7/10	 8/10	
Very close pack	 9/10	 9+/10	
Compact/consolidated ice	 10/10		

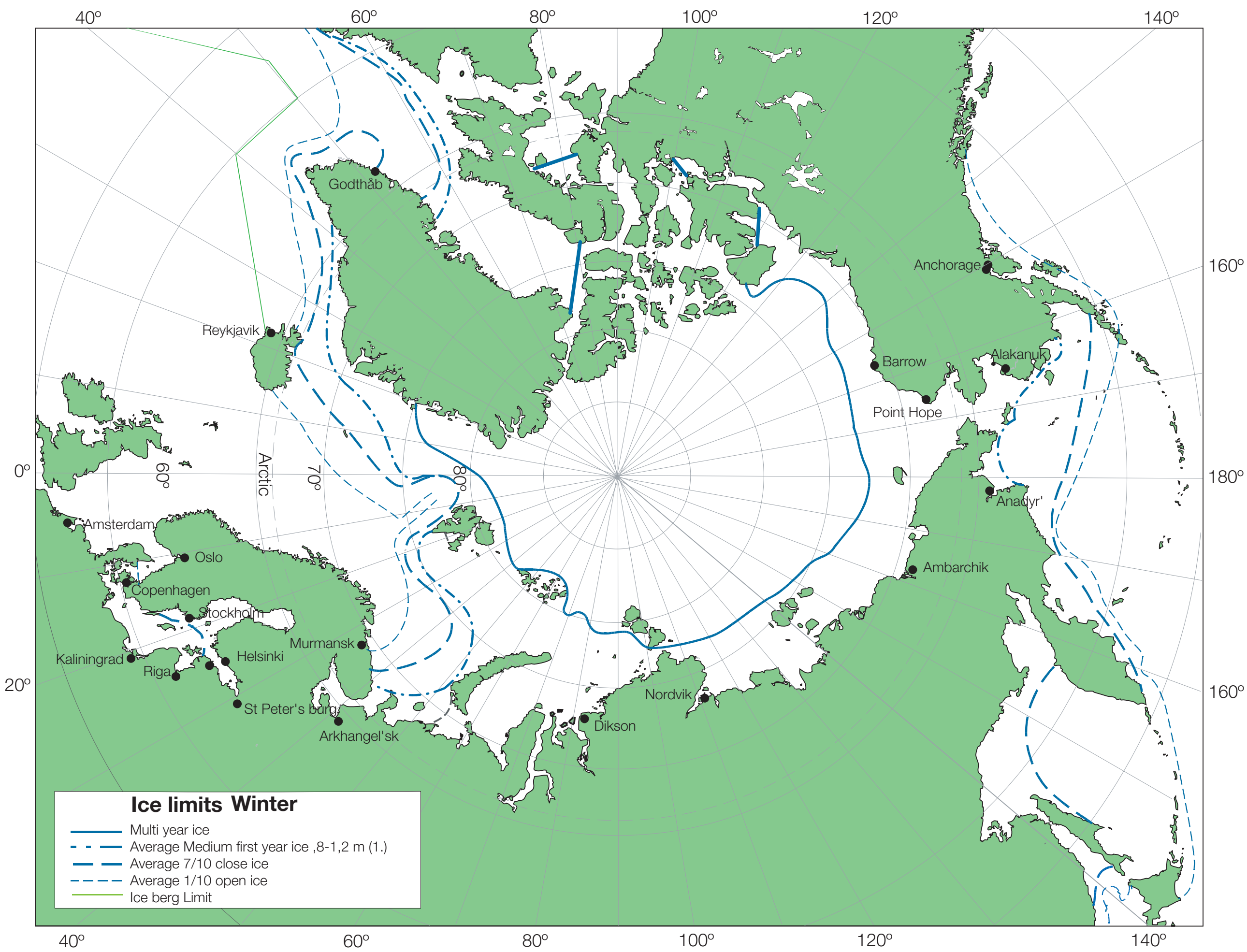


Fig. 1.2.1 Ice Limits for the Arctic Winter

2.3.3 Operation in the region between 7/10 and 1/10 in the ice-covered regions is possible with due care for ships with no ice class. For ships operating for extended periods in these areas, it will be necessary to specify and design for a minimum temperature for the hull materials. To cover all situations for a non-ice class ship, the material requirements of *The Provisional Rules for the Winterisation of Ships* are recommended.

2.4 Ice Class notations

2.4.1 Where the requirements of Chapter 2 are complied with, the ship will be eligible for a special features notation as defined in Pt 1, Ch 2,2.1.9, *see also* Table 1.1.1.

2.4.2 In general, an **Ice Class** Notation contained in this Part of the Rules will only be assigned where the vessel has been assigned a **✠LMC** notation. A **[✠]LMC** notation may be accepted where ice class machinery items are not included within the scope of the propulsion arrangements for acceptance of a manufacturer's certificate, *see* Pt 1, Ch 1.

2.5 National Authority requirements

2.5.1 Certain areas of operation may require compliance or demonstration of equivalence with National Authority requirements. Table 1.2.2 gives the equivalence of National Authority requirements.

2.5.2 The standards of ice strengthening required by the Rules have been accepted by the Finnish and Swedish Boards of Navigation as being such as to warrant assignment of the Ice Classes given in Table 1.2.2.

2.5.3 Ships intending to navigate in the Canadian Arctic must comply with the *Canadian Arctic Shipping Pollution Prevention Regulations established by the Consolidated Regulations of Canada, 1978, Chapter 353*, in respect of which Lloyd's Register is authorised to issue Arctic Pollution Prevention Certificates.

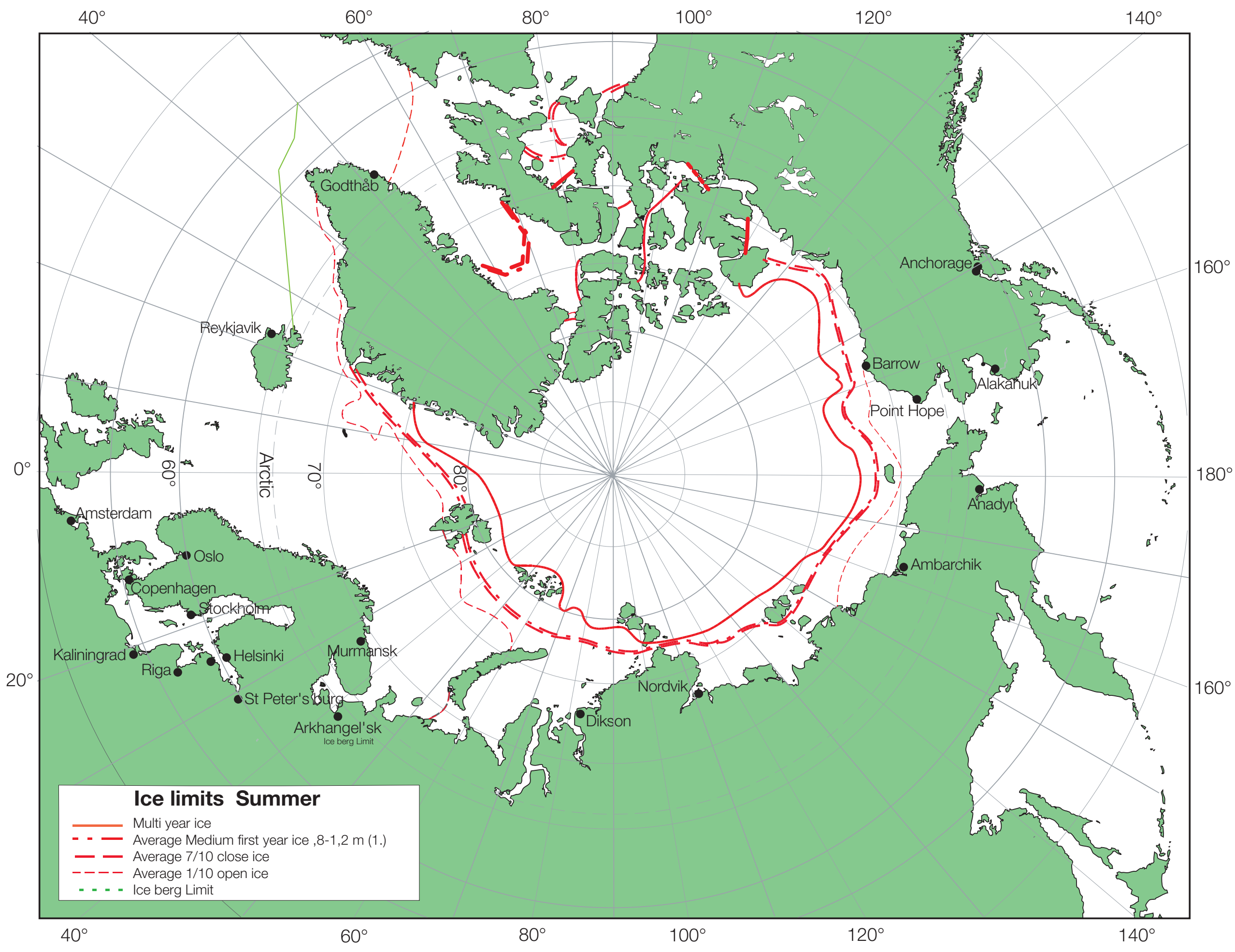


Fig. 1.2.2 Ice Limits for the Arctic Summer

2.5.4 The Canadian Arctic areas have been divided into zones relative to the severity of the ice conditions experienced and, in addition to geographic boundaries, each zone has seasonal limits affecting the necessary Ice Class notation required to permit operations at a particular time of year. It is the responsibility of the Owner to determine which notation is most suitable for their requirements.

2.5.5 The Canadian Authorities recognise that in the period November 6 to July 31 and any extension to that period declared by the Canadian Coast Guard, oil and bulk chemical tankers which qualify for Canadian Type A, B, C and D as indicated in Table 1.2.2 are suitable for operating in designated ice control zones within Canadian waters, off the east coast of Canada south of 60° north latitude. For all Type E tankers operating in this zone during the specified period, the Canadian Authorities will require either additional hull strength in way of the forward wing cargo tanks port and starboard, or the level of oil or chemical in these tanks to be not higher than one metre below the waterline of the ship in her condition of transit. Where the latter arrangement is adopted, the effect on longitudinal strength is to be considered.

2.5.6 For ships intending to navigate in Finnish-Swedish waters and having a **Polar Ice Class notation**, consideration may need to be given to the installed engine power such that it complies with the applicable *Finnish-Swedish Ice Class Rules*, *see* Ch 2,7.

2.6 Ice conditions

2.6.1 Charts and images for the current and recent ice conditions in all areas of the world plus information on icebergs can be found from the National Ice Centre on the world wide web at:

www.natice.noaa.gov

2.6.2 Daily ice information and consultation is available from the Canadian ice service which is part of the Canadian department of the environment. Their web site can be found at:

www.ice-glaces.ec.gc.ca

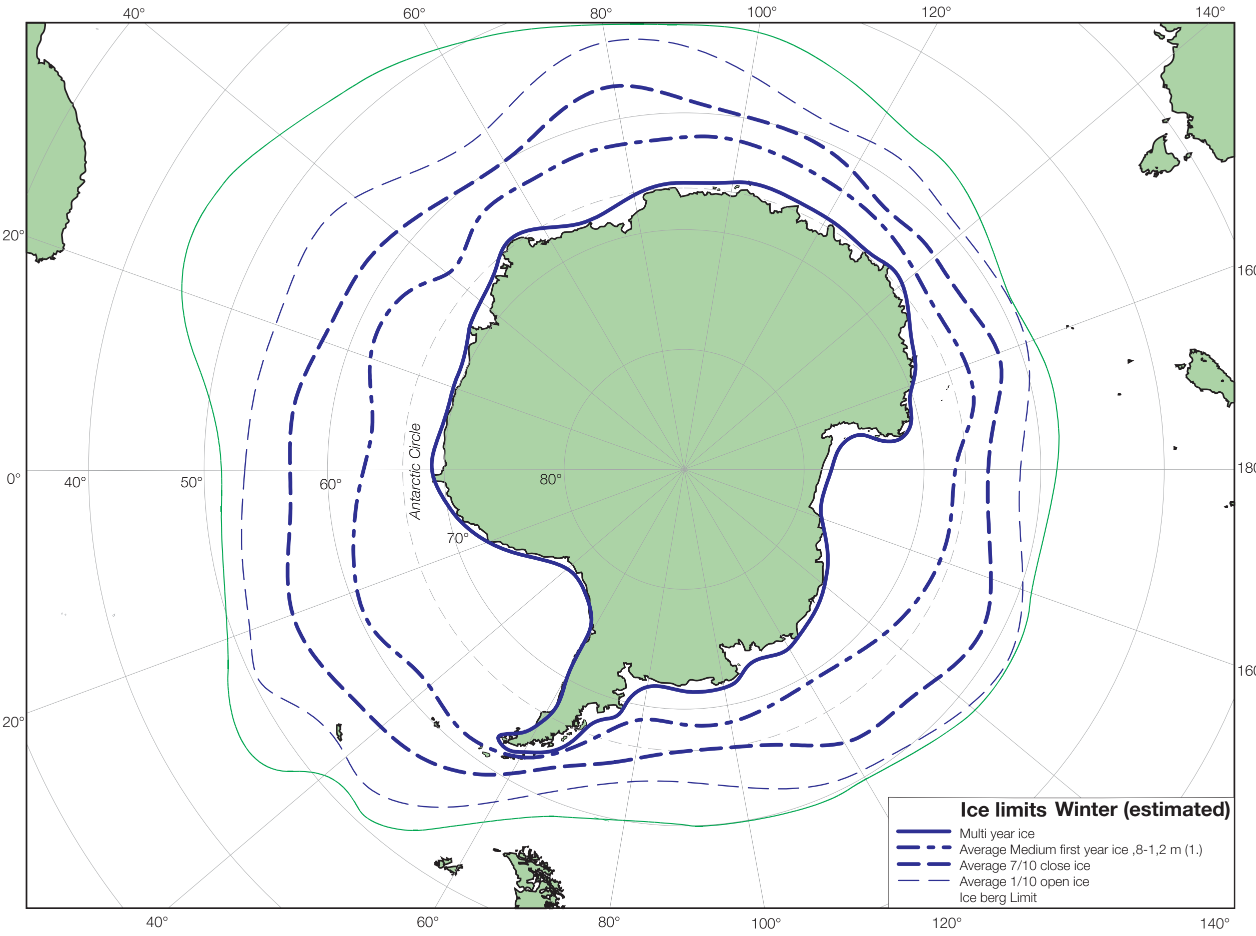


Fig. 1.2.3 Ice Limits for the Antarctic Winter

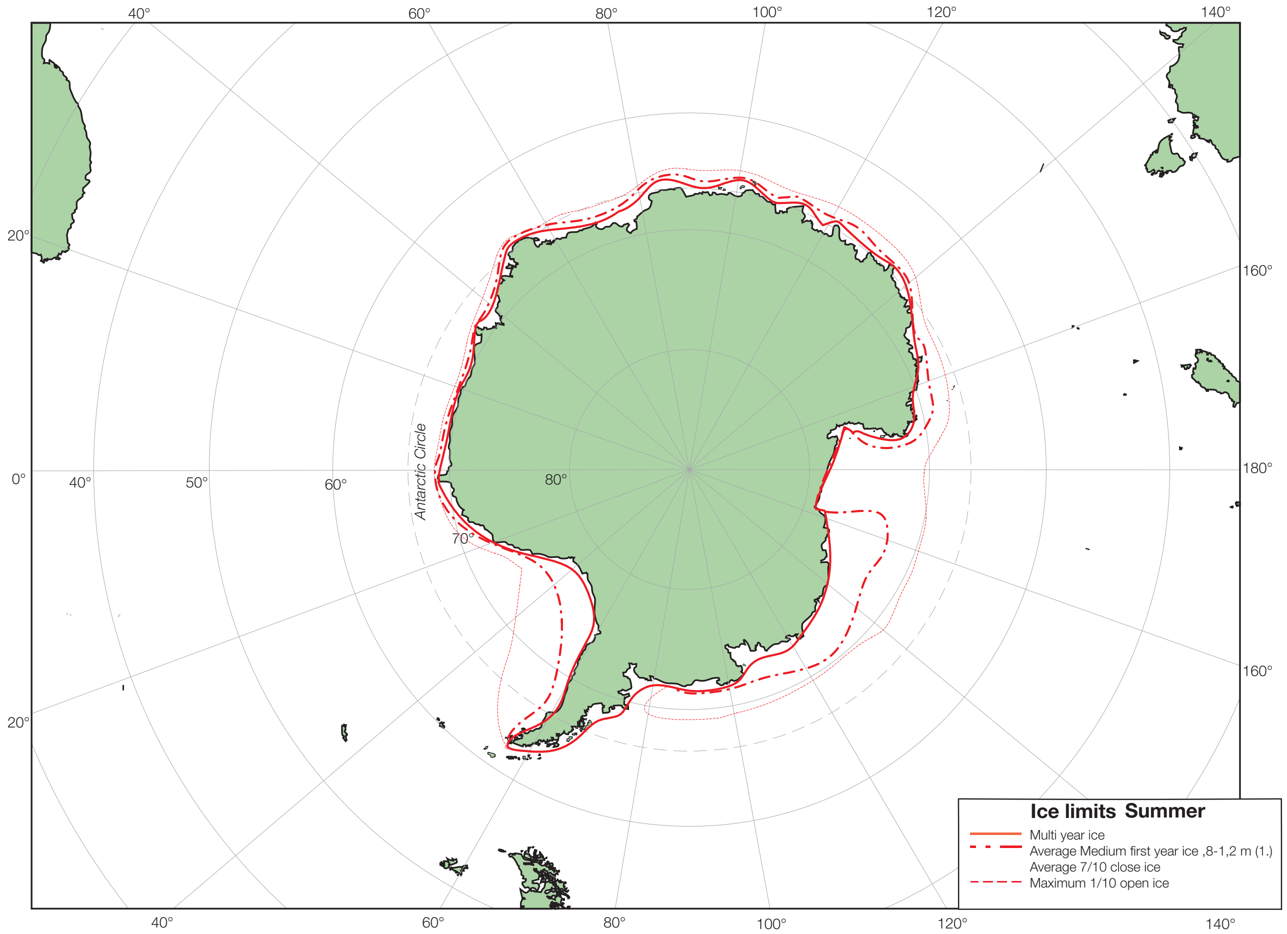


Fig. 1.2.4 Ice Limits for the Antarctic Summer

Section 3
Air environment

3.1 Air temperature

3.1.1 For ships intended to operate in cold regions, the temperature on exposed surfaces is to be considered. *See The Provisional Rules for the Winterisation of Ships*.

3.1.2 The average external design air temperature is to be taken as the lowest mean daily average air temperature in the area of operation:

where

Mean = statistical mean over a minimum of 20 years
Average = average during one day and one night
Lowest = lowest during the year
MDHT = Mean Daily High Temperature
MDAT = Mean Daily Average Temperature
MDLT = Mean Daily Low Temperature

Fig. 1.3.1 shows the definition graphically.

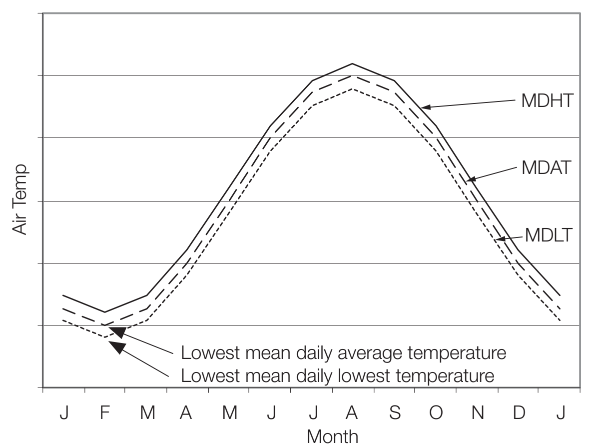


Fig. 1.3.1 Air temperature

3.1.3 The lowest external design air temperature is to be taken as the lowest mean daily lowest air temperature in the area of operation. Where reliable environmental records for contemplated operational areas exist, the lowest external design air temperature may be obtained after the exclusions of all recorded values having a probability of occurrence of less than 3 per cent.

3.1.4 Lowest mean daily average air temperatures for the Arctic and Antarctic are provided in Figs. 1.3.2 and 1.3.3.

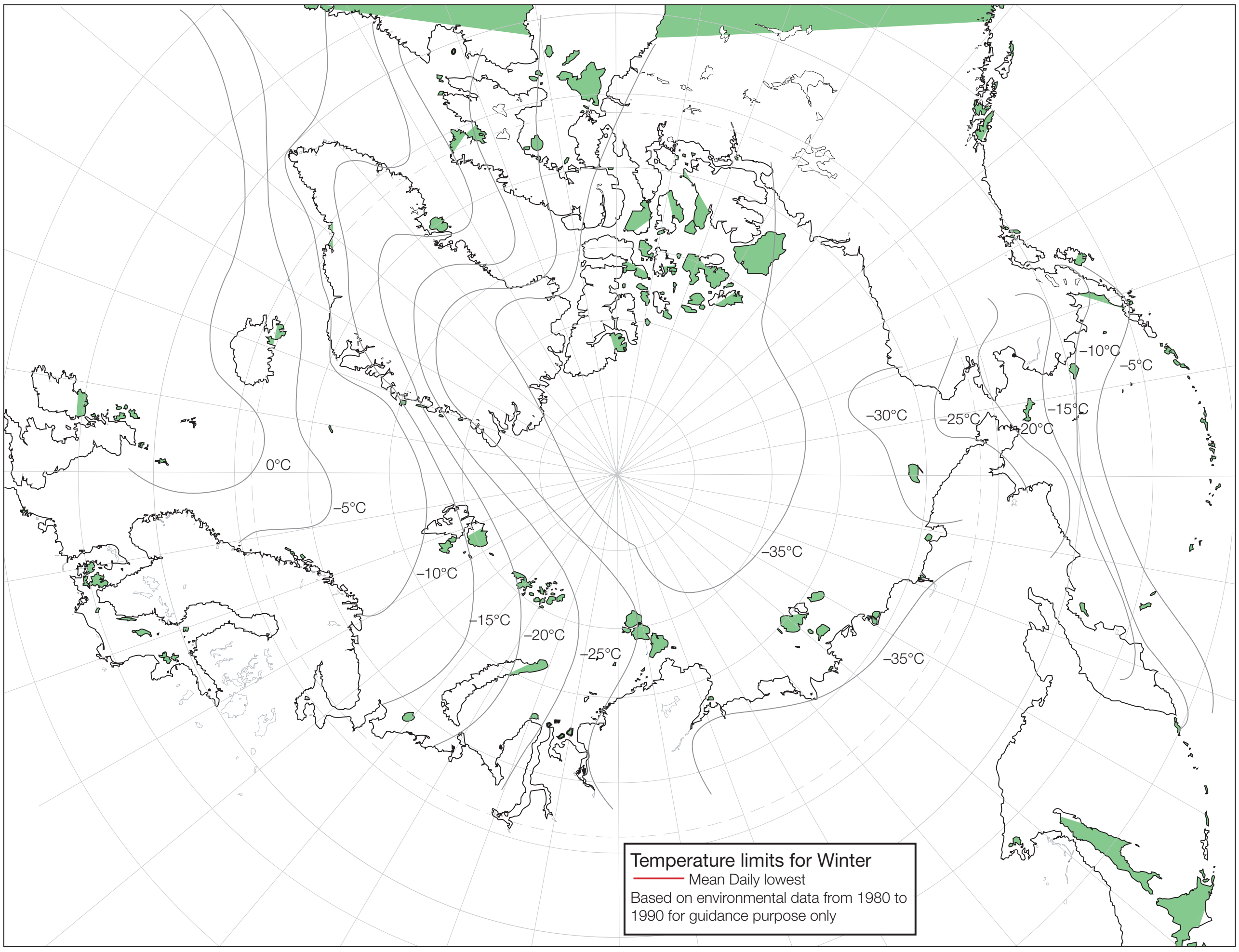


Fig. 1.3.2 Lowest mean daily air temperatures for the Arctic

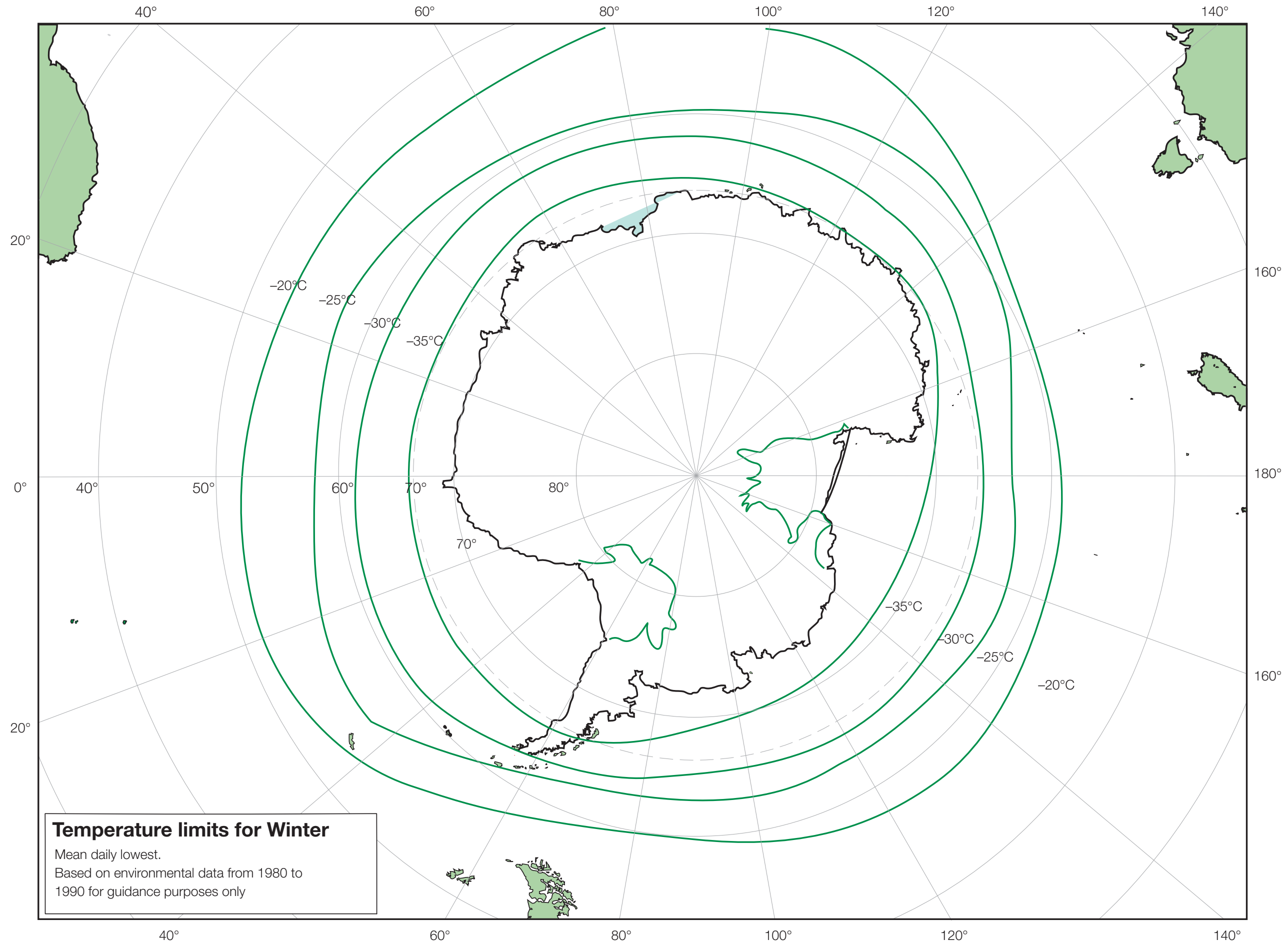


Fig. 1.3.3 Lowest mean daily air temperatures for the Antarctic

Section 4
Icing environment

4.1 Ice accretion

4.1.1 For ships intended to operate in cold regions, the build up of ice on exposed surfaces is to be considered. *See The Provisional Rules for the Winterisation of Ships*.

4.1.2 Icing is to be considered for vessels operating in the following areas, *see* Figs. 1.4.1 and 1.4.2.

- The area north of latitude 65°30´N, between longitude 28°W and the West coast of Iceland; north of the north coast of Iceland; north of the rhumb line running from latitude 66°N, longitude 15°W to latitude 73°30´N, longitude 15°E, north of latitude 73°30´N between longitude 15°E and 35°E, and east of longitude 35°E, as well as north of latitude 56°N in the Baltic Sea.
- The area north of latitude 43°N bounded in the west by the North American coast and the east by the rhumb line running from latitude 43°N, longitude 48°W to latitude 63°N, longitude 28°W and thence along longitude 28°W.
- All sea areas north of the North American continent west of the areas defined in subparagraphs above.
- The Bering and Okhotsk Seas and the Tartary Strait during the icing season.
- South of latitude 60°S.

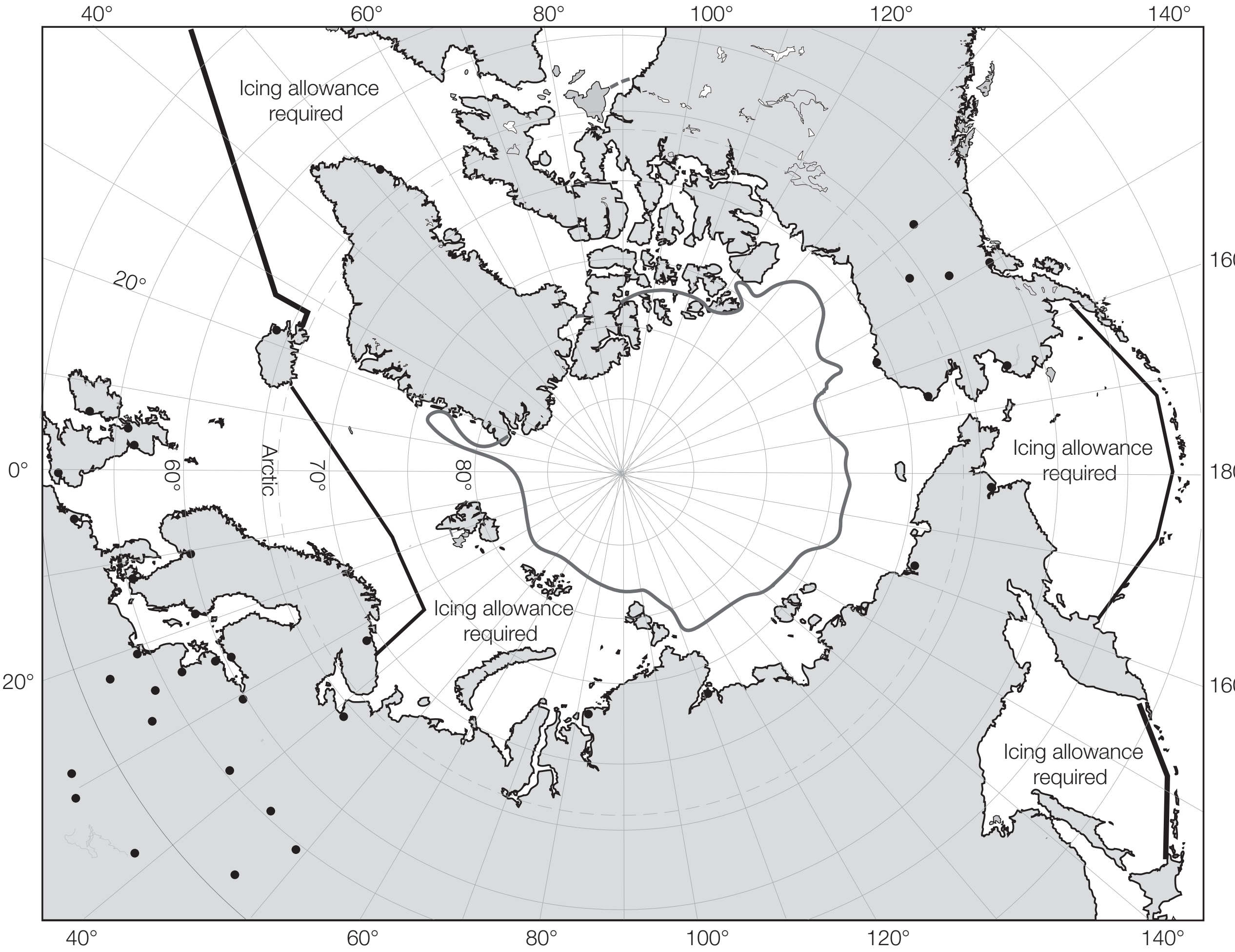


Fig. 1.4.1 Ice accretion limits for the Arctic

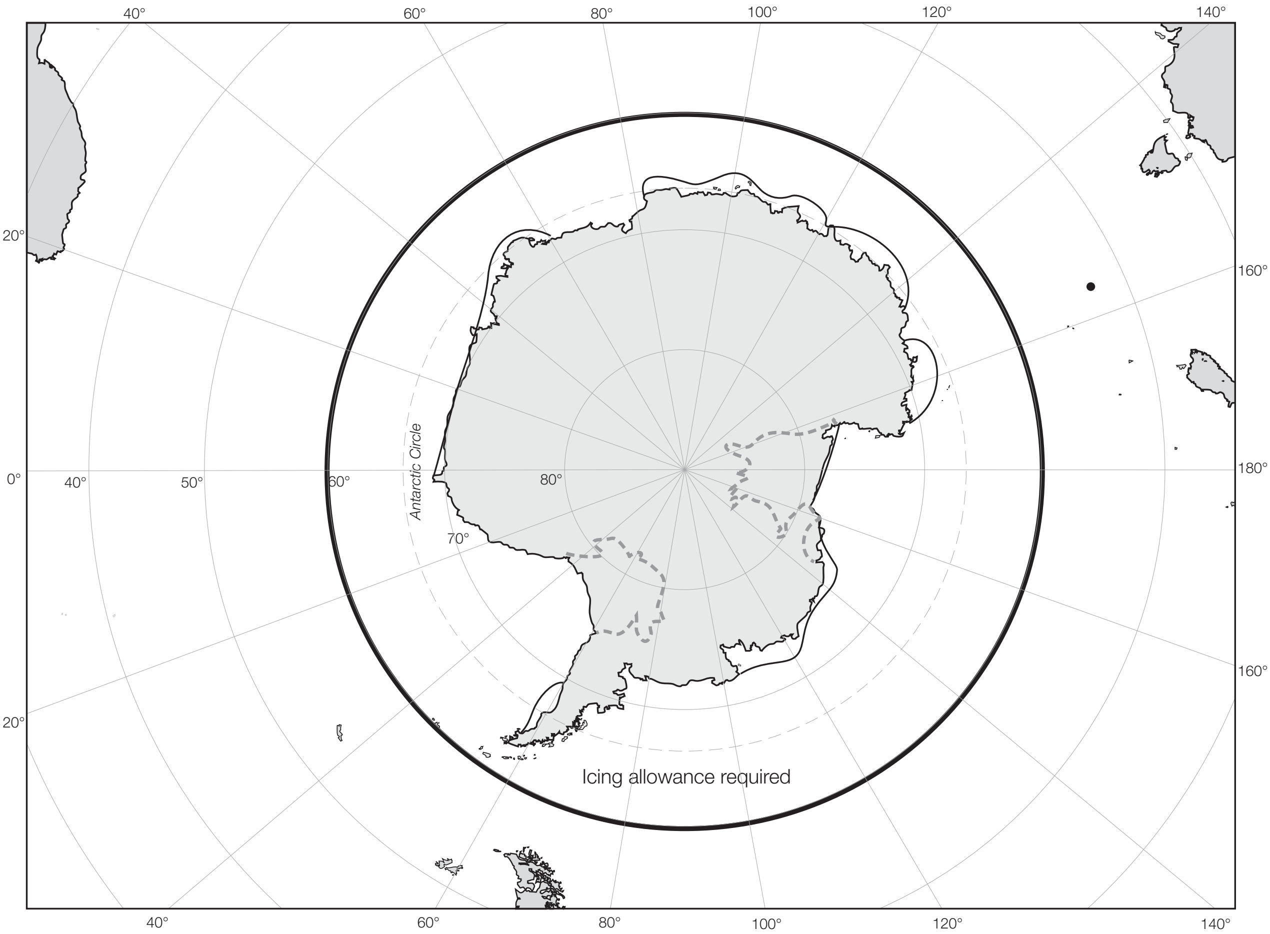


Fig. 1.4.2 Ice accretion limits for the Antarctic

■ *Section 1* Strengthening requirements for navigation in ice – Application of requirements

1.1 Additional strengthening

1.1.1 Where additional strengthening is fitted in accordance with the requirements given in this Chapter, an appropriate special features notation will be assigned. It is the responsibility of the Owner to determine which notation is most suitable for his requirements.

1.1.2 Where a special features notation is desired, the ship is to comply with the requirements of the applicable Sections, in addition to those for sea-going service, so far as they are applicable.

1.1.3 Where the hull and machinery are constructed so as to comply with the requirements of different ice classes, then the assigned Ice Class Notation will be indicated for the combination as the lower of these classes on the Certificate of Class. Any compliance of the hull or machinery with the requirements of a higher ice class will be indicated in square brackets after the main notation. Other supplementary information that would influence the ice performance will also be indicated. For example, a ship hull built in compliance with **1B FS** and the machinery in compliance with **1AS FS** would be assigned the Notation **Ice Class 1B FS [1AS FS Machinery]** or **Ice Class 1B FS [1AS FS azimuth thrusters]** where azimuth thrusters are included in the approval.

1.1.4 The vertical extent of the ice strengthening is related to the ice light and ice load waterlines, which are defined in 2.2. The maximum and minimum draughts at the fore, amidships and aft ends (for the lowest ice class) will be stated on the Certificate of Class.

1.1.5 The installed and required minimum engine output (for the lowest ice class), *see* Section 7, will be stated on the Certificate of Class.

1.2 Application for light ice conditions

1.2.1 The requirements for **Ice Class IE** are for ships with length less than 150 m and are intended to navigate in very light first-year ice conditions, such as in brash ice and small ice pieces. The requirements of Sections 4 and 5 are to be complied with.

1.2.2 The requirements for **Ice Class 1D** are for ships intended to navigate in light first-year ice conditions. The requirements for strengthening the forward region, the rudder and steering arrangements for **Ice Class 1C FS** are applicable.

1.3 Application for first-year ice conditions

1.3.1 Ships that comply with the requirements of the Finnish Swedish Ice Class Rules and Sections 6 and 7, for **Ice Class IA Super**, **IA**, **IB** and **IC** may be assigned the corresponding notations **Ice Class 1AS FS**, **Ice Class 1A FS**, **Ice Class 1B FS** or **Ice Class 1C FS**. The *Finnish-Swedish Ice Class Rules* may be obtained from the following website:
www.trafi.fi

1.3.2 For ships where the ice class notation **Ice Class 1AS FS(+)**, **Ice Class 1A FS(+)**, **Ice Class 1B FS(+)** or **Ice Class 1C FS(+)** is requested, the requirements of the *Finnish-Swedish Ice Class Rules*, and Sections 8 and 9 are to be complied with.

1.4 Application for multi-year ice conditions

1.4.1 The requirements for strengthening for navigation in ice, as given in Sections 10 and 11, are intended for ships operating in multi-year ice in Arctic or Antarctic ice conditions under their own power and constructed of steel, except icebreakers, *see* 1.5.1.

1.4.2 Ships that comply with Sections 10 and 11 can be considered for a Polar Class (**PC**) notation as listed in Table 2.1.1.

Table 2.1.1 Polar class descriptions

Polar Class	Ice description (based on WMO Sea Ice Nomenclature)
Ice Class PC 1	Year-round operation in all Polar waters
Ice Class PC 2	Year-round operation in moderate multi-year ice conditions
Ice Class PC 3	Year-round operation in second-year ice which may include multi-year ice inclusions
Ice Class PC 4	Year-round operation in thick first-year ice which may include old ice inclusions
Ice Class PC 5	Year-round operation in medium first-year ice which may include old ice inclusions
Ice Class PC 6	Summer/autumn operation in medium first-year ice which may include old ice inclusions
Ice Class PC 7	Summer/autumn operation in thin first-year ice which may include old ice inclusions

1.4.3 The Polar Class (**PC**) notations and descriptions are given in Table 2.1.1. It is the responsibility of the Owner to select an appropriate Polar Class. The descriptions in Table 2.1.1 are intended to guide owners, designers and administrations in selecting an appropriate Polar Class to match the requirements for the ship with its intended voyage or service.

1.4.4 The Polar Class notation is used throughout Sections 10 and 11 to convey the differences between classes with respect to operational capability and strength.

1.5 Icebreakers

1.5.1 Sea-going ships specially designed for ice-breaking duties will be assigned the ship type notation 'Icebreaker' in addition to the special features notation appropriate to the degree of ice strengthening provided. 'Icebreaker' refers to any ship having an operational profile that includes escort or ice management functions, having powering and dimensions that allow it to undertake aggressive operations in ice-covered waters, and having a class certificate endorsed with this notation. The additional ship type notations may be assigned as follows:

Icebreaker Refers to a ship having an operational profile that includes escort, research or support functions, having powering and dimensions that allow it to undertake aggressive operations in ice-covered waters, *see* 10.8.4.

Icebreaker(+) Refers to a ship for which the powering and dimensions of the hull structure and propulsion machinery necessary to undertake the operational profile as determined by selection of a primary function have been assessed, *see* Section 12.

1.6 Loading manual

1.6.1 Sufficient information is to be supplied to the Master of every ship to enable him to arrange loading and ballasting in such a way as to avoid the creation of unacceptable stresses in the ship's structure. The following information is to be included in the vessel's loading manual:

(a) Upper and lower ice waterline.
(b) Propeller immersion.
(c) Indication of whether the vessel is strengthened for icebreaker towing.

■ *Section 2* General hull requirements for navigation in ice – All Ice Classes

2.1 General

2.1.1 The following Sections are to be complied with for all Ice Classes, where applicable. Alternative arrangements to attain similar performance will be specially considered.

2.1.2 The ballast capacity of the ship is to be sufficient to give adequate propeller immersion in all ice navigating conditions without trimming the ship in such a manner that the actual waterline at the bow is below the lower ice waterline.

2.1.3 Fresh water and sea-water ballast tanks, the tops of which are situated above the design ballast waterline and adjacent to the shell, which are intended to be used in ice and cold navigating conditions, are to be provided with means to prevent freezing. Measures are to be provided to demonstrate that they protect against the following:

(a) hull structural damage from pumping water creating a vacuum beneath a layer of ice across the top of the water in the tank, and
(b) hull structural damage from ice expansion, and
(c) engineering systems, such as piping systems and components, damage from ice expansion or ice blockage, and
(d) engineering systems, such as piping systems and components, damage from ice pieces melting or dislodging from upper sections of the tank.

Heating coils are considered an effective means for tanks entirely above the waterline. Heating coils or other effective means such as continuous circulation, air bubbling and/or tank pressure/engineering systems alarms are considered effective for tanks partially below the waterline. Alternatively, demonstration that the above hazards have been mitigated is to be submitted through theoretical calculations, service experience, experimental tests, or a combination thereof.

2.1.4 These Rules are formulated for both transverse and longitudinal framing systems but it is recommended that, whenever practicable, transverse framing is selected.

2.1.5 These Rules assume that when approaching ice infested waters, the ship's speed will be reduced appropriately. The vertical extent of ice strengthening for ships intended to operate at speeds exceeding 15 knots in areas containing isolated ice floes will be specially considered.

2.1.6 An icebreaking ship is to have a hull form at the fore end adapted to break ice effectively. It is recommended that bulbous bows are not fitted to **Ice Class 1AS** ships.

2.1.7 The stern of an icebreaking ship is to have a form such that broken ice is effectively displaced.

2.1.8 Where it is desired to make provision for short tow operations, the bow area is to be suitably reinforced. Similarly, icebreakers may require local reinforcement in way of the stern fork.

2.1.9 Shell strakes in way of ice strengthening area for plates are to be grade B/AH.

2.1.10 To prevent unintended contact and permit close tow operations, provision of a bow ice knife (plate fitted between stem and bulbous bow) is not recommended for ships intended to navigate with icebreaker escort.

2.2 Definitions

2.2.1 The upper and lower ice waterlines upon which the design of the vessel has been based is to be indicated in the classification certificate. The upper ice waterline (UIWL) is to be defined by the maximum draughts fore, amidships and aft. The lower ice waterline (LIWL) is to be defined by the minimum draughts fore, amidships and aft.

2.2.2 The lower ice waterline is to be determined with due regard to the vessel's ice-going capability in the ballast loading conditions (e.g. propeller submergence).

2.2.3 The upper ice waterline (UIWL) and lower ice waterline (LIWL) are to be indicated on the plans. For navigation in certain geographical areas, the relevant National Authority may require the maximum Ice Class draught to be marked on the ship in a specified manner.

2.2.4 **Displacement** Δ is the displacement at the upper ice waterline (UIWL) when floating in water having a relative density of 1,0. For first-year ice class Rules, the displacement is in tonnes. For multi-year ice class Rules, the displacement is in kilo tonnes.

2.2.5 **Shaft power**, P_0, is the maximum propulsion shaft power, in kW, for which the machinery is to be classed.

2.3 Rudder and steering arrangements

2.3.1 Rudder stoppers working on the rudder blade or rudder head are to be fitted.

■ *Section 3* General machinery requirements for navigation in ice – All Ice Classes

3.1 Materials for shafting

3.1.1 The following Sections are to be complied with for all Ice Classes, where applicable. Alternative arrangements to attain similar performance will be considered.

3.1.2 All components of the main propulsion system are to be of steel or other approved ductile material.

3.2 Materials for propellers

3.2.1 Propellers and propeller blades are to be of cast steel or copper alloys and are to be manufactured, tested and certified in accordance with Ch 4,1, Ch 4,5 and Ch 9,1 of the Rules for Materials respectively.

3.2.2 For steel propellers, the elongation of the material used is to be not less than 15 per cent for a test piece length of 5*d*. Charpy impact tests are to be carried out in accordance with the requirements of the Rules for Materials.

3.2.3 Cast steel load transmitting components of controllable pitch mechanisms are to be manufactured, tested and certified in accordance with the requirements of Ch 4,5 of the Rules for Materials.

3.2.4 Forged steel load transmitting components of controllable pitch propellers are to be manufactured, tested, and certified in accordance with Ch 5,1 and Ch 5,2 of the Rules for Materials. Impact tests are to be carried out at minus 10°C and the average energy value is to be not less than 20 J.

3.2.5 Spheroidal cast iron load transmitting-components of controllable-pitch mechanisms are to be manufactured, tested and certified in accordance with the requirements of Table 7.3.2 in Ch 7,3 of the Rules for Materials.

3.3 Ship-side valves

3.3.1 The sea inlet and overboard discharge valves which are situated at or below the maximum Load Line, are to be provided with low pressure steam or compressed air connection for clearing purposes, *see* Pt 5, Ch 13. Provisions need not be applied for the discharge from the main engine and central cooling water system for first-year and multi-year ice classes.

3.3.2 When steam is not available for clearing, it is recommended that arrangements be made for supplying water for machinery cooling purposes by circulating from ballast tanks(s) of adequate capacity, preferably situated in the double bottom. Such tank(s) must be used only for storage of water ballast or fresh water.

3.4 Fire pumps in motor ships

3.4.1 In motor ships where clearing steam is not available, fire pumps are to be provided with suctions from a suitable sea water inlet which is maintained ice-free at all times.

3.4.2 At least one of the fire pumps is to be connected to a sea chest which is provided with de-icing arrangements.

3.5 Main propulsion and essential auxiliary engines

3.5.1 Sea inlets for the cooling water system are to be provided with arrangements to maintain ice free cooling water arrangements as given by IMO *Guidance on Design and Construction of Sea Inlets under Slush Ice Conditions MSC/Circ.504* or by the *Finnish Swedish Ice Class Rules*. Alternative arrangements will be considered, such as by circulating engine cooling water via designated tanks where heat balance calculations have demonstrated that the engines are capable of operating at their maximum continuous rating.

3.5.2 For electric propulsion systems, the total engine output for propulsion provided by generator sets/central generation system is to be based on the calculation with one set out of action, *see* Pt 6, Ch 2,16.

■ *Section 4* Hull requirements for light ice conditions – Ice Classes 1D and 1E

4.1 Ice Class 1D

4.1.1 The requirements for strengthening the forward region for **Ice Class 1C FS** are applicable. *See* Section 6.

4.2 Ice Class 1E – General

4.2.1 These requirements apply to ships with length less than 150 m and which are intended to operate in very light first-year ice conditions. Where additional strengthening is fitted in accordance with the requirements of this sub-Section, the notation **Ice Class 1E** will be assigned.

4.2.2 The requirements for shell plating need only be applied in the shaded region shown in Fig. 2.4.1. The requirements for framing need only be applied forward of the flat of side.

4.2.3 For longitudinally framed ships, the scantlings of shell plating and framing are to comply with the requirements of **Ice Class 1C FS** using 0,9 times the ice pressure.

4.2.4 For transversely framed ships, the requirements of 4.3 to 4.7 are to be applied.

4.2.5 Where the structural requirements of **Ice Class 1C FS** give lesser scantlings than the requirements of this sub-Section, the lesser scantlings may be applied.

4.3 Shell plating

4.3.1 The shell plating thickness within the region shown in Fig. 2.4.1 is not to be less than:

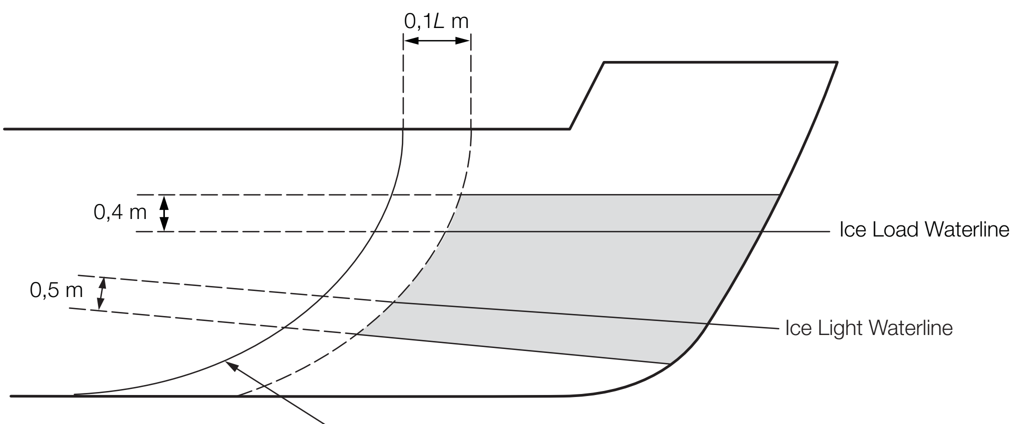
$$t = 21{,}75s\sqrt{k\left(\frac{BL^2}{110000}+1\right)\left(1{,}3-\frac{4{,}2}{(0{,}26/s+1{,}8)^2}\right)} + 2 \text{ mm}$$

where

s = spacing of main frames, in metres

L and B = are defined in Pt 3, Ch 1,6.1

k = is defined in Pt 3, Ch 2,1.2.



Ice Load Waterline and Ice Light Waterline are defined in 7.2
L, as defined in Ch 1,6.1

Fig. 2.4.1 Extent of application of plating requirements

4.4 Transverse framing

4.4.1 The section modulus of main frames forward of the flat of side is not to be less than:

$$z = 6{,}08slk\left(\frac{BL^2}{140000} + 1{,}23\right)\left(7 - \frac{1}{2l}\right) \text{ cm}^3$$

but need not be taken as greater than:

$z = s\,L\,T$

where

s = spacing of main frames, in metres
l = span, in metres
L and B = are defined in Pt 3, Ch 1,6.1
k = is defined in Pt 3, Ch 2,1.2.

4.4.2 Intermediate ice frames are to be fitted in the region forward of the flat of side and are to extend from 0,62 m above the upper ice waterline to 1 m below the lower ice waterline.

4.4.3 Intermediate ice frames aft of the collision bulkhead are to have a section modulus not less than 65 per cent of that given in 4.4.1.

4.4.4 Intermediate ice frames forward of the collision bulkhead are to have a section modulus not less than 40 per cent of that given in 4.4.1.

4.5 Primary longitudinal members supporting ice frames

4.5.1 Forward of the collision bulkhead, in single deck ships, an ice stringer is to be fitted approximately 0,25 m below the upper ice waterline and is to have scantlings in accordance with Table 5.4.4 in Pt 3, Ch 5.

4.5.2 Aft of the collision bulkhead a series of tripping brackets are to be fitted at each main and intermediate frame at the same level as the ice stringer to a distance 0,1*L* aft of the flat of side.

4.6 Stern frame and rudder

4.6.1 The rudder and stern frame scantlings are to be in accordance with 6.5. However, the ship's speed need not be taken as greater than 14 knots. The hull form factor and the rudder profile coefficients are to be taken as 1,0.

4.7 Weld connections

4.7.1 Weld connections to the shell plating forward of the collision bulkhead are to be double continuous.

■ *Section 5* Machinery requirements for light ice conditions – Ice Classes 1D and 1E

5.1 General

5.1.1 Where the notation **Ice Class 1D** or **Ice Class 1E** is desired, the requirements of this Section, in addition to those for open water service, are to be complied with.

5.1.2 The requirements need not be taken as greater than those for **Ice Class 1C FS**.

5.2 Engine power

5.2.1 The total engine output is to be not less than determined by the following formula:

$P = 0{,}72LB$ kW

where

L = Rule length, in metres, *see* Pt 3, Ch 1,6.1.1
B = moulded breadth of ship, in metres, *see* Pt 3, Ch 1,6.1.3.

5.3 Main engine shafting and propellers

5.3.1 The diameters of the shafting and propeller blade thickness as required by the Rules for open water service are to be increased by the percentages as given in Table 2.5.1. No increase in the diameter of crankshafts, thrustshafts or intermediate shafts is required.

Table 2.5.1 Increase for main engine shafting and propellers

Screwshaft, increase in diameter as required by Pt 5, Ch 6,3.5	5%
Propeller, increase in blade thickness at root and at 60 per cent radius as required by Pt 5, Ch 7,3.1	8%
Keyless propeller fitting, increase in mean torque as defined in Pt 5, Ch 7,3.2	15%

5.3.2 The screwshaft may be tapered at the forward end in accordance with Pt 5, Ch 6,3.5.3 and Pt 5, Ch 6,3.5.4 subject to the increase in diameter of 5 per cent as required by 5.3.1.

5.4 Minimum propeller blade tip thickness

5.4.1 The tip thickness, t, of the blade at 95 per cent radius is to be not less than that obtained by the following formula:

$$t = 0{,}14\,(T + 57)\sqrt[3]{\frac{430}{\sigma_u}} \text{ mm}$$

where

T = blade root thickness required by 5.3.1, in mm

σ_u = specified minimum tensile strength of material, in N/mm^2.

5.5 Blade edge thickness

5.5.1 The edges of the blades are to be suitably thickened for the operating conditions but are to be not less than 50 per cent of the required tip thickness, t, measured at 1,25 times tip thickness, t, from the edge. For controllable pitch propellers, this requirement need only be applied to the leading edges of the blades.

5.6 Cooling water lines

5.6.1 Connections are to be fitted between the cooling water overboard discharge lines and sea inlets for main and/or auxiliary engine cooling water systems so that warm water may be used to assist in maintaining the suction pipes free from ice.

5.6.2 Where the cooling water inlet valves are fitted to a common water box, the connections from the cooling water discharge lines may be led to the water box in a position as near as possible to the inlet valves.

■ *Section 6*
Hull requirements for first-year ice conditions – Ice Classes 1AS FS, 1A FS, 1B FS, 1C FS and 1D

6.1 General

6.1.1 In addition to the requirements of the *Finnish-Swedish Ice Class Rules*, the following Sections are to be complied with for **Ice Class 1AS FS**, **Ice Class 1A FS**, **Ice Class 1B FS**, **Ice Class 1C FS** and **Ice Class 1D**, where applicable. Alternative arrangements to attain similar performance will be considered.

6.2 Framing – General requirements

6.2.1 Where a frame intersects a boundary between two of the hull regions the scantling requirements applicable will be those for the forward region if the forward midship boundary is intersected or for the midship region if the aft midship boundary is intersected.

6.2.2 The effective weld area attaching ice frames to primary members is not to be less than the shear area for the frames.

6.2.3 Asymmertrical frames and frames which are not at right angles to the shell (web less than 90 degrees to the shell) shall be supported against tripping by brackets, intercostals, stringers or similar, at a distance not exceeding 1300 mm. For **Ice Class 1D**, the distance may be increased to 2000 mm. For frames with spans greater than 4 m the extent of anti-tripping supports is to be applied to all regions. For frames with spans less than or equal to 4 m the extent is to be as given in Table 2.6.1. FEA may be carried out to demonstrate equivalent support of alternative arrangements.

Table 2.6.1 Extent of anti-tripping supports

Ice Class	Extent of anti-tripping supports
1AS FS	All regions
1A FS	Forward and midship regions
1B FS	Forward region
1C FS	Forward region
1D	Forward region

6.3 Primary longitudinal members supporting transverse ice framing

6.3.1 The webs of primary longitudinal members supporting transverse ice frames are to be stiffened and connected to the main or intermediate frames so that the distance, r, between such stiffening is not to be greater than given according to the following formula:

$$r = \sqrt{\frac{291t^3}{\alpha_o\,\gamma^2}} \text{ mm}$$

where

t = thickness, in mm, of the primary longitudinal member adjacent to the shell plating

α_o = longitudinal distribution factor as given in Table 2.6.2

γ = (a) Forward region

$$\gamma = 0{,}653 + 3{,}217\sqrt{P_0\,\Delta} \times 10^{-5}$$

$$\gamma = 0{,}876 + 9{,}908\sqrt{P_0\,\Delta} \times 10^{-6}$$

or

γ = 1,0, whichever is the least

= (b) Midship and aft regions

$$\gamma = 0{,}653 + 9{,}908\sqrt{P_0\,\Delta} \times 10^{-6}$$

or

γ = 1,0, whichever is the least

P_0 and Δ = are as defined in 2.2.

6.3.2 The minimum thickness of the web plating of longitudinal primary members is to comply with the requirements of Pt 3, Ch 10,4.

6.4 Stem

6.4.1 The stem is to be made of rolled, cast or forged steel or of shaped steel plates. A sharp edged stem, as shown in Fig. 2.6.1, improves the manoeuvrability of the ship in ice. Where a sharp angle stem is fitted, the section modulus as given in 6.4.2 and 6.4.3 is to apply to the stem section only, otherwise the section modulus may be applied including side plates.

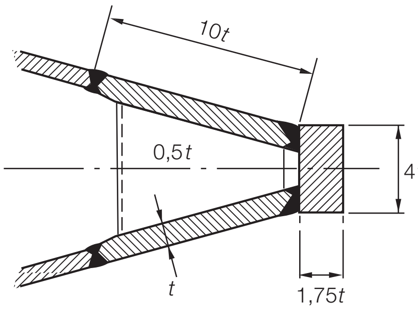


Fig. 2.6.1 A sharp edged stem

6.4.2 The section modulus of the stem in the fore and aft direction is not to be less than determined in accordance with the following formula:

$Z = 1500\,(\alpha_o\,\gamma^2)^{3/2}$ cm^3

where

α_o = longitudinal distribution factor for the forward region as given in Table 2.6.2

γ = is defined in 6.3.1.

Table 2.6.2 Longitudinal distribution factor α_o

Ice Class	α_o		
	Forward	Midship	Aft
1AS FS	1,00	0,98	0,89
1A FS	0,87	0,75	0,64
1B FS	0,78	0,64	0,51
1C FS	0,68	0,53	0,37
1D	0,68	–	–

6.4.3 The dimensions of a welded stem constructed as shown in Fig. 2.6.1 are to be determined in accordance with the following formula:

$t = 31\sqrt{\alpha_o\,\gamma^2}$ mm

where

t = thickness of the side plates, in mm.

6.4.4 In bulbous bow constructions, the extent of plating below the Ice Light Waterline should be such as to cover that part of the bulb forward of the vertical line originating at the intersection of the Ice Light Waterline and the stem contour at the centreline. A suitably tapered transition piece should be arranged between the reinforced stem plating and keel. However, in no case should the reinforced stem plating extend vertically below the Ice Light Waterline for less than 750 mm. The adjacent strake to the reinforced shaped stem plating of the bulb should be in accordance with the requirements for shell plating.

6.4.5 Where in the ice belt region the radius of the stem or bulb front plating is large, one or more vertical stiffeners are to be fitted in order to meet the section modulus requirement of 6.4.2. In addition, vertical ring stiffening will be required for the bulb.

6.4.6 The dimensions of the stem may be tapered to the requirements of Pt 3, Ch 5,3.3 at the upper deck. The connections of the shell plating to the stem are to be flush.

6.5 Stern

6.5.1 Where the screwshaft diameter exceeds the Rule diameter, the propeller post is to be correspondingly strengthened, *see* Pt 3, Ch 6,7.

6.6 Renewal criteria within ice strengthening area for CSR ships

6.6.1 For double hull oil tankers and bulk carriers that are compliant with the *IACS Common Structural Rules for Double Hull Tankers and IACS Common Structural Rules for Bulk Carriers* respectively, the renewal criteria of the local structure for general corrosion is to be calculated in accordance with the applicable Common Structural Rules renewal criteria.

6.7 Rudder and steering arrangements

6.7.1 Rudder scantlings, posts, rudder horns, solepieces, rudder stocks, steering engine and pintles are to be dimensioned in accordance with Pt 3, Ch 6 and 13 as appropriate. The speed used in the calculations is to be the maximum service speed or that given in Table 2.6.3, whichever is the greater. When used in association with the speed given in Table 2.6.3, the rudder profile coefficients are to be taken as 1,1.

Table 2.6.3 Minimum speed

Ice Class	Minimum speed, in knots
1AS FS	20
1A FS	18
1B FS	16
1C FS	14
1D	14

6.7.2 For double plate rudders, the minimum thickness of plating and horizontal and vertical webs in the main ice belt zone is to be determined as for shell plating in the aft region. For the horizontal and vertical webs, the corrosion-abrasion increment, need not be added. For **Ice Class 1D**, the minimum thickness of plating and webs, of double plate rudders and the extent of application are to be determined as for those in **Ice Class 1C FS**.

6.7.3 Where an ice class notation is included in the class of a ship, the nozzle construction requirements, as defined in Table 13.3.1 in Pt 3, Ch 13, are to be upgraded to include abrasion allowance as follows:

Ice Class	Thickness increment
1AS FS	5 mm
1A FS	4 mm
1B FS	3 mm
1C FS	2 mm
1D	2 mm

However, the thickness of the shroud plating is not to be less than the shell plating for the aft region taking frame spacing s in the formula as 500 mm.

6.7.4 The scantlings of the stock, pintles, gudgeon and solepiece associated with the nozzle are to be increased on the basis given in 6.7.1. However, the diameter of the nozzle stock is to be not less than that calculated in the astern condition taking the astern speed as half the speed given in Table 2.6.3 or the actual astern speed, whichever is the greater.

6.7.5 Nozzles with articulated flaps will be subject to special consideration.

6.7.6 For the Ice Classes **1AS FS** and **1A FS**, the rudder stock and the upper edge of the rudder shall be protected against ice pressure by an ice knife or equivalent means. The ice knife is to extend down to the ice light waterline; this requirement may be waived where this would lead to impracticable ice knifes, e.g. for ships with large draught variations.

6.7.7 For the Ice Classes **1AS FS** and **1A FS**, due regard is to be paid to the excessive load caused by the rudder being forced out of the midship position when backing into an ice ridge. When vessels are intended to operate with significant time in astern operation, then the hull strength is to be based on the method used in the forward region; however, due consideration may be given to the anticipated power in this mode of operation.

6.7.8 Relief valves for hydraulic pressure are to be effective, *see* Pt 5, Ch 19,3.3. The components of the rudder steering gear are to be able to withstand the yield torque of the rudder stock, *see* Pt 5, Ch 19,3.2.2.

■ *Section 7*
Machinery requirements for first-year ice conditions – Ice Classes 1AS FS, 1A FS, 1B FS and 1C FS

7.1 General

7.1.1 In addition to the requirements of the *Finnish-Swedish Ice Class Rules*, the following Sections are to be complied with for **Ice Class 1AS FS**, **Ice Class 1A FS**, **Ice Class 1B FS** and **Ice Class 1C FS**, where applicable. Alternative arrangements to attain similar performance will be specially considered.

7.2 Determination of ice torque

7.2.1 If the propeller is not fully submerged when the ship is in ballast condition, the requirements for **Ice Class 1A FS** is to be used for **Ice Class 1B FS** and **Ice Class 1C FS**.

7.3 Propeller blade sections

7.3.1 Where the blade thickness derived from the *Finnish-Swedish Ice Class Rules* is less than the blade thickness derived by Pt 5, Ch 7,3.1, the latter is to apply.

7.4 Intermediate blade sections

7.4.1 The thickness of other sections is to conform to a smooth curve connecting the section thicknesses as determined by the *Finnish-Swedish Ice Class Rules*.

7.5 Blade edge thickness

7.5.1 The thickness of blade edges is to be not less than 50 per cent of the derived tip thickness, t, measured at 1,25t from edge. For controllable pitch propellers, this applies only to the leading edge.

7.6 Mechanisms for controllable pitch propellers

7.6.1 The strength of mechanisms in the boss of a controllable pitch propeller is to be 1,5 times that of the blade when a load is applied at the radius 0,9D/2 in the weakest direction of the blade.

7.7 Keyless propellers

7.7.1 When it is proposed to use keyless propellers, the fit of the propeller boss to the screwshaft will be specially considered.

7.8 Screwshafts

7.8.1 Where the screwshaft diameter as derived by the *Finnish-Swedish Ice Class Rules* is less than the diameter derived by Pt 5, Ch 6,3.5.1, the latter is to apply.

7.8.2 The diameter, d_s, of the screwshaft determined in accordance with the *Finnish-Swedish Ice Class Rules* is to extend over a length not less than that to the forward edge of the bearing immediately forward of the propeller or $2{,}5d_s$ whichever is the greater.

7.8.3 The shaft may be tapered at the forward end in accordance with Pt 5, Ch 6,3.5.3 and Pt 5, Ch 6,3.5.4, except for **Ice Class 1AS FS** ice strengthening, where these diameters are to be increased by 10 per cent.

7.8.4 For screwshafts in ships intended for the notation **Ice Class 1AS FS** or **Ice Class 1A FS** and where the connection between the propeller and the screwshaft is by means of a key, Charpy impact tests are to be made in accordance with the requirements of Ch 5,3.4.12 of the Rules for Materials.

7.9 Intermediate and thrust shafts

7.9.1 The diameters of intermediate shafts and thrust shafts in external bearings are to comply with Pt 5, Ch 6,3.1 and Pt 5, Ch 6,3.4 respectively, except for **Ice Class 1AS FS** ice strengthening where these diameters are to be increased by 10 per cent.

■ *Section 8*
Hull requirements for first-year ice conditions – Ice Classes 1AS FS(+), 1A FS(+), 1B FS(+) and 1C FS(+)

8.1 General

8.1.1 The requirements for **Ice Class 1AS FS**, **Ice Class 1A FS**, **Ice Class 1B FS** and **Ice Class 1C FS**, as applicable, are to be applied using the installed engine power as given by Section 9.

■ *Section 9*
Machinery requirements for first-year ice conditions – Ice Classes 1AS FS(+), 1A FS(+), 1B FS(+) and 1C FS(+)

9.1 Powering of ice strengthened ships

9.1.1 For ships that require additional strengthening in ice, the total shaft power installed is to be calculated using the following Sections, but is not to be less than required by the *Finnish-Swedish Ice Class Rules* in force at the time of contract.

9.1.2 Ice strengthened ships which are to be considered to have an icebreaking capability are to be able to develop sufficient thrust to permit continuous mode icebreaking at a speed of at least five knots in ice having a thickness equal to the nominal value for the desired Ice Class and a snow cover of at least 0,3 m.

9.1.3 The shaft power necessary to provide an ice-breaking capability can be determined by the equation:

$$P_1 = 0{,}736 C_1\, C_2\, C_3\, C_4 \left[240Bh\,(1 + h + 0{,}035v^2) + 70S_c\sqrt{L}\right] \text{ kW}$$

where

B = moulded breath of ship, in metres, *see* Pt 3, Ch 1,6.1.3
L = Rule length, in metres, *see* Pt 3, Ch 1,6.1.1
Δ = displacement, in tonnes, *see* Pt 3, Ch 9,7.2.1
$C_1 = \dfrac{1{,}2B}{\sqrt[3]{\Delta}}$ but is not to be taken as less than 1,0
C_2 = 0,9 if the ship is fitted with a controllable pitch propeller, otherwise 1,0
C_3 = 0,9 if the rake of the stem is 45° or less, otherwise 1,0. The product $C_2\, C_3$ is not to be taken as less than 0,85
C_4 = 1,1 if the ship is fitted with a bulbous bow, otherwise 1,0
h = ice thickness
= 1,0 for **Ice Class 1AS FS(+)**
= 0,8 for **Ice Class 1A FS(+)**
= 0,6 for **Ice Class 1B FS(+)**
= 0,4 for **Ice Class 1C FS(+)**
S_c = depth of snow cover
v = ship speed, in knots, when breaking ice of thickness h.

9.2 Materials for shafting

9.2.1 For screwshafts in ships intended for the notation **Ice Class 1AS FS(+)** or **Ice Class 1A FS(+)** and where the connection between the propeller and the screwshaft is by means of a key, Charpy impact tests are to be made in accordance with the requirements of Ch 5,3.4.12 of the Rules for Materials.

Section 10
Hull strengthening requirements for navigation in multi-year ice conditions – Ice Classes PC1, PC2, PC3, PC4, PC5, PC6, PC7 and Icebreaker

10.1 Hull areas

10.1.1 The hull of all polar class ships is divided into areas reflecting the magnitude of the loads that are expected to act upon them, *see* Fig. 2.10.1. In the longitudinal direction, there are four regions:
(a) bow, (*B*);
(b) bow intermediate, (B_i);
(c) midbody, (*M*), and
(d) stern (*S*).
The bow intermediate, midbody and stern regions are further divided in the vertical direction into three regions:
(i) bottom, (*b*)
(ii) lower, (*l*) and
(iii) icebelt (*i*).

10.1.2 The upper ice waterline, UIWL, and lower ice waterline, LIWL, are as defined in 2.2.

10.1.3 In addition to Fig. 2.10.1, at no time is the boundary between the bow and bow intermediate regions to be forward of the intersection point of the line of the stem and the ship baseline.

10.1.4 In addition to Fig. 2.10.1, the aft boundary of the bow region need not be more than 0,45*L* aft of the forward perpendicular, *FP*.

10.1.5 The boundary between the bottom and lower regions is to be taken at the point where the tangent to the shell is inclined 7° from horizontal.

10.1.6 If a ship is intended to operate astern in ice regions, the aft section of the ship is to be designed based on the bow and bow intermediate hull area requirements.

10.2 Design ice loads – General

10.2.1 For ships of all Polar Classes, a glancing impact on the bow is the design scenario for determining the scantlings required to resist ice loads.

10.2.2 The design ice load is characterised by an average pressure, P_a, uniformly distributed over a rectangular load patch of height, *b*, and width, *w*.

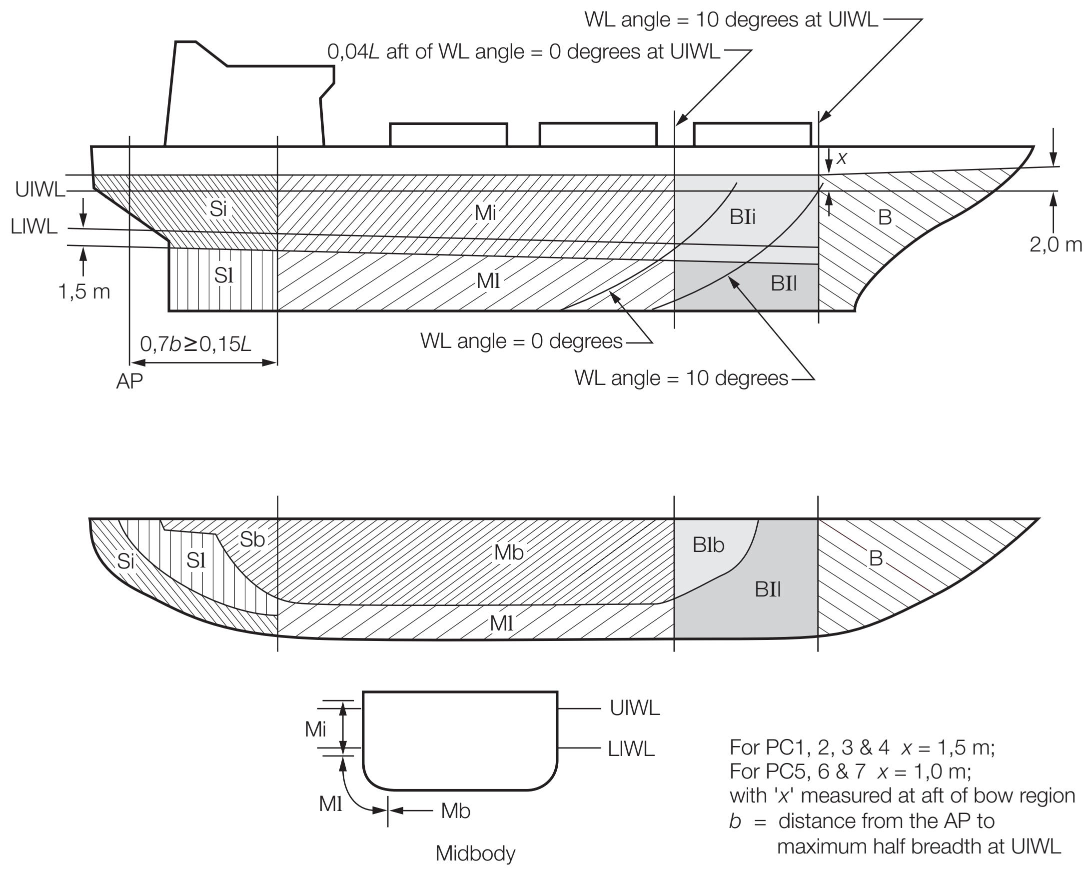


Fig. 2.10.1 Extent of hull areas

10.2.3 Within the bow area of all polar classes, and within the bow intermediate icebelt area of polar classes **PC6** and **PC7**, the ice load parameters are functions of the actual bow shape. To determine the ice load parameters, P_a, b and w, it is required to calculate the following ice load characteristics for sub-regions of the bow area; shape coefficient, f_{ai}, total glancing impact force, F_i, line load, Q_i, and pressure, P_i.

10.2.4 In other ice-strengthened areas, the ice load parameters, P_a, b_{NB} and w_{NB}, are determined independently of the hull shape and based on a fixed load patch aspect ratio, AR = 3.6.

10.2.5 Design ice forces calculated according to 10.3 are only valid for vessels with icebreaking forms. Design ice forces for any other bow forms are to be specially considered.

10.2.6 Ship structures that are not directly subjected to ice loads may still experience inertial loads of stowed cargo and equipment resulting from ship/ice interaction. These inertial loads are to be considered in the design of these structures.

10.3 Glancing impact load characteristics

10.3.1 The parameters defining the glancing impact load characteristics are reflected in the class factors listed in Table 2.10.1.

10.4 Bow area

10.4.1 In the bow area, the force, F, line load, Q, pressure, P, and load patch aspect ratio, AR, associated with the glancing impact load scenario are functions of the hull angles measured at the upper ice waterline, UIWL. The influence of the hull angles is captured through calculation of a bow shape coefficient, fa. The hull angles are defined in Fig. 2.10.2.

10.4.2 The waterline length of the bow region is generally to be divided into four sub-regions of equal length. The force, F, line load, Q, pressure, P, and load patch aspect ratio, AR, are to be calculated with respect to the mid-length position of each sub-region (each maximum of F, Q and P is to be used in the calculation of the ice load parameters P_a, b and w).

10.4.3 The bow area load characteristics are determined as follows:

(a) The shape coefficient, fa_i, is to be taken as

fa_i = $fa_{i,1}$
$fa_{i,2}$
$fa_{i,3}$ whichever is the lesser

where

$$fa_{i,1} = \left(0{,}097 - 0{,}68\left(\frac{x}{L} - 0{,}15\right)^2\right)\frac{\alpha_i}{\sqrt{\beta'_i}}$$

$$fa_{i,2} = \frac{1{,}2C_F}{\sin(\beta'_i)\,C_C\,\Delta^{0{,}64}}$$

$fa_{i,3}$ = 0,60
i = sub-region considered
L = ship length as defined in Pt 3, Ch 1,6.1.1, but measured on the upper ice waterline (UIWL), in metres
x = distance from the forward perpendicular (FP) to station under consideration, in metres
α = waterline angle, in degrees, *see* Fig. 2.10.2
β' = normal frame angle, in degrees, *see* Fig. 2.10.2
Δ = ship displacement, in kilo tonnes, not to be taken less than 5
C_C = crushing failure class factor from Table 2.10.1
C_F = flexural failure class factor from Table 2.10.1

(b) Force, F_i:

$F_i = fa_i\,C_C\,\Delta^{0{,}64}$ MN

where
i = sub-region considered
fa_i = shape coefficient of sub-region, i
C_C = crushing failure class factor from Table 2.10.1
Δ = ship displacement, in kilo tonnes, not to be taken less than 5

(c) Load patch aspect ratio, AR_i:

$AR_i = 7{,}46 \sin(\beta'_i)$
$AR_i \geq 1{,}3$

where
i = sub-region considered
β'_i = normal frame angle of sub-region i, in degrees

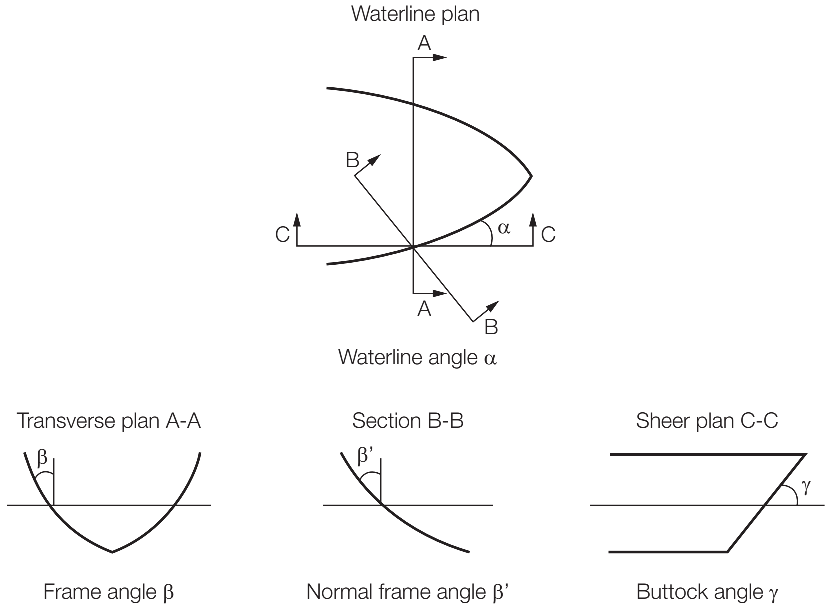
(d) Line load, Q_i:

$$Q_i = \frac{F_i^{0{,}61}\,C_D}{AR_i^{0{,}35}} \quad \text{MN/m}$$

where
i = sub-region considered
F_i = force of sub-region i, in MN
C_D = load patch dimensions class factor from Table 2.10.1
AR_i = load patch aspect ratio of sub-region i

Table 2.10.1 Class factors

Polar Class	Crushing failure class factor	Flexural failure class factor	Load patch dimensions class factor	Displacement class factor	Longitudinal strength class factor
	C_C	C_F	C_D	C_{DI}	C_L
PC1	17,69	68,60	2,01	250	7,46
PC2	9,89	46,80	1,75	210	5,46
PC3	6,06	21,17	1,53	180	4,17
PC4	4,50	13,48	1,42	130	3,15
PC5	3,10	9,00	1,31	70	2,50
PC6	2,40	5,49	1,17	40	2,37
PC7	1,80	4,06	1,11	22	1,81



where

β' = normal frame angle at upper ice waterline, in degrees

α_S = upper ice waterline angle, in degrees

γ = buttock angle at upper ice waterline (angle of buttock line measured from horizontal), in degrees

$\tan(\beta) = \dfrac{\tan(\alpha)}{\tan(\gamma)}$

$\tan(\beta') = \tan(\beta)\cos(\alpha)$

Fig. 2.10.2 Definition of hull angles

(e) Pressure, P_i:

$P_i = F_i^{0,22} C_D^2 AR_i^{0,3}$ MPa

where

I = sub-region considered

F_i = force of sub-region i, in MN

C_D = load patch dimensions class factor from Table 2.10.1

AR_i = load patch aspect ratio of sub-region i.

10.5 Hull areas other than the bow

10.5.1 In the hull areas other than the bow, the force, F_{NB}, and line load, Q_{NB}, used in the determination of the load patch dimensions, b_{NB}, w_{NB}, and design pressure, P_a, are determined as follows:

(a) Force, F_{NB}:

$F_{NB} = 0{,}36 C_C\ \Delta_F$ MN

where

C_C = crushing force class factor from Table 2.10.1

Δ_F = ship displacement factor

= $\Delta^{0,64}$ if $\Delta \le C_{DI}$

= $C_{DI}^{0,64} + 0{,}10\,(\Delta - C_{DI})$ if $\Delta > C_{DI}$

Δ = ship displacement, in kilo tonnes, not to be taken less than 10

C_{DI} = displacement class factor from Table 2.10.1

(b) Line Load, Q_{NB}:

$Q_{NB} = 0{,}639 F_{NB}^{0,61} C_D$ MN/m

where

F_{NB} = force from 10.5.1(a), in MN

C_D = load patch dimensions class factor from Table 2.10.1.

10.6 Design load patch

10.6.1 In the bow area, and the bow Intermediate Icebelt area for ships with class notation **PC6** and **PC7**, the design load patch has dimensions of width, w_B, and height, b_B, defined as follows:

$$w_B = \frac{F_B}{Q_B} \text{ m}$$

$$b_B = \frac{Q_B}{P_B} \text{ m}$$

where

F_B = maximum F_i in the bow area, in MN

Q_B = maximum Q_i in the bow area, in MN/m

P_B = maximum P_i in the bow area, in MPa.

10.6.2 In hull areas other than those covered by 10.6.1, the design load patch has dimensions of width, w_{NB}, and height, b_{NB}, defined as follows:

$$w_{NB} = \frac{F_{NB}}{Q_{NB}} \text{ m}$$

$$b_{NB} = \frac{w_{NB}}{3{,}6} \text{ m}$$

where

F_{NB} = force determined using 10.5.1(a), in MN

Q_{NB} = line load determined using 10.5.1(b), in MN/m.

10.7 Pressure within the design load patch

10.7.1 The average pressure, P_a, within a design load patch is determined as follows:

$$P_a = \frac{F}{bw} \text{ MPa}$$

where

F = F_B or F_{NB} as appropriate for the hull area under consideration, in MN
b = b_B or b_{NB} as appropriate for the hull area under consideration, in metres
w = w_B or w_{NB} as appropriate for the hull area under consideration, in metres.

10.7.2 Areas of higher, concentrated pressure exist within the load patch. In general, smaller areas have higher local pressures. Accordingly, the peak pressure factors listed in Table 2.10.2 are used to account for the pressure concentration on localised structural members.

10.8 Hull area factors

10.8.1 Associated with each hull area is an area factor that reflects the relative magnitude of the load expected in that area. The area factor, *AF*, for each hull area is listed in Table 2.10.3.

10.8.2 In the event that a structural member spans across the boundary of a hull area, the largest hull area factor is to be used in the scantling determination of the member.

Table 2.10.2 Peak pressure factors

Structural member		Peak pressure factor, K_i
Plating	Transversely framed Longitudinally framed	$K_p = (1,8 - s) \geq 1,2$ $K_p = (2,2 - 1,2s) \geq 1,5$
Frames in transverse framing systems	With load distributing stringers With no load distributing stringers	$K_t = (1,6 - s) \geq 1,0$ $K_t = (1,8 - s) \geq 1,2$
Load carrying stringers Side and bottom longitudinals Web frames		$K_s = 1$ if $S_w \geq 0,5w$ $K_s = 2 - \frac{2S_w}{w}$ if $S_w < 0,5w$
Symbols		
s = frame or longitudinal spacing, in metres S_w = web frame spacing, in metres w = ice load patch width, in metres		

Table 2.10.3 Hull area factors (*AF*)

Hull area		Area	Polar Class						
			PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**
Bow (*B*)	All	B	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Bow intermediate (*BI*)	Icebelt	BI_i	0,90	0,85	0,85	0,80	0,80	1,00 *see* Note 1	1,00 *see* Note 1
	Lower	BI_l	0,70	0,65	0,65	0,60	0,55	0,55	0,50
	Bottom	BI_b	0,55	0,50	0,45	0,40	0,35	0,30	0,25
Midbody (*M*)	Icebelt	M_i	0,70	0,65	0,55	0,55	0,50	0,45	0,45
	Lower	M_l	0,50	0,45	0,40	0,35	0,30	0,25	0,25
	Bottom	M_b	0,30	0,30	0,25	*see* Note 2	*see* Note 2	*see* Note 2	*see* Note 2
Stern (*S*)	Icebelt	S_i	0,75	0,70	0,65	0,60	0,50	0,40	0,35
	Lower	S_l	0,45	0,40	0,35	0,30	0,25	0,25	0,25
	Bottom	S_b	0,35	0,30	0,30	0,25	0,15	*see* Note 2	*see* Note 2

NOTES
1. *See* 10.2.3.
2. Indicates that strengthening for ice loads is not necessary.

10.8.3 Due to their increased manoeuvrability, ships having propulsion arrangements with azimuthing thruster(s) or podded propellers shall have specially considered stern icebelt, S_i, and stern lower, S_l, hull area factors.

10.8.4 Area factors to be applied to ships assigned the notation **Icebreaker** are given in Table 2.10.4.

10.9 Shell plate requirements

10.9.1 The required minimum shell plate thickness, t, is given by:

$$t = t_{net} + t_s \quad \text{mm}$$

where

t_{net} = plate thickness required to resist ice loads according to 10.9.2, in mm

t_s = corrosion and abrasion allowance according to 10.16, in mm.

10.9.2 The thickness of shell plating required to resist the design ice load, t_{net}, depends on the orientation of the framing. The plating, including all bottom plating, i.e., plating in hull areas B_{lb}, M_b and S_b, the net thickness is given by Table 2.10.5.

10.10 Framing – General

10.10.1 Framing members of Polar class ships are to be designed to withstand the ice loads defined in 10.2.

10.10.2 The term 'framing member' refers to transverse and longitudinal local frames, load-carrying stringers and web frames in the areas of the hull exposed to ice pressure, *see* Fig. 2.10.1. Where load-distributing stringers have been fitted, the arrangement and scantlings of these are to be suitably designed.

10.10.3 The strength of a framing member is dependent upon the fixity that is provided at its supports. Fixity can be assumed where framing members are either continuous through the support or attached to a supporting section with a connection bracket. In other cases, simple support is to be assumed unless the connection can be demonstrated to provide significant rotational restraint. Fixity is to be ensured at the support of any framing which terminates within an ice-strengthened area.

10.10.4 The details of framing member intersection with other framing members, including plated structures, as well as the details for securing the ends of framing members at supporting sections, are to be in accordance with Pt 3, Ch 10.

10.10.5 The design span of a framing member is to be determined on the basis of its moulded length. If brackets are fitted, the design span may be reduced in accordance with Pt 3, Ch 3.

10.10.6 When calculating the section modulus and shear area of a framing member, the net thicknesses of the web, flange (if fitted) and attached shell plating are to be used. The shear area of a framing member may include that material contained over the full depth of the member, i.e. web area including portion of flange, if fitted, but excluding attached shell plating.

10.10.7 The actual net effective shear area, A_w, of a framing member is given by:

$$A_w = \frac{h\, t_{wn} \sin\varphi_w}{100} \quad \text{cm}^2$$

where

h = height of stiffener, in mm, *see* Fig. 2.10.4

t_{wn} = net web thickness, in mm

= $t_w - t_c$

t_w = as built web thickness, in mm, *see* Fig. 2.10.4

t_c = corrosion deduction, in mm, to be subtracted from the web and flange thickness (as specified by t_s in 10.16.3)

φ_w = smallest angle between shell plate and stiffener web, measured at the midspan of the stiffener, *see* Fig. 2.10.4. The angle φ_w may be taken as 90° provided the smallest angle is not less than 75°.

Table 2.10.4 Hull area factors (AF) for icebreaker

	Bi	B*l*i	B*ll*	Blb	Mi	M*l*	Mb	Si	S*l*	Sb
PC1	1	0,90	0,70	0,55	0,70	0,50	0,30	0,94	0,56	0,35
PC2	1	0,85	0,65	0,50	0,65	0,45	0,30	0,88	0,50	0,30
PC3	1	0,85	0,65	0,45	0,55	0,40	0,25	0,81	0,44	0,30
PC4	1	0,85	0,65	0,45	0,55	0,40	0,25	0,81	0,44	0,30
PC5	1	0,85	0,65	0,45	0,55	0,40	0,25	0,81	0,44	0,30
PC6	1	1	0,65	0,45	0,55	0,40	0,25	0,81	0,44	0,30
PC7	1	1	0,65	0,45	0,55	0,40	0,25	0,81	0,44	0,30

Table 2.10.5 Shell plate thickness

Transversely framed plating	Obliquely framed plating	Longitudinally framed plating	
$\Omega \geq 70°$	$70° > \Omega > 20°$	$\Omega \leq 20°$	
		$b \geq s$	$b < s$
$t_{net} = \dfrac{500s\sqrt{\dfrac{AF\,K_p\,P_a}{\sigma_y}}}{1 + \dfrac{s}{2b}}$ mm	linear interpolation	$t_{net} = \dfrac{500s\sqrt{\dfrac{AF\,K_p\,P_a}{\sigma_y}}}{1 + \dfrac{s}{2l}}$ mm	$t_{net} = \dfrac{500s\sqrt{\dfrac{AF\,K_p\,P_a}{\sigma_y}}\sqrt{\dfrac{2b}{s} - \left(\dfrac{b}{s}\right)^2}}{1 + \dfrac{s}{2l}}$ mm

Symbols

Ω = smallest angle between the chord of the waterline and the line of the first level framing as illustrated in Fig. 2.10.3, in degrees
s = transverse frame spacing in transversely-framed ships or longitudinal frame spacing in longitudinally-framed ships, in metres
AF = hull area factor from Table 2.10.3
K_p = peak pressure factor from Table 2.10.2
P_a = average patch pressure according to 10.7.1, in MPa
σ_y = minimum upper yield stress of the material, in N/mm^2
b = height of design load patch, in m, where $b \leq l - \dfrac{s}{4}$ in the case of transversely framed plating
l = distance between frame supports, i.e. equal to the frame span as given in 10.10.5, but not reduced for any fitted end brackets, in metres. When a load-distributing stringer is fitted, the length, l, need not be taken larger than the distance from the stringer to the most distant frame support

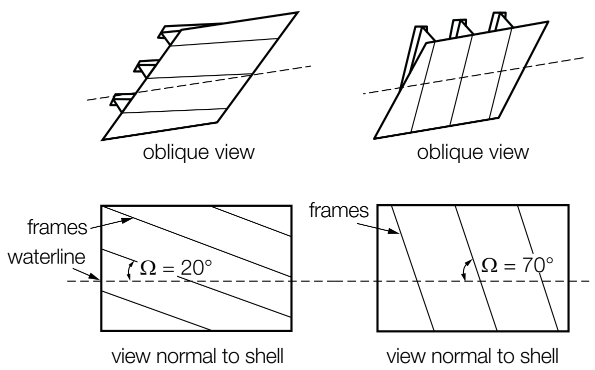


Fig. 2.10.3 Shell framing angle Ω

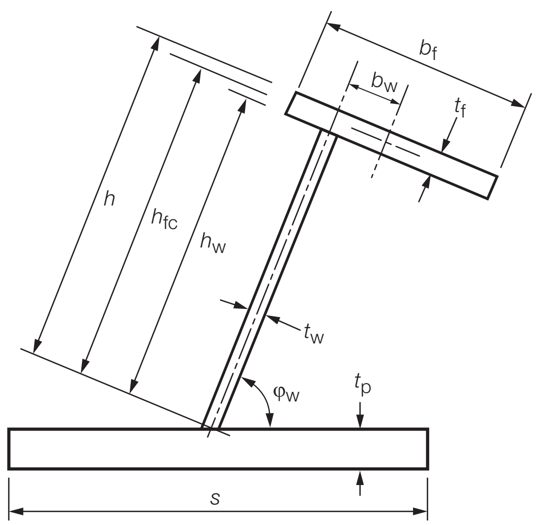


Fig. 2.10.4 Stiffener geometry

10.10.8 When the cross-sectional area of the attached plate flange exceeds the cross-sectional area of the local frame, the actual net effective plastic section modulus, Z_p, is given by:

$$Z_p = \frac{A_{pn}\, t_{pn}}{20} + \frac{h_w^2\, t_{wn} \sin\varphi_w}{2000} + \frac{A_{fn}\,(h_{fc} \sin\varphi_w - b_w \cos\varphi_w)}{10} \ \text{cm}^3$$

where

A_{pn} = net cross-sectional area of the local frame, in cm^2
t_{pn} = fitted net shell plate thickness, in mm, (shall comply with t_{net} as required by 10.9.2)
h_w = height of local frame web, in mm, *see* Fig. 2.10.4
A_{fn} = net cross-sectional area of local frame flange, in cm^2
h_{fc} = height of local frame measured to centre of the flange area, in mm, *see* Fig. 2.10.4
b_w = distance from mid thickness plane of local frame web to the centre of the flange area, in mm, *see* Fig. 2.10.4

h, t_w, t_c and φ_w are as given in 10.10.7
s as given in 10.9.2.

10.10.9 When the cross-sectional area of the local frame exceeds the cross-sectional area of the attached plate flange, the plastic neutral axis is located a distance z_{na} above the attached shell plate, given by:

$$z_{na} = \frac{100\, A_{fn} + h_w\, t_{wn} - 1000 t_{pn}\, s}{2 t_{wn}} \ \text{mm}$$

and the net effective plastic section modulus, Z_p, is given by:

$$Z_p = t_{pn}\, s \left(z_{na} \; \frac{t_{pn}}{2}\right) \sin\varphi_w + \left(\frac{((h_w - z_{na})^2 + z_{na}^2)\, t_{wn} \sin\varphi_w}{2000} + \frac{A_{fn}\,((h_{fc} - z_{na}) \sin\varphi_w - b_w \cos\varphi_w)}{10}\right) \text{cm}^3$$

10.10.10 In the case of oblique framing arrangement (70° > Ω > 20°, where Ω is defined as given in 10.9.2), linear interpolation is to be used.

10.11 Framing – Transversely-framed side structures and bottom structures

10.11.1 The local frames in transversely-framed side structures and in bottom structures (i.e., hull areas B_{Ib}, M_b and S_b) are to be dimensioned such that the combined effects of shear and bending do not exceed the plastic strength of the member. The plastic strength is defined by the magnitude of midspan load that causes the development of a plastic collapse mechanism.

10.11.2 The actual net effective shear area of the frame, A_w, as defined in 10.10.7, is to comply with the following condition:

$$A_w \geq A_t$$

where

$$A_t = 5000\, l_L\, s\, \frac{AF\, K_t\, P_a}{0{,}577 \sigma_y} \ \text{cm}^2$$

l_L = length of loaded portion of span, in metres
= need not exceed the lesser of a and b
a = frame span as defined in 10.10.5, in metres
b = height of design ice load patch according to 10.6, in metres
s = transverse frame spacing, in metres
AF = hull area factor from Table 2.10.3
K_t = peak pressure factor from Table 2.10.2
P_a = average pressure within load patch according to 2.10.7, in MPa
σ_y = minimum upper yield stress of the material, in N/mm^2

10.11.3 The actual net effective plastic section modulus of the plate/stiffener combination, Z_p, as defined in 10.10.8 or 10.10.9, is to comply with the following conditions and is to be the greatest of the two load conditions:

(a) ice load acting at the midspan of the transverse frame, and
(b) the ice load acting near a support.

$$Z_p \geq Z_{pt}$$

where

$$Z_{pt} = \frac{100^3\, l_L\, Y\, s\, AF\, K_t\, P_a\, a\, A_1}{4 \sigma_y} \ \text{cm}^3$$

$$Y = 1 - \frac{l_L}{2a}$$

A_1 = reflects the two conditions and is to be taken as the greater of A_{1A} or A_{1B}

$$A_{1A} = \frac{1}{1 + \frac{j}{2} + k_w \frac{j}{2}\left(\sqrt{1 - a_1^2} - 1\right)}$$

$$A_{1B} = \frac{1 - \frac{1}{2 a_1 Y}}{0{,}275 + 1{,}44 k_z^{0{,}7}}$$

j = 1 for framing with one simple support outside the ice strengthened areas
= 2 for framing without any simple supports

$$a_1 = \frac{A_t}{A_w}$$

A_t = rule minimum shear area of transverse frame as given in 10.11.2, in cm^2
A_w = effective net shear area of transverse frame (calculated according to 10.10.7), in cm^2

$$k_w = \frac{1}{1 + \frac{2 A_{fn}}{A_w}}$$

A_{fn} = as given in 10.10.8

$k_z = \dfrac{z_p}{Z_p}$ in general

$= 0$ when the frame is arranged with end bracket

z_p = sum of individual plastic section modulii of flange and shell plate as fitted, in cm^3

$$= \frac{\dfrac{b_f\, t_{fn}^2}{4} + \dfrac{b_e\, t_{pn}^2}{4}}{1000}$$

b_f = flange breadth, in mm, *see* Fig. 2.10.4

t_{fn} = net flange thickness, in mm

$= t_f - t_c$

t_c = as given in 10.10.7

t_f = as-built flange thickness, in mm, *see* Fig. 2.10.4

t_{pn} = the fitted net shell plate thickness, in mm, but is not to be less than t_n as given in 10.9

b_e = effective width of shell plate flange, in mm

$= 500s$

Z_p = net effective plastic section modulus of transverse frame (calculated according to 10.10.8 or 10.10.9), in cm^3

AF, K_t, P_a, l_L, b, s, a and σ_y are as given in 10.11.2.

10.11.4 The scantlings of the frame are to meet the structural stability requirements of 10.14.

10.12 Framing – Side longitudinals (longitudinally framed ships)

10.12.1 Side longitudinals are to be dimensioned such that the combined effects of shear and bending do not exceed the plastic strength of the member. The plastic strength is defined by the magnitude of midspan load that causes the development of a plastic collapse mechanism.

10.12.2 The actual net effective shear area of the frame, A_w, as defined in 10.10.7, is to comply with the following condition:

$A_w \geq A_L$

where

$$A_L = \frac{5000\, AF\, K_s\, P_a\, b_1\, a}{0{,}577\sigma_y} \text{ cm}^2$$

AF = hull area factor from Table 2.10.3

K_s = peak pressure factor from Table 2.10.2

P_a = average pressure within load patch according to 10.7.1, in MPa

$b_1 = k_o\, b_2$ m

$k_o = 1 - \dfrac{0{,}3}{b'}$

$b' = \dfrac{b}{s}$

b = height of design ice load patch from 10.6, in metres

s = spacing of longitudinal frames, in metres

$b_2 = b\,(1 - 0{,}25b')$ m if $b' < 2$

$= s$ m if $b' \geq 2$

a = longitudinal design span as given in 10.10.5, in metres

σ_y = minimum upper yield stress of the material, in N/mm^2

10.12.3 The actual net effective plastic section modulus of the plate/stiffener combination, Z_p, as defined in 10.10.8 or 10.10.9, is to comply with the following condition:

$Z_p \geq Z_{pL}$

where

$$Z_{pL} = \frac{100^3\, AF\, K_s\, P_a\, b_1\, a^2\, A_4}{8\sigma_y} \text{ cm}^3$$

$$A_4 = \frac{1}{2 + k_{wl}\left(\sqrt{1 - a_4^2} - 1\right)}$$

$$a_4 = \frac{A_L}{A_w}$$

A_L = rule minimum shear area for longitudinal as given in 10.12.2, in cm^2

A_w = net effective shear area of longitudinal (calculated according to 10.10.7), in cm^2

$$k_{wl} = \frac{1}{1 + \dfrac{2A_{fn}}{A_w}}$$

A_{fn} = as given in 10.10.8

AF, K_s, P_a, b_1, a and σ_y are as given in 10.12.2.

10.12.4 The scantlings of the longitudinals are to meet the structural stability requirements of 10.14.

10.13 Framing – Web frame and load carrying stringers

10.13.1 Web frames and load-carrying stringers are to be designed to withstand the ice load patch as defined in 10.7. The load patch is to be applied at locations where the capacity of these members under the combined effects of bending and shear is minimised.

10.13.2 Web frames and load-carrying stringers are to be dimensioned to take into account the combined effects of shear and bending. Where these members form part of a structural grillage system, appropriate methods of analysis are to be used. Where the structural configuration is such that members do not form part of a grillage system, the appropriate peak pressure factor, K_i, from Table 2.10.2 is to be used. Special attention is to be paid to the shear capacity in way of lightening holes and cut-outs in way of intersecting members.

10.13.3 The scantlings of web frames and load-carrying stringers are to meet the structural stability requirements of 10.14.

10.14 Framing – Structural stability

10.14.1 To prevent local buckling in the web, the ratio of web height, h_w, to net web thickness, t_{wn}, of any framing member is not to exceed:

For flat bar sections: $\dfrac{h_w}{t_{wn}} \le \dfrac{282}{\sqrt{\sigma_y}}$

For bulb, tee and angle sections: $\dfrac{h_w}{t_{wn}} \le \dfrac{805}{\sqrt{\sigma_y}}$

where
h_w = web height
t_{wn} = net web thickness
σ_y = minimum upper yield stress of the shell plate in way of the framing member, in N/mm^2

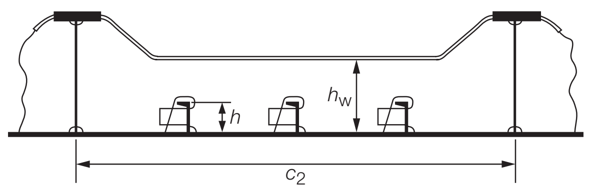


Fig. 2.10.5 Parameter definition for web stiffening

10.14.2 Framing members for which it is not practicable to meet the requirements of 10.14.1 (e.g., load carrying stringers or deep web frames) are required to have their webs effectively stiffened. The scantlings of the web stiffeners are to ensure the structural stability of the framing member. The minimum net web thickness for these framing members is given by:

$$t_{wn} = 2{,}63 \times 10^{-3}\, c_1 \sqrt{\frac{\sigma_y}{5{,}34 + 4\left(\frac{c_1}{c_2}\right)^2}} \text{ mm}$$

where
c_1 = $h_w - 0{,}8h$ mm
h_w = web height of stringer/web frame, in mm, *see* Fig. 2.10.5
h = height of framing member penetrating the member under consideration (to be taken as zero if no such framing member is fitted), in mm, *see* Fig. 2.10.5
c_2 = spacing between supporting structure oriented perpendicular to the member under consideration, in mm, *see* Fig. 2.10.5
σ_y = minimum upper yield stress of the material, in N/mm^2

10.14.3 In addition, the following is to be satisfied:

$$t_{wn} \ge 0{,}35 t_{pn} \sqrt{\frac{\sigma_y}{235}}$$

where
σ_y = minimum upper yield stress of the shell plate in way of the framing member, in N/mm^2
t_{wn} = net thickness of the web, in mm
t_{pn} = net thickness of the shell plate in way the framing member, in mm.

10.14.4 To prevent local flange buckling of welded profiles, the following are to be satisfied:

(a) The flange width, b_f, in mm, is not to be less than five times the net thickness of the web, t_{wn}.
(b) The flange outstand, b_o, in mm, is to meet the following requirement:

$$\frac{b_o}{t_{fn}} \le \frac{155}{\sqrt{\sigma_y}}$$

where
t_{fn} = net thickness of flange, in mm
σ_y = minimum upper yield stress of the material, in N/mm^2.

10.15 Plated structures

10.15.1 Plated structures are those stiffened plate elements in contact with the hull and subject to ice loads. These requirements are applicable to an inboard extent which is the lesser of:

(a) web height of adjacent parallel web frame or stringer; or
(b) 2,5 times the depth of framing that intersects the plated structure.

10.15.2 The thickness of the plating and the scantlings of attached stiffeners are to be such that the degree of end fixity necessary for the shell framing is ensured.

10.15.3 The stability of the plated structure is to adequately withstand the ice loads defined in 10.7.

10.16 Corrosion/abrasion additions and steel renewal

10.16.1 Effective protection against corrosion and ice-induced abrasion is recommended for all external surfaces of the shell plating for all Polar ships.

10.16.2 The values of corrosion/abrasion additions, t_s, to be used in determining the shell plate thickness for each Polar Class are listed in Table 2.10.6.

10.16.3 Polar ships are to have a minimum corrosion/abrasion addition of t_s = 1,0 mm applied to all internal structures within the ice strengthened hull areas, including plated members adjacent to the shell, as well as stiffener webs and flanges.

10.16.4 Steel renewal for ice strengthened structures is required when the gauged thickness is less than t_n + 0,5 mm.

10.17 Materials

10.17.1 Plating materials for hull structures are to be not less than those given in Tables 2.10.8 to 2.10.11 based on the as-built thickness of the material, the Polar ice class notation assigned to the ship and the material class of structural members given in 10.17.2.

Table 2.10.6 Corrosion/abrasion additions for shell plating

Hull area	t_s, in mm					
	With effective protection			Without effective protection		
	PC1 to **PC3**	**PC4** and **PC5**	**PC6** and **PC7**	**PC1** to **PC3**	**PC4** and **PC5**	**PC6** and **PC7**
Bow; Bow Intermediate Icebelt	3,5	2,5	2,0	7,0	5,0	4,0
Bow Intermediate Lower; Midbody & Stern Icebelt	2,5	2,0	2,0	5,0	4,0	3,0
Midbody and Stern Lower; Bottom	2,0	2,0	2,0	4,0	3,0	2,5

10.17.2 Material classes specified in Table 2.2.1 in Pt 3, Ch 2, are applicable to polar ships regardless of the ship's length. In addition, material classes for weather and sea exposed structural members and for members attached to the weather and sea exposed plating are given in Table 2.10.7. Where the material classes in Table 2.10.7 and those in Table 2.2.1 in Pt 3, Ch 2 differ, the higher material class is to be applied.

10.17.3 Steel grades for all plating and attached framing of hull structures and appendages situated below the level of 0,3 m below the lower waterline, as shown in Fig. 2.10.6, are to be obtained from Table 2.2.2 in Pt 3, Ch 2, based on the material class for Structural Members in Table 2.10.7 above, regardless of Polar Class.

10.17.4 Steel grades for all weather exposed plating of hull structures and appendages situated above the level of 0,3 m below the lower ice waterline, as shown in Fig. 2.10.6, are to be not less than given in Table 2.10.8 to Table 2.10.10.

10.17.5 Steel grades for all inboard framing members attached to weather exposed plating are to be not less than given in Table 2.10.11. This applies to all inboard framing members as well as to other contiguous inboard members (e.g. bulkheads, decks) within 600 mm of the exposed plating.

Table 2.10.7 Material classes for structural members of polar ships

Structural members	Material Class
Shell plating within the bow and bow intermediate icebelt hull areas (B, B_{Ii})	II
Plating materials for stem and stern frames, rudder horn, rudder, propeller nozzle, shaft brackets, ice skeg, ice knife and other appendages subject to ice impact loads	II
All weather and sea exposed SPECIAL, as defined in Table 2.2.1 in Pt 3, Ch 2, structural members within 0,2L from FP	II
All weather and sea exposed SECONDARY and PRIMARY, as defined in Table 2.2.1 in Pt 3, Ch 2, structural members outside 0,4L amidships	I
All inboard framing members attached to the weather and sea-exposed plating including any contiguous inboard member within 600 mm of the plating	I
Weather-exposed plating and attached framing in cargo holds of ships which by nature of their trade have their cargo hold hatches open during cold weather operations	I

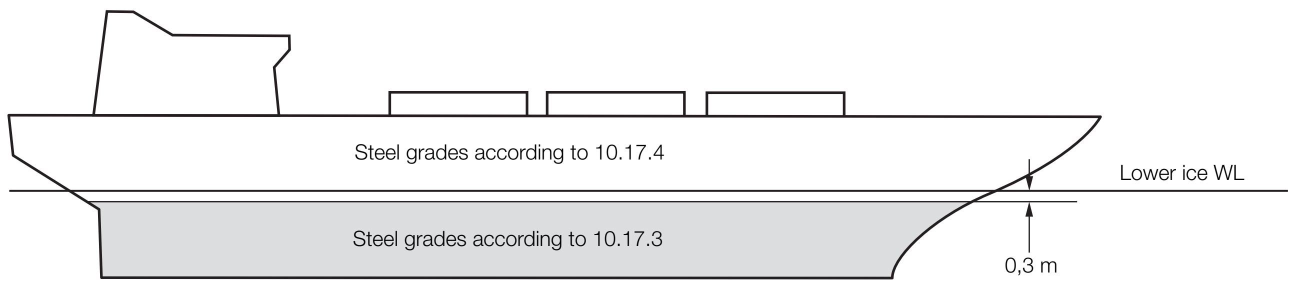


Fig. 2.10.6 Steel grade requirements for submerged and weather exposed shell plating

Table 2.10.8 Steel grades for weather exposed plating

Thickness, t mm	Material Class I			
	PC1 to **5**		**PC6** and **7**	
	MS	HT	MS	HT
$t \leq 10$	B	AH	B	AH
$10 < t \leq 15$	B	AH	B	AH
$15 < t \leq 20$	D	DH	B	AH
$20 < t \leq 25$	D	DH	B	AH
$25 < t \leq 30$	D	DH	B	AH
$30 < t \leq 35$	D	DH	B	AH
$35 < t \leq 40$	D	DH	D	DH
$40 < t \leq 45$	E	EH	D	DH
$45 < t \leq 50$	E	EH	D	DH

NOTE
Includes weather exposed plating of hull structures and appendages, as well as their outboard framing members, situated above a level of 0,3 m below the lowest ice waterline.

Table 2.10.9 Steel grades for weather exposed plating

Thickness, t mm	Material Class II			
	PC1 to **5**		**PC6** and **7**	
	MS	HT	MS	HT
$t \leq 10$	B	AH	B	AH
$10 < t \leq 15$	D	DH	B	AH
$15 < t \leq 20$	D	DH	B	AH
$20 < t \leq 25$	D	DH	B	AH
$25 < t \leq 30$	E	EH, *see* Note 2	D	DH
$30 < t \leq 35$	E	EH	D	DH
$35 < t \leq 40$	E	EH	D	DH
$40 < t \leq 45$	E	EH	D	DH
$45 < t \leq 50$	E	EH	D	DH

NOTES
1. Includes weather exposed plating of hull structures and appendages, as well as their outboard framing members, situated above a level of 0,3 m below the lowest ice waterline.
2. Grades D, DH are allowed for a single strake of side shell plating not more than 1,8 m wide from 0,3 m below the lowest ice waterline.

10.17.6 Castings are to have specified properties consistent with the expected service temperature for the cast component.

10.18 Longitudinal strength – Application

10.18.1 Ice loads need only be combined with still water loads. The combined stresses are to be compared against permissible bending and shear stresses at different locations along the ship's length. In addition, sufficient local buckling strength is also to be verified.

Table 2.10.10 Steel grades for weather exposed plating

Thickness, t mm	Material Class III					
	PC1 to **3**		**PC4** and **5**		**PC6** and **7**	
	MS	HT	MS	HT	MS	HT
$t \leq 10$	E	EH	E	EH	B	AH
$10 < t \leq 15$	E	EH	E	EH	D	DH
$15 < t \leq 20$	E	EH	E	EH	D	DH
$20 < t \leq 25$	E	EH	E	EH	D	DH
$25 < t \leq 30$	E	EH	E	EH	E	EH
$30 < t \leq 35$	E	EH	E	EH	E	EH
$35 < t \leq 40$	F	FH	E	EH	E	EH
$40 < t \leq 45$	F	FH	E	EH	E	EH
$45 < t \leq 50$	F	FH	F	FH	E	EH

NOTE
Includes weather exposed plating of hull structures and appendages, as well as their outboard framing members, situated above a level of 0,3 m below the lowest ice waterline.

Table 2.10.11 Steel grades for inboard framing members attached to weather exposed plating

Thickness, t mm	**PC1** to **PC5**		**PC6** and **7**	
	MS	HT	MS	HT
$t \leq 20$	B	AH	B	AH
$20 < t \leq 35$	D	DH	B	AH
$35 < t \leq 45$	D	DH	D	DH
$45 < t \leq 50$	E	EH	D	DH

10.19 Design vertical ice force at the bow

10.19.1 The design vertical ice force at the bow, F_{IB}, is to be taken as the lesser of $F_{IB,1}$ or $F_{IB,2}$:

$$F_{IB,1} = 0{,}534 C_L K_I^{0,15} \sin^{0,2}(\gamma_s)\sqrt{DK_h} \quad \text{MN}$$

$$F_{IB,2} = 1{,}2 C_F \quad \text{MN}$$

where

K_I = indentation parameter

$= \dfrac{K_f}{K_h}$

K_f = for blunt bow forms:

$$K_f = \left(\frac{2C\,B^{(1-e_b)}}{1+e_b}\right)^{0,9} \tan(\gamma_s)^{-0,9(1+e_b)}$$

= for wedge bow forms (α_s < 80 deg), e_b = 1 and the above simplifies to:

$$K_f = \left(\frac{\tan(\alpha_s)}{\tan^2(\gamma_s)}\right)^{0,9}$$

α_s = waterline angle measured in way of the stem at the upper ice waterline (UIWL), in degrees, *see* Fig. 2.10.7

K_h = $0{,}01 A_{wp}$ MN/m

C_L = longitudinal strength class factor from Table 2.10.1

e_b = bow shape exponent which best describes the waterplane (*see* Figs. 2.10.7 and 2.10.8). An approximate e_b determined by a simple fit is acceptable

= 1,0 for a simple wedge bow form
= 0,4 to 0,6 for a spoon bow form
= 0 for a landing craft bow form

γ_s = stem angle to be measured between the horizontal axis and the stem tangent at the upper ice waterline, in degrees (buttock angle as per Fig. 2.10.2 measured on the centreline)

$$C = \frac{1}{2\left(\dfrac{L_B}{B}\right)^{eb}}$$

B = ship moulded breadth, in metres

L_B = bow length, in m, used in the equation:

$$y = \frac{B}{2\left(\dfrac{x}{L_B}\right)^{eb}} \quad \text{(\textit{see} Figs. 2.10.7 and 2.10.8)}$$

Δ = ship displacement, in kilo tonnes, not to be taken less than 10

A_{wp} = ship waterplane area, in m^2

C_F = flexural failure class factor from Table 2.10.1

Where applicable, draught dependent quantities are to be determined at the waterline corresponding to the loading condition under consideration.

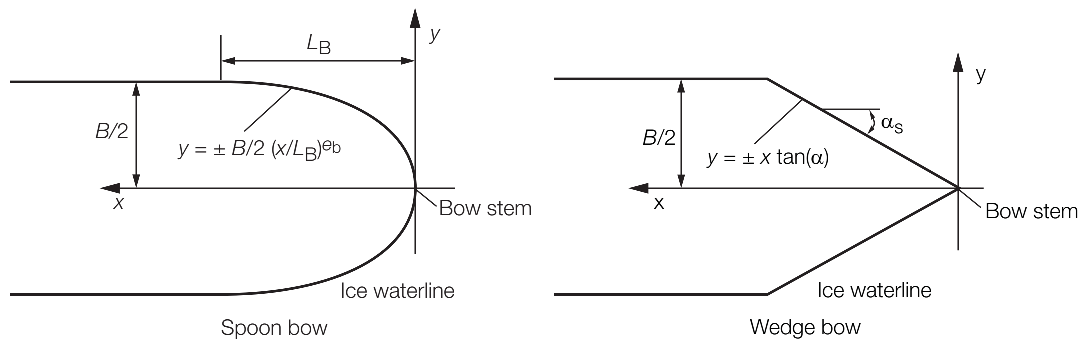


Fig. 2.10.7 Bow shape definition

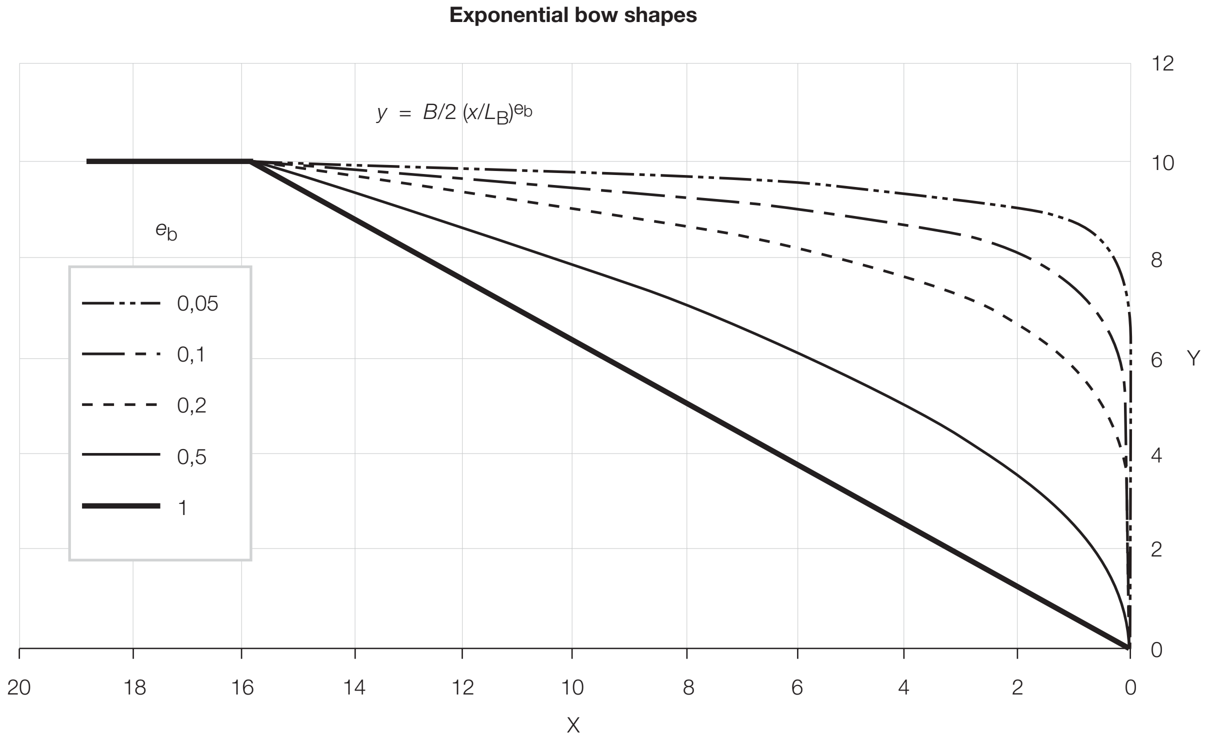


Fig. 2.10.8 Illustration of effect on the bow shape e_b, for B = 20 and L_B = 16

10.20 Design vertical shear force

10.20.1 The design vertical ice shear force, F_I, along the hull girder is to be taken as:

$F_I = C_f \, F_{IB}$ MN

where

C_f = longitudinal distribution factor to be taken as follows:

(a) Positive shear force

C_f = 0,0 between the aft end of L and 0,6L from aft

C_f = 1,0 between 0,9L from aft and the forward end of L

(b) Negative shear force

C_f = 0,0 at the aft end of L

C_f = –0,5 between 0,2L and 0,6L from aft

C_f = 0,0 between 0,8L from aft and the forward end of L

Intermediate values are to be determined by linear interpolation.

10.20.2 The applied vertical shear stress, τ_a, is to be determined along the hull girder in a similar manner as in Pt 3, Ch 4 by substituting the design vertical ice shear force for the design vertical wave shear force.

10.21 Design vertical ice bending moment

10.21.1 The design vertical ice bending moment, M_I, along the hull girder is to be taken as:

$M_I = 0{,}1 C_m \, L \sin^{-0,2}(\gamma_s) \, F_{IB}$ MNm

where

L = ship length, as defined in Pt 3, Ch 1,6.1.1, but measured on the upper ice waterline (UIWL), in metres

γ_{stem} = as given in 10.19.1

F_{IB} = design vertical ice force at the bow, in MN

C_m = longitudinal distribution factor for design vertical ice bending moment to be taken as follows:

C_m = 0,0 at the aft end of L

C_m = 1,0 between 0,5L and 0,7L from aft

C_m = 0,3 at 0,95L from aft

C_m = 0,0 at the forward end of L

Intermediate values are to be determined by linear interpolation.

Where applicable, draught dependent quantities are to be determined at the waterline corresponding to the loading condition under consideration.

10.21.2 The applied vertical bending stress, σ_a, is to be determined along the hull girder in a similar manner as in Pt 3, Ch 4, by substituting the design vertical ice bending moment for the design vertical wave bending moment. The ship still water bending moment is to be taken as the maximum sagging moment.

10.22 Longitudinal strength criteria

10.22.1 The strength criteria provided in Table 2.10.12 are to be satisfied. The design stress is not to exceed the permissible stress.

Table 2.10.12 Longitudinal strength criteria

Failure mode	Applied stress	Permissible stress $\frac{\sigma_y}{\sigma_u} \le 0{,}7$	Permissible stress $\frac{\sigma_y}{\sigma_u} > 0{,}7$
Tension	σ_a	$\eta \, \sigma_y$	$\eta \, 0{,}41(\sigma_u + \sigma_y)$
Shear	τ_a	$\frac{\eta \, \sigma_y}{\sqrt{3}}$	$\frac{\eta \, 0{,}41(\sigma_u + \sigma_y)}{\sqrt{3}}$
Buckling	σ_a	σ for plating and for web plating of stiffeners $\frac{\sigma_c}{1{,}1}$ for stiffeners	
	τ_a	τ_c	

Symbols

σ_a = applied vertical bending stress, in N/mm^2
τ_a = applied vertical shear stress, in N/mm^2
σ_y = minimum upper yield stress of the material, in N/mm^2
σ_u = ultimate tensile strength of material, in N/mm^2
σ_c = critical buckling stress in compression, according to Pt 3, Ch 4, in N/mm^2
τ_c = critical buckling stress in shear, according to Pt 3, Ch 4, in N/mm^2
η = 0,8

10.23 Stem and stern frames

10.23.1 The stem and stern frame are to be suitably designed. The stem and stern requirements of the *Finnish-Swedish Ice Class Rules* are to be additionally considered, *see* Section 1.

10.24 Appendages

10.24.1 All appendages are to be designed to withstand forces appropriate for the location of their attachment to the hull structure or their position within a hull area.

10.25 Local details

10.25.1 Local design details are to be suitably designed to transfer ice-induced loads to supporting structure (bending moments and shear forces).

10.25.2 The loads carried by a member in way of cut-outs are not to cause instability. Where necessary, the structure is to be stiffened.

10.26 Direct calculations

10.26.1 Direct calculations are not to be utilised as an alternative to the analytical procedures prescribed in this Section.

10.26.2 Where direct calculation is used to check the strength of structural systems, the load patch specified in 10.2 is to be applied.

10.27 Welding

10.27.1 All welding within ice-strengthened areas is to be of the double continuous type.

10.27.2 Continuity of strength is to be ensured at all structural connections.

Section 11 Machinery strengthening requirements for navigation in multi-year ice conditions – Ice Classes PC1, PC2, PC3, PC4, PC5, PC6 and PC7

11.1 Application

11.1.1 The contents of this Section apply to main propulsion, steering gear, emergency and essential auxiliary systems essential for the safety of the ship and the survivability of the crew and systems and equipment required by assigned optional classification notations, e.g. navigational equipment associated with the notations **NAV1** or **IBS**.

11.1.2 For **PC6** and **PC7**, the requirements will be considered with respect to compliance with the *Finnish-Swedish Ice Class Rules*.

11.2 Drawings and particulars to be submitted

11.2.1 The following drawings and particulars to be submitted:

(a) Details of the environmental conditions and the required ice class for the machinery, if different from ship's ice class.

(b) Detailed drawings of the main propulsion machinery. Description of the main propulsion, steering, emergency and essential auxiliaries are to include operational limitations. Information on essential main propulsion load control functions.

(c) Description detailing how main, emergency and auxiliary systems are located and protected to prevent problems from freezing, ice and snow and evidence of their capability to operate in intended environmental conditions.

(d) Calculations and documentation indicating compliance with the requirements of this Section.

11.3 System design

11.3.1 Systems, subject to damage by freezing, are to be drainable.

11.3.2 Single screw vessels classed PC1 to PC5 inclusive are to have means provided to ensure sufficient vessel operation in the case of propeller damage including CP mechanism.

11.4 Materials exposed to sea-water

11.4.1 Materials exposed to sea-water, such as propeller blades, propeller hub and blade bolts are to have an elongation not less than 15 per cent on a test piece the length of which is five times the diameter. Charpy V impact test are to be carried out for other than bronze and austenitic steel materials. Test pieces taken from the propeller castings are to be representative of the thickest section of the blade. An average impact energy value of 20 J taken from three Charpy V tests is to be obtained at minus 10°C.

11.5 Materials exposed to sea-water temperature

11.5.1 Materials exposed to sea-water temperature are to be of steel or other approved ductile material. An average impact energy value of 20 J taken from three tests is to be obtained at minus 10°C.

11.6 Materials exposed to low air temperature

11.6.1 Materials of essential components exposed to low air temperature shall be of steel or other approved ductile material. An average impact energy value of 20 J taken from three Charpy V tests is to be obtained at 10°C below the lowest design temperature. *See also The Provisional Rules for the Winterisation of Ships*.

11.7 Propeller ice interaction

11.7.1 These Rules cover open and ducted type propellers situated at the stern of a vessel having controllable pitch or fixed pitch blades. Ice loads on bow propellers and pulling type propellers are to receive special consideration. The given loads are expected, single occurrence, maximum values for the whole ship's service life for normal operational conditions. These loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice. These Rules apply also for azimuthing (geared and podded) thrusters considering loads due to propeller ice interaction. However, ice loads due to ice impacts on the body of azimuthing thrusters are not covered by this Section.

11.7.2 The loads given in 11.7 are total loads (unless otherwise stated) during ice interaction and are to be applied separately (unless otherwise stated) and are intended for component strength calculations only. The different loads given here are to be applied separately.

11.7.3 F_b is a force bending a propeller blade backwards when the propeller mills an ice block while rotating ahead. F_f is a force bending a propeller blade forwards when a propeller interacts with an ice block while rotating ahead.

11.8 Ice class factors

11.8.1 Table 2.11.1 lists the design ice thickness and ice strength index to be used for estimation of the propeller ice loads.

Table 2.11.1 Propeller ice loads index

Ice Class	H_{ice}, in metres	S_{ice}	S_{qice}
PC1	4,0	1,2	1,15
PC2	3,5	1,1	1,15
PC3	3,0	1,1	1,15
PC4	2,5	1,1	1,15
PC5	2,0	1,1	1,15
PC6	1,75	1,0	1,00
PC7	1,5	1,0	1,00
where H_{ice} = ice thickness for machinery strength design S_{ice} = ice strength index for blade ice force S_{qice} = ice strength index for blade ice torque			

11.9 Design ice loads for open propeller

11.9.1 The maximum backward blade force, F_b, is to be taken as:
when
$D < D_{limit}$

$$F_b = -27 S_{ice} (nD)^{0,7} \left(\frac{EAR}{Z}\right)^{0,3} D^2 \quad \text{kN}$$

when
$D \geq D_{limit}$

$$F_b = -23 S_{ice} (nD)^{0,7} \left(\frac{EAR}{Z}\right)^{0,3} (H_{ice})^{1,4} D \quad \text{kN}$$

where
D_{limit} = $0,85(H_{ice})^{1,4}$
n = the nominal rotational speed in rev/sec (at MCR free running condition) for CP-propeller and 85 per cent of the nominal rotational speed (at MCR free running condition) for a FP-propeller (regardless of driving engine type).

11.9.2 F_b is to be applied as a uniform pressure distribution to an area on the back (suction) side of the blade for the following load cases:
(a) Load case 1: from 0,6R to the tip and from the blade leading edge to a value of 0,2 chord length
(b) Load case 2: a load equal to 50 per cent of the F_b is to be applied on the propeller tip area outside of 0,9R
(c) Load case 5: for reversible propellers, a load equal to 60 per cent of the F_b is to be applied from 0,6R to the tip and from the blade trailing edge to a value of 0,2 chord length.
See load cases 1, 2, and 5 in Table 2.11.4.

11.9.3 The maximum forward blade force, F_f, is to be taken as:
when
$D < D_{limit}$

$$F_f = 250 \left(\frac{EAR}{Z}\right) D^2 \quad \text{kN}$$

when
$D \geq D_{limit}$

$$F_f = 500 \left(\frac{1}{1 - \frac{d}{D}}\right) H_{ice} \left(\frac{EAR}{Z}\right) D \quad \text{kN}$$

where

$$D_{limit} = \left(\frac{2}{1 - \frac{d}{D}}\right) H_{ice} \quad \text{m}$$

d = propeller hub diameter, in metres
D = propeller diameter, in metres
EAR = expanded blade area ratio
Z = number of propeller blades.

11.9.4 F_f is to be applied as a uniform pressure distribution to an area on the face (pressure) side of the blade for the following loads cases:
(a) Load case 3: from 0,6R to the tip and from the blade leading edge to a value of 0,2 chord length.
(b) Load case 4: a load equal to 50 per cent of F_f is to be applied on the propeller tip area outside of 0,9R.
(c) Load case 5: for reversible propellers a load equal to 60 per cent of F_f is to be applied from 0,6R to the tip and from the blade trailing edge to a value of 0,2 chord length.
See load cases 3, 4 and 5 in Table 2.11.4.

11.9.5 The blade spindle torque, Q_{smax}, around the spindle axis of the blade fitting is to be calculated both for the load cases described in 11.9.1 and 11.9.3 for F_h and F_f. If these spindle torque values are less than the default value given below, the default minimum value is to be used:

$$Q_{smax} = 0,25 F C_{0,7} \quad \text{kNm}$$

where
$C_{0,7}$ = length of the blade chord at 0,7R radius, in m
F = F_h or F_f whichever has the greater absolute value.

11.9.6 The maximum propeller ice torque applied to the propeller is to be taken as:

when $D < D_{limit}$

$$Q_{max} = 105\left(1 - \frac{d}{D}\right) S_{qice}\left(\frac{P_{0,7}}{D}\right)^{0,16}\left(\frac{t_{0,7}}{D}\right)^{0,6}(nD)^{0,17} D^3 \quad \text{kNm}$$

when $D \geq D_{limit}$

$$Q_{max} = 202\left(1 - \frac{d}{D}\right) S_{qice} H_{ice}^{1,1}\left(\frac{P_{0,7}}{D}\right)^{0,16}\left(\frac{t_{0,7}}{D}\right)^{0,6}(nD)^{0,17} D^{1,9} \quad \text{kNm}$$

where

D_{limit} = $1,81H_{ice}$

S_{qice} = ice strength index for blade ice torque

$P_{0,7}$ = propeller pitch at 0,7*R*, in m

= for CP propellers, $P_{0,7}$ is to correspond to MCR in bollard condition. If not known, $P_{0,7}$ is to be taken as $0,7P_{0,7n}$

$P_{0,7n}$ = propeller pitch at MCR free running condition

$t_{0,7}$ = maximum thickness at 0,7*R*

n = the rotational propeller speed in rev/sec , at bollard condition. If not known, n is to be taken as follows:
for CP propellers and FP propellers driven by turbine or electric motor = n_n
for FP propellers driven by diesel engine = $0,85n_n$

n_n = the nominal rotational speed at MCR, free running condition.

11.9.7 The maximum propeller ice thrust applied to the shaft is to be taken as:

T_f = $1,1F_f$

T_b = $1,1F_b$.

11.10 Design ice loads for ducted propellers

11.10.1 The maximum backward blade force, F_b is to be taken as:

when $D < D_{limit}$

$$F_b = -9,5\, S_{ice}\left(\frac{EAR}{Z}\right)^{0,3}(nD)^{0,7} D^2$$

when $D \geq D_{limit}$

$$F_b = -66\, S_{ice}\left(\frac{EAR}{Z}\right)^{0,3}(nD)^{0,7} D^{0,6}(H_{ice})^{1,4}$$

where

D_{limit} = $4\, H_{ice}$

n = as in 11.9.1.

11.10.2 F_b is to be applied as a uniform pressure distribution to an area on the back side for the following load cases:

(a) Load case 1: on the back of the blade from 0,6*R* to the tip and from the blade leading edge to a value of 0,2 chord length

(b) Load case 5: for reversible rotation propellers a load equal to 60 per cent of F_b is applied on the blade face from 0,6*R* to the tip and from the blade trailing edge to a value of 0,2 chord length.

See load cases 1 and 5 in Table 2.11.5.

11.10.3 The maximum forward blade force, F_f, is to be taken as:

when

$D \leq D_{limit}$

$$F_f = 250\left(\frac{EAR}{Z}\right) D^2 \quad \text{kN}$$

when

$D > D_{limit}$

$$F_f = 500\left(\frac{EAR}{Z}\right) D\left(\frac{1}{1 - \frac{d}{D}}\right) H_{ice} \quad \text{kN}$$

where

$$D_{limit} = \left(\frac{2}{1 - \frac{d}{D}}\right) H_{ice} \quad \text{m}$$

11.10.4 F_f is to be applied as a uniform pressure distribution to an area on the face (pressure) side for the following load cases:

(a) Load case 3: on the blade face from 0,6*R* to the tip and from the blade leading edge to a value of 0,5 chord length.

(b) Load case 5: a load equal to 60 per cent F_f is to be applied from 0,6*R* to the tip and from the blade leading edge to a value of 0,2 chord length.

See load cases 3 and 5 in Table 2.11.5.

11.10.5 The maximum propeller ice torque, Q_{max}, applied to the propeller is to be taken as:

when $D \leq D_{limit}$

$$Q_{max} = 74\left(1 - \frac{d}{D}\right)\left(\frac{P_{0,7}}{D}\right)^{0,16}\left(\frac{t_{0,7}}{D}\right)^{0,6}(nD)^{0,17} S_{qice} D^3 \quad \text{kNm}$$

when $D > D_{limit}$

$$Q_{max} = 141\left(1 - \frac{d}{D}\right)\left(\frac{P_{0,7}}{D}\right)^{0,16}\left(\frac{t_{0,7}}{D}\right)^{0,6}(nD)^{0,17} S_{qice} D^{1,9} H_{ice}^{1,1} \quad \text{kNm}$$

where

D_{limit} = $1,8H_{ice}$ in metres

n = the rotational propeller speed, in rps, at bollard condition. If not known, n is to be taken as follows:
for CP propellers and FP propellers driven by turbine or electric motor = n_n
for FP propellers driven by diesel engine = $0,85n_n$

n_n = the nominal rotational speed at MCR at free running condition

$P_{0,7}$ = for CP propellers, propeller pitch, $P_{0,7}$ is to correspond to MCR in bollard condition. If not known, $P_{0,7}$ is to be taken as $0,7P_{0,7n}$

$P_{0,7n}$ = propeller pitch at MCR free running condition.

11.10.6 The spindle torque for CP-mechanism design, Q_{smax}, around the spindle axis of the blade fitting is to be calculated for the load case described in 11.7. If these spindle torque values are less than the default value given below, the default value is to be used:

$$Q_{smax} = 0,25F\, c_{0,7} \quad \text{kNm}$$

where

$C_{0,7}$ = the length of the blade section at 0,7*R*

F = F_b or F_f whichever has the greater absolute value.

11.10.7 The maximum propeller ice thrust (applied to the shaft at the location of the propeller) is to be taken as:

T_f = $1,1F_f$
T_b = $1,1F_b$.

11.11 Design loads on propulsion line – Torque

11.11.1 The propeller ice torque excitation for shaft line dynamic analysis is to be described by a sequence of blade impacts which are of half sine shape and occur at the blade. The torque due to a single blade ice impact as a function of the propeller rotation angle is to be taken as:

when

$\varphi = 0...\alpha_i$

$$Q(\varphi) = C_q\, Q_{max} \sin\left(\varphi \left(\frac{180}{\alpha_i}\right)\right)$$

when

$\varphi = \alpha_i...360$
$Q(\varphi) = 0$

where

C_q = as given in Table 2.11.2
α_i = as given in Table 2.11.2.

11.11.2 The total ice torque is obtained by summing the torque of single blades taking into account the phase shift 360°/Z. The number of propeller revolutions during a milling sequence is to be obtained with the formula:

$N_Q = 2H_{ice}$

where

number of impacts = $Z\, N_Q$ *see* Fig. 2.11.1.

Table 2.11.2 Torque load factors

Torque excitation	Propeller-ice interaction	C_q	α_i.
Case 1	Single ice block	0,50	45
Case 2	Single ice block	0,75	90
Case 3	Single ice block	1,00	135
Case 4	Two ice blocks with 45 degree phase in rotation angle	0,50	45

11.11.3 The milling torque sequence duration is not valid for pulling bow propellers, which are subject to special consideration. The response torque at any shaft component is to be analysed considering excitation torque $Q(\varphi)$ at the propeller, actual engine torque, Q_e, and mass elastic system. Where Q_e is the actual maximum engine torque at considered speed.

11.11.4 The design torque, Q_r, of the shaft component is to be determined by means of torsional vibration analysis of the propulsion line. Calculations are to be carried out for all excitation cases given above and the response is to be applied on top of the mean hydrodynamic torque in bollard condition at considered propeller rotational speed.

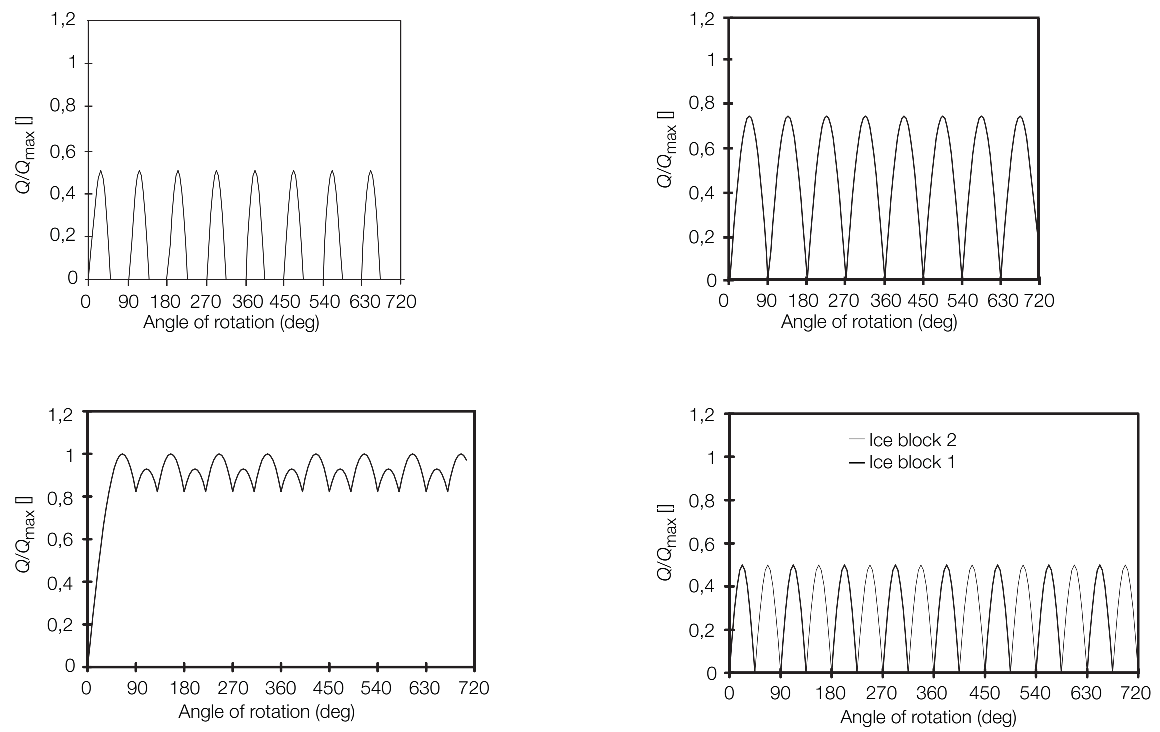


Fig. 2.11.1
The shape of the propeller ice torque excitation for 45, 90, 135 degrees single blade impact sequences and 45 degrees double blade impact sequence (two ice pieces) on a four bladed propeller

11.12 Design loads on propulsion line – Maximum response thrust

11.12.1 The maximum thrust along the propeller shaft line is to be calculated with the formulae below. The factors 2,2 and 1,5 take into account the dynamic magnification due to axial vibration. Alternatively, the propeller thrust magnification factor may be calculated by dynamic analysis

Maximum shaft thrust forwards

$T_r = T_n + 2,2T_f$ kN

Maximum shaft thrust backwards

$T_r = 1,5T_b$ kN

where

T_n = hydrodynamic propeller bollard thrust, in kN. If not known, T_n is to be as given in Table 2.11.3

T_f = maximum forward propeller ice thrust, in kN.

Table 2.11.3 Propeller thrust factor

Propeller type	T_n
CP propellers (open)	1,25T
CP propellers (ducted)	1,10T
FP propellers driven by turbine or electric motor	T
FP propellers driven by diesel engine (open)	0,85T
FP propellers driven by diesel engine (ducted)	0,75T
Symbols	
T = nominal propeller thrust at MCR at free running open water conditions	

Table 2.11.4 Load cases for open propeller

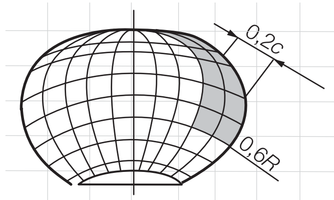
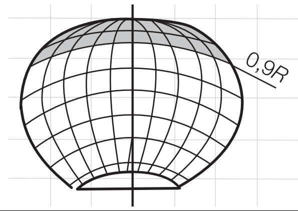
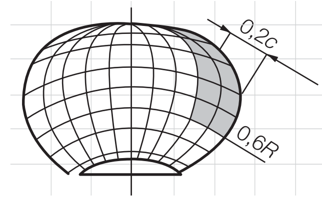
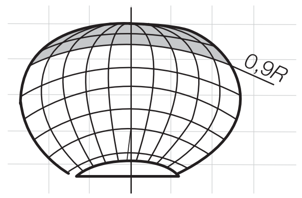
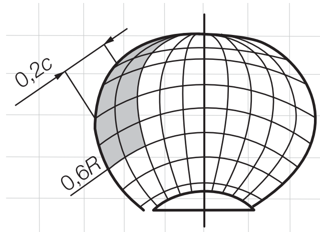
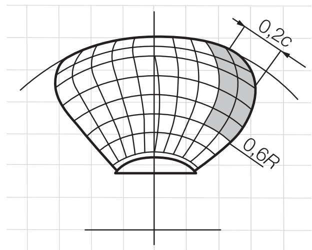
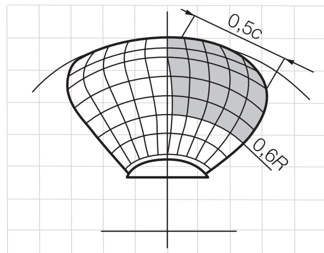
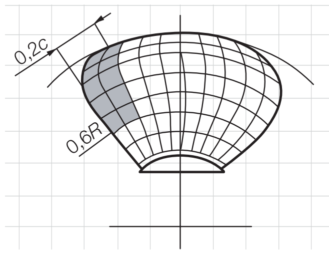
Load case	Force	Loaded area	Right handed propeller blade seen from back
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0,6*R* to the tip and from the leading edge to 0,2 times the chord length.	
Load case 2	50% of F_b	Uniform pressure applied on the back of the blade (suction side) on the propeller tip area outside of 0,9*R* radius.	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0,6*R* to the tip and from the leading edge to 0,2 times the chord length.	
Load case 4	50% of F_f	Uniform pressure applied on propeller face (pressure side) on the propeller tip area outside of 0,9*R* radius.	
Load case 5	60% of F_f or F_b whichever is the greater	Uniform pressure applied on propeller face (pressure side) to an area from 0,6*R* to the tip and from the trailing edge to 0,2 times the chord length.	

Table 2.11.5 Load cases for ducted propeller

Load case	Force	Loaded area	Right handed propeller blade seen from back
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0,6*R* to the tip and from the leading edge to 0,2 times the chord length	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0,6*R* to the tip and from the leading edge to 0,5 times the chord length	
Load case 5	60% of F_f or F_b	Uniform pressure applied on propeller face (pressure side) to an area from 0,6*R* to the tip and from the trailing edge to 0,2 times the chord length	

11.13 Design loads on propulsion line – Blade failure load for both open and nozzle propellers

11.13.1 The force is acting at 0,8*R* in the weakest direction of the blade and at a spindle arm of 2/3 of the distance of axis of blade rotation of leading and trailing edge whichever is the greatest. The blade failure load is to be taken as:

$$F_{ex} = \frac{0{,}3c\, t^2\, \sigma_{ref}}{0{,}8D - 2r} \times 10^3 \quad \text{kN}$$

where

σ_{ref} = $0{,}6\sigma_{0,2} + 0{,}4\sigma_u$

$\sigma_{0,2}$ and σ_u = representative values for the blade material

c, *t* and r = the actual chord length, thickness and radius of the cylindrical root section of the blade at the weakest section outside root fillet and typically will be at the termination of the fillet into the blade profile.

11.14 Design – Design principle

11.14.1 The strength of the propulsion line is to be designed:

(a) for maximum loads in 11.7;
(b) such that the plastic bending of a propeller blade will not cause damage in other propulsion line components;
(c) with sufficient fatigue strength.

11.15 Design – Azimuthing main propulsors

11.15.1 In addition to the above requirements, special consideration will be given to the loading cases which are extraordinary for propulsion units when compared with conventional propellers. Estimation of the loading cases must reflect the operational realities of the ship and the thrusters. In this respect, for example, the loads caused by impacts of ice blocks on the propeller hub of a pulling propeller are to be considered. Also, loads due to thrusters operating in an oblique angle to the flow are to be considered. The steering mechanism, the fitting of the unit and the body of the thruster is to be designed to withstand the loss of a blade without damage. The plastic bending of a blade is to be considered in the propeller blade position, which causes the maximum load on the studied component.

11.15.2 Azimuth thrusters are also to be designed for estimated loads due to thruster body/ice interaction as in 10.24.

11.16 Blade design – Maximum blade stresses

11.16.1 Blade stresses are to be calculated using the backward and forward loads given in 11.9 and 11.10. The stresses are to be calculated with recognised and well documented FE-analysis or another acceptable alternative method. The stresses on the blade are not to exceed the allowable stresses, σ_{all}, for the blade material given below. The calculated blade stress for the maximum ice load is to comply with the following:

$$\sigma_{calc} < \sigma_{all} = \frac{\sigma_{ref}}{S}$$

where

S = 1,5

σ_{ref} = reference stress, defined as:
$0,7\sigma_u$
$0,6\ \sigma_{0,2} + 0,4\sigma_u$ whichever is less

σ_u and $\sigma_{0,2}$ = representative values for the blade material.

11.17 Blade design – Blade edge thickness

11.17.1 The blade edge thicknesses, t_{ed}, and tip thickness t_{tip}, are to be greater than t_{edge} given by the following formula:

$$t_{edge} \geq x\ S\ S_{ice} \sqrt{\frac{3P_{ice}}{\sigma_{ref}}}$$

where

x = distance from the blade edge measured along the cylindrical sections from the edge and is to be 2,5 per cent of chord length, however not to be taken greater than 45 mm.
In the tip area (above 0,975R radius) x is to be taken as 2,5 per cent of 0,975R section length and is to be measured perpendicularly to the edge, however not to be taken greater than 45 mm.

S = safety factor
= 2,5 for trailing edges
= 3,5 for leading edges
= 5,0 for tip

S_{ice} = as given in 11.8

p_{ice} = ice pressure
= 16 MPa for leading edge and tip thickness

σ_{ref} = as given in 11.16.

11.17.2 The requirement for edge thickness is to be applied for leading edge and in case of reversible rotation open propellers also for the trailing edge. Tip thickness refers to the maximum measured thickness in the tip area above 0,975R radius. The edge thickness in the area between the position of maximum tip thickness and edge thickness at 0,975 radius has to be interpolated between edge and tip thickness value and smoothly distributed.

11.18 Prime movers

11.18.1 The main engine is to be capable of being started and running the propeller with the CP in full pitch.

11.18.2 Provisions are to be made for heating arrangements to ensure ready starting of the cold emergency power units at an ambient temperature applicable to the Polar class of the ship.

11.18.3 Emergency power units are to be equipped with starting devices with a stored energy capability of at least three consecutive starts at the design temperature in 11.18.2. The source of stored energy is to be protected to preclude critical depletion by the automatic starting system, unless a second independent means of starting is provided. A second source of energy is to be provided for an additional three starts within 30 min., unless manual starting can be demonstrated to be effective.

11.19 Machinery fastening loading accelerations

11.19.1 Essential equipment and main propulsion machinery supports are to be suitable for the accelerations as indicated in the following. Accelerations are to be considered acting independently.

11.19.2 The maximum longitudinal impact acceleration, a_l, at any point along the hull girder is to be taken as:

$$a_l = \left(\frac{F_{IB}}{\Delta}\right)\left\{[1,1\ \tan(\gamma + \phi)] + \frac{7H}{L}\right\} \quad \text{m/s}^2$$

where

F_{IB} = vertical impact force, defined in 10.19

H = distance from the waterline to the point being considered, in metres

L = length between perpendiculars, in metres

ϕ = maximum friction angle between steel and ice, normally taken as 10, in degrees

γ = bow stem angle at waterline, in degrees

Δ = Displacement.

11.19.3 The combined vertical impact acceleration, a_v, at any point along the hull girder, is to be taken as:

$$a_v = 2,5\left(\frac{F_{IB}}{\Delta}\right)F_x \quad \text{m/s}^2$$

where

F_X = 1,3 at the FP
= 0,2 at midships
= 0,4 at the AP
= 1,3 at the AP for vessels conducting icebreaking astern
= intermediate values are to be determined by linear interpolation.

11.19.4 The combined transverse impact acceleration, a_t, at any point along hull girder, is to be taken as:

$$a_t = 3F_i\left(\frac{F_x}{\Delta}\right) \quad \text{m/s}^2$$

where

F_X = 1,5 at the FP
= 0,25 at midships
= 0,5 at the AP
= 1,5 at the AP for vessels conducting icebreaking astern
= intermediate values are to be determined by linear interpolation

F_i = total force normal to shell plating in the bow area due to oblique ice impact, defined in 10.19.

11.20 Auxiliary systems

11.20.1 Machinery is to be protected from the harmful effects of ingestion or accumulation of ice or snow. Where continuous operation is necessary, means are to be provided to purge the system of accumulated ice or snow.

11.20.2 Means are to be provided to prevent damage due to freezing, to tanks containing liquids.

11.20.3 Vent pipes, intake and discharge pipes and associated systems are to be designed to prevent blockage due to freezing or ice and snow accumulation.

11.21 Sea inlets and cooling water systems

11.21.1 Cooling water systems for machinery that are essential for the propulsion and safety of the vessel, including sea chest inlets, are to be designed for the environmental conditions applicable to the ice class.

11.21.2 At least two sea chests are to be arranged as ice boxes for classes **PC1** to **PC5** inclusive. The calculated volume for each of the ice boxes is to be at least 1 m^3 for every 750 kW of the total installed power. For **PC6** and **PC7**, there is to be at least one ice box located preferably near centreline.

11.21.3 Ice boxes are to be designed for an effective separation of ice and venting of air.

11.21.4 Sea inlet valves are to be secured directly to the ice boxes. The valves are to be a full bore type.

11.21.5 Ice boxes and sea bays are to have vent pipes and are to have shut off valves connected directly to the shell.

11.21.6 Means are to be provided to prevent freezing of sea bays, ice boxes, ship side valves and fittings above the load waterline.

11.21.7 Efficient means are to be provided to re-circulate cooling seawater to the ice box. The total sectional area of the circulating pipes is not to be less than the area of the cooling water discharge pipe.

11.21.8 Detachable gratings or manholes are to be provided for ice boxes. Manholes are to be located above the deepest load line. Access is to be provided to the ice box from above.

11.21.9 Openings in ship sides for ice boxes are to be fitted with gratings, or holes or slots in shell plates. The net area through these openings is to be not less than 5 times the area of the inlet pipe. The diameter of holes and width of slot in shell plating is to be not less than 20 mm. Gratings of the ice boxes are to be provided with a means of clearing. Clearing pipes are to be provided with screw-down type non-return valves.

11.22 Ballast tanks

11.22.1 Efficient means are to be provided to prevent freezing in fore and after peak tanks and wing tanks located above the waterline and where otherwise found necessary. *See* 2.1.3 and *The Provisional Rules for the Winterisation of Ships*, 3.2.1.

11.23 Ventilation system

11.23.1 The air intakes for machinery and accommodation ventilation are to be located on both sides of the ship.

11.23.2 Accommodation and ventilation air intakes are to be provided with means of heating.

11.23.3 The temperature of the inlet air provided to machinery from the air intakes is to be suitable for the safe operation of the machinery.

11.24 Alternative design

11.24.1 As an alternative a comprehensive design study may be submitted and may be requested to be validated by an agreed test programme.

■ *Section 12*
Requirements for Icebreaker(+)

12.1 Scope

12.1.1 Where the notation **Icebreaker(+)** is assigned, the arrangement, powering and dimensions of the hull structure and propulsion machinery are to be determined based on the operational profile that corresponds to that which the icebreaker is envisaged to undertake.

12.1.2 The assignment of the notation **Icebreaker(+)** is in addition to the requirements of Section 10 and Section 11 and is assigned in addition to the ice class notations given in Table 2.1.1. *See* 1.5.

12.2 Operational profile

12.2.1 The operational profile to be used for the basis of assignment of the notation **Icebreaker(+)** is to be derived from the icebreaker's function, as selected from 12.4.

12.2.2 The operational profile is only used to select a design basis. It is the responsibility of the Owner and/or Builder to determine the appropriate operational profile of the icebreaker.

12.3 Information to be submitted

12.3.1 For assignment of the notation **Icebreaker(+)**, the operational envelope criteria are to be submitted, which may include the following information, where applicable:

(a) the level icebreaking capability, in terms of speed and ice thickness;
(b) the turning capability in level ice, in terms of diameter and ice thickness; and
(c) the ramming capability, in terms of speed and ice condition.

12.3.2 In addition to the information submitted in 12.3.1, a scenario document, which is design specific, is required to document the operational profile and is to include details of the scenarios selected for deriving and applying ice loads.

12.3.3 The scenario document is to address the requirements in Sections 10 and 11 and provide justification for deviation from those requirements.

12.3.4 The following is to be contained within the submitted scenario document:

(a) icebreaker function;
(b) details of ice conditions assumed;
(c) operational scenarios for hull and propulsion machinery;
(d) identification of critical hull and propulsion machinery scenarios;
(e) description of propulsion machinery and/or hull loading areas with reasons for selection;
(f) proposed strengthening standards for each load area;
(g) arrangement of propulsion devices;
(h) derived load data-based full scale measurement or other predictive means; and
(j) details of, and justification for, deviation from the Rules.

12.3.5 In addition to the information submitted in 12.3.4, an ice pressure plan that indicates the design ice pressures used for the determination of the hull structure is to be submitted.

12.3.6 The operational envelope criteria is to be placed on board the ship.

12.4 Typical operational profiles

12.4.1 Typical operational profiles may be derived from the icebreaker function. Primary icebreaker functions are described in Table 2.12.1. These functions are to form the basis of operational scenarios as required in 12.3.4. Where an alternative function is selected a description of the icebreaker's operational functions is to be included in the scenario document.

12.5 General arrangement

12.5.1 Consideration is to be given to the protection of fuel tanks and other tanks with harmful substances, both in terms of thermal insulation and ice impact protection. A double bottom and double side tanks are to be fitted as specified in Pt 4, Ch 9,1.2.17. However, double side tanks may not be required for small icebreakers (typically less than 60 m), nor complete double bottom height in way of complex hullform arrangements in the fore and aft ends or heeling tanks.

12.5.2 Consideration is to be given to minimise transom sterns, as these hinder the icebreaker's ability to back in ice, and in particular the navigation of ice ridges. A transom stern should not normally extend below the Upper Ice Waterline. Where this cannot be avoided, the transom should be kept as narrow as possible and the scantlings of plating and stiffeners are to be as required for the stern section.

12.5.3 The requirements are based on an effective icebreaker bow form. Icebreaking angles vary depending on the icebreaking form; however, in general, the bow stem angle is not to be greater than 45°, and the bow waterline angle not greater than 40°, *see* Fig. 2.12.1. Where flare of the side shell amidships is proposed, it is recommended that the slope of the side be at least 8°.

Table 2.12.1 Primary icebreaker functions

Primary function	General description	Assumed criticality of operation
Escort	Engaged in icebreaker fleet operations in ice,patrol and search/rescue missions Breaking channel for supporting other ships, close manoeuvring, freeing of beset vessels and, where appropriate, towing vessels	May attempt to follow easiest course when operating alone. Search and rescue operations are undertaken within the bounds of safe operation to the icebreaker and escorted ship
Research	Engaged in independent operations in ice, including deployment of scientists and research equipment Breaking of channels to reach scientific/research bases and escort of ships for re-supply purposes	May re-route or re-schedule to avoid perceived difficult ice conditions
Support	Engaged in independent or icebreaker fleet operations in ice, supply/transit runs to support offshore installations Ice management activities which may include breaking of ice floes and engagement in ice defence of offshore operations/installations	May actively break large/strong ice features to defend the installation

12.5.4 Ice arresters (ice skeg) are recommended for all icebreakers to prevent riding up of the bow and submergence of the aftermost deck edge.

12.5.5 For icebreakers provided with a heel inducing system, it is recommended that the depth of the icebreaker be such that immersion of the deck edge does not occur when the ship, whilst floating at the Upper Ice Waterline, is heeled to an angle of 5° greater than the nominal capacity of the system or 15°, whichever is the greater.

12.5.6 For icebreakers intended to navigate continuously in thick multi-year ice, i.e., PC1, PC2 and PC3, and in relation to the icebreaker function, consideration should be given to the mass of the icebreaker to enable effective ice breaking.

12.5.7 For icebreakers installed with podded propulsion or azimuth thrusters, *see* the *Provisional Rules for Stern First Ice Class Ships*.

12.6 Hull strength

12.6.1 An ice pressure plan is to be submitted as required in 12.3.5. The ice pressure is to consider the adjustment of area factors for additional ice interaction scenarios as well as the crushing failure class factors due to the increased impact speed as well as application with due cognisance of low displacements.

12.6.2 The area factors associated with the ice pressure plan in 12.6.1 are, as a minimum, to comply with the hull area factors given in Table 2.10.3 for the ice class assigned.

12.7 Propulsion and machinery arrangements

12.7.1 Icebreakers are to be equipped with means of propulsion that meet the operational envelope criteria. Demonstration of suitable propulsion power for the operational envelope criteria as specified in 12.3.1, as appropriate, may be from any of the following or other appropriate methods:
(a) theoretical formulation, as given in 12.7.2 and 12.7.3;
(b) technical investigations based on engineering principles;
(c) service experience at the operating ice conditions; and
(d) ice model tests.
Consideration should be given to the applicable speed in relation to the ice thickness, as provided in 12.3.1, and the operational profile.

12.7.2 The propulsion power, at 2 knots, for icebreakers may be expressed as follows, where the ice thickness and icebreaker breadth form the dominant role:

$$P = 1000B^{0,7}\, h^{\left(1{,}4-\frac{2h}{B}\right)} \text{ kW}$$

where
B = breadth of icebreaker, as defined in Pt 3, Ch 1,6.1, in metres
h = nominal level ice thickness, in metres.

12.7.3 The propulsion power, at 2 knots, for icebreakers may be expressed as follows, where 12.7.2 is modified to account for the hullform:

$$P = 96\left(\frac{\theta_{stem}}{\arctan\left(\frac{h}{B}\right)} + \frac{\alpha_{waterline}}{\arctan\left(\frac{B}{L}\right)}\right) B^{0,7}\, h^{\left(1{,}4-\frac{2h}{B}\right)} \text{ kW}$$

where
L = length of icebreaker, as defined in Pt 3, Ch 1,6.1, in metres
B = breadth of icebreaker, as defined in Pt 3, Ch 1,6.1, in metres
h = nominal level ice thickness, in metres
θ_{stem} = stem angle, *see* Fig. 2.12.1
$\alpha_{waterline}$ = waterline angle, *see* Fig. 2.12.1.

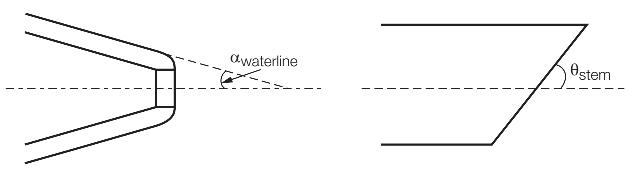


Fig. 2.12.1 Icebreaker stem angles

12.7.4 The formulae given in 12.7.2 and 12.7.3 are based on the broad fleet of icebreaker designs ($60 \le L \le 140$m and $15 \le B \le 28$) and level ice thicknesses ($0{,}5 \le h \le 2$m). Adjustments may therefore be required to account for specific propulsion arrangements, alternative speed criteria, size-mass effects, other L/B ratios and ice conditions.

12.7.5 The propulsion power condition is to be considered, whereby 100 per cent of the rated ahead speed is available for a minimum of 30 minutes. A minimum astern power condition is to be considered, whereby 70 per cent of the rated astern speed is available for a minimum of 30 minutes.

12.7.6 Consideration should be given to machinery protection against over-speeding, excess torque, overloading and overheating.

12.7.7 Propulsion system redundancy is to be considered. Where a machinery redundancy (**PMR**, **SMR** or **PSMR**) notation is to be assigned in addition to an **Icebreaker(+)** notation, the requirements of Pt 5, Ch 22 are to be complied with.

12.7.8 Icebreakers are prone to additional noise and vibration. Conditions when icebreaking are to be considered when applying the rules, see Pt 5, Ch 1,4.3 and Pt 7, Ch 13.

12.8 Rudder and steering arrangements

12.8.1 Rudder posts, rudder horns, solepieces, rudder stocks and pintles are to be dimensioned in accordance with Part 3, Chapters 6 and 13 as appropriate. The speed used in the calculations is to be the maximum service speed or that given in Table 2.12.2, whichever is the greater.

Table 2.12.2 Minimum speeds

Ice thickness, m	Ship speed, kn
1	25
1,5	27
2	29
3	31

12.8.2 In the case of twin rudders operated by a single steering gear, provision is to be made for each rudder to be readily disconnected and secured.

12.8.3 Rudders should be located inboard, clear of the aft end, and as low as practicable to reduce the impact of ice.

12.9 Towing

12.9.1 For escort icebreakers, arrangements for towing are to be provided, including a notch shape in the stern and provision of two chock pipes and two bitts. Consideration should be given for stern plating and framing to be strengthened to withstand impact loads for escorted ship collisions, as well as the propulsion and steering gear layout and protection from contact with bulbous bows. *See* Pt 4, Ch 3, Section 7.

12.10 Winterisation

12.10.1 Where a winterisation notation is assigned in compliance with the *Provisional Rules for the Winterisation of Ships*, the following features are to be additionally considered:
(a) bridge wings are to be fully enclosed;
(b) ice removal measures, through heating arrangements, are to be provided to access routes to towing equipment for escort icebreakers;
(c) provisions for evacuation onto ice;
(d) additional search lights for mooring, astern manoeuvring and towing operations;
(e) consideration of a red (flashing) navigation light to be used to indicate when an escort icebreaker is stopped;
(f) provisions to prevent water freezing in water and fluid systems, including research laboratories and services;
(g) consideration of ice accretion in damage condition; and
(h) protection from ice accretion by enclosed aft walkways for icebreakers with an exposed aft deck.

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Common Structural Rules for Bulk Carriers

July 2013

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Common Structural Rules for Bulk Carriers

Chapters 1 to 6

July 2013

Lloyd's Register

COMMON STRUCTURAL RULES FOR

BULK CARRIERS

Foreword

1. This version of the Rules is effective as of 1st July 2012.

2. This version incorporates rule changes made to the 1 July 2010 consolidated edition.

3. The Rules contain structural requirements for the Classification of Bulk Carriers of 90 m in length or greater.

4. The Rules contain thirteen chapters.

5. The following table provides a revision history of the Rules.

	Amendment Type / No.	Approval Date	Effective Date *	Reference Rule Edition
1	Corrigenda 1	15 May 2006	1 Apr. 2006	1 Jan 2006 edition
2	Corrigenda 2	29 Jan 2007	1 Apr. 2006	1 Jan 2006 edition
3	Corrigenda 3	19 July 2007	1 Apr. 2006	1 Jan 2006 edition
4	Corrigenda 4	3 Sept 2007	1 Apr. 2006	1 Jan 2006 edition
5	Rule Change Notice 1	30 Nov 2007	1 Apr. 2008	1 Jan 2006 edition
6	Rule Change Notice 2	25 Feb 2008	1 July 2008	1 Jan 2006 edition
7	Corrigenda 5	15 May 2008	1 April 2006	1 Jan 2006 edition

	Amendment Type / No.	Approval Date	Effective Date *	Reference Rule Edition
8	Rule Change Notice 3 (Urgent)	12 Sept 2008	12 Sept 2008	1 Jan 2006 edition
9	Rule Change Notice 1 (1 July 2008 consolidated edition)	30 Jan 2009	1 July 2009	1 July 2008 consolidated edition
10	Rule Change Notice 2 (1 July 2008 consolidated edition)	12 Apr 2010	1 July 2010	1 July 2008 consolidated edition
11	Rule Change Notice 1 (1 July 2010 consolidated edition)	30 Dec 2011	1 July 2012	1 July 2010 consolidated edition
12	Corrigenda 1 (1 July 2012 consolidated edition)	16 July 2012	1 July 2012	1 July 2012 consolidated edition
13	Corrigenda 2 (1 July 2012 consolidated edition)	21 Nov 2012	1 July 2012	1 July 2012 consolidated edition

* For effective date, refer to the implementation statements of relevant Corrigenda / Rule Changes.

Note: When the word '(void)' appears in the text, it means that the concerned part has been deleted. This is to keep the numbering of the remainder unchanged.

Table of Contents

Chapter 13 – Ships in Operation, Renewal Criteria

Chapter 1

General Principles

Section 1 - APPLICATION

1. General

1.1 Structural requirements

1.1.1

These Rules apply to ships classed with the Society and contracted for construction on or after 1 April 2006.

Note: The "contracted for construction" means the date on which the contract to build the ship is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contracted for construction", refer to IACS Procedural Requirement (PR) No.29.

1.1.2

These Rules apply to the hull structures of single side skin and double side skin bulk carriers with unrestricted worldwide navigation, having length L of 90 m or above.

With bulk carrier is intended sea going self-propelled ships which are constructed generally with single deck, double bottom, hopper side tanks and topside tanks and with single or double side skin construction in cargo length area and intended primarily to carry dry cargoes in bulk, excluding ore and combination carriers.

Hybrid bulk carriers, where at least one cargo hold is constructed with hopper tank and topside tank, are covered by the present Rules. The structural strength of members in holds constructed without hopper tank and/or topside tank is to comply with the strength criteria defined in the Rules.

1.1.3

The present Rules contain the IACS requirements for hull scantlings, arrangements, welding, structural details, materials and equipment applicable to all types of bulk carriers having the following characteristics:

- $L < 350$ m
- $L / B > 5$
- $B / D < 2.5$
- $C_B \geq 0.6$

1.1.4

The Rule requirements apply to welded hull structures made of steel having characteristics complying with requirements in Ch 3, Sec 1. The requirements apply also to welded steel ships in which parts of the hull, such as superstructures or small hatch covers, are built in material other than steel, complying with requirements in Ch 3, Sec 1.

1.1.5

Ships whose hull materials are different than those given in [1.1.4] and ships with novel features or unusual hull design are to be individually considered by the Society, on the basis of the principles and criteria adopted in the present Rules.

1.1.6

The scantling draught considered when applying the present Rules is to be not less than that corresponding to the assigned freeboard.

1.1.7
Where scantlings are obtained from direct calculation procedures which are different from those specified in Ch 7, adequate supporting documentation is to be submitted to the Society, as detailed in Sec 2.

1.2 Limits of application to lifting appliances

1.2.1
The fixed parts of lifting appliances, considered as an integral part of the hull, are the structures permanently connected by welding to the ship's hull (for instance crane pedestals, masts, king posts, derrick heel seatings, etc., excluding cranes, derrick booms, ropes, rigging accessories, and, generally, any dismountable parts), only for that part directly interacting with the hull structure. The shrouds of masts embedded in the ship's structure are considered as fixed parts.

1.2.2
The fixed parts of lifting appliances and their connections to the ship's structure may be covered by the Society's Rules for lifting appliances, and / or by the certification (especially the issuance of the Cargo Gear Register) of lifting appliances when required.

1.2.3
The design of the structure supporting fixed lifting appliances and the structure that might be called to support a mobile appliance should be designed taking into account the additional loads that will be imposed on them by the operation of the appliance as declared by the shipbuilder or its sub-contractors.

1.3 Limits of application to welding procedures

1.3.1
The requirements of the present Rules apply also for the preparation, execution and inspection of welded connections in hull structures.
They are to be complemented by the general requirements relevant to fabrication by welding and qualification of welding procedures given by the Society when deemed appropriate by the Society.

2. Rule application

2.1 Ship parts

2.1.1 General
For the purpose of application of the present Rules, the ship is considered as divided into the following three parts:

- fore part
- central part
- aft part.

2.1.2 Fore part
The fore part includes the structures located forward of the collision bulkhead, i.e.:

- the fore peak structures
- the stem.

In addition, it includes:

- the reinforcements of the flat bottom forward area
- the reinforcements of the bow flare area.

2.1.3 Central part

The central part includes the structures located between the collision bulkhead and the after peak bulkhead.

Where the flat bottom forward area or the bow flare area extend aft of the collision bulkhead, they are considered as belonging to the fore part.

2.1.4 Aft part

The aft part includes the structures located aft of the after peak bulkhead.

2.2 Rules applicable to various ship parts

2.2.1

The various chapters and sections are to be applied for the scantling of ship parts according to Tab 1.

Table 1: Chapters and sections applicable for the scantling of ship parts

<table>
<tr><th rowspan="2">Part</th><th colspan="2">Applicable Chapters and Sections</th></tr>
<tr><th>General</th><th>Specific</th></tr>
<tr><td>Fore part</td><td rowspan="3">Ch 1
Ch 2
Ch 3
Ch 4
Ch 5
Ch 9 (1), excluding:
Ch 9, Sec 1
Ch 9, Sec 2
Ch 11</td><td>Ch 9, Sec 1</td></tr>
<tr><td>Central part</td><td>Ch 6
Ch 7
Ch 8</td></tr>
<tr><td>Aft part</td><td>Ch 9, Sec 2</td></tr>
<tr><td colspan="3">(1) See also [2.3].</td></tr>
</table>

2.3 Rules applicable to other ship items

2.3.1

The various Chapters and Sections are to be applied for the scantling of other ship items according to Tab 2.

Table 2: Chapters and sections applicable for the scantling of other items

Item	Applicable Chapters and Sections
Machinery spaces	Ch 9, Sec 3
Superstructures and deckhouses	Ch 9, Sec 4
Hatch covers	Ch 9, Sec 5
Hull and superstructure openings	Ch 9, Sec 6
Rudders	Ch 10, Sec 1
Bulwarks and guard rails	Ch 10, Sec 2
Equipment	Ch 10, Sec 3

3. Class Notations

3.1 Additional service features BC-A, BC-B and BC-C

3.1.1

The following requirements apply to ships, as defined in [1.1.2], having length *L* of 150 m or above.

3.1.2

Bulk carriers are to be assigned one of the following additional service features:

a) **BC-A**: for bulk carriers designed to carry dry bulk cargoes of cargo density 1.0 t/m^3 and above with specified holds empty at maximum draught in addition to **BC-B** conditions.

b) **BC-B**: for bulk carriers designed to carry dry bulk cargoes of cargo density of 1.0 t/m^3 and above with all cargo holds loaded in addition to **BC-C** conditions.

c) **BC-C**: for bulk carriers designed to carry dry bulk cargoes of cargo density less than 1.0 t/m^3.

3.1.3

The following additional service features are to be provided giving further detailed description of limitations to be observed during operation as a consequence of the design loading condition applied during the design in the following cases:

- **{maximum cargo density (in t/m^3)}** for additional service features **BC-A** and **BC-B** if the maximum cargo density is less than 3.0 t/m^3(see also Ch 4, Sec 7, [2.1]).
- **{no MP}** for all additional service features when the ship has not been designed for loading and unloading in multiple ports in accordance with the conditions specified in Ch 4, Sec 7, [3.3].
- **{allowed combination of specified empty holds}** for additional service feature **BC-A** (see also Ch 4, Sec 7, [2.1]).

3.2 Additional class notation GRAB [X]

3.2.1 Application

The additional class notation **GRAB [X]** is mandatory for ships having one of the additional service features **BC-A** or **BC-B**, according to [3.1.2]. For these ships the requirements for the **GRAB [X]** notation given in Ch 12, Sec 1 are to be complied with for an unladen grab weight X equal to or greater than 20 tons.

For all other ships the additional class notation **GRAB [X]** is voluntary.

3.3 Class notation CSR

3.3.1 Application

In addition to the class notations granted by the assigning Society and to the service features and additional class notations defined hereabove, ships fully complying with the present Rules will be assigned the notation **CSR**.

Section 2 - VERIFICATION OF COMPLIANCE

1. General

1.1 New buildings

1.1.1

For new buildings, the plans and documents submitted for approval, as indicated in [2], are to comply with the applicable requirements in Ch 1 to Ch 12 of the present Rules, taking account of the relevant criteria, as the additional service features and classification notation assigned to the ship or the ship length.

1.1.2

When a ship is surveyed by the Society during construction, the Society:

- approves the plans and documentation submitted as required by the Rules
- proceeds with the appraisal of the design of materials and equipment used in the construction of the ship and their inspection at works
- carries out surveys or obtains appropriate evidence to satisfy itself that the scantlings and construction meet the rule requirements in relation to the approved drawings
- attends tests and trials provided for in the Rules
- assigns the construction mark.

1.1.3

The Society defines in specific Rules which materials and equipment used for the construction of ships built under survey are, as a rule, subject to appraisal of their design and to inspection at works, and according to which particulars.

1.1.4

As part of his interventions during the ship's construction, the Surveyor will:

- conduct an overall examination of the parts of the ship covered by the Rules
- examine the construction methods and procedures when required by the Rules
- check selected items covered by the rule requirements
- attend tests and trials where applicable and deemed necessary.

1.2 Ships in service

1.2.1

For ships in service, the requirements in Ch 13 of the present Rules are to be complied with.

2. Documentation to be submitted

2.1 Ships surveyed by the Society during the construction

2.1.1 Plans and documents to be submitted for approval

The plans and documents to be submitted to the Society for approval are listed in Tab 1. In addition, the Society may request for approval or information, other plans and documents deemed necessary for the review of the design.

Structural plans are to show details of connections of the various parts and are to specify the design materials, including, in general, their manufacturing processes, welding procedures and heat treatments. See also Ch 11, Sec 2, [1.4].

2.1.2 Plans and documents to be submitted for information

In addition to those in [2.1.1], the following plans and documents are to be submitted to the Society for information:

- general arrangement
- capacity plan, indicating the volume and position of the centre of gravity of all compartments and tanks
- lines plan
- hydrostatic curves
- lightweight distribution
- docking plan.

In addition, when direct calculation analyses are carried out by the Designer according to the rule requirements, they are to be submitted to the Society (see [3]).

2.2 Ships for which the Society acts on behalf of the relevant Administration

2.2.1 Plans and documents to be submitted for approval

The plans required by the National Regulations concerned are to be submitted to the Society for approval, in addition to those in [2.1].

Table 1: Plans and documents to be submitted for approval

Plan or document	Containing also information on
Midship section Transverse sections Shell expansion Decks and profiles Double bottom Pillar arrangements Framing plan Deep tank and ballast tank bulkheads, wash bulkheads	Class characteristics Main dimensions Minimum ballast draught Frame spacing Contractual service speed Density of cargoes Design loads on decks and double bottom Steel grades Corrosion protection Openings in decks and shell and relevant compensations Boundaries of flat areas in bottom and sides Details of structural reinforcements and/or discontinuities Bilge keel with details of connections to hull structures
Watertight subdivision bulkheads Watertight tunnels	Openings and their closing appliances, if any
Fore part structure	
Aft part structure	
Machinery space structures Foundations of propulsion machinery and boilers	Type, power and rpm of propulsion machinery Mass and centre of gravity of machinery and boilers
Superstructures and deckhouses Machinery space casing	Extension and mechanical properties of the aluminium alloy used (where applicable)
Hatch covers and hatch coamings	Design loads on hatch covers Sealing and securing arrangements, type and position of locking bolts Distance of hatch covers from the summer load waterline and from the fore end
Transverse thruster, if any, general arrangement, tunnel structure, connections of thruster with tunnel and hull structures	
Bulwarks and freeing ports	Arrangement and dimensions of bulwarks and freeing ports on the freeboard deck and superstructure deck
Windows and side scuttles, arrangements and details	
Scuppers and sanitary discharges	
Rudder and rudder horn (1)	Maximum ahead service speed
Sternframe or sternpost, sterntube Propeller shaft boss and brackets (1)	
Plan of watertight doors and scheme of relevant manoeuvring devices	Manoeuvring devices Electrical diagrams of power control and position indication circuits
Plan of outer doors and hatchways	
Derricks and cargo gear Cargo lift structures	Design loads (forces and moments) Connections to the hull structures
Sea chests, stabiliser recesses, etc.	
Hawse pipes	
Plan of manholes	

Plan or document	Containing also information on
Plan of access to and escape from spaces	
Plan of ventilation	Use of spaces and location and height of air vent outlets of various compartments
Plan of tank testing	Testing procedures for the various compartments Height of pipes for testing
Loading manual and loading instruments	Loading conditions as defined in Ch 4, Sec 7 (see also Ch 4, Sec 8)
Equipment number calculation	Geometrical elements for calculation List of equipment Construction and breaking load of steel wires Material, construction, breaking load and relevant elongation of synthetic ropes
(1) Where other steering or propulsion systems are adopted (e.g. steering nozzles or azimuth propulsion systems), the plans showing the relevant arrangement and structural scantlings are to be submitted. For azimuth propulsion systems, see Ch 10, Sec 1, [11].	

3. Computer programs

3.1 General

3.1.1

In order to increase the flexibility in the structural design direct calculations with computer programs are acceptable (see Ch 7). The aim of such analyses is to assess the structure compliance with the rule requirements.

3.2 General programs

3.2.1

The choice of computer programs according to currently available technology is free. The programs are to be able to manage the model and load cases as required in Ch 7 and/or Ch 8. The programs may be checked by the Society through comparative calculations with predefined test examples. A generally valid approval for a computer program is, however, not given by the Society.

3.2.2

Direct calculations may be used in the following fields:

- global strength
- longitudinal strength
- beams and grillages
- detailed strength.

3.2.3

For such calculation the computer model, the boundary condition and load cases are to be agreed upon with the Society.

The calculation documents are to be submitted including input and output. During the examination it may prove necessary that the Society performs independent comparative calculations.

Section 3 – FUNCTIONAL REQUIREMENTS

1. General

1.1 Application

1.1.1

This section defines the set of requirements relevant to the functions of the ship structures to be complied with during design and construction, to meet the following objectives.

1.2 Design life

1.2.1

The ship is to remain safe and environment-friendly, if properly operated and maintained, for her expected design life, which, unless otherwise specifically stated, is assumed to be equal to 25 years. The actual ship life may be longer or shorter than the design life, depending on the actual conditions and maintenance of the ship, taking into account aging effects, in particular fatigue, coating deterioration, corrosion, wear and tear.

1.3 Environmental conditions

1.3.1

The ship's structural design is to be based on the assumption of trading in the North Atlantic environment for the entire design life. Hence the respective wave conditions, i.e. the statistical wave scatter takes into account the basic principle for structural strength layout.

1.4 Structural safety

1.4.1

The ship is to be designed and constructed, and subsequently operated and maintained by its builders and operators, to minimise the risk for the safety of life at sea and the pollution of the marine environment as the consequence of the total loss of the ship due to structural collapse and subsequent flooding, loss of watertight integrity.

1.5 Structural accessibility

1.5.1

The ship is to be designed and constructed to provide adequate means of access to all spaces and internal structures to enable overall and close-up inspections and thickness measurements.

1.6 Quality of construction

1.6.1

As an objective, ships are to be built in accordance with controlled quality production standards using approved materials as necessary.

2. Definition of functional requirements

2.1 General

2.1.1

The functional requirements relevant to the ship structure are indicated in [2.2] to [2.6].

2.2 Structural strength

2.2.1

Ships are to be designed to withstand, in the intact condition, the environmental conditions during the design life, for the appropriate loading conditions. Structural strength is to be determined against buckling and yielding. Ultimate strength calculations have to include ultimate hull girder capacity and ultimate strength of plates and stiffeners.

2.2.2

Ships are to be designed to have sufficient reserve strength to withstand the wave and internal loads in damaged conditions that are reasonably foreseeable, e.g. collision, grounding or flooding scenarios. Residual strength calculations are to take into account the ultimate reserve capacity of the hull girder, considering permanent deformation and post-buckling behaviour.

2.2.3

Ships are to be assessed according to the expected design fatigue life for representative structural details.

2.3 Coating

2.3.1

Coating, where required, is to be selected as a function of the declared use of the ship spaces, e.g. holds, tanks, cofferdams, etc., materials and application of other corrosion prevention systems, e.g. cathodic protection or other alternative means. The protective coating systems, applied and maintained in accordance with manufacturer’s specifications concerning steel preparation, coating selection, application and maintenance, are to comply with the SOLAS requirements, the flag administration requirements and the Owner specifications.

2.4 Corrosion addition

2.4.1

The corrosion addition to be added to the net scantling required by structural strength calculations is to be adequate for the operating life. The corrosion addition is to be assigned in accordance with the use and exposure of internal and external structure to corrosive agents, such as water, cargo or corrosive atmosphere, in addition to the corrosion prevention systems, e.g. coating, cathodic protection or by alternative means.

2.5 Means of access

2.5.1

Ship structures subject to overall and close-up inspection and thickness measurements are to be provided with means capable of ensuring safe access to the structures. The means of access are to be described in a Ship Structure Access Manual for bulk carriers of 20,000 gross tonnage and over. Reference is made to SOLAS, Chapter II-1, Regulation 3-6.

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2.6 Construction quality procedures

2.6.1

Specifications for material manufacturing, assembling, joining and welding procedures, steel surface preparation and coating are to be included in the ship construction quality procedures.

3. Other regulations

3.1 International regulations

3.1.1

Attention of designers, shipbuilders and shipowners of ships covered by these Rules is drawn on the following :

Ships are designed, constructed and operated in a complex regulatory framework prescribed internationally by IMO and implemented by flag states or by classification societies on their behalf. Statutory requirements set the standard for statutory aspects of ships such as life saving, subdivisions, stability, fire protection, etc.

These requirements influence the operational and cargo carrying arrangements of the ship and therefore may affect its structural design.

The main international instruments normally to be applied with regard to the strength of bulk carriers are:

- **International Convention for Safety of Life at Sea (SOLAS)**
- **International Convention on Load Lines**

3.2 National regulations

3.2.1

Attention is drawn on the applicable national flag state regulations.

Compliance with these regulations of national administrations is not conditional for class assignment.

4. Workmanship

4.1 Requirements to be complied with by the manufacturer

4.1.1

The manufacturing plant is to be provided with suitable equipment and facilities to enable proper handling of the materials, manufacturing processes, structural components, etc.

The manufacturing plant is to have at its disposal sufficiently qualified personnel. The Society is to be advised of the names and areas of responsibility of the supervisory and control personnel in charge of the project.

4.2 Quality control

4.2.1

As far as required and expedient, the manufacturer's personnel has to examine all structural components both during manufacture and on completion, to ensure that they are complete, that the dimensions are correct and that workmanship is satisfactory and meets the standard of good shipbuilding practice.

Upon inspection and corrections by the manufacturing plant, the structural components are to be shown to the surveyor of the Society for inspection, in suitable sections, normally in unpainted condition and enabling proper access for inspection.

The Surveyor may reject components that have not been adequately checked by the plant and may demand their re-submission upon successful completion of such checks and corrections by the plant.

5. Structural Details

5.1 Details in manufacturing documents

5.1.1

Significant details concerning quality and functional ability of the component concerned are to be entered in the manufacturing documents (workshop drawings, etc.). This includes not only scantlings but - where relevant - such items as surface conditions (e.g. finishing of flame cut edges and weld seams), and special methods of manufacture involved as well as inspection and acceptance requirements and where relevant permissible tolerances. So far as for this aim a standard is used (works or national standard etc.) it is to be submitted to the Society. For weld joint details, see Ch 11, Sec 2.

If, due to missing or insufficient details in the manufacturing documents, the quality or functional ability of the component is doubtful, the Society may require appropriate improvements to be submitted by the manufacturer. This includes the provision of supplementary or additional parts (for example reinforcements) even if these were not required at the time of plan approval.

Section 4 – SYMBOLS AND DEFINITIONS

1. Primary symbols and units

1.1

1.1.1

Unless otherwise specified, the general symbols and their units used in the present Rules are those defined in Tab 1.

Table 1: Primary symbols

Symbol	Meaning	Units
A	Area	m^2
	Sectional area of ordinary stiffeners and primary members	cm^2
B	Moulded breadth of ship (see [2])	m
C	Coefficient	-
D	Depth of ship (see [2])	m
E	Young's modulus	N/mm^2
F	Force and concentrated loads	kN
I	Hull girder inertia	m^4
	Inertia of ordinary stiffeners and primary members	cm^4
L	Length of ship (see [2])	m
M	Bending moment	kN.m
Q	Shear force	kN
S	Spacing of primary supporting members	
T	Draught of ship (see [2])	m
V	Ship's speed	knot
Z	Hull girder section modulus	m^3
a	Acceleration	m/s^2
b	Width of attached plating	m
	Width of face plate of ordinary stiffeners and primary members	mm
g	Gravity acceleration (see [2])	m/s^2
h	Height	m
	Web height of ordinary stiffeners and primary members	mm
k	Material factor (see [2])	-
ℓ	Length / Span of ordinary stiffeners and primary supporting members	m
m	Mass	t
n	Number of items	-
p	Pressure	kN/m^2
r	Radius	mm
	Radius of curvature of plating or bilge radius	m
s	Spacing of ordinary stiffeners	m
t	Thickness	mm
w	Section modulus of ordinary stiffeners and primary supporting members	cm^3
x	X coordinate along longitudinal axis (see [4])	m
y	Y coordinate along transverse axis (see [4])	m
z	Z coordinate along vertical axis (see [4])	m

Symbol	Meaning	Units
γ	Safety factor	-
δ	Deflection / Displacement	mm
θ	Angle	deg
ξ	Weibull shape parameter	-
ρ	Density	t/m^3
σ	Bending stress	N/mm^2
τ	Shear stress	N/mm^2

2. Symbols

2.1 Ship's main data

2.1.1

L : Rule length, in m, defined in [3.1]

L_{LL} : Freeboard length, in m, defined in [3.2]

L_{BP} : Length between perpendiculars, in m, is the length of the ship measured between perpendiculars taken at the extremities of the deepest subdivision load line, i.e. of the waterline which corresponds to the greatest draught permitted by the subdivision requirements which are applicable

FP_{LL} : Forward freeboard perpendicular. The forward freeboard perpendicular is to be taken at the forward end of the length L_{LL} and is to coincide with the foreside of the stem on the waterline on which the length L_{LL} is measured

AP_{LL} : After freeboard perpendicular. The after freeboard perpendicular is to be taken at the aft end of the length L_{LL}.

B : Moulded breadth, in m, defined in [3.4]

D : Depth, in m, defined in [3.5]

T : Moulded draught, in m, defined in [3.6]

T_S : Scantling draught, in m, taken equal to the maximum draught (see also Ch 1, Sec 1, [1.1.6])

T_B : Minimum ballast draught at midship, in m, in normal ballast condition as defined in Ch 4, Sec 7, [2.2.1]

T_{LC} : Midship draught, in m, in the considered loading condition

Δ : Moulded displacement, in tonnes, at draught T, in sea water (density $\rho = 1.025$ t/m^3)

C_B : Total block coefficient

$$C_B = \frac{\Delta}{1.025LBT}$$

V : Maximum ahead service speed, in knots, means the greatest speed which the ship is designed to maintain in service at her deepest seagoing draught at the maximum propeller RPM and corresponding engine MCR (Maximum Continuous Rating).

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system.

2.2 Materials

2.2.1

E : Young's modulus, in N/mm^2, to be taken equal to:

$E = 2.06.10^5$ N/mm^2, for steels in general

$E = 1.95.10^5$ N/mm^2, for stainless steels

$E = 7.0.10^4$ N/mm^2, for aluminium alloys

R_{eH} : Minimum yield stress, in N/mm^2, of the material

k : Material factor, defined in Ch 3, Sec 1, [2.2]

v : Poisson's ratio. Unless otherwise specified, a value of 0.3 is to be taken into account,

R_m : Ultimate minimum tensile strength, in N/mm^2, of the material

R_Y : Nominal yield stress, in N/mm^2, of the material, to be taken equal to $235/k$ N/mm^2, unless otherwise specified.

2.3 Loads

2.3.1

g : Gravity acceleration, taken equal to 9.81 m/s^2

ρ : Sea water density, taken equal to 1.025 t/m^3

ρ_L : Density, in t/m^3, of the liquid carried

ρ_C : Density, in t/m^3, of the dry bulk cargo carried

C : Wave parameter, taken equal to:

$$C = 10.75 - \left(\frac{300 - L}{100}\right)^{1,5} \quad \text{for } 90 \le L < 300\text{m}$$

$$C = 10.75 \quad \text{for } 300 \le L < 350\text{m}$$

h : Height, in m, of a tank, to be taken as the vertical distance from the bottom to the top of the tank, excluding any small hatchways

z_{TOP} : Vertical distance, in m, of the highest point of the tank from the baseline. For ballast holds, z_{TOP} is the vertical distance, in m, of the top of the hatch coaming from the baseline

ℓ_H : Length, in m, of the compartment

M_{SW} : Design still water bending moment, in kN.m, at the hull transverse section considered:

$M_{SW} = M_{SW,H}$ in hogging conditions

$M_{SW} = M_{SW,S}$ in sagging conditions

M_{WV} : Vertical wave bending moment, in kN.m, at the hull transverse section considered:

$M_{WV} = M_{WV,H}$ in hogging conditions

$M_{WV} = M_{WV,S}$ in sagging conditions

M_{WH} : Horizontal wave bending moment, in kN.m, at the hull transverse section considered,

Q_{SW} : Design still water shear force, in kN, at the hull transverse section considered

Q_{WV} : Vertical wave shear force, in kN, at the hull transverse section considered

p_S : Still water pressure, in kN/m^2

p_W : Wave pressure or dynamic pressures, in kN/m^2

p_{SF}, p_{WF} : Still water and wave pressure, in kN/m^2, in flooded conditions

σ_X : Hull girder normal stress, in N/mm^2

a_X, a_Y, a_Z : Accelerations, in m/s^2, along X, Y and Z directions, respectively

T_R : Roll period, in s

θ : Roll single amplitude, in deg

T_P : Pitch period, in s

Φ : Single pitch amplitude, in deg

k_r : Roll radius of gyration, in m

GM : Metacentric height, in m

λ : Wave length, in m

2.4 Scantlings

2.4.1 Hull girder scantlings

I_Y : Moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis

I_Z : Moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis

Z_{AB},Z_{AD} : Section moduli, in m^3, at bottom and deck, respectively

N : Vertical distance, in m, from the base line to the horizontal neutral axis of the hull transverse section

2.4.2 Local scantlings

s : Spacing, in m, of ordinary stiffeners, measured at mid-span along the chord

S : Spacing, in m, of primary supporting members, measured at mid-span along the chord

ℓ : Span, in m, of ordinary stiffener or primary supporting member, as the case may be, measured along the chord

ℓ_b : Length, in m, of brackets

t_C : Corrosion addition, in mm

h_w : Web height, in mm, of ordinary stiffener or primary supporting member, as the case may be

t_w : Net web thickness, in mm, of ordinary stiffener or primary supporting member, as the case may be

b_f : Face plate width, in mm, of ordinary stiffener or primary supporting member, as the case may be

t_f : Net face plate thickness, in mm, of ordinary stiffener or primary supporting member, as the case may be

t_p : Net thickness, in mm, of the plating attached to an ordinary stiffener or a primary supporting member, as the case may be

b_p : Width, in m, of the plating attached to the stiffener or the primary supporting member, for the yielding check

A_s : Net sectional area, in cm^2, of the stiffener or the primary supporting member, with attached plating of width s

A_{sh} : Net shear sectional area, in cm^2, of the stiffener or the primary supporting member

I : Net moment of inertia, in cm^4, of ordinary stiffener or primary supporting member, as the case may be, without attached plating, around its neutral axis parallel to the plating

I_p : Net polar moment of inertia, in cm^4, of ordinary stiffener or primary supporting member, as the case may be, about its connection to plating

I_w : Net sectional moment of inertia, in cm^6, of ordinary stiffener or primary supporting member, as the case may be, about its connection to plating

I_S : Net moment of inertia, in cm^4, of the stiffener or the primary supporting member, with attached shell plating of width s, about its neutral axis parallel to the plating

Z : Net section modulus, in cm^3, of an ordinary stiffener or a primary supporting member, as the case may be, with attached plating of width b_p

3. Definitions

3.1 Rule length

3.1.1

The rule length L is the distance, in m, measured on the summer load waterline, from the forward side of the stem to the after side of the rudder post, or to the centre of the rudder stock where there is no rudder post. L is to be not less than 96% and need not exceed 97% of the extreme length on the summer load waterline.

3.1.2

In ships without rudder stock (e.g. ships fitted with azimuth thrusters), the rule length L is to be taken equal to 97% of the extreme length on the summer load waterline.

3.1.3

In ships with unusual stem or stern arrangements, the rule length L is considered on a case by case basis.

3.2 Freeboard length

3.2.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 3(1,a))

The freeboard length L_{LL} is the distance, in m, on the waterline at 85% of the least moulded depth from the top of the keel, measured from the forward side of the stem to the centre of the rudder stock. L_{LL} is to be not less than 96% of the extreme length on the same waterline.

3.2.2

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 3(1,c))

Where the stem contour is concave above the water-line at 85% of the least moulded depth, both the forward end of the extreme length and the forward side of the stem are to be taken at the vertical projection to that waterline of the aftermost point of the stem contour (above that waterline) (see Fig 1).

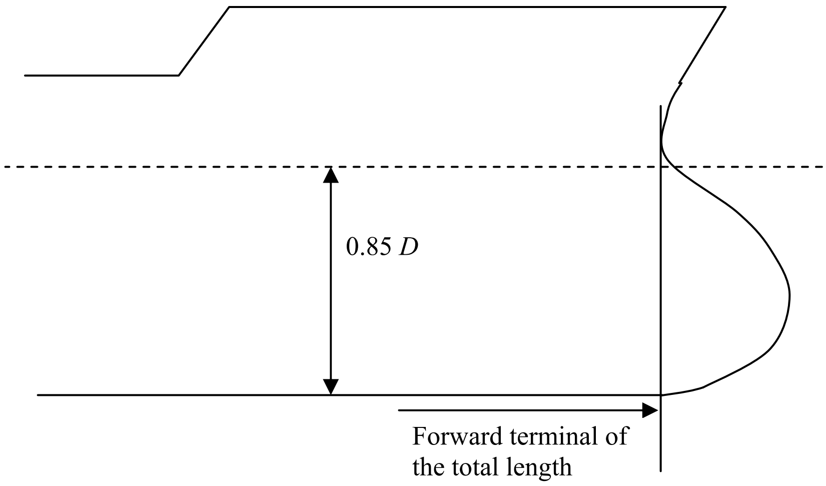

Figure 1: Concave stem contour

3.3 Ends of rule length *L* and midship

3.3.1 Fore end

The fore end (FE) of the rule length *L*, see Fig 2, is the perpendicular to the summer load waterline at the forward side of the stem.

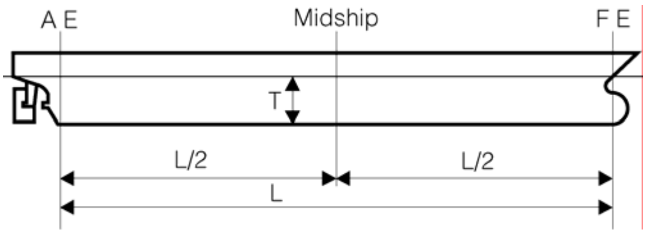

Figure 2: Ends and midship

The aft end (AE) of the rule length *L*, see Fig 2, is the perpendicular to the waterline at a distance *L* aft of the fore end.

3.3.2 Midship

The midship is the perpendicular to the waterline at a distance 0.5*L* aft of the fore end.

3.3.3 Midship part

The midship part of a ship is the part extending 0.4*L* amidships, unless otherwise specified.

3.4 Moulded breadth

3.4.1

The moulded breadth *B* is the greatest moulded breadth, in m, measured amidships below the weather deck.

3.5 Depth

3.5.1

The depth D is the distance, in m, measured vertically on the midship transverse section, from the moulded base line to the top of the deck beam at side on the upper-most continuous deck.

3.6 Moulded draught

3.6.1

The moulded draught T is the distance, in m, measured vertically on the midship transverse section, from the moulded base line to the summer load line.

3.7 Lightweight

3.7.1

The lightweight is the displacement, in t, without cargo, fuel, lubricating oil, ballast water, fresh water and feed water, consumable stores and passengers and crew and their effects.

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3.8 Deadweight

3.8.1

The deadweight is the difference, in t, between the displacement, at the summer draught in sea water of density $\rho = 1.025$ t/m^3, and the lightweight.

3.9 Freeboard deck

3.9.1

Ref. ILLC, as amended (Resolution MSC. 143(77) Reg. 3(9))

The freeboard deck is defined in Regulation 3 of the International Load Line Convention, as amended.

3.10 Bulkhead deck

3.10.1

Ref. SOLAS Reg.II-1/2 .5

The bulkhead deck is the uppermost deck to which the transverse watertight bulkheads, except both peak bulkheads, extend and are made effective.

3.11 Strength deck

3.11.1

The strength deck at a part of ship's length is the uppermost continuous deck at that part to which the shell plates extend.

3.12 Superstructure

3.12.1 General

Ref. ILLC. As amended (Resolution MSC.143(77) Reg. 3(10,a))

A superstructure is a decked structure on the free-board deck, extending from side to side of the ship or with the side plating not being inboard of the shell plating more than 0.04B.

3.12.2 Enclosed and open superstructure

A superstructure may be:

- enclosed, where:
    1) it is enclosed by front, side and aft bulkheads complying with the requirements of Ch 9, Sec 4
    2) all front, side and aft openings are fitted with efficient weathertight means of closing
- open, where it is not enclosed.

3.13 Forecastle

3.13.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 3(10,g))

A forecastle is a superstructure which extends from the forward perpendicular aft to a point which is forward of the after perpendicular. The forecastle may originate from a point forward of the forward perpendicular.

3.14 Raised quarterdeck

3.14.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 3(10,i))

A raised quarterdeck is a superstructure which extends forward from the after perpendicular, generally has a height less than a normal superstructure, and has an intact front bulkhead (sidescuttles of the non-opening type fitted with efficient deadlights and bolted man hole covers)(see Fig 3). Where the forward bulkhead is not intact due to doors and access openings, the superstructure is then to be considered as a poop.

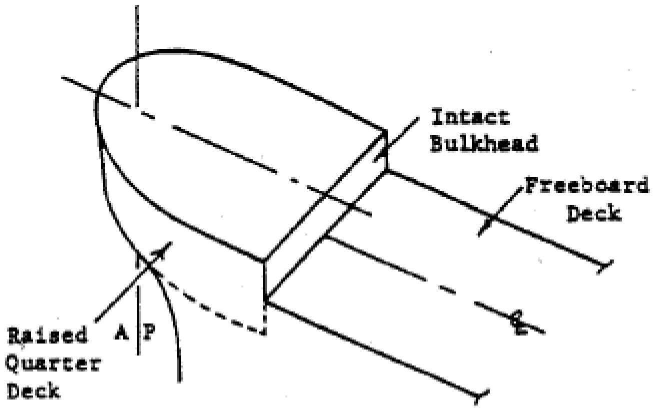

Figure 3: Raised quarter deck

3.15 Deckhouse

3.15.1

A deckhouse is a decked structure other than a superstructure, located on the freeboard deck or above.

3.16 Trunk

3.16.1

A trunk is a decked structure similar to a deckhouse, but not provided with a lower deck.

3.17 Wash bulkhead

3.17.1

A wash bulkhead is a perforated or partial bulkhead in a tank.

3.18 Standard height of superstructure

3.18.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 33)

The standard height of superstructure is defined in Tab 2.

Table 2: Standard height of superstructure

Freeboard length L_{LL}, in m	Standard height h_S, in m	
	Raised quarter deck	All other superstructures
$90 < L_{LL} < 125$	$0.3 + 0.012\ L_{LL}$	$1.05 + 0.01\ L_{LL}$
$L_{LL} \geq 125$	1.80	2.30

3.19 Type A and Type B ships

3.19.1 Type A ship

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 27.1)

A Type A ship is one which:

- is designed to carry only liquid cargoes in bulk;
- has a high integrity of the exposed deck with only small access openings to cargo compartments, closed by watertight gasketed covers of steel or equivalent material
- has low permeability of loaded cargo compartments.

A Type A ship is to be assigned a freeboard following the requirements reported in the International Load Line Convention 1966, as amended.

3.19.2 Type B ship

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 27.5)

All ships which do not come within the provisions regarding Type A ships stated in [3.19.1] are to be considered as Type B ships.

A Type B ship is to be assigned a freeboard following the requirements reported in the International Load Line Convention 1966, as amended.

3.19.3 Type B-60 ship

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 27.9)

A Type B-60 ship is any Type B ship of over 100 metres in length which, according to applicable requirements of in the International Load Line Convention 1966, as amended, is assigned with a value of tabular freeboard which can be reduced up to 60 per cent of the difference between the "B" and "A" tabular values for the appropriate ship lengths.

3.19.4 Type B-100 ship

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 27.10)

A Type B-100 ship is any Type B ship of over 100 metres in length which, according to applicable requirements of in the International Load Line Convention 1966, as amended, is assigned with a value of tabular freeboard which can be reduced up to 100 per cent of the difference between the "B" and "A" tabular values for the appropriate ship lengths.

3.20 Positions 1 and 2

3.20.1 Position 1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 13)

Position 1 includes:

- exposed freeboard and raised quarter decks,
- exposed superstructure decks situated forward of 0.25 L_{LL} from the perpendicular, at the forward side of the stem, to the waterline at 85% of the least moulded depth measured from the top of the keel.

3.20.2 Position 2

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 13)

Position 2 includes:

- exposed superstructure decks situated aft of 0.25 L_{LL} from the perpendicular, at the forward side of the stem, to the waterline at 85% of the least moulded depth measured from the top of the keel and located at least one standard height of superstructure above the freeboard deck,
- exposed superstructure decks situated forward of 0.,25 L_{LL} from the perpendicular, at the forward side of the stem, to the waterline at 85% of the least moulded depth measured from the top of the keel and located at least two standard heights of superstructure above the freeboard deck.

3.21 Single Side Skin and Double Side Skin construction

3.21.1 Single side skin construction

A hold of single side skin construction is bounded by the side shell between the inner bottom plating or the hopper tank plating when fitted, and the deck plating or the topside tank plating when fitted.

3.21.2 Double side skin construction

A hold of double side skin construction is bounded by a double side skin, including hopper tank and topside tank when fitted.

RCN 1 to July 2010 version (effective from 1July 2012)

3.22 Bilge

3.22.1 Bilge plating

The bilge plating is the curved plating between the bottom shell and side shell. It is to be taken as follows:

- within the cylindrical part of the ship (see Fig.4):
  from the start of the curvature at the lower turn of bilge on the bottom to the end of the curvature at the upper turn of the bilge,
- outside the cylindrical part of the ship (see Fig.5):
  From the start of the curvature at the lower turn of the bilge on the bottom to the lesser of:
  - a point on the side shell located 0.2D above the baseline/local centreline elevation.
  - the end of the curvature at the upper turn of the bilge.

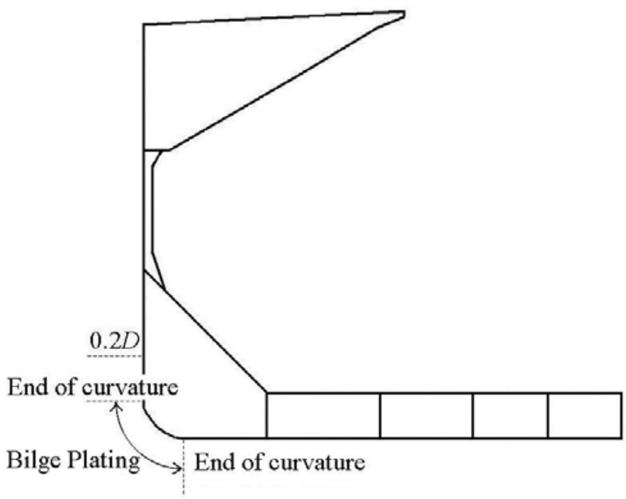

Figure 4: vertical extent of bilge plating within the cylindrical part of the hull

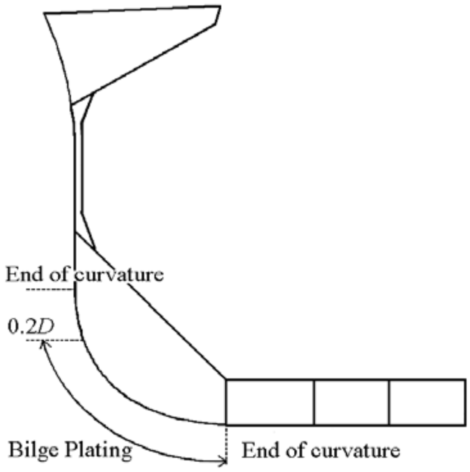

Figure 5: vertical extent of bilge plating outside the cylindrical part of the hull

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4. Reference co-ordinate system

4.1

4.1.1

The ship's geometry, motions, accelerations and loads are defined with respect to the following right-hand co-ordinate system (see Fig 6):

- Origin: at the intersection among the longitudinal plane of symmetry of ship, the aft end of L and the baseline
- *X* axis: longitudinal axis, positive forwards
- *Y* axis: transverse axis, positive towards portside
- *Z* axis: vertical axis, positive upwards.

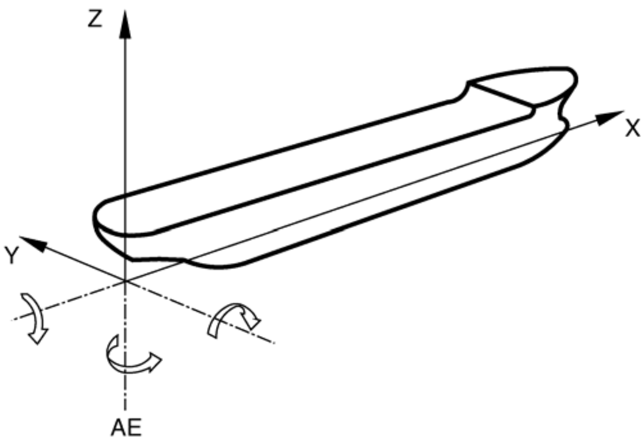

Figure 6: Reference co-ordinate system

4.1.2

Positive rotations are oriented in anti-clockwise direction about the *X*, *Y* and *Z* axes.

Chapter 2

General Arrangement Design

Section 1 - SUBDIVISION ARRANGEMENT

1. Number and arrangement of transverse watertight bulkheads

1.1 Number of watertight bulkheads

1.1.1 General

All ships, in addition to complying with the requirements of [1.1.2], are to have at least the following transverse watertight bulkheads:

- one collision bulkhead
- one after peak bulkhead
- two bulkheads forming the boundaries of the machinery space in ships with machinery amidships, and a bulkhead forward of the machinery space in ships with machinery aft. In the case of ships with an electrical propulsion plant, both the generator room and the engine room are to be enclosed by watertight bulkheads.

1.1.2 Additional bulkheads

For ships not required to comply with subdivision regulations, transverse bulkheads adequately spaced, and not less in number than indicated in Tab 1, are to be fitted.

Table 1: Number of bulkheads

Length (m)	Number of bulkheads for ships with aft machinery (1)	Numbers of bulkheads for other ships
$90 \le L < 105$	4	5
$105 \le L < 120$	5	6
$120 \le L < 145$	6	7
$145 \le L < 165$	7	8
$165 \le L < 190$	8	9
$L \ge 190$	To be defined on a case by case basis	
(1) After peak bulkhead and aft machinery bulkhead are the same.		

2. Collision bulkhead

2.1 Arrangement of collision bulkhead

2.1.1

Ref. SOLAS Ch. II-1, Part B-2, Reg. 12

A collision bulkhead is to be fitted which is to be watertight up to the bulkhead deck. This bulkhead is to be located at a distance from the forward perpendicular FP_{LL} of not less than $0.05L_{LL}$ or 10 m, whichever is the less, and, except as may be permitted by the Society, *not more than $0.08L_{LL}$ or $0.05L_{LL}$+3 m, whichever is the greater.*

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2.1.2

Ref. SOLAS Ch. II-1, Part B, Reg. 11

Where any part of the ship below the waterline extends forward of the forward perpendicular, e.g. a bulbous bow, the distances, in metres, stipulated in [2.1.1] are to be measured from a point either:

• at the mid-length of such extension, or

• at a distance 1.5 per cent of the length L_{LL} of the ship forward of the forward perpendicular, or

• at a distance 3 metres forward of the forward perpendicular,

whichever gives the smallest measurement.

2.1.3

Ref. SOLAS Ch. II-1, Part B, Reg. 11

The bulkhead may have steps or recesses provided they are within the limits prescribed in [2.1.1] or [2.1.2].

No door, manhole, ventilation duct or any other opening is to be fitted in this bulkhead.

3. After peak, machinery space bulkheads and stern tubes

3.1 General

3.1.1

An aft peak bulkhead, enclosing the stern tube and rudder trunk in a watertight compartment, is to be provided. Where the shafting arrangements make enclosure of the stern tube in a watertight compartment impractical alternative arrangements will be specially considered.

3.1.2

The aft peak bulkhead may be stepped below the bulkhead deck, provided that the degree of safety of the ship as regards subdivision is not thereby diminished.

3.1.3

The aft peak bulkhead location on ships powered and/or controlled by equipment that does not require the fitting of a stern tube and/or rudder trunk will also be subject to special consideration.

3.1.4

The aft peak bulkhead may terminate at the first deck above the summer load waterline, provided that this deck is made watertight to the stern or to a watertight transom floor.

RCN 1 to July 2010 version (effective from 1July 2012)

3.1.5 Sterntubes

Ref. SOLAS Ch. II-1, Part B-2, Reg.12

Sterntubes are to be enclosed in a watertight space (or spaces) of moderate volume. Other measures to minimise the danger of water penetrating into the ship in case of damage to sterntube arrangements may be taken at the discretion of the Society.

Corrigenda 1 to July 2012 version (effective from 1July 2012)

4. Number and arrangement of tank bulkheads

4.1 Bulkheads in compartments intended for the carriage of liquid cargoes

4.1.1

The number and location of transverse and longitudinal watertight bulkheads in compartments intended for the carriage of liquid cargoes are to comply with the subdivision requirements to which the ship is subject.

5. Arrangement of transverse watertight bulkheads

5.1 General

5.1.1

Where it is not practicable to arrange a watertight bulkhead in one plane, a stepped bulkhead may be fitted. In this case, the part of the deck which forms the step is to be watertight and equivalent in strength to the bulkhead.

6. Openings in watertight bulkheads

6.1 General

6.1.1

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9 and IMO Res. A.684(17) - Part B

The number of openings in watertight subdivisions is to be kept to a minimum compatible with the design and proper working of the ship. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity. The Society may permit relaxation in the watertightness of openings above the freeboard deck, provided that it is demonstrated that any progressive flooding can be easily controlled and that the safety of the ship is not impaired.

6.1.2

No door, manhole ventilation duct or any other opening is permitted in the collision bulkhead below the subdivision deck.

6.1.3

Lead or other heat sensitive materials may not be used in systems which penetrate watertight subdivision bulkheads, where deterioration of such systems in the event of fire would impair the watertight integrity of the bulkheads.

6.1.4

Valves not forming part of a piping system are not permitted in watertight subdivision bulkheads.

6.1.5

The requirements relevant to the degree of tightness, as well as the operating systems, for doors or other closing appliances complying with the provisions in [6.2] and [6.3] are specified in Tab 2.

6.2 Openings in the watertight bulkheads below the freeboard deck

6.2.1 Openings used while at sea

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9

Doors provided to ensure the watertight integrity of internal openings which are used while at sea are to be sliding watertight doors capable of being remotely closed from the bridge and are also to be operable locally from each side of the bulkhead. Indicators are to be provided at the control position showing whether the doors are open or closed, and an audible alarm is to be provided at the door closure. The power, control and indicators are to be operable in the event of main power failure. Particular attention is to be paid to minimise the effect of control system failure. Each power-operated sliding watertight door is to be provided with an individual hand-operated mechanism. The possibility of opening and closing the door by hand at the door itself from both sides is to be assured.

6.2.2 Openings normally closed at sea

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9

Access doors and access hatch covers normally closed at sea, intended to ensure the watertight integrity of internal openings, are to be provided with means of indication locally and on the bridge showing whether these doors or hatch covers are open or closed. A notice is to be affixed to each such door or hatch cover to the effect that it is not to be left open. The use of such doors and hatch covers is to be authorised by the officer of the watch.

6.2.3 Doors or ramps in large cargo spaces

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9

Watertight doors or ramps of satisfactory construction may be fitted to internally subdivide large cargo spaces, provided that the Society is satisfied that such doors or ramps are essential. These doors or ramps may be hinged, rolling or sliding doors or ramps, but are not to be remotely con-trolled.

Such doors are to be closed before the voyage commences and are to be kept closed during navigation. Should any of the doors or ramps be accessible during the voyage, they are to be fitted with a device which prevents unauthorised opening.

The word “satisfactory” means that scantlings and sealing requirements for such doors or ramps are to be sufficient to withstand the maximum head of the water at the flooded waterline.

6.2.4 Openings permanently kept closed at sea

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9

Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of internal openings are to be provided with a notice which is to be affixed to each such closing appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

6.3 Openings in the bulkheads above the freeboard deck

6.3.1 General

The openings in flooding boundaries located below the waterline at the equilibrium of the final stage of flooding are to be watertight. The openings immersed within the range of the positive righting lever curve are only to be weathertight.

Table 2: Doors

			Sliding type			Hinged type			Rolling type (cargo between deck spaces)
			Remote operation indication on the bridge	Indicator on the bridge	Local operation only	Remote operation indication on the bridge	Indicator on the bridge	Local operation only	
Watertight	Below the freeboard deck	Open at sea	X						
		Normally closed (2)		X			X (3)		
		Remain closed (2)			X (4) (5)			X (4) (5)	X (4) (5)
Weathertight / watertight (1)	Above the freeboard deck	Open at sea	X						
		Normally closed (2)		X			X		
		Remain closed (2)						X (4) (5)	

(1) Watertight doors are required when they are located below the waterline at the equilibrium of the final stage of flooding; otherwise a weathertight door is accepted.
(2) Notice to be affixed on both sides of the door: “to be kept closed at sea”.
(3) Type A ships of 150 m and upwards, and Type B ships with a reduced freeboard may have a hinged watertight door between the engine room and the steering gear space, provided that the sill of this door is above the summer load waterline.
(4) The door is to be closed before the voyage commences.
(5) If the door is accessible during the voyage, a device which prevents unauthorised opening is to be fitted.

6.3.2 Doors used while at sea

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9×

The doors used while at sea are to be sliding doors capable of being remotely closed from the bridge and are also to be operable locally from each side of the bulkhead. Indicators are to be provided at the control position showing whether the doors are open or closed, and an audible alarm is to be provided at the door closure. The power, control and indicators are to be operable in the event of main power failure. Particular attention is to be paid to minimise the effect of control system failure. Each power-operated sliding watertight door is to be provided with an individual hand-operated mechanism. It should be possible to open and close the door by hand at the door itself from both sides.

6.3.3 Doors normally closed at sea

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9

The doors normally closed at sea are to be provided with means of indication locally and on the bridge showing whether these doors are open or closed. A notice is to be affixed to each door to the effect that it is not to be left open.

6.3.4 Openings kept permanently closed at sea

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9

The doors kept closed at sea are to be hinged doors. Such doors and the other closing appliances which are kept closed at sea are to be provided with a notice affixed to each closing appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

Section 2 - COMPARTMENT ARRANGEMENT

1. Definitions

1.1 Cofferdam

1.1.1

A cofferdam means an empty space arranged so that compartments on each side have no common boundary; a cofferdam may be located vertically or horizontally. As a rule, a cofferdam is to be properly ventilated and of sufficient size to allow proper inspection, maintenance and safe evacuation.

1.2 Machinery spaces of category A

1.2.1

Ref. SOLAS Ch. II-2, Part A, Reg. 3.31

Machinery spaces of category A are those spaces or trunks to such spaces which contain:

- *internal combustion machinery used for main propulsion; or*
- *internal combustion machinery used for purposes other than propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or*
- *any oil fired boiler or fuel oil unit.*

2. Cofferdams

2.1 Cofferdam arrangement

2.1.1

Cofferdams are to be provided between compartments intended for liquid hydrocarbons (fuel oil, lubricating oil) and those intended for fresh water (drinking water, water for propelling machinery and boilers) as well as tanks intended for the carriage of liquid foam for fire extinguishing.

2.1.2

Cofferdams separating fuel oil tanks from lubricating oil tanks and the latter from those intended for the carriage of liquid foam for fire extinguishing or fresh water or boiler feed water may be waived when deemed impracticable or unreasonable by the Society in relation to the characteristics and dimensions of the spaces containing such tanks, provided that:

- the thickness of common boundary plates of adjacent tanks is increased, with respect to the thickness obtained according to Ch 6, Sec 1, by 2 mm in the case of tanks carrying fresh water or boiler feed water, and by 1 mm in all other cases
- the sum of the throats of the weld fillets at the edges of these plates is not less than the thickness of the plates themselves
- the structural test is carried out with a head increased by 1 m with respect to Ch 11, Sec 3.

2.1.3

(Void)

RCN 1 to July 2010 version (effective from 1July 2012)

2.1.4

Cofferdams are only required between fuel oil double bottoms and tanks immediately above where the inner bottom plating is subjected to the head of fuel oil contained therein, as in the case of a double bottom with its top raised at the sides.

Where a corner to corner situation occurs, tanks are not be considered to be adjacent.

Adjacent tanks not separated by cofferdams are to have adequate dimensions to ensure easy inspection.

3. Double bottoms

3.1 General

3.1.1

Ref. SOLAS Ch. II-1, Part B, Reg. 12-1

A double bottom is to be fitted extending from the collision bulkhead to the after peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

3.1.2

Ref. SOLAS Ch. II-1, Part B, Reg. 12-1

Where a double bottom is required to be fitted, its depth is to satisfy the provisions of Ch 3, Sec 6, [6] and the inner bottom is to be continued out to the ship side in such a manner as to protect the bottom to the turn of the bilge.

3.1.3

Ref. SOLAS Ch. II-1, Part B, Reg. 12-1

Small wells constructed in the double bottom, in connection with the drainage arrangements of holds, are not to extend in depth more than necessary. A well extending to the outer bottom, may, however, be permitted at the after end of the shaft tunnel of the ship. Other wells may be permitted by the Society if it is satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with [3.1].

3.1.4

Ref. SOLAS Ch. II-1, Part B, Reg. 12-1

A double bottom need not be fitted in way of water-tight compartments used exclusively for the carriage of liquids, provided the safety of the ship in the event of bottom damage is not, in the opinion of the Society, thereby impaired.

4. Compartment forward of the collision bulkhead

4.1 General

4.1.1

The fore peak and other compartments located forward of the collision bulkhead may not be arranged for the carriage of fuel oil or other flammable products.

5. Minimum bow height

5.1 General

5.1.1

Ref. ILLC, as amended (Resolution MSC.223(82) Reg. 39(1))

The bow height F_b, defined as the vertical distance at the forward perpendicular between the waterline corresponding to the assigned summer freeboard and the designed trim and the top of the exposed deck at side, is to be not less than:

$F_b = (6075(L_{LL}/100) - 1875(L_{LL}/100)^2 + 200(L_{LL}/100)^3)(2.08 + 0.609C_B - 1.603C_{wf} - 0.0129(L/T_1))$

where:

F_b : *Calculated minimum bow height, in mm*

T_1 : *Draught at 85% of the least moulded depth, in m*

C_{wf} : *Waterplane area coefficient forward of $L_{LL}/2$:*

$$C_{wf} = \frac{A_{wf}}{\frac{L_{LL}}{2}B}$$

A_{wf} : *Waterplane area forward of $L_{LL}/2$ at draught T_1, in m^2.*

For ships to which timber freeboards are assigned, the summer freeboard (and not the timber summer freeboard) is to be assumed when applying the formula above.

RCN 1 to July 2010 version (effective from 1July 2012)

5.1.2

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 39.(2))

Where the bow height required in paragraph [5.1.1] is obtained by sheer, the sheer is to extend for at least 15% of the length of the ship measured from the forward perpendicular. Where it is obtained by fitting a superstructure, such superstructure is to extend from the stem to a point at least 0.07L abaft the forward perpendicular, and is to be enclosed as defined Ch 9, Sec 4.

5.1.3

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 39(3))

Ships which, to suit exceptional operational requirements, cannot meet the requirements in [5.1.1] and [5.1.2] will be considered by the Society on a case by case basis.

5.1.4

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 39(4, a))

The sheer of the forecastle deck may be taken into account, even if the length of the forecastle is less than 0.15L, but greater than 0.07L, provided that the forecastle height is not less than one half of standard height of superstructure between 0.07L and the forward perpendicular.

5.1.5

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 39(4, b))

Where the forecastle height is less than one half of the standard height of superstructure, the credited bow height may be determined as follows:

a) *Where the freeboard deck has sheer extending from abaft 0.15L, by a parabolic curve having its origin at 0.15L abaft the forward perpendicular at a height equal to the midship depth of the ship, extended through the point of intersection of forecastle bulkhead and deck, and up to a point at the forward perpendicular not higher than the level of the forecastle deck (as illustrated in Fig 1). However, if the value of the height denoted h_t in Fig 1 is smaller than the value of the height denoted h_b then h_t may be replaced by h_b in the available bow height, where:*

$$h_t = Z_b \left(\frac{0.15L}{x_b} \right)^2 - Z_t$$

Z_b : *As defined in Fig 1*

Z_t : *As defined in Fig 1*

h_f : *Half standard height of superstructure*

b) *Where the freeboard deck has sheer extending for less than 0.15L or has no sheer, by a line from the forecastle deck at side at 0.07L extended parallel to the base line to the forward perpendicular (as illustrated in Fig 2).*

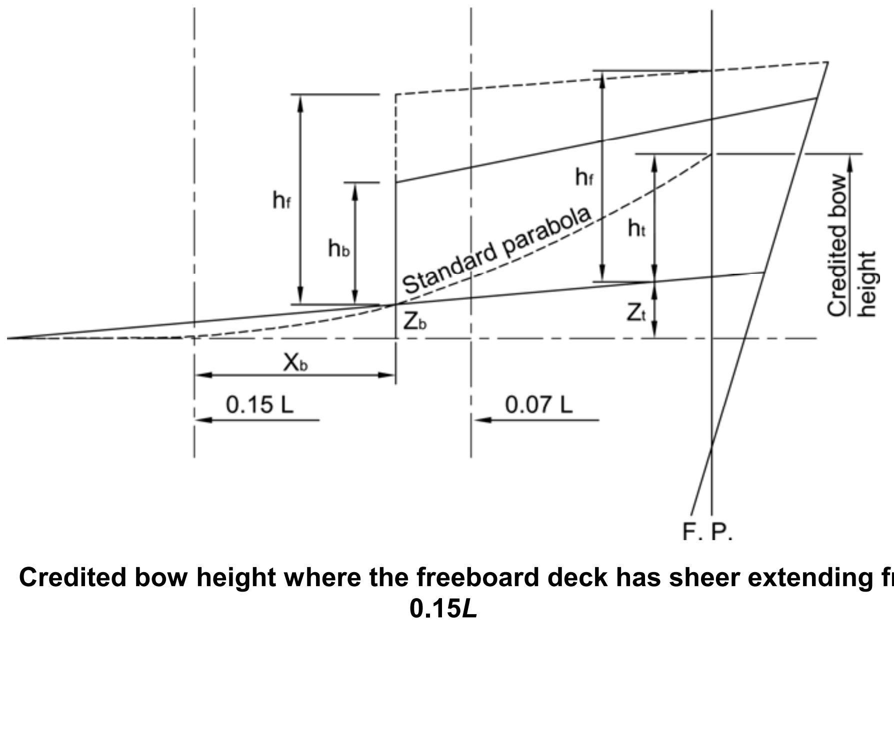

Figure 1: Credited bow height where the freeboard deck has sheer extending from abaft 0.15*L*

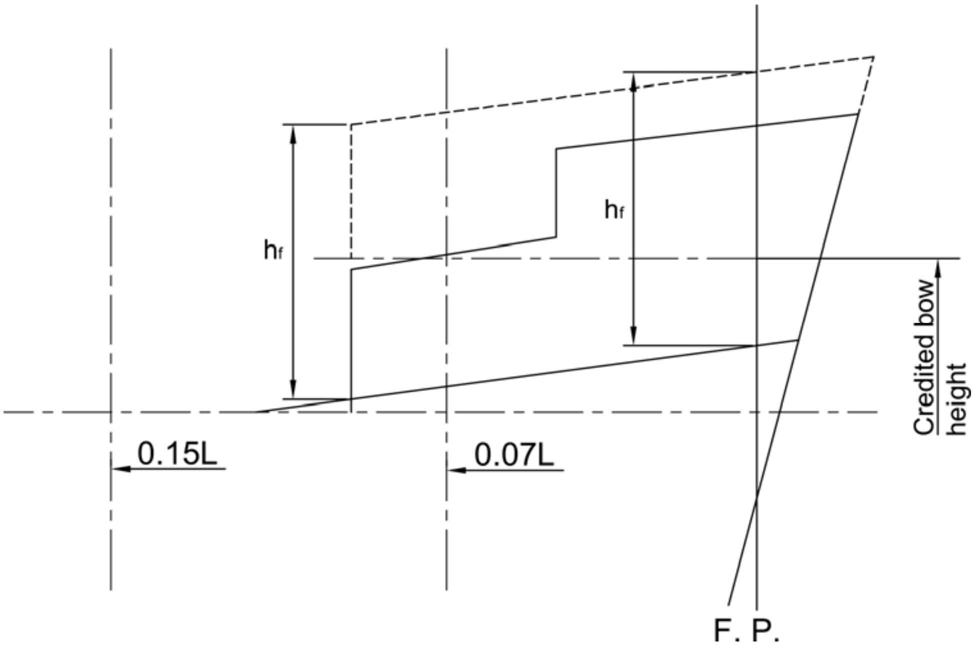

Figure 2: Credited bow height where the freeboard deck has sheer extending for less than 0.15*L*

6. Shaft tunnels

6.1 General

6.1.1

Shaft tunnels are to be watertight.

7. Watertight ventilators and trunks

7.1 General

7.1.1

Ref. SOLAS Ch. II-1, Part B, Reg. 19.1

Watertight ventilators and trunks are to be carried at least up to the freeboard deck.

8. Fuel oil tanks

8.1 General

8.1.1

Ref. SOLAS Ch. II-2, Part B, Reg. 4.2

The arrangements for the storage, distribution and utilisation of the fuel oil are to be such as to ensure the safety of the ship and persons on board.

8.1.2

Ref. SOLAS Ch. II-2, Part B, Reg. 4.2

As far as practicable, fuel oil tanks are to be part of the ship's structure and are to be located outside machinery spaces of category A.

Where fuel oil tanks, other than double bottom tanks, are necessarily located adjacent to or within machinery spaces of category A, at least one of their vertical sides is to be contiguous to the machinery space boundaries, they are preferably to have a common boundary with the double bottom tanks and the area of the tank boundary common with the machinery spaces is to be kept to a minimum.

Where such tanks are situated within the boundaries of machinery spaces of category A, they may not contain fuel oil having a flashpoint of less than 60°C.

8.1.3

Ref. SOLAS Ch. II-2, Part B, Reg. 4.2

Fuel oil tanks may not be located where spillage or leakage therefrom can constitute a hazard by falling on heated surfaces.

Precautions are to be taken to prevent any oil that may escape under pressure from any pump, filter or heater from coming into contact with heated surfaces.

Fuel oil tanks in boiler spaces may not be located immediately above the boilers or in areas subjected to high temperatures, unless special arrangements are provided in agreement with the Society.

8.1.4

Where a compartment intended for goods or coal is situated in proximity of a heated liquid container, suitable thermal insulation is to be provided.

Section 3 - ACCESS ARRANGEMENT

1. General

1.0 Application

1.0.1

This section applies to ships of 20,000 gross tonnage and over.

RCN 2 to July 2008 version (effective from 1 July 2010)

1.1 Means of access to cargo and other spaces

1.1.1

Ref. SOLAS Reg.II-1/3-6 .2.1 (Resolution MSC.151(78))

Each space is to be provided with means of access to enable, throughout the life of a ship, overall and close-up inspections and thickness measurements of the ship's structures. Such means of access are to comply with [1.3] and [2].

1.1.2

Ref. SOLAS Reg.II-1/3-6 .2.2 (Resolution MSC.151(78))

Where a permanent means of access may be susceptible to damage during normal cargo loading and unloading operations or where it is impracticable to fit permanent means of access, the Administration may allow, in lieu thereof, the provision of movable or portable means of access, as specified in [2], provided that the means of attaching, rigging, suspending or supporting the portable means of access forms a permanent part of the ship's structure. All portable equipment are to be capable of being readily erected or deployed by ship's personnel.

1.1.3

Ref. SOLAS Reg.II-1/3-6 .2.3 (Resolution MSC.151(78))

The construction and materials of all means of access and their attachment to the ship's structure are to be to the satisfaction of the Society.

1.2 Safe access to cargo holds, ballast tanks and other spaces

1.2.1

Ref. SOLAS Reg.II-1/3-6 .3.1 (Resolution MSC.151(78)) and IACS UI SC191

Safe access to cargo holds, cofferdams, ballast tanks and other spaces in the cargo area are to be direct from the open deck and such as to ensure their complete inspection. Safe access to double bottom spaces or to forward ballast tanks may be from a pump-room, deep cofferdam, pipe tunnel, cargo hold, double hull space or similar compartment not intended for the carriage of oil or hazardous cargoes.

Access to a double side skin space may be either from a topside tank or double bottom tank or from both.

1.2.2

Ref. SOLAS Reg.II-1/3-6 .3.2 (Resolution MSC.151(78))

Tanks, and subdivisions of tanks, having a length of 35 m or more, are to be fitted with at least two access hatchways and ladders, as far apart as practicable.

Tanks less than 35 m in length are to be served by at least one access hatchway and ladder.

When a tank is subdivided by one or more swash bulkheads or similar obstructions which do not allow ready means of access to the other parts of the tank, at least two hatchways and ladders are to be fitted.

1.2.3

Ref. SOLAS Reg.II-1/3-6 .3.3 (Resolution MSC.151(78))

Each cargo hold is to be provided with at least two means of access as far apart as practicable. In general, these accesses are to be arranged diagonally, for example one access near the forward bulkhead on the port side, the other one near the aft bulkhead on the starboard side.

1.3 General technical specifications

1.3.1

Ref. SOLAS Reg.II-1/3-6 .5.1 (Resolution MSC.151(78)) and IACS UI SC191

For access through horizontal openings, hatches or manholes, the dimensions are to be sufficient to allow a person wearing a self-contained air-breathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening is to be not less than 600 mm × 600 mm, with corner radii up to 100 mm maximum.

In such a case where as a consequence of structural analysis the stress is to be reduced around the opening, it is considered appropriate to take measures to increase the clear opening, e.g. 600 × 800 with 300 mm radii, in which a clear opening of 600 × 600 mm with corner radii up to 100 mm maximum fits.

When access to a cargo hold is arranged through the cargo hatch, the top of the ladder is to be placed as close as possible to the hatch coaming. Access hatch coamings having a height greater than 900 mm are also to have steps on the outside in conjunction with the ladder.

1.3.2

Ref. SOLAS Reg.II-1/3-6 .5.2 (Resolution MSC.151(78)) and IACS UI SC191

For access through vertical openings, or manholes, in swash bulkheads, floors, girders and web frames providing passage through the length and breadth of the space, the minimum opening is to be not less than 600 mm × 800 mm with corner radii of 300 mm *at a height of not more than 600 mm from the bottom shell plating unless gratings or other foot holds are provided.*

Subject to verification of easy evacuation of injured person on a stretcher the vertical opening 850 mm × 620 mm with wider upper half than 600 mm, while the lower half may be less than 600 mm with the overall height not less than 850 mm is considered acceptable alternative to the opening of 600 mm × 800 mm with corner radii of 300 mm (see Fig 1).

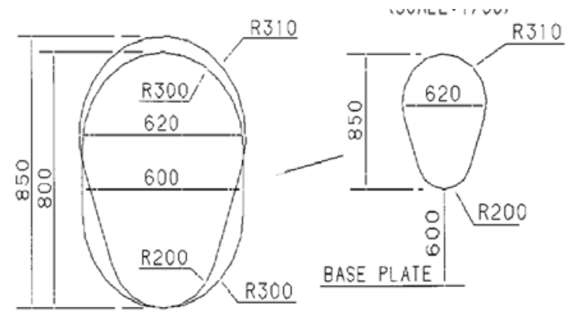

Figure 1: Alternative vertical opening

2. Technical provisions for means of access

2.1 Definitions

Ref. IMO Technical Provisions, 2 (Resolution MSC.158(78))

2.1.1 Rung

Rung means the step of vertical ladder or step on the vertical surface.

2.1.2 Tread

Tread means the step of inclined ladder, or step for the vertical access opening.

2.1.3 Flight of a ladder

Flight of an inclined ladder means the actual stringer length of an inclined ladder.

For vertical ladders, it is the distance between the platforms.

2.1.4 Stringer

Stringer means:

1) *the frame of a ladder; or*
2) *the stiffened horizontal plating structure fitted on side shell, transverse bulkheads and/or longitudinal bulkheads in the space. For the purpose of ballast tanks of less than 5 m width forming double side spaces, the horizontal plating structure is credited as a stringer and a longitudinal permanent means of access, if it provides a continuous passage of 600 mm or more in width past frames or stiffeners on the side shell or longitudinal bulkhead. Openings in stringer plating utilized as permanent means of access are to be arranged with guard rails or grid covers to provide safe passage on the stringer or safe access to each transverse web.*

2.1.5 Vertical ladder

Vertical ladder means a ladder of which the inclined angle is 70º and over up to 90º. Vertical ladder is to be not skewed by more than 2º.

2.1.6 Overhead obstructions

Overhead obstructions mean the deck or stringer structure including stiffeners above the means of access.

2.1.7 Distance below deck head

Distance below deck head means the distance below the plating.

2.1.8 Cross deck

Cross deck means the transverse area of main deck which is located inboard and between hatch coamings.

2.2 Permanent means of access

2.2.1

Ref. IMO Technical Provisions, 3.1 & 3.2 (Resolution MSC.158(78))

Structural members, except those in double bottom spaces, are to be provided with a permanent means of access to the extent as specified in [2.7] to [2.13].

Permanent means of access are, as far as possible, to be integral to the structure of the ships , thus ensuring that they are robust and at the same time contributing to the overall strength of the structure, of the ship.

2.2.2

Ref. IMO Technical Provisions, 3.3 (Resolution MSC.158(78)) and IACS UI SC191

Elevated passageways forming sections of a permanent means of access, where fitted, are to have a minimum clear width of 600 mm, except for going around vertical webs where the minimum clear width may be reduced to 450 mm, and to have guard rails over the open side of their entire length. For stand alone passageways guard rails are to be fitted on both sides of these structures.

Sloping structure providing part of the access and that are sloped by 5 or more degrees from horizontal plane when a ship is in upright position at even-keel, *is to be of a non-skid construction.*

Guard rails are to be 1000 mm in height and consist of a rail and intermediate bar 500 mm in height and of substantial construction. Stanchions are to be not more than 3 m apart.

2.2.3

Ref. IMO Technical Provisions, 3.4 (Resolution MSC.158(78))

Access to permanent means of access and vertical openings from the ship's bottom are to be provided by means of easily accessible passageways, ladders or treads. Treads are to be provided with lateral support for the foot. Where the rungs of ladders are fitted against a vertical surface, the distance from the centre of the rungs to the surface is to be at least 150 mm. Where vertical manholes are fitted higher than 600 mm above the walking level, access is to be facilitated by means of treads and hand grips with platform landings on both sides.

2.3 Construction of ladders

2.3.1 General

Ref. IMO Technical Provisions, 3.5 (Resolution MSC.158(78))

Permanent inclined ladders are to be inclined at an angle of less than 70º. There are to have no obstructions within 750 mm of the face of the inclined ladder, except that in way of an opening this clearance may be reduced to 600 mm. Resting platforms of adequate dimensions are normally to be provided at a maximum of 6 m vertical height. Ladders and handrails are to be constructed of steel or equivalent material of adequate strength and stiffness and securely attached to the tank structure by stays. The method of support and length of stay is to be such

that vibration is reduced to a practical minimum. In cargo holds, ladders are to be designed and arranged so that cargo handling difficulties are not increased and the risk of damage from cargo handling gear is minimized.

2.3.2 Inclined ladders

Ref. IMO Technical Provisions, 3.6 (Resolution MSC.158(78))

The width of inclined ladders between stringers is to be not less than 400 mm. The treads are to be equally spaced at a distance apart, measured vertically, of between 200 mm and 300 mm. When steel is used, the treads are to be formed of two square bars of not less than 22 mm by 22 mm in section, fitted to form a horizontal step with the edges pointing upward. The treads are to be carried through the side stringers and attached thereto by double continuous welding. All inclined ladders are to be provided with handrails of substantial construction on both sides, fitted at a convenient distance above the treads.

2.3.3 Vertical or spiral ladders

Ref. IMO Technical Provisions, 3.7 (Resolution MSC.158(78))

For vertical ladders or spiral ladders, the width and construction are to be in accordance with international or national standards.

2.4 Access through openings

2.4.1 Access through horizontal openings, hatches or manholes

Ref. IMO Technical Provisions, 3.10 (Resolution MSC.158(78))

For access through horizontal openings, hatches or manholes, the minimum clear opening is to be not less than 600 mm × 600 mm. When access to a cargo hold is arranged through the cargo hatch, the top of the ladder is to be placed as close as possible to the hatch coaming.

Access hatch coamings having a height greater than 900 mm are also to have steps on the outside in conjunction with the ladder.

2.4.2 Access through vertical openings, or manholes

Ref. IMO Technical Provisions, 3.11 (Resolution MSC.158(78))

For access through vertical openings, or manholes, in swash bulkheads, floors, girders and web frames providing passage through the length and breadth of the space, the minimum opening is to be not less than 600 mm × 800 mm at a height of not more than 600 mm from the passage unless gratings or other foot holds are provided.

2.5 Access ladders to cargo holds and other spaces

2.5.1 General

Ref. IMO Technical Provisions, 3.13.1 & 3.13.2 (Resolution MSC.158(78))

Access ladders to cargo holds and other spaces are to be:

a) where the vertical distance between the upper surface of adjacent decks or between deck and the bottom of the cargo space is not more than 6 m, either a vertical ladder or an inclined ladder.

b) where the vertical distance between the upper surface of adjacent decks or between deck and the bottom of the cargo space is more than 6 m, an inclined ladder or series of inclined ladders at one end of the cargo hold, except the uppermost 2.5 m of a cargo space measured clear of overhead obstructions and the lowest 6 m may

have vertical ladders, provided that the vertical extent of the inclined ladder or ladders connecting the vertical ladders is not less than 2.5 m.

2.5.2

Ref. IMO Technical Provisions, 3.13.2 (Resolution MSC.158(78))

The second means of access at the other end of the cargo hold may be formed of a series of staggered vertical ladders, which have to comprise one or more ladder linking platforms spaced not more than 6 m apart vertically and displaced to one side of the ladder. Adjacent sections of ladder are to be laterally offset from each other by at least the width of the ladder. The uppermost, entrance section, of the ladder directly exposed to a cargo hold is to be vertical for a distance of 2.5 m measured clear of overhead obstructions and connected to a ladder-linking platform.

2.5.3

Ref. IMO Technical Provisions, 3.13.3 (Resolution MSC.158(78))

A vertical ladder may be used as a means of access to topside tanks, where the vertical distance is 6 m or less between the deck and the longitudinal means of access in the tank or the stringer or the bottom of the space immediately below the entrance. The uppermost, entrance section from deck, of the vertical ladder of the tank is to be vertical for a distance of 2.5 m measured clear of the overhead obstructions and comprises a ladder linking platform unless landing on the longitudinal means of access, the stringer or the bottom within the vertical distance, it should be displaced to one side of a vertical ladder.

2.5.4

Ref. IMO Technical Provisions, 3.13.4 (Resolution MSC.158(78))

Unless allowed in [2.5.3], an inclined ladder or combination of ladders are to be used for access to a tank or a space where the vertical distance is greater than 6 m between the deck and a stringer immediately below the entrance, between stringers, or between the deck or a stringer and the bottom of the space immediately below the entrance.

2.5.5

Ref. IMO Technical Provisions, 3.13.5 (Resolution MSC.158(78))

In case of [2.5.4], the uppermost, entrance section from deck, of the ladder is to be vertical for a distance of 2.5 m clear of the overhead obstructions and connected to a landing platform and continued with an inclined ladder. The flights of inclined ladders are to be not more than 9 m in actual length and the vertical height is normally to be not more than 6 m. The lowermost section of the ladders may be vertical for a vertical distance of not less than 2.5 m.

2.5.6

Ref. IMO Technical Provisions, 3.13.6 (Resolution MSC.158(78))

In double side skin spaces of less than 2.5 m width, the access to the space may be by means of vertical ladders that comprises one or more ladder linking platforms spaced not more than 6 m apart vertically and displace to one side of the ladder.

Adjacent sections of ladder are to be laterally offset from each other by at least the width of the ladder.

2.5.7

Ref. IMO Technical Provisions, 3.13.7 (Resolution MSC.158(78))

A spiral ladder is considered acceptable as an alternative for inclined ladders. In this regard, the uppermost 2.5 m can continue to be comprised of the spiral ladder and need not change over to vertical ladders.

2.6 Access ladders to tanks

2.6.1

Ref. IMO Technical Provisions, 3.14 (Resolution MSC.158(78))

The uppermost, entrance section from deck, of the vertical ladder providing access to a tank should be vertical for a distance of 2.5 m measured clear of the overhead obstructions and comprises a ladder linking platform. It should be displaced to one side of a vertical ladder. The vertical ladder can be between 1.6 m and 3 m below deck structure if it lands on a longitudinal or athwartship permanent means of access fitted within that range.

2.7 Access to underdeck structure of cargo holds

2.7.1

Ref. IMO Technical Provisions, Tab 2, 1.1 (Resolution MSC.158(78))

Permanent means of access are to be fitted to provide access to the overhead structure at both sides of the cross deck and in the vicinity of the centerline.

Each means of access is to be accessible from the cargo hold access or directly from the main deck and installed at a minimum of 1.6 m to a maximum of 3 m below the deck.

2.7.2

Ref. IMO Technical Provisions, Tab 2, 1.2 (Resolution MSC.158(78))

An athwartship permanent means of access fitted on the transverse bulkhead at a minimum 1.6 m to a maximum 3 m below the cross-deck head is accepted as equivalent to [2.7.1].

2.7.3

Ref. IMO Technical Provisions, Tab 2, 1.3 (Resolution MSC.158(78))

Access to the permanent means of access to overhead structure of the cross deck may also be via the upper stool.

2.7.4

Ref. IMO Technical Provisions, Tab 2, 1.4 (Resolution MSC.158(78)) and IACS UI SC191

Ships having transverse bulkheads with full upper stools, i.e. stools with a full extension between top side tanks and between hatch end beams, *with access from the main deck which allows monitoring of all framing and plates from inside, do not require permanent means of access of the cross deck.*

2.7.5

Ref. IMO Technical Provisions, Tab 2, 1.5 (Resolution MSC.158(78))

Alternatively, movable means of access may be utilized for access to the overhead structure of cross deck if its vertical distance is 17 m or less above the tank top.

2.8 Access to double side skin tanks of double side skin construction

RCN 1 to July 2010 version (effective from 1July 2012)

2.8.1

Ref. IMO Technical Provisions, Tab 2, 2.8 & Tab 1, 2.1 (Resolution MSC.158(78))

For double side spaces above the upper knuckle point of the bilge hopper sections, permanent means of access are to be provided in accordance with the following requirements:

a) where the vertical distance between horizontal uppermost stringer and deck head is 6 m or more, one continuous longitudinal permanent means of access is to be provided for the full length of the tank with a means to allow passing through transverse webs installed at a minimum of 1.6 m to a maximum of 3 m below the deck head with a vertical access ladder at each end of the tank;

b) continuous longitudinal permanent means of access, which are integrated in the structure, at a vertical distance not exceeding 6 m apart; and

c) plated stringers are to be, as far as possible, in alignment with horizontal girders of transverse bulkheads.

2.9 Access to vertical structures of cargo holds of single side skin construction

RCN 1 to July 2010 version (effective from 1July 2012)

2.9.1

Ref. IMO Technical Provisions, Tab 2, 1.6 (Resolution MSC.158(78))

Permanent means of vertical access are to be provided in all cargo holds and built into the structure to allow for an inspection of a minimum of 25 % of the total number of hold frames port and starboard equally distributed throughout the hold including at each end in way of transverse bulkheads. But in no circumstance is this arrangement to be less than 3 permanent means of vertical access fitted to each side (fore and aft ends of hold and mid-span).

Permanent means of vertical access fitted between two adjacent hold frames is counted for an access for the inspection of both hold frames. A means of portable access may be used to gain access over the sloping plating of lower hopper ballast tanks.

2.9.2

Ref. IMO Technical Provisions, Tab 2, 1.7 (Resolution MSC.158(78))

In addition, portable or movable means of access are to be utilized for access to the remaining hold frames up to their upper brackets and transverse bulkheads.

2.9.3

Ref. IMO Technical Provisions, Tab 2, 1.8 (Resolution MSC.158(78))

Portable or movable means of access may be utilized for access to hold frames up to their upper bracket in place of the permanent means required in [2.9.1]. These means of access are to be carried on board the ship and readily available for use.

2.9.4

Ref. IMO Technical Provisions, Tab 2, 1.9 (Resolution MSC.158(78))

The width of vertical ladders for access to hold frames is to be at least 300 mm, measured between stringers.

2.9.5

Ref. IMO Technical Provisions, Tab 2, 1.10 (Resolution MSC.158(78))

A single vertical ladder over 6 m in length is acceptable for the inspection of the hold side frames in a single skin construction.

2.10 Access to vertical structures of cargo holds of double side skin construction

RCN 1 to July 2010 version (effective from 1July 2012)

2.10.1

Ref. IMO Technical Provisions, Tab 2, 1.11 (Resolution MSC.158(78))

For double side skin construction no vertical ladders for the inspection of the cargo hold surfaces are required. Inspection of this structure should be provided from within the double hull space.

2.11 Access to top side ballast tanks

RCN 1 to July 2010 version (effective from 1July 2012)

2.11.1

Ref. IMO Technical Provisions, Tab 2, 2.1 (Resolution MSC.158(78))

For each topside tank of which the height is 6 m and over, one longitudinal continuous permanent means of access is to be provided along the side shell webs and installed at a minimum of 1.6 m to a maximum of 3 m below deck with a vertical access ladder in the vicinity of each access to that tank.

2.11.2

Ref. IMO Technical Provisions, Tab 2, 2.2 (Resolution MSC.158(78))

If no access holes are provided through the transverse webs within 600 mm of the tank base and the web frame rings have a web height greater than 1 m in way of side shell and sloping plating, then step rungs/grab rails are to be provided to allow safe access over each transverse web frame ring.

2.11.3

Ref. IMO Technical Provisions, Tab 2, 2.3 (Resolution MSC.158(78))

Three permanent means of access, fitted at the end bay and middle bay of each tank, are to be provided spanning from tank base up to the intersection of the sloping plate with the hatch side girder. The existing longitudinal structure, if fitted on the sloping plate in the space may be used as part of this means of access.

2.11.4

Ref. IMO Technical Provisions, Tab 2, 2.4 (Resolution MSC.158(78))

For topside tanks of which the height is less than 6 m, alternative or a portable means may be utilized in lieu of the permanent means of access.

2.12 Access to bilge hopper ballast tanks

2.12.1

Ref. IMO Technical Provisions, Tab 2, 2.5 (Resolution MSC.158(78)) and IACS UI SC191

For each bilge hopper tank of which the height is 6 m and over, one longitudinal continuous permanent means of access is to be provided along the side shell webs and installed at a minimum of 1.2 m below the top of the clear opening of the web ring with a vertical access ladder in the vicinity of each access to the tank.

An access ladder between the longitudinal continuous permanent means of access and the bottom of the space is to be provided at each end of the tank.

Alternatively, the longitudinal continuous permanent means of access can be located through the upper web plating above the clear opening of the web ring, at a minimum of 1.6 m below the deck head, when this arrangement facilitates more suitable inspection of identified structurally critical areas. An enlarged longitudinal frame, of at least 600 mm clear width *can be used for the purpose of the walkway.*

For double side skin bulk carriers the longitudinal continuous permanent means of access may be installed within 6 m from the knuckle point of the bilge, if used in combination with alternative methods to gain access to the knuckle point.

2.12.2

Ref. IMO Technical Provisions, Tab 2, 2.6 (to Resolution MSC.158(78))

If no access holes are provided through the transverse ring webs within 600 mm of the tank base and the web frame rings have a web height greater than 1 m in way of side shell and sloping plating, then step rungs/grab rails are to be provided to allow safe access over each transverse web frame ring.

2.12.3

Ref. IMO Technical Provisions, Tab 2, 2.7 (Resolution MSC.158(78))

For bilge hopper tanks of which the height is less than 6 m, alternative or a portable means may be utilized in lieu of the permanent means of access. Such means of access are to be demonstrated that they can be deployed and made readily available in the areas where needed.

2.13 Access to fore peak tanks

2.13.1

Ref. IMO Technical Provisions, Tab 2, 2.9 (Resolution MSC.158(78))

For fore peak tanks with a depth of 6 m or more at the centreline of the collision bulkhead, a suitable means of access is to be provided for access to critical areas such as the underdeck structure, stringers, collision bulkhead and side shell structure.

2.13.2

Ref. IMO Technical Provisions, Tab 2, 2.9.1 (Resolution MSC.158(78))

Stringers of less than 6 m in vertical distance from the deck head or a stringer immediately above are considered to provide suitable access in combination with portable means of access.

2.13.3

Ref. IMO Technical Provisions, Tab 2, 2.9.2 (Resolution MSC.158(78))

In case the vertical distance between the deck head and stringers, stringers or the lowest stringer and the tank bottom is 6 m or more, alternative means of access are to be provided.

3. Shaft tunnels

3.1 General

3.1.1

Tunnels are to be large enough to ensure easy access to shafting.

3.1.2

Access to the tunnel is to be provided by a watertight door fitted on the aft bulkhead of the engine room in compliance with Ch 2, Sec 1, [6], and an escape trunk which can also act as watertight ventilator is to be fitted up to the subdivision deck, for tunnels greater than 7 m in length.

4. Access to steering gear compartment

4.1 General

4.1.1

The steering gear compartment is to be readily accessible and, as far as practicable, separated from machinery spaces.

4.1.2

Suitable arrangements to ensure working access to steering gear machinery and controls are to be provided.

These arrangements are to include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

Chapter 3

Structural Design Principles

Section 1 – MATERIAL

1. General

1.1 Standard of material

1.1.1

The requirements in this Section are intended for ships of welded construction using steels having characteristics complying with the Society Rules for Materials.

1.1.2

Materials with different characteristics may be accepted, provided their specification (manufacture, chemical composition, mechanical properties, welding, etc.) is submitted to the Society for approval.

1.2 Testing of materials

1.2.1

Materials are to be tested in compliance with the applicable requirements of Society Rules for Materials.

1.3 Manufacturing processes

1.3.1

The requirements of this Section presume that welding and other cold or hot manufacturing processes are carried out in compliance with current sound working practice defined in IACS UR W and the applicable requirements of Society Rules for Materials. In particular:

- parent material and welding processes are to be within the limits stated for the specified type of material for which they are intended
- specific preheating may be required before welding
- welding or other cold or hot manufacturing processes may need to be followed by an adequate heat treatment.

2. Hull structural steel

2.1 General

2.1.1

Tab 1 gives the mechanical characteristics of steels currently used in the construction of ships.

Table 1: Mechanical properties of hull steels

Steel grades for plates with $t \leq 100$ mm	Minimum yield stress R_{eH} , in N/mm^2	Ultimate tensile strength R_m , in N/mm^2
A-B-D-E	235	400 – 520
*AH*32-*DH*32-*EH*32-*FH*32	315	440 – 570
*AH*36-*DH*36-*EH*36-*FH*36	355	490 – 630
*AH*40-*DH*40-*EH*40-*FH*40	390	510 – 660

2.1.2

Where higher strength steels are to be used for hull construction, the drawings showing the scope and locations of the used place together with the type and scantlings are to be submitted for the approval of the Society.

2.1.3

Higher strength steels other than those indicated in Tab 1 are considered by the Society on a case by case basis.

2.1.4

When steels with a minimum guaranteed yield stress R_{eH} other than 235 N/mm^2 are used on a ship, hull scantlings are to be determined by taking into account the material factor k defined in [2.2].

2.1.5

It is required to keep on board a plan indicating the steel types and grades adopted for the hull structures. Where steels other than those indicated in Tab 1 are used, their mechanical and chemical properties, as well as any workmanship requirements or recommendations, are to be available on board together with the above plan.

2.2 Material factor *k*

2.2.1

Unless otherwise specified, the material factor k of normal and higher strength steel for scantling purposes is to be taken as defined in Tab 2, as a function of the minimum yield stress R_{eH}.

For intermediate values of R_{eH}, k may be obtained by linear interpolation.

Steels with a yield stress greater than 390 N/mm^2 are considered by the Society on a case by case basis.

Table 2: Material factor *k*

Minimum yield stress R_{eH} , in N/mm^2	k
235	1.0
315	0.78
355	0.72
390	0.68

2.3 Grades of steel

2.3.1

Steel materials in the various strength members are not to be of lower grade than those corresponding to classes I, II and III, as given in Tab 3 for the material classes and grades given in Tab 4-1, while additional requirements for ships with length (L) exceeding 150m and 250m, BC-A and BC-B ships are given in Tab 4-2 to Tab 4-4.

For strength members not mentioned in Tab 4-1 to Tab 4-4, grade *A/AH* may be used.

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Table 3: Material grade requirements for classes I, II and III

Class	I		II		III	
As-built thickness (mm)	NSS	HSS	NSS	HSS	NSS	HSS
$t \leq 15$	*A*	*AH*	*A*	*AH*	*A*	*AH*
$15 < t \leq 20$	*A*	*AH*	*A*	*AH*	*B*	*AH*
$20 < t \leq 25$	*A*	*AH*	*B*	*AH*	*D*	*DH*
$25 < t \leq 30$	*A*	*AH*	*D*	*DH*	*D*	*DH*
$30 < t \leq 35$	*B*	*AH*	*D*	*DH*	*E*	*EH*
$35 < t \leq 40$	*B*	*AH*	*D*	*DH*	*E*	*EH*
$40 < t \leq 50$	*D*	*DH*	*E*	*EH*	*E*	*EH*
Notes : NSS : Normal strength steel HSS : Higher strength steel						

Table 4: (void)

RCN 2 to July 2008 version (effective from 1 July 2010)

Table 4-1: Material Classes and Grades for ships in general

Structural member category	Material class/grade
SECONDARY: A1 Longitudinal bulkhead strakes, other than that belonging to the Primary category A2 Deck plating exposed to weather, other than that belonging to the Primary or Special category A3 Side plating	- Class I within 0.4*L* amidships - Grade *A/AH* outside 0.4*L* amidships
PRIMARY: B1 Bottom plating, including keel plate B2 Strength deck plating, excluding that belonging to the Special category B3 Continuous longitudinal members above strength deck, excluding hatch coamings. B4 Uppermost strake in longitudinal bulkhead B5 Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank	- Class II within 0.4*L* amidships - Grade *A/AH* outside 0.4*L* amidships
SPECIAL: C1. Sheer strake at strength deck (1) C2 Stringer plate in strength deck (1) C3 Deck strake at longitudinal bulkhead, excluding deck plating in way of inner-skin bulkhead of double-hull ships (1)	- Class III within 0.4*L* amidships - Class II outside 0.4*L* amidships - Class I outside 0.6*L* amidships
C5 Strength deck plating at corners of cargo hatch openings	- Class III within 0.6*L* amidships - Class II within rest of cargo region
C6 Bilge strake in ships with double bottom over the full breadth and length less than 150 m (1)	- Class II within 0.6*L* amidships - Class I outside 0.6*L* amidships
C7 Bilge strake in other ships (1)	- Class III within 0.4*L* amidships - Class II outside 0.4*L* amidships - Class I outside 0.6*L* amidships
C8 Longitudinal hatch coamings of length greater than 0.15*L* C9 End brackets and deck house transition of longitudinal cargo hatch coamings (2)	- Class III within 0.4*L* amidships - Class II outside 0.4*L* amidships - Class I outside 0.6*L* amidships - Not to be less than Grade *D/DH*
(1) Single strakes required to be of Class III within 0.4*L* amidships are to have breadths not less than 800+5*L* (mm), and need not be greater than 1800 (mm), unless limited by the geometry of the ship's design. (2) Applicable to bulk carriers having the longitudinal hatch coaming of length greater than 0.15*L*.	

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Table 4-2: Minimum material grades for ships with ship's length (*L*) exceeding 150m and single strength deck

Structural member category	Material Grade
Longitudinal strength members of strength deck plating	Grade *B/AH* within 0.4*L* amidships
Continuous longitudinal strength members above strength deck	Grade *B/AH* within 0.4*L* amidships
Single side strakes for ships without inner continuous longitudinal bulkheads between bottom and the strength deck	Grade *B/AH* within cargo region

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Table 4-3: Minimum Material Grades for ships with ship's length (*L*) exceeding 250m

Structural member category	Material Grade
Shear strake at strength deck (1)	Grade *E/EH* within 0.4*L* amidships
Stringer plate in strength deck (1)	Grade *E/EH* within 0.4*L* amidships
Bilge strake (1)	Grade *D/DH* within 0.4*L* amidships
(1) Single strakes required to be of Class III within 0.4*L* amidships are to have breadths not less than 800 + 5*L* (mm), and need not be greater than 1800 (mm), unless limited by the geometry of the ship's design	

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Table 4-4: Minimum material grades for BC-A and BC-B ships

Structural member category	Material Grade
Lower bracket of ordinary side frame(1), (2)	Grade *D/DH*
Side shell strakes included totally or partially between the two points located to 0.125 *l* above and below the intersection of side shell and bilge hopper sloping plate or inner bottom plate (2)	Grade *D/DH*
(1) The term "lower bracket" means webs of lower brackets and webs of the lower part of side frames up to the point 0.125 *l* above the intersection of side shell and bilge hopper sloping plate or inner bottom plate. (2) The span of the side frame, *l*, is defined as the distance between the supporting structure (See Ch. 3 Sec 6 Fig.19)	

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2.3.2

Plating materials for stern frames, rudders, rudder horns and shaft brackets are in general not to be of lower grades than corresponding to class II. For rudder and rudder body plates subjected to stress concentrations (e.g. in way of lower support of semi-spade rudders or at upper part of spade rudders) class III is to be applied.

2.3.3

Bedplates of seats for propulsion and auxiliary engines inserted in the inner bottom within 0.6*L* amidships are to be of class I. In other cases, the steel is to be at least of grade *A/AH*.

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2.3.4

(void)

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2.3.5

The steel grade is to correspond to the as-built thickness.

2.3.6

Steel grades of plates or sections of as-built thickness greater than the limiting thicknesses in Tab 3 are considered by the Society on a case by case basis.

2.3.7

In specific cases, such as [2.3.8], with regard to stress distribution along the hull girder, the classes required within 0.4L amidships may be extended beyond that zone, on a case by case basis.

2.3.8

The material classes required for the strength deck plating, the sheerstrake and the upper strake of longitudinal bulkheads within 0.4L amidships are to be maintained for an adequate length across the poop front and at the ends of the bridge, where fitted.

2.3.9

Rolled products used for welded attachments of length greater than 0.15L on outside of hull plating, such as gutter bars, are to be of the same grade as that used for the hull plating in way.

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2.3.10

In the case of full penetration welded joints located in positions where high local stresses may occur perpendicular to the continuous plating, the Society may, on a case by case basis, require the use of rolled products having adequate ductility properties in the through thickness direction, such as to prevent the risk of lamellar tearing (Z type steel).

2.3.11

(void)

2.4 Structures exposed to low air temperature

2.4.1

The application of steels for ships designed to operate in area with low air temperatures is to comply with [2.4.2] to [2.4.6].

2.4.2

For ships intended to operate in areas with low air temperatures (below and including –20 °C), e.g. regular service during winter seasons to Arctic or Antarctic waters, the materials in exposed structures are to be selected based on the design temperature t_D , to be taken as defined in [2.4.3].

2.4.3

The design temperature t_D is to be taken as the lowest mean daily average air temperature in the area of operation, where:

Mean : Statistical mean over observation period (at least 20 years).

Average : Average during one day and night.

Lowest : Lowest during year.

Fig 1 illustrates the temperature definition for Arctic waters.

For seasonally restricted service the lowest value within the period of operation applies.

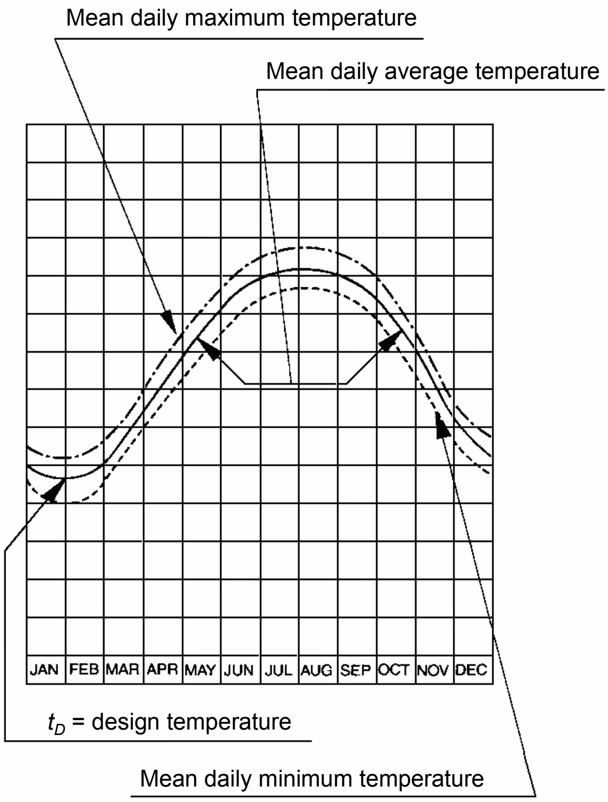


Figure 1: Commonly used definitions of temperatures

2.4.4

Materials in the various strength members above the lowest ballast water line (BWL) exposed to air are not to be of lower grades than those corresponding to classes I, II and III as given in Tab 5 depending on the categories of structural members (SECONDARY, PRIMARY and SPECIAL).

For non-exposed structures and structures below the lowest ballast water line, see [2.3]

2.4.5

The material grade requirements for hull members of each class depending on thickness and design temperature are defined in Tab 6, Tab 7 and Tab 8. For design temperatures $t_D < -55$ °C, materials are to be specially considered by the Society.

2.4.6

Single strakes required to be of class III or of grade *E /EH* and *FH* are to have breadths not less than the values, in m, given by the following formula, but need not to be greater than 1.8 m:

$b = 0.005L + 0.8$

Table 5: Application of material classes and grades - Structures exposed at low temperature

Structural member category	Material class	
	Within 0.4*L* amidship	**Outside 0.4*L* amidship**
SECONDARY		
Deck plating exposed to weather, in general	I	I
Side plating above BWL		
Transverse bulkheads above BWL		
PRIMARY		
Strength deck plating (1)	II	I
Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings		
Longitudinal bulkhead above BWL		
Top wing tank bulkhead above BWL		
SPECIAL		
Sheer strake at strength deck (2)	III	II
Stringer plate in strength deck (2)		
Deck strake at longitudinal bulkhead (3)		
Continuous longitudinal hatch coamings (4)		

Notes:

(1) Plating at corners of large hatch openings to be specially considered. Class III or grade *E/EH* to be applied in positions where high local stresses may occur.

(2) Not to be less than grade *E/EH* within 0.4*L* amidships in ships with length exceeding 250 m.

(3) In ships with a breadth exceeding 70 m at least three deck strakes to be class III.

(4) Not to be less than grade *D/DH*.

Table 6: Material grade requirements for class I at low temperature

As-built thickness (mm)	-20 / -25 °C		-26 / -35 °C		-36 / -45 °C		-45 / -55 °C	
	NSS	**HSS**	**NSS**	**HSS**	**NSS**	**HSS**	**NSS**	**HSS**
$t \leq 10$	*A*	*AH*	*B*	*AH*	*D*	*DH*	*D*	*DH*
$10 < t \leq 15$	*B*	*AH*	*D*	*DH*	*D*	*DH*	*D*	*DH*
$15 < t \leq 20$	*B*	*AH*	*D*	*DH*	*D*	*DH*	*E*	*EH*
$20 < t \leq 25$	*D*	*DH*	*D*	*DH*	*D*	*DH*	*E*	*EH*
$25 < t \leq 30$	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*
$30 < t \leq 35$	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*
$35 < t \leq 45$	*D*	*DH*	*E*	*EH*	*E*	*EH*	-	*FH*
$45 < t \leq 50$	*E*	*EH*	*E*	*EH*	-	*FH*	-	*FH*

Note: ”NSS” and “HSS” mean, respectively “Normal Strength Steel” and “Higher Strength Steel”

Table 7: Material grade requirements for class II at low temperature

As-built thickness (mm)	-20 / -25 °C		-26 / -35 °C		-36 / -45 °C		-45 / -55 °C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
$t \leq 10$	*B*	*AH*	*D*	*DH*	*D*	*DH*	*E*	*EH*
$10 < t \leq 20$	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*
$20 < t \leq 30$	*D*	*DH*	*E*	*EH*	*E*	*EH*	-	*FH*
$30 < t \leq 40$	*E*	*EH*	*E*	*EH*	-	*FH*	-	*FH*
$40 < t \leq 45$	*E*	*EH*	-	*FH*	-	*FH*	-	-
$45 < t \leq 50$	*E*	*EH*	-	*FH*	-	*FH*	-	-
Note: ”NSS” and “HSS” mean, respectively “Normal Strength Steel” and “Higher Strength Steel”								

Table 8: Material grade requirements for class III at low temperature

As-built thickness (mm)	-20 / -25 °C		-26 / -35 °C		-36 / -45 °C		-45 / -55 °C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
$t \leq 10$	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*
$10 < t \leq 20$	*D*	*DH*	*E*	*EH*	*E*	*EH*	-	*FH*
$20 < t \leq 25$	*E*	*EH*	*E*	*EH*	-	*FH*	-	*FH*
$25 < t \leq 30$	*E*	*EH*	*E*	*EH*	-	*FH*	-	*FH*
$30 < t \leq 40$	*E*	*EH*	-	*FH*	-	*FH*	-	-
$40 < t \leq 45$	*E*	*EH*	-	*FH*	-	*FH*	-	-
$45 < t \leq 50$	-	*FH*	-	*FH*	-	-	-	-
Note: ”NSS” and “HSS” mean, respectively “Normal Strength Steel” and “Higher Strength Steel”								

3. Steels for forging and casting

3.1 General

3.1.1

Mechanical and chemical properties of steels for forging and casting to be used for structural members are to comply with the applicable requirements of the Society Rules for Materials.

3.1.2

Steels of structural members intended to be welded are to have mechanical and chemical properties deemed appropriate for this purpose by the Society on a case by case basis.

3.1.3

The steels used are to be tested in accordance with the applicable requirements of the Society Rules for Materials.

3.2 Steels for forging

3.2.1

Rolled bars may be accepted in lieu of forged products, after consideration by the Society on a case by case basis.

In such case, compliance with the applicable requirements of the Society Rules for Materials, relevant to the quality and testing of rolled parts accepted in lieu of forged parts, may be required.

3.3 Steels for casting

3.3.1

Cast parts intended for stems, sternframes, rudders, parts of steering gear and deck machinery in general may be made of C and C-Mn weldable steels, having specified minimum tensile strength R_m = 400 N/mm^2 or 440 N/mm^2, in accordance with the applicable requirements of the Society Rules for Materials.

3.3.2

The welding of cast parts to main plating contributing to hull strength members is considered by the Society on a case by case basis.

The Society may require additional properties and tests for such casting, in particular impact properties which are appropriate to those of the steel plating on which the cast parts are to be welded and non-destructive examinations.

3.3.3

Heavily stressed cast parts of steering gear, particularly those intended to form a welded assembly and tillers or rotors mounted without key, are to be subjected to surface and volumetric non-destructive examination to check their internal structure.

4. Aluminium alloy structures

4.1 General

4.1.1

The characteristics of aluminium alloys are to comply with the requirements of the Society Rules for Materials.

Series 5000 aluminium-magnesium alloys or series 6000 aluminium-magnesium-silicon alloys are to be used.

4.1.2

In the case of structures subjected to low service temperatures or intended for other specific applications, the alloys to be employed are to be agreed by the Society.

4.1.3

Unless otherwise agreed, the Young's modulus for aluminium alloys is equal to 70000 N/mm^2 and the Poisson's ratio equal to 0.33.

4.2 Extruded plating

4.2.1

Extrusions with built-in plating and stiffeners, referred to as extruded plating, may be used.

4.2.2
In general, the application is limited to decks, bulkheads, superstructures and deckhouses. Other uses may be permitted by the Society on a case by case basis.

4.2.3
Extruded plating is to be oriented so that the stiffeners are parallel to the direction of main stresses.

4.2.4
Connections between extruded plating and primary members are to be given special attention.

4.3 Mechanical properties of weld joints

4.3.1
Welding heat input lowers locally the mechanical strength of aluminium alloys hardened by work hardening (series 5000 other than condition O or H111) or by heat treatment (series 6000).

4.3.2
The as-welded properties of aluminium alloys of series 5000 are in general those of condition O or H111.
Higher mechanical characteristics may be taken into account, provided they are duly justified.

4.3.3
The as-welded properties of aluminium alloys of series 6000 are to be agreed by the Society.

4.4 Material factor *k*

4.4.1
The material factor *k* for aluminium alloys is to be obtained from the following formula:

$$k = \frac{235}{R'_{\lim}}$$

where:

$R'_{\lim}$: Minimum guaranteed yield stress of the parent metal in welded condition $R'_{p0.2}$, in N/mm^2, but not to be taken greater than 70% of the minimum guaranteed tensile strength of the parent metal in welded condition R'_m, in N/mm^2

$$R'_{p0.2} = \eta_1 R_{p0.2}$$

$$R'_m = \eta_2 R_m$$

$R_{p0.2}$: Minimum guaranteed yield stress, in N/mm^2, of the parent metal in delivery condition

R_m : Minimum guaranteed tensile strength, in N/mm^2, of the parent metal in delivery condition

η_1 , η_2 : Specified in Tab 9.

4.4.2
In the case of welding of two different aluminium alloys, the material factor *k* to be considered for the scantlings is the greater material factor of the aluminium alloys of the assembly.

Table 9: Aluminium alloys for welded construction

Aluminium alloy	η_1	η_2
Alloys without work-hardening treatment (series 5000 in annealed condition O or annealed flattened condition H111)	1	1
Alloys hardened by work hardening (series 5000 other than condition O or H111)	$R'_{p0.2} / R_{p0.2}$	R'_m / R_m
Alloys hardened by heat treatment (series 6000) (1)	$R'_{p0.2} / R_{p0.2}$	0.6

Notes:

(1) : When no information is available, coefficient η_1 is to be taken equal to the metallurgical efficiency coefficient β defined in Tab 10.

$R'_{p0.2}$: Minimum guaranteed yield stress, in N/mm^2, of material in welded condition

R'_m : Minimum guaranteed tensile strength, in N/mm^2, of material in welded condition

Table 10: Aluminium alloys - Metallurgical efficiency coefficient β

Aluminium alloy	Temper condition	Gross thickness, in mm	β
6005 A (Open sections)	T5 or T6	$t \leq 6$	0.45
		$t > 6$	0.40
6005 A (Closed sections)	T5 or T6	All	0.50
6061 (Sections)	T6	All	0.53
6082 (Sections)	T6	All	0.45

5. Other materials and products

5.1 General

5.1.1

Other materials and products such as parts made of iron castings, where allowed, products made of copper and copper alloys, rivets, anchors, chain cables, cranes, masts, derrick posts, derricks, accessories and wire ropes are to comply with the applicable requirements of the Society Rules for Materials.

5.1.2

The use of plastics or other special materials not covered by these Rules is to be considered by the Society on a case by case basis. In such cases, the requirements for the acceptance of the materials concerned are to be agreed by the Society.

5.1.3

Materials used in welding processes are to comply with the applicable requirements of the Society Rules for Materials.

5.2 Iron cast parts

5.2.1

As a rule, the use of grey iron, malleable iron or spheroidal graphite iron cast parts with combined ferritic/perlitic structure is allowed only to manufacture low stressed elements of secondary importance.

5.2.2

Ordinary iron cast parts may not be used for windows or sidescuttles; the use of high grade iron cast parts of a suitable type will be considered by the Society on a case by case basis.

Section 2 – NET SCANTLING APPROACH

Symbols

t_{as_built} : *As-built Thickness*: the actual thickness, in mm, provided at the newbuilding stage, including $t_{voluntary\_addition}$, if any.

t_C : *Corrosion Addition Thickness*: as defined in Ch 3, Sec 3, in mm.

$t_{gross\_offered}$: *Gross Thickness Offered*: the actual gross (full) thickness, in mm, provided at the newbuilding stage, excluding $t_{voluntary\_addition}$, the owner's extra margin for corrosion wastage, if any.

$t_{gross\_required}$: *Gross Thickness Required*: the gross (full) thickness, in mm, obtained by adding t_C to the Net Thickness Required.

$t_{net\_offered}$: *Net Thickness Offered*: the net thickness, in mm, obtained by subtracting t_C from the Gross Thickness Offered

$t_{net\_required}$: *Net Thickness Required*: the net thickness, in mm, as required by the Rules that satisfy all the structural strength requirements, rounded to the closest half millimetre.

$t_{voluntary\_addition}$: *Thickness for Voluntary Addition*: the thickness, in mm, voluntarily added as the owner's extra margin for corrosion wastage in addition to t_C.

1. General philosophy

1.1

1.1.1

Net Scantling Approach is to clearly specify the "net scantling" that is to be maintained right from the newbuilding stage throughout the ship's design life to satisfy the structural strength requirements. This approach clearly separates the net thickness from the thickness added for corrosion that is likely to occur during the ship-in-operation phase.

2. Application criteria

2.1 General

2.1.1

The scantlings obtained by applying the criteria specified in this Rule are net scantlings as specified in [3.1] to [3.3]; i.e. those which provide the strength characteristics required to sustain the loads, excluding any addition for corrosion and voluntarily added thickness such as the owner's extra margin, if any. The following gross offered scantlings are exceptions; i.e. they already include additions for corrosion but without voluntarily added values such as the owner's extra margin:

- scantlings of superstructures and deckhouses, according to Ch 9, Sec 4
- scantlings of rudder structures, according to Ch 10, Sec 1
- scantlings of massive pieces made of steel forgings, steel castings.

2.1.2

The required strength characteristics are:

- thickness, for plating including that which constitutes primary supporting members
- section modulus, shear area, moments of inertia and local thickness for ordinary stiffeners and, as the case may be, primary supporting members
- section modulus, moments of inertia and first moment for the hull girder.

2.1.3

The ship is to be built at least with the gross scantlings obtained by adding the corrosion additions, specified in Ch 3, Sec 3, to the net scantlings. The thickness for voluntary addition is to be added as an extra.

3. Net scantling approach

3.1 Net scantling definition

3.1.1 Required thickness

The gross thickness required, $t_{gross\_required}$, is not less than the gross thickness which is obtained by adding the corrosion addition t_C as defined in Ch 3, Sec 3 to net thickness required, as follows:

$$t_{gross\_required} = t_{net\_required} + t_C$$

3.1.2 Offered thickness

The gross thickness offered, $t_{gross\_offered}$, is the gross thickness provided at the newbuilding stage, which is obtained by deducting the thickness for voluntary addition from the as-built thickness, as follows:

$$t_{gross\_offered} = t_{as\_built} - t_{voluntary\_addition}$$

3.1.3 Net thickness for plate

Net thickness offered, $t_{net\_offered}$, is obtained by subtracting t_C from the gross thickness offered, as follows:

$$t_{net\_offered} = t_{gross\_offered} - t_C = t_{as\_built} - t_{voluntary\_addition} - t_C$$

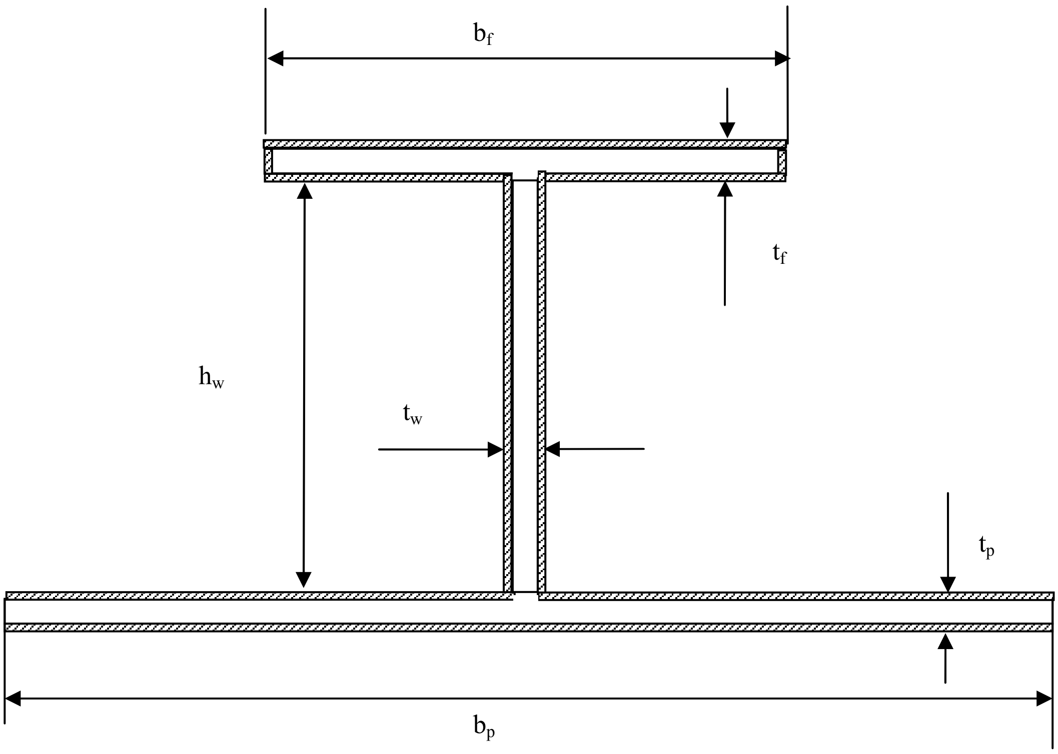
3.1.4 Net section modulus for stiffener

The net transverse section scantling is to be obtained by deducting t_C from the gross thickness offered of the elements which constitute the stiffener profile as shown in Fig 1.

For bulb profiles, an equivalent angle profile, as specified in Ch 3, Sec 6 [4.1.1], may be considered.

The net strength characteristics are to be calculated for the net transverse section.

In assessing the net strength characteristics of stiffeners reflecting the hull girder stress and stress due to local bending of the local structure such as double bottom structure, the section modulus of hull girder or rigidity of structure is obtained by deducting $0.5t_C$ from the gross thickness offered of the related elements.



Shadow area is corrosion addition.

For attached plate, the half of the considered corrosion addition specified in 3.2 is deducted from both sides of the attached plate.

Figure 1: Net scantling of stiffener

3.2 Considered net scantling

3.2.1 Yielding check of the hull girder

The net thickness of structural members to be considered for the yielding check of the hull girder, according to Ch 5, Sec 1, is to be obtained by deducting $0.5t_C$ from the gross thickness offered.

3.2.2 Global stress such as stress due to hull girder bending moment and shear force

The net thickness of structural members to be considered for stress due to hull girder bending moment and shear force according to Ch 5, Sec1, is to be obtained by deducting $0.5t_C$ from the gross thickness offered.

3.2.3 Buckling check of the hull girder

The net thickness of structural members to be considered for the buckling check, according to Ch 6, Sec 3, is to be obtained by deducting t_C from the gross thickness offered.

3.2.4 Ultimate strength check of the hull girder

The net thickness of structural members to be considered for the ultimate strength check of the hull girder, according to Ch 5, Sec 2, is to be obtained by deducting $0.5t_C$ from the gross thickness offered.

3.2.5 Direct strength analysis

The net thickness of plating which constitutes primary supporting members to be checked stresses according to Ch 7 is to be obtained by deducting $0.5t_C$ from the gross thickness offered.

The net thickness of plating members to be considered for the buckling check according to Ch 6, Sec 3, using the stresses obtained from direct strength analysis, is to be obtained by deducting t_C from the gross thickness offered.

3.2.6 Fatigue check

The net thickness of structural members to be checked for fatigue according to Ch 8 is to be obtained by deducting $0.5t_C$ from the gross thickness offered.

3.2.7 Check of primary supporting members for ships less than 150 m in length *L*

The net thickness of plating which constitutes primary supporting members for ships less than 150 m in length L, to be checked according to Ch.6, Sec.4, [2], is to be obtained by deducting t_c from the gross thickness.

3.3 Available information on structural drawings

3.3.1

The structural drawings are to indicate for each structural element the gross scantling and the renewal thickness as specified in Ch 13, Sec 2.

If thickness for voluntary addition is included in the as-built thicknesses, this is to be clearly mentioned and identified on the drawings.

Section 3 – CORROSION ADDITIONS

Symbols

t_C : Total corrosion addition, in mm, defined in [1.2]

t_{C1}, t_{C2} : Corrosion addition, in mm, on one side of the considered structural member, defined in Tab 1

$t_{reserve}$: Reserve thickness, in mm, defined in Ch 13, Sec 2 and taken equal to:

$$t_{reserve} = 0.5$$

1. Corrosion additions

1.1 General

1.1.1

The values of the corrosion additions specified in this section are to be applied in relation with the relevant protective coatings required by Sec 5.

For materials different from carbon steel, special consideration is to be given to the corrosion addition.

1.2 Corrosion addition determination

1.2.1 Corrosion additions for steel

The corrosion addition for each of the two sides of a structural member, t_{C1} or t_{C2}, is specified in Tab 1.

The total corrosion addition t_C, in mm, for both sides of the structural member is obtained by the following formula:

$$t_C = Roundup_{0.5}(t_{C1} + t_{C2}) + t_{reserve}$$

For an internal member within a given compartment, the total corrosion addition t_C is obtained from the following formula:

$$t_C = Roundup_{0.5}(2t_{C1}) + t_{reserve}$$

where t_{C1} is the value specified in Tab 1 for one side exposure to that compartment.

When a structural member is affected by more than one value of corrosion addition (e.g. a plate in a dry bulk cargo hold extending above the lower zone), the scantling criteria are generally to be applied considering the severest value of corrosion addition applicable to the member.

The corrosion addition of a longitudinal stiffener is determined according to the coordinate of the connection of the stiffener to the attached plating.

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In addition, the total corrosion addition t_C is not to be taken less than 2 mm, except for web and face plate of ordinary stiffeners.

1.2.2 Corrosion additions for aluminium alloys

For structural members made of aluminium alloys, the corrosion addition t_C is to be taken equal to 0.

Table 1: Corrosion addition on one side of structural members

<table>
<tr><th rowspan="2">Compartment Type</th><th rowspan="2" colspan="2">Structural member</th><th colspan="2">Corrosion addition, t_{C1} or t_{C2} in mm</th></tr>
<tr><th>BC-A or BC-B ships with $L \geq 150$ m</th><th>Other</th></tr>
<tr><td rowspan="4">Ballast water tank [(2)]</td><td rowspan="2">Face plate of primary members</td><td>Within 3m below the top of tank [(3)]</td><td colspan="2">2.0</td></tr>
<tr><td>Elsewhere</td><td colspan="2">1.5</td></tr>
<tr><td rowspan="2">Other members</td><td>Within 3 m below the top of tank [(3)]</td><td colspan="2">1.7</td></tr>
<tr><td>Elsewhere</td><td colspan="2">1.2</td></tr>
<tr><td rowspan="9">Dry bulk cargo hold [(1)]</td><td rowspan="3">Transverse bulkhead</td><td>Upper part [(4)]</td><td>2.4</td><td>1.0</td></tr>
<tr><td>Lower stool: sloping plate, vertical plate and top plate</td><td>5.2</td><td>2.6</td></tr>
<tr><td>Other parts</td><td>3.0</td><td>1.5</td></tr>
<tr><td rowspan="4">Other members</td><td>Upper part [(4)]</td><td rowspan="2">1.8</td><td rowspan="2">1.0</td></tr>
<tr><td>Webs and flanges of the upper end brackets of side frames of single side bulk carriers</td></tr>
<tr><td>Webs and flanges of lower brackets of side frames of single side bulk carriers</td><td>2.2</td><td>1.2</td></tr>
<tr><td>Other parts</td><td>2.0</td><td>1.2</td></tr>
<tr><td rowspan="2">Sloped plating of hopper tank, inner bottom plating</td><td>Continuous wooden ceiling</td><td>2.0</td><td>1.2</td></tr>
<tr><td>No continuous wooden ceiling</td><td>3.7</td><td>2.4</td></tr>
<tr><td rowspan="2">Exposed to atmosphere</td><td colspan="2">Horizontal member and weather deck [(5)]</td><td colspan="2">1.7</td></tr>
<tr><td colspan="2">Non horizontal member</td><td colspan="2">1.0</td></tr>
<tr><td colspan="3">Exposed to sea water [(7)]</td><td colspan="2">1.0</td></tr>
<tr><td colspan="3">Fuel oil tanks and lubricating oil tanks [(2)]</td><td colspan="2">0.7</td></tr>
<tr><td colspan="3">Fresh water tanks</td><td colspan="2">0.7</td></tr>
<tr><td>Void spaces [(6)]</td><td colspan="2">Spaces not normally accessed, e.g. access only through bolted manholes openings, pipe tunnels, etc.</td><td colspan="2">0.7</td></tr>
<tr><td>Dry spaces</td><td colspan="2">Internal of deck houses, machinery spaces, stores spaces, pump rooms, steering spaces, etc.</td><td colspan="2">0.5</td></tr>
<tr><td colspan="3">Other compartments than above</td><td colspan="2">0.5</td></tr>
</table>

Notes

(1) Dry bulk cargo hold includes holds, intended for the carriage of dry bulk cargoes, which may carry water ballast.

(2) The corrosion addition of a plating between water ballast and heated fuel oil tanks is to be increased by 0.7 mm.

(3) This is only applicable to ballast tanks with weather deck as the tank top.

(4) Upper part of the cargo holds corresponds to an area above the connection between the top side and the inner hull or side shell. If there is no top side, the upper part corresponds to the upper one third of the cargo hold height.

(5) Horizontal member means a member making an angle up to 20° as regard as a horizontal line.

(6) The corrosion addition on the outer shell plating in way of pipe tunnel is to be considered as water ballast tank.

(7) Outer side shell between normal ballast draught and scantling draught is to be increased by 0.5 mm.

RCN 1 to July 2008 version (effective from 1 July 2009)

Section 4 – LIMIT STATES

1. General

1.1 General principle

1.1.1

The structural strength assessments indicated in Tab 1 are covered by the requirements of the present Rules.

Table 1: Structural strength assessment

		Yielding check	Buckling check	Ultimate strength check	Fatigue check
Local Structures	Ordinary stiffeners	✓	✓	✓ (1)	✓ (2)
	Plating subjected to lateral pressure	✓	✓	✓ (3)	—
Primary supporting members		✓	✓	✓	✓ (2)
Hull girder		✓	✓ (4)	✓	—

Note: ✓ indicates that the structural assessment is to be carried out.

(1) The ultimate strength check of stiffeners is included in the buckling check of stiffeners.

(2) The fatigue check of stiffeners and primary supporting members is the fatigue check of connection details of these members.

(3) The ultimate strength check of plating is included in the yielding check formula of plating.

(4) The buckling check of stiffeners and plating taking part in hull girder strength is performed against stress due to hull girder bending moment and hull girder shear force.

1.1.2

Strength of hull structures in flooded condition is to be assessed.

1.2 Limit states

1.2.1 Serviceability limit state

Serviceability limit state, which concerns the normal use, includes:

- local damage which may reduce the working life of the structure or affect the efficiency or appearance of structural members
- unacceptable deformations which affect the efficient use and appearance of structural members or the functioning of equipment.

1.2.2 Ultimate limit state

Ultimate limit state, which corresponds to the maximum load-carrying capacity, or in some cases, the maximum applicable strain or deformation, includes:

- attainment of the maximum resistance capacity of sections, members or connections by rupture or excessive deformations

- instability of the whole structure or part of it.

1.2.3 Fatigue limit state
Fatigue limit state relate to the possibility of failure due to cyclic loads.

1.2.4 Accidental limit state
Accidental limit state considers the flooding of any one cargo hold without progression of the flooding to the other compartments and includes:

- the maximum load-carrying capacity of hull girder
- the maximum load-carrying capacity of double bottom structure
- the maximum load-carrying capacity of bulkhead structure

Accidental single failure of one structural member of any one cargo hold is considered in the assessment of the ultimate strength of the entire stiffened panel.

2. Strength criteria

2.1 Serviceability limit states

2.1.1 Hull girder
For the yielding check of the hull girder, the stress corresponds to a load at 10^{-8} probability level.

2.1.2 Plating
For the yielding check and buckling check of platings constituting a primary supporting member, the stress corresponds to a load at 10^{-8} probability level.

2.1.3 Ordinary stiffener
For the yielding check of an ordinary stiffener, the stress corresponds to a load at 10^{-8} probability level.

2.2 Ultimate limit states

2.2.1 Hull girder
The ultimate strength of the hull girder is to withstand the maximum vertical longitudinal bending moment obtained by multiplying the partial safety factor and the vertical longitudinal bending moment at 10^{-8} probability level.

2.2.2 Plating
The ultimate strength of the plating between ordinary stiffeners and primary supporting members is to withstand the load at 10^{-8} probability level.

2.2.3 Ordinary stiffener
The ultimate strength of the ordinary stiffener is to withstand the load at 10^{-8} probability level.

2.3 Fatigue limit state

2.3.1 Structural details

The fatigue life of representative structural details such as connections of ordinary stiffeners and primary supporting members is obtained from reference pressures at 10^{-4}.

2.4 Accidental limit state

2.4.1 Hull girder

Longitudinal strength of hull girder in cargo hold flooded condition is to be assessed in accordance with Ch 5, Sec 2.

2.4.2 Double bottom structure

Double bottom structure in cargo hold flooded condition is to be assessed in accordance with Ch 6, Sec 4.

2.4.3 Bulkhead structure

Bulkhead structure in cargo hold flooded condition is to be assessed in accordance with Ch 6, Sec 1, Sec 2 and Sec 3.

3. Strength check against impact loads

3.1 General

3.1.1

Structural response against impact loads such as forward bottom slamming, bow flare slamming and grab falling depends on the loaded area, magnitude of loads and structural grillage.

3.1.2

The ultimate strength of structural members that constitute the grillage, i.e. platings between ordinary stiffeners and primary supporting members and ordinary stiffeners with attached plating, is to withstand the maximum impact loads acting on them.

Section 5 – CORROSION PROTECTION

1. General

1.1 Structures to be protected

1.1.1

All seawater ballast tanks, cargo holds and ballast holds are to have a corrosion protective system fitted in accordance with [1.2], [1.3] and [1.4] respectively.

1.1.2

Void double side skin spaces in cargo length area for vessels having a length (L_{LL}) of not less than 150 m are to be coated in accordance with [1.2].

1.1.3

Corrosion protective coating is not required for internal surfaces of spaces intended for the carriage of fuel oil.

1.1.4

Narrow spaces are generally to be filled by an efficient protective product, particularly at the ends of the ship where inspections and maintenance are not easily practicable due to their inaccessibility.

1.2 Protection of seawater ballast tanks and void double side skin spaces

1.2.1

All dedicated seawater ballast tanks anywhere on the ship (excluding ballast hold) for vessels having a length (L) of not less than 90 m and void double side skin spaces in the cargo length area for vessels having a length (L_{LL}) of not less than 150 m are to have an efficient corrosion prevention system, such as hard protective coatings or equivalent, applied in accordance with the manufacturer's recommendation.

The coatings are to be of a light colour, i.e. a colour easily distinguishable from rust which facilitates inspection.

Where appropriate, sacrificial anodes, fitted in accordance with [2], may also be used.

1.2.2

For ships contracted for construction on or after 8 December 2006, the date of IMO adoption of the amended SOLAS regulation II-1/3-2, by which an IMO "Performance standard for protective coatings for ballast tanks and void spaces" will be made mandatory, the coatings of internal spaces subject to the amended SOLAS regulation are to satisfy the requirements of the IMO performance standard.

For ships contracted for construction on or after 1 July 2012, the IMO performance standard is to be applied as interpreted by IACS UI SC 223 and UI SC 227. In applying IACS UI SC 223, "Administration" is to be read to be the "Classification Society".

Consistent with IMO Resolution A.798(19) and IACS UI SC 122, the selection of the coating system, including coating selection, specification, and inspection plan, are to be agreed between the shipbuilder, coating system supplier and the owner, in consultation with the Society, prior to commencement of construction. The

specification for the coating system for these spaces is to be documented and this documentation is to be verified by the Society and is to be in full compliance with the coating performance standard.

The shipbuilder is to demonstrate that the selected coating system with associated surface preparation and application methods is compatible with the manufacturing processes and methods.

The shipbuilder is to demonstrate that the coating inspectors have proper qualification as required by the IMO standard.

The attending surveyor of the Society will not verify the application of the coatings but will review the reports of the coating inspectors to verify that the specified shipyard coating procedures have been followed.

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1.3 Protection of cargo hold spaces

1.3.1 Coating

It is the responsibility of the shipbuilder and of the owner to choose coatings suitable for the intended cargoes, in particular for the compatibility with the cargo.

1.3.2 Application

All internal and external surfaces of hatch coamings and hatch covers, and all internal surfaces of cargo holds (side and transverse bulkheads), excluding the inner bottom area and part of the hopper tank sloping plate and lower stool sloping plate, are to have an efficient protective coating, of an epoxy type or equivalent, applied in accordance with the manufacturer's recommendation.

The side and transverse bulkhead areas to be coated are specified in [1.3.3] and [1.3.4] respectively.

1.3.3 Side areas to be coated

The areas to be coated are the internal surfaces of:

- the inner side plating
- the internal surfaces of the topside tank sloping plates
- the internal surfaces of the hopper tank sloping plates for a distance of 300 mm below the frame end bracket for holds of single side skin construction or below the hopper tank upper end for holds of double side skin construction.

RCN 1 to July 2010 version (effective from 1July 2012)

These areas are shown in Fig 1.

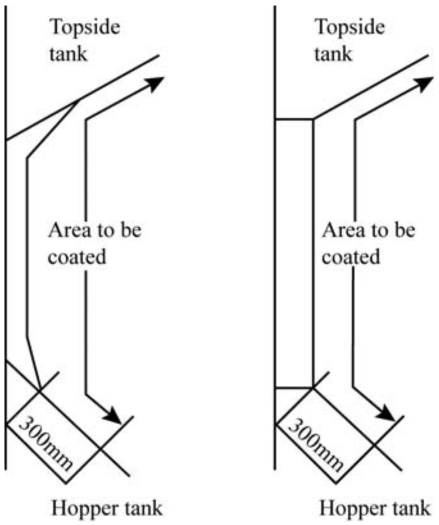

Figure 1: Side areas to be coated

1.3.4 Transverse bulkhead areas to be coated

The areas of transverse bulkheads to be coated are all the areas located above an horizontal level located at a distance of 300 mm below the frame end bracket for holds of single side skin construction or below the hopper tank upper end for holds of double side skin construction.

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1.4 Protection of ballast hold spaces

1.4.1 Application

All internal and external surfaces of hatch coamings and hatch covers, and all internal surfaces of ballast holds are to have an effective protective coating, of an epoxy type or equivalent, applied in accordance with the manufacturer's recommendation.

2. Sacrificial anodes

2.1 General

2.1.1

Anodes are to have steel cores and are to be fitted sufficiently rigid by the anode support designed so that they retain the anode even when it is wasted.

The steel inserts are to be attached to the structure by means of a continuous weld. Alternatively, they may be attached to separate supports by bolting, provided a minimum of two bolts with lock nuts are used. However, other mechanical means of clamping may be accepted.

2.1.2

The supports at each end of an anode may not be attached to separate items which are likely to move independently.

2.1.3

Where anode inserts or supports are welded to the structure, the welds are to be smoothly.

3. Protection of inner bottom by ceiling

3.1 General

3.1.1

Ceiling on the inner bottom, if any, is to comply with [3.2] and [3.3].

3.2 Arrangement

3.2.1

Planks forming ceiling over the bilges and on the inner bottom are to be easily removable to permit access for maintenance.

3.2.2

Where the double bottom is intended to carry fuel oil, ceiling on the inner bottom is to be separated from the plating by means of battens 30 mm high, in order to facilitate the drainage of oil leakages to the bilges.

3.2.3

Where the double bottom is intended to carry water, ceiling on the inner bottom may lie next to the plating, provided a suitable protective composition is applied beforehand.

3.2.4

The shipyard is to take care that the attachment of ceiling does not affect the tightness of the inner bottom.

3.3 Scantlings

3.3.1

The thickness of ceiling boards, when made of pine, is to be not less than 60 mm. Under cargo hatchways, the thickness of ceiling is to be increased by 15 mm.

Where the floor spacing is large, the thicknesses may be considered by the Society on a case by case basis.

Section 6 – STRUCTURAL ARRANGEMENT PRINCIPLES

Symbols

For symbols not defined in this Section, refer to the list defined in Ch 1, Sec 4.

b_h : Breadth, in m, of cargo hatch opening

ℓ_b : Length, in m, of the free edge of the end bracket

1. Application

If not specified otherwise, the requirements of this section apply to the hull structure except superstructures and deckhouses. For areas outside the cargo holds area, supplementary requirements are to be found in Ch. 9 Sec 1 to Ch. 9 Sec 3.

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2. General principles

2.1 Definition

2.1.1 Primary frame spacing

Primary frame spacing, in m, is defined as the distance between the primary supporting members.

2.1.2 Secondary frame spacing

Secondary frame spacing, in m, is defined as the distance between ordinary stiffeners.

2.2 Structural continuity

2.2.1 General

The reduction in scantling from the midship part to the end parts is to be effected as gradually as practicable.

Attention is to be paid to the structural continuity in way of changes in the framing system, at the connections of primary supporting members or ordinary stiffeners and in way of the ends of the fore and aft parts and machinery space and in way of the ends of superstructures.

2.2.2 Longitudinal members

Longitudinal members are to be so arranged as to maintain the continuity of strength.

Longitudinal members contributing to the hull girder longitudinal strength are to extend continuously for a sufficient distance towards the end of ship.

In particular, the continuity of the longitudinal bulkheads, including vertical and horizontal primary supporting members, extended over the cargo hold area is to be ensured beyond the cargo hold area. Scarfing brackets are a possible means.

2.2.3 Primary supporting members

Primary supporting members are to be arranged in such a way that they ensure adequate continuity of strength.

Abrupt changes in height or cross section are to be avoided.

2.2.4 Ordinary stiffeners

Ordinary stiffeners contributing to the hull girder longitudinal strength are generally to be continuous when crossing primary supporting members.

2.2.5 Platings

A change in plating thickness in as-built is not to exceed 50% of thicker plate thickness for load carrying direction. The butt weld preparation is to be in accordance with the requirements of Ch 11, Sec 2, [2.2].

2.2.6 Stress concentrations

Where stress concentration may occur in way of structural discontinuity, sufficient consideration is to be paid to reduce the stress concentration and adequate compensation and reinforcements are to be provided.

Openings are to be avoided, as far as practicable, in way of highly stressed areas.

Where openings are arranged, the shape of openings is to be such that the stress concentration remains within acceptable limits.

Openings are to be well rounded with smooth edges.

Weld joints are to be properly shifted from places where the stress may highly concentrate.

2.3 Connections with higher tensile steel

2.3.1 Connections with higher tensile steel

Where steels of different strengths are mixed in a hull structure, due consideration is to be given to the stress in the lower tensile steel adjacent to higher tensile steel.

Where stiffeners of lower tensile steel are supported by primary supporting members of higher tensile steel, due consideration is to be given to the stiffness of primary supporting members and scantlings to avoid excessive stress in the stiffeners due to the deformation of primary supporting members.

Where higher tensile steel is used at deck structures and bottom structure, longitudinal members not contributing to the hull girder longitudinal strength and welded to the strength deck or bottom plating and bilge strake, such as longitudinal hatch coamings, gutter bars, strengthening of deck openings, bilge keel, etc., are to be made of the same higher tensile steel. The same requirement is generally applicable for non continuous longitudinal stiffeners welded on the web of a primary member contributing to the hull girder longitudinal strength as hatch coamings, stringers and girders.

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3. Plating

3.1 Structural continuity of plating

3.1.1 Insert plate

Where a local increase in plating thickness is generally to be achieved to through insert plates, an insert plate is to be made of the materials of a quality (yield & grade) at least equal to that of the plates on which they are welded.

4. Ordinary stiffener

4.1 Profile of stiffeners

4.1.1 Stiffener profile with a bulb section

The properties of bulb profile sections are to be determined by exact calculations. If it is not possible, a bulb section may be taken as equivalent to a built-up section. The dimensions of the equivalent angle section are to be obtained, in mm, from the following formulae.

$$h_w = h'_w - \frac{h'_w}{9.2} + 2$$

$$b_f = \alpha\left(t'_w + \frac{h'_w}{6.7} - 2\right)$$

$$t_f = \frac{h'_w}{9.2} - 2$$

where:

h'_w , t'_w : Height and net thickness of a bulb section, in mm, as shown in Fig 1.

α : Coefficient equal to:

$$\alpha = 1.1 + \frac{(120 - h'_w)^2}{3000} \qquad \text{for } h'_w \le 120$$

$$\alpha = 1.0 \qquad \text{for } h'_w > 120$$

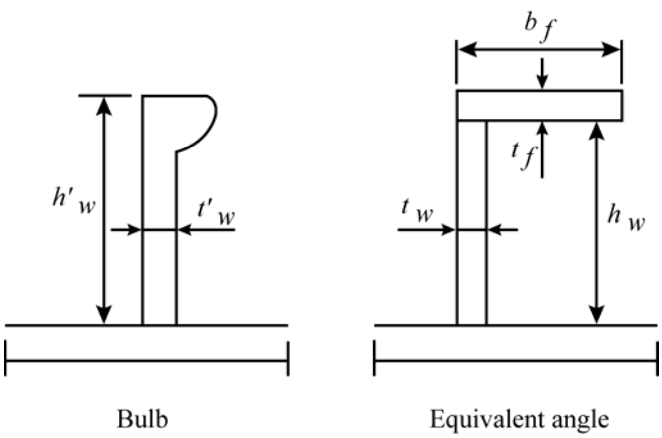

Figure 1: Dimensions of stiffeners

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4.2 Span of ordinary stiffeners

4.2.1 Ordinary stiffener

The span ℓ of ordinary stiffeners is to be measured as shown in Fig 2. For curved stiffeners, the span is measured along the chord.

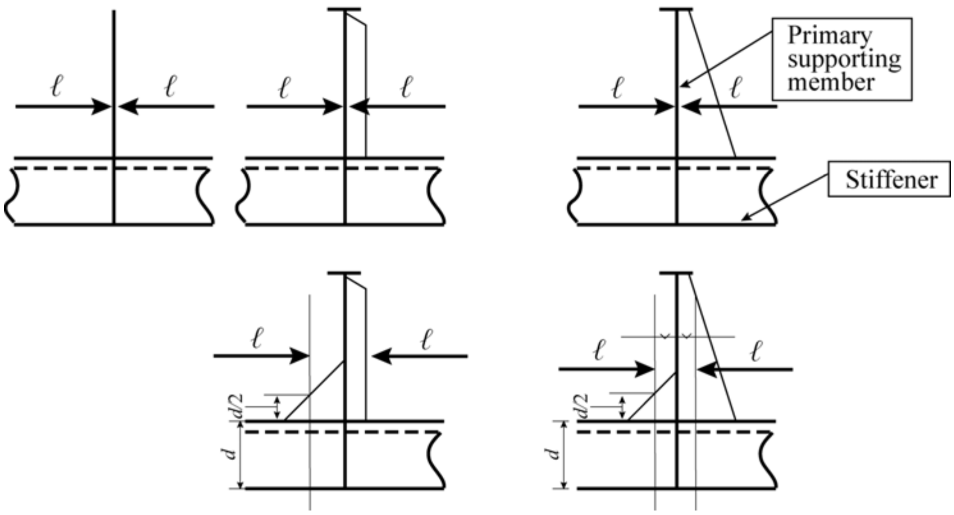

Figure 2: Span of ordinary stiffeners

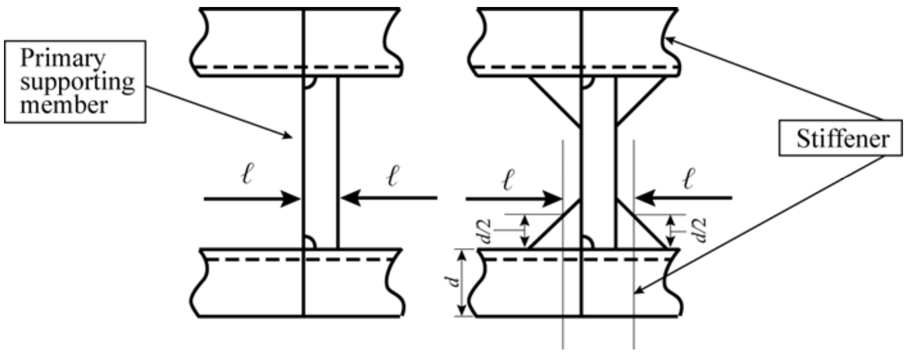

Figure 3: Span of ordinary stiffeners within a double hull

4.2.2 Ordinary stiffener within a double hull

The span ℓ of ordinary stiffeners fitted inside a double hull, i.e. when the web of the primary supporting members is connected with the inner hull and the outer shell acting as its flanges, is to be measured as shown in Fig 3.

4.2.3 Ordinary stiffeners supported by struts

The arrangement of ordinary stiffeners supported by struts is not allowed for ships over 120 m in length.

The span ℓ of ordinary stiffeners supported by one strut fitted at mid distance of the primary supporting members is to be taken as $0.7\ell_2$.

In case where two struts are fitted between primary supporting members, the span ℓ of ordinary stiffeners is to be taken as the greater of $1.4\ell_1$ and $0.7\ell_2$.

ℓ_1 and ℓ_2 are the spans defined in Figs 4 and 5.

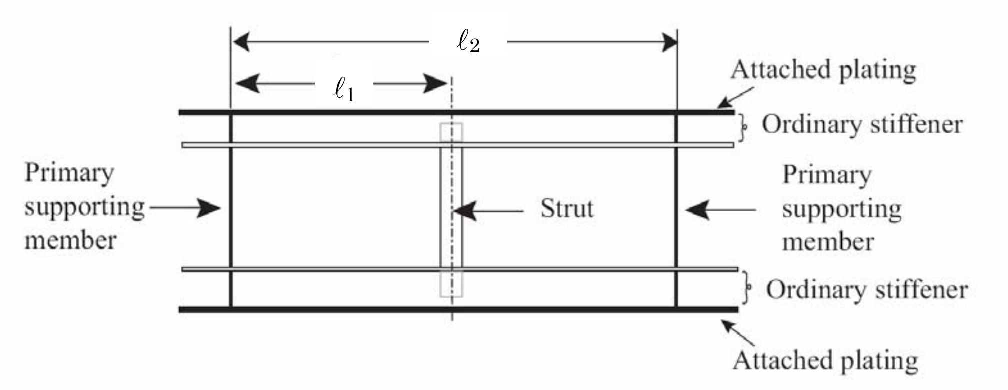

Figure 4: Span of ordinary stiffeners with one strut

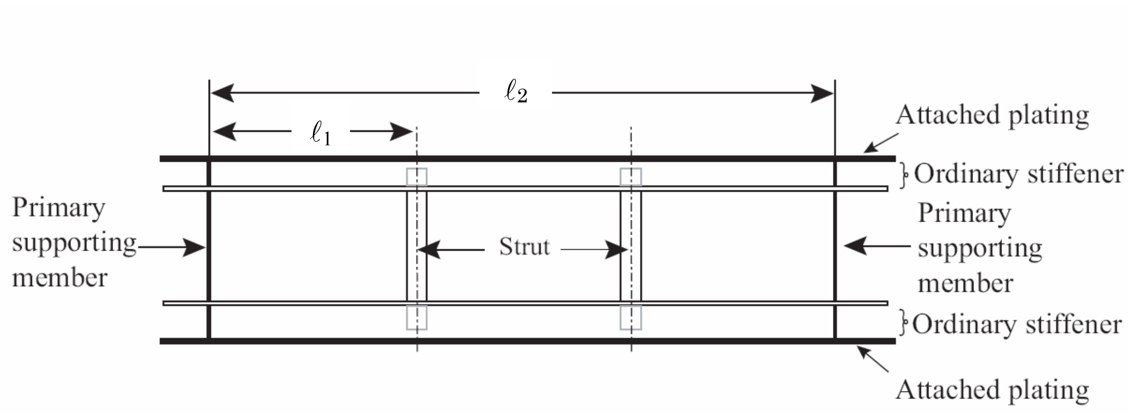

Figure 5: Span of ordinary stiffeners with two struts

4.3 Attached plating

4.3.1 Effective breadth for yielding check

The effective width b_p of the attached plating to be considered in the actual net section modulus for the yielding check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- where the plating extends on both sides of the ordinary stiffener:

  $b_p = 0.2\ell$, or

  $b_p = s$

  whichever is lesser.

- where the plating extends on one side of the ordinary stiffener (i.e. ordinary stiffeners bounding openings):

  $b_p = 0.5s$

  $b_p = 0.1\ell$

  whichever is lesser.

4.3.2 Effective width for buckling check

The effective width of the attached plating of ordinary stiffeners for checking the buckling of ordinary stiffeners is defined in Ch 6, Sec 3, [5].

4.4 Geometric property of ordinary stiffeners

4.4.1 General

Geometric properties of stiffeners such as moment of inertia, section modulus, shear sectional area, slenderness ratio of web plating, etc., are to be calculated based on the net thickness as defined in Ch 3, Sec 2.

4.4.2 Stiffener not perpendicular to the attached plating

The actual stiffener's net section modulus is to be calculated about an axis parallel to the attached plating.

Where the stiffener is not perpendicular to the attached plating, the actual net section modulus can be obtained, in cm^3, from the following formula:

$$w = w_0 \sin\alpha$$

where:

w_0 : Actual net section modulus, in cm^3, of the stiffener assumed to be perpendicular to the attached plating

α : Angle, in degrees, between the stiffener web and the attached plating, as shown in Fig 6, but not to be taken less than 50.

The correction is to be applied when α is between 50 and 75 degrees.

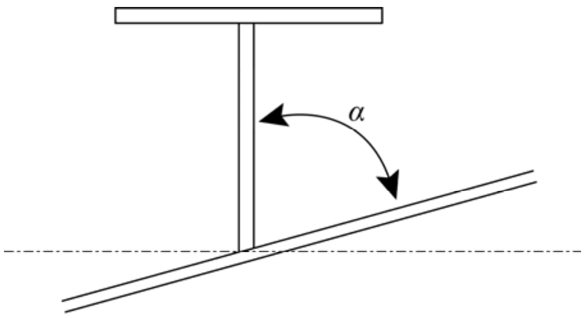

Figure 6: Angle between stiffener web and attached plating

Where the angle between the web plate of stiffener and the attached plating is less than 50 degrees, tripping bracket is to be fitted at suitable spacing. If the angle between the web plate of an unsymmetrical stiffener and the attached plating is less than 50 degrees, the face plate of the stiffener is to be fitted on the side of open bevel, as shown in Fig 7.

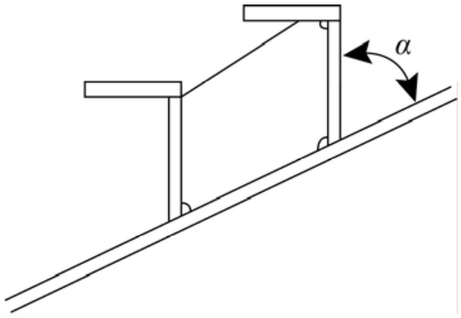

Figure 7: Orientation of stiffener when the angle is less than 50 degrees

4.5 End connections of ordinary stiffeners

4.5.1 General

Where ordinary stiffeners are to be continuous through primary supporting members, they are to be properly connected to the web plating so as to ensure proper transmission of loads. Some sample connections are shown in Fig 8 to Fig 11.

(a) (b)

Figure 8: (a) Connection without collar plate and (b) Connection with stiffener at side of longitudinal

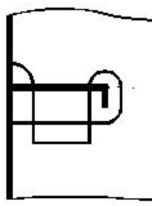

Figure 9: Connection with collar plate

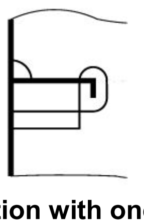

Figure 10: Connection with one large collar plate

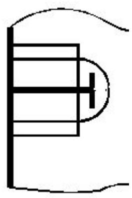

Figure 11: Connection with two large collar plates

4.5.2 Structural continuity of stiffeners

Where ordinary stiffeners are cut at primary supporting members, brackets are to be fitted to ensure structural continuity. In this case, the net section modulus and net sectional area of the brackets are to be not less than those of the ordinary stiffener.

The minimum net thickness of brackets is to be not less than that required for web plate of ordinary stiffeners.

The brackets are to be flanged or stiffened by a welded face plate where:

- the net thickness of the bracket, in mm, is less than $15\ell_b$, where ℓ_b is the length, in m, of the free edge of the end bracket or brackets; or
- the longer arm of the bracket is greater than 800 mm.

The net sectional area, in cm^2, of the flanged edge or faceplate is to be at least equal to $10\ell_b$.

4.5.3 End connections

End connection of stiffeners is to be sufficiently supported by the primary supporting members. Generally, a stiffener or a bracket to support the ordinary stiffener is to be provided.

Where slots for penetration of stiffeners are reinforced with collars, they are to be of the same materials as the primary supporting members.

Brackets or stiffeners to support the ordinary stiffeners are to be of sufficient sectional area and moment of inertia with respect to structural continuity, and are to have appropriate shape with respect to fatigue strength. If brackets or stiffeners to support the ordinary stiffeners are not fitted, or special slot configurations considering the fatigue strength are provided, fatigue strength assessment for slots are required by the Society.

5. Primary supporting members

5.1 General

5.1.1

Primary supporting members are to be arranged in such a way that they ensure adequate continuity of strength. Abrupt changes in height or in cross-section are to be avoided.

5.1.2

Where arrangements of primary supporting members are ensured adequate based on the results of FE analysis, fatigue assessment and ultimate strength assessment, primary supporting members are to be arranged in accordance with the result of such assessment.

5.2 Stiffening arrangement

5.2.1

Webs of primary supporting members are to be stiffened where the height, in mm, is greater than $100t$, where t is the net web thickness, in mm, of the primary supporting member.

In general, the web stiffeners of primary supporting members are to be spaced not more than $110t$.

The net thickness of web stiffeners and brackets, in mm, are not to be less than the value obtained from the following formula:

$t = 3 + 0.015\, L_2$

where:

L_2 : Rule length L, but to be taken not greater than 300 m

Additional stiffeners are to be fitted in way of end brackets, at the connection with cross ties, etc. of transverse primary supporting members where shearing stress and/or compressive stress is expected to be high. These parts are not to have holes. Cut outs for penetration of ordinary stiffeners in these parts are to be reinforced with collar plates.

Depth of stiffener of flat bar type is in general to be more than 1/12 of stiffener length. A smaller depth of stiffener may be accepted based on calculations showing compliance with Ch 6 Sec 2 [2.3.1], Ch 6 Sec 2 [4] and Ch 6 Sec 3 [4].

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5.2.2

Tripping brackets (see Fig 12) welded to the face plate are generally to be fitted:

- at every fourth spacing of ordinary stiffeners, without exceeding 4 m.
- at the toe of end brackets
- at rounded face plates
- in way of concentrated loads
- near the change of section.

Where the width of the symmetrical face plate is greater than 400 mm, backing brackets are to be fitted in way of the tripping brackets.

Where the face plate of the primary supporting member exceeds 180 mm on either side of the web, tripping bracket is to support the face plate as well.

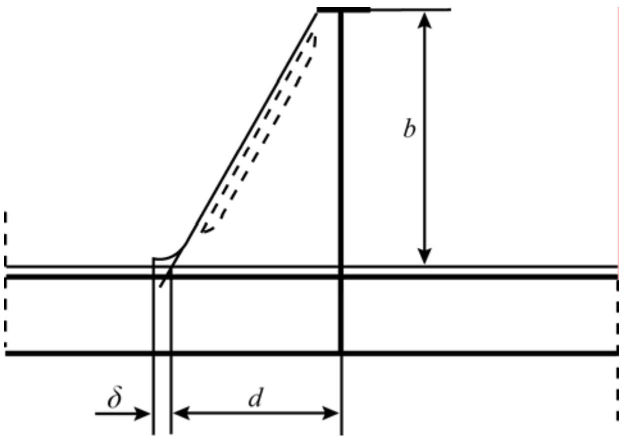


Figure 12: Primary supporting member: web stiffener in way of ordinary stiffener

5.2.3

The width of face plate of the primary supporting member except ring shape such as transverse ring in bilge hopper tanks and top side tank is to be not less than one tenth of the depth of the web, where tripping brackets are spaced as specified in [5.2.2].

5.2.4

The arm length of tripping brackets is to be not less than the greater of the following values, in m:

$$d = 0.38b$$

$$d = 0.85\sqrt{\frac{s_t}{t}}$$

where:

b : Height, in m, of tripping brackets, shown in Fig 12

s_t : Spacing, in m, of tripping brackets

t : Net thickness, in mm, of tripping brackets.

5.2.5

Tripping brackets with a net thickness, in mm, less than $10\ell_b$ are to be flanged or stiffened by a welded face plate.

The net sectional area, in cm^2, of the flanged edge or the face plate is to be not less than $7\ell_b$, where ℓ_b is the length, in m, of the free edge of the bracket.

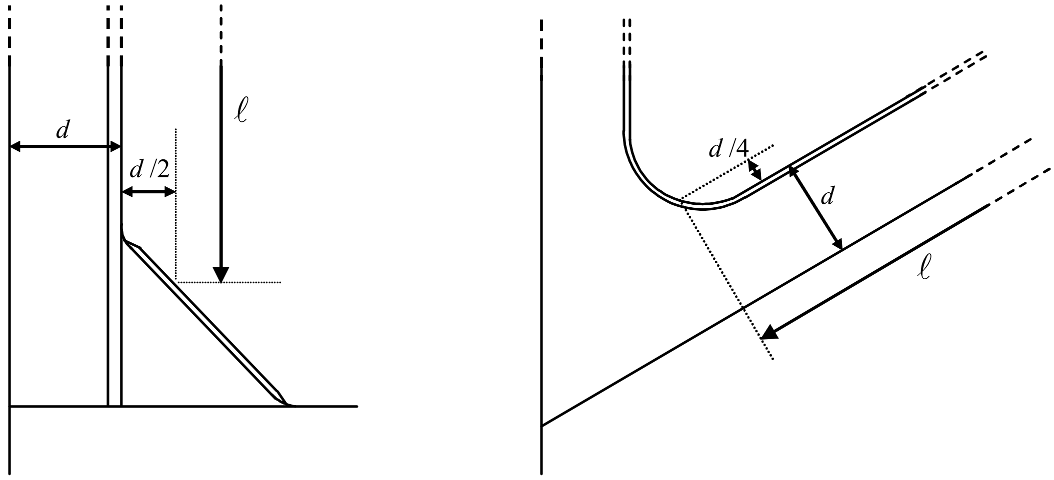
Where the height or breadth of tripping brackets is greater than 3 m, an additional stiffener is to be fitted parallel to the bracket free edge.

5.3 Span of primary supporting members

5.3.1 Definitions

The span ℓ, in m, of a primary supporting member without end bracket is to be taken as the length of the member between supports.

The span ℓ, in m, of a primary supporting member with end brackets is taken between points where the depth of the bracket is equal to half the depth of the primary supporting member as shown in Fig 13(a).
However, in case of curved brackets where the face plate of the member is continuous along the face of the bracket, as shown in Fig 13(b), the span is taken between points where the depth of the bracket is equal to one quarter the depth of the primary supporting member.



(a) **(b)**

Figure 13: Span of primary support member

5.4 Effective breadth of primary supporting member

5.4.1 General

The effective breadth b_p of the attached plating of a primary supporting member to be considered in the actual net section modulus for the yielding check is to be determined according to [4.3.1].

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5.5 Geometric properties

5.5.1 General

Geometric properties of primary supporting members such as moment of inertia, section modulus, shear sectional area, slenderness ratio of web plating, etc., are to be calculated based on the net thickness as specified in Ch 3, Sec 2.

5.6 Bracketed end connection

5.6.1 General

Where the ends of the primary supporting members are connected to bulkheads, inner bottom, etc., the end connections of all primary supporting members are to be balanced by effective supporting members on the opposite side of bulkheads, inner bottoms, etc..
Tripping brackets are to be provided on the web plate of the primary supporting members at the inner edge of end brackets and connection parts of the other primary supporting members and also at the proper intervals to support the primary supporting members effectively.

5.6.2 Dimensions of brackets

Arm length of bracket is generally not to be less than one-eighth of span length of the primary member, unless otherwise specified. Arm lengths of brackets at both ends are to be equal, as far as practicable.

The height of end brackets is to be not less than that of the primary supporting member. The net thickness of the end bracket web is not to be less than that of the web plate of the primary supporting member.

The scantlings of end brackets are to be such that the section modulus of the primary supporting member with end brackets is not less than that of the primary supporting member at mid-span point.

The width, in mm, of the face plate of end brackets is to be not less than $50(\ell_b+1)$.

Moreover, the net thickness of the face plate is to be not less than that of the bracket web.

Stiffening of end brackets is to be designed such that it provides adequate buckling web stability.

The following prescriptions are to be applied:

- where the length ℓ_b is greater than 1.5 m, the web of the bracket is to be stiffened
- the net sectional area, in cm^2, of web stiffeners is to be not less than 16.5ℓ, where ℓ is the span, in m, of the stiffener
- tripping flat bars are to be fitted to prevent lateral buckling of web stiffeners. Where the width of the symmetrical face plate is greater than 400 mm, additional backing brackets are to be fitted.

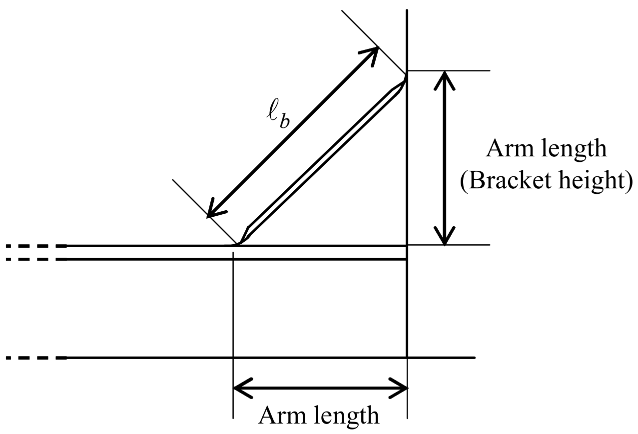

Figure 14: Dimension of brackets

5.7 Cut-outs and holes

5.7.1

Cut-outs for the passage of ordinary stiffeners are to be as small as possible and well rounded with smooth edges.

The depth of cut-outs is to be not greater than 50% of the depth of the primary supporting member.

5.7.2

Where openings such as lightening holes are cut in primary supporting members, they are to be equidistant from the face plate and corners of cut-outs and, in general, their height is to be not greater than 20% of the web height.

Where lightening holes with free edges are provided, the dimensions and locations of lightening holes are generally to be as shown in Fig 15.

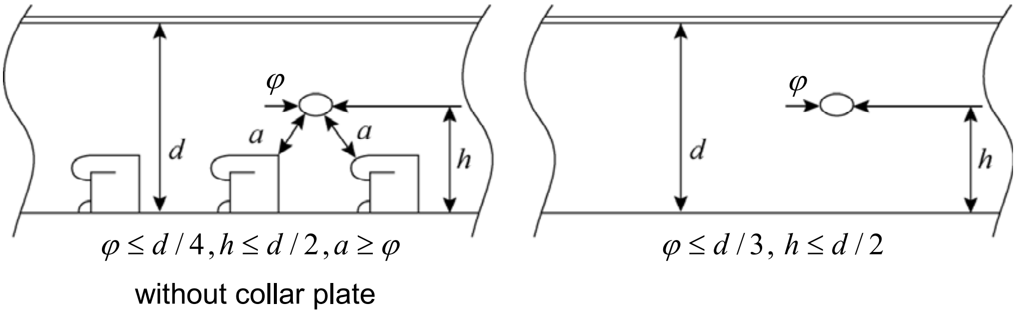

Figure 15: Location and dimensions of lightening holes

Where lightening holes are cut in the brackets, the distance from the circumference of the hole to the free flange of brackets is not to be less than the diameter of the lightening hole.

5.7.3

Openings are not be fitted in way of toes of end brackets.

5.7.4

At the mid-part within 0.5 times of the span of primary supporting members, the length of openings is to be not greater than the distance between adjacent openings.

At the ends of the span, the length of openings is to be not greater than 25% of the distance between adjacent openings.

5.7.5

In the case of large openings in the web of primary supporting members (e.g. where a pipe tunnel is fitted in the double bottom), the secondary stresses in primary supporting members are to be considered for the reinforcement of the openings.

This may be carried out by assigning an equivalent net shear sectional area to the primary supporting member obtained, in cm^2, according from the following formula:

$$A_{sh} = \frac{A_{sh1}}{1 + \dfrac{0.0032\ell^2 A_{sh1}}{I_1}} + \frac{A_{sh2}}{1 + \dfrac{0.0032\ell^2 A_{sh2}}{I_2}}$$

where (see Fig 16):

I_1, I_2 : Net moments of inertia, in cm^4, of deep webs (1) and (2), respectively, with attached plating around their neutral axes parallel to the plating

A_{sh1}, A_{sh2} : Net shear sectional areas, in cm^2, of deep webs (1) and (2), respectively, taking account of the web height reduction by the depth of the cut out for the passage of the ordinary stiffeners, if any

ℓ : Span, in cm, of deep webs (1) and (2).

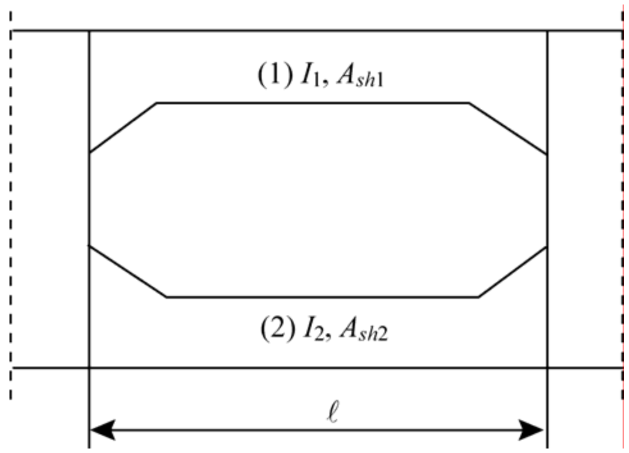

Figure 16: Large openings in the web of primary supporting members

6. Double bottom

6.1 General

6.1.1 Double bottom extend

Ref. SOLAS Ch. II-1, Part B, Reg. 12-1

A double bottom is to be fitted extending from the collision bulkhead to the afterpeak bulkhead.

6.1.2 Framing system

For ships greater than 120 m in length, the bottom, the double bottom and the sloped bulkheads of hopper tanks are to be of longitudinal system of frame arrangement at least within the cargo hold area. The spacing of the floors and bottom girders is not only governed by frame spaces but requirement in absolute value, in metres, is also indicated in [6.3.3] and [6.4.1].

6.1.3 Height of double bottom

Where a double bottom is required to be fitted the inner bottom shall be continued transversely in such a manner as to protect the bottom to the turn of the bilge.

Such protection will be deemed satisfactory if the inner bottom is not lower at any part than a plane parallel with the keel line and which is located not less than a vertical distance h measured from the keel line, as calculated by the formula:

$h = B/20$

However, in no case is the value of h to be less than 760 mm, and need not be taken as more than 2,000 mm.

Where the height of the double bottom varies, the variation is generally to be made gradually and over an adequate length; the knuckles of inner bottom plating are to be located in way of plate floors.

Where this is impossible, suitable longitudinal structures such as partial girders, longitudinal brackets etc., fitted across the knuckle are to be arranged.

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6.1.4 Dimensions of double bottom

The breadth of double bottom is taken as shown in Fig 17.

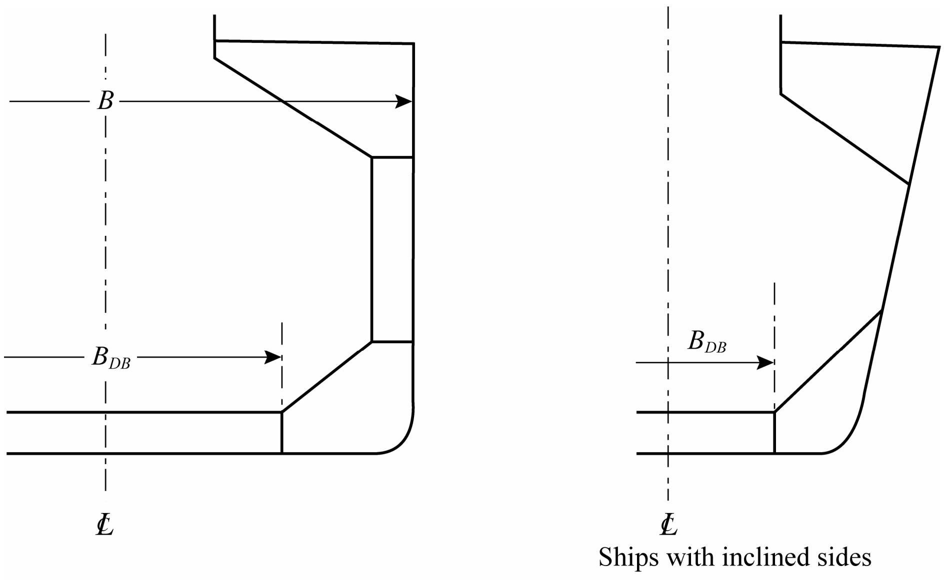

Figure 17: Breadth of double bottom

6.1.5 Docking

The bottom is to have sufficient strength to withstand the loads resulting from the dry-docking of the ship.

Where docking brackets are provided between solid floors and connecting the centreline girder to the bottom shell plating, the docking brackets are to be connected to the adjacent bottom longitudinals.

6.1.6 Continuity of strength

Where the framing system changes from longitudinal to transverse, special attention is to be paid to the continuity of strength by means of additional girders or floors. Where this variation occurs within $0.6L$ amidships, the inner bottom is generally to be maintained continuous by means of inclined plating.

Bottom and inner bottom longitudinal ordinary stiffeners are generally to be continuous through the floors.

The actual net thickness and the yield stress of the lower strake of the sloped bulkhead of hopper tanks, if any, are not to be less than these ones of the inner bottom with which the connection is made.

6.1.7 Reinforcement

The bottom is to be locally stiffened where concentrated loads are envisaged such as under the main engine and thrust seat.

Girders and floors are to be fitted under each line of pillars, toes of end brackets of bulkhead stiffeners and slant plate of lower stool of bulkhead. In case girders and floors are not fitted, suitable reinforcement is to be provided by means of additional primary supporting members or supporting brackets.

When solid ballast is fitted, it is to be securely positioned. If necessary, intermediate floors may be required for this purpose.

6.1.8 Manholes and lightening holes

Manholes and lightening holes are to be provided in floors and girders to ensure accessibility and ventilation as a rule.

The number of manholes in tank tops is to be kept to the minimum compatible with securing free ventilation and ready access to all parts of the double bottom.

Manholes may not be cut in the girders and floors below the heels of pillars.

6.1.9 Air holes and drain holes

Air and drain holes are to be provided in floors and girders.

Air holes are to be cut as near to the inner bottom and draining holes as near to the bottom shell as practicable.

Air holes and drain holes are to be designed to aid full ballast water and sediment removal to allow for effective ballast water exchange.

6.1.10 Drainage of tank top

Effective arrangements are to be provided for draining water from the tank top. Where wells are provided for the drainage, such wells are not to extend for more than one-half depth of the height of double bottom

6.1.11 Striking plate

Striking plates of adequate thickness or other equivalent arrangements are to be provided under sounding pipes to prevent the sounding rod from damaging the bottom plating.

6.1.12 Duct keel

Where a duct keel is arranged, the centre girder may be replaced by two girders generally spaced, no more than 3 m apart.

The structures in way of the floors are to ensure sufficient continuity of the latter.

6.2 Keel

6.2.1

The width of the keel is to be not less than the value obtained, in m, from the following formula:

$$b = 0.8 + L/200$$

6.3 Girders

6.3.1 Centre girder

The centre girder is to extend within the cargo hold area and is to extend forward and aft as far as practicable, and structural continuity thereof to be continuous within the full length of the ship.

Where double bottom compartments are used for the carriage of fuel oil, fresh water or ballast water, the centre girder is to be watertight, except for the case such as narrow tanks at the end parts or when other watertight girders are provided within $0.25B$ from the centreline, etc.

6.3.2 Side girders

The side girders are to extend within the parallel part of cargo hold area and are to extend forward and aft of cargo hold area as far as practicable.

6.3.3 Spacing

The spacing of adjacent girders is generally to be not greater than 4.6 m or 5 times the spacing of bottom or inner bottom ordinary stiffeners, whichever is the smaller. Greater spacing may be accepted depending on the result of the analysis carried out according to Ch 7.

6.4 Floors

6.4.1 Spacing

The spacing of floors is generally to be not greater than 3.5 m or 4 frame spaces as specified by the designer, whichever is the smaller. Greater spacing may be accepted depending on the result of the analysis carried out according to Ch 7.

6.4.2 Floors in way of transverse bulkheads

Where transverse bulkhead is provided with lower stool, solid floors are to be fitted in line with both sides of lower stool. Where transverse bulkhead is not provided with lower stool, solid floors are to be fitted in line with both flanges of the vertically corrugated transverse bulkhead or in line of plane transverse bulkhead.

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6.4.3 Web stiffeners

Floors are to be provided with web stiffeners in way of longitudinal ordinary stiffeners. Where the web stiffeners are not provided, fatigue strength assessment for the cut out and connection of longitudinal stiffener is to be carried out.

6.5 Bilge strake and bilge keel

6.5.1 Bilge strake

Where some of the longitudinal stiffeners at the bilge part are omitted, longitudinal stiffeners are to be provided as near to the turns of bilge as practicable.

6.5.2 Bilge keel

Bilge keels are not be welded directly to the shell plating. An intermediate flat is required on the shell plating. The ends of the bilge keel are to be sniped as shown in Fig.18 or rounded with large radius. The ends are to be located in way of transverse bilge stiffeners inside the shell plating and the ends of intermediate flat are not to be located at the block joints.

The bilge keel and the intermediate flat are to be made of steel with the same yield stress as the one of the bilge strake. The bilge keel with a length greater than $0.15L$ is to be made with the same grade of steel as the one of bilge strake.

The net thickness of the intermediate flat is to be equal to that of the bilge strake. However, this thickness may generally not be greater than 15 mm.

Scallops in the bilge keels are to be avoided.

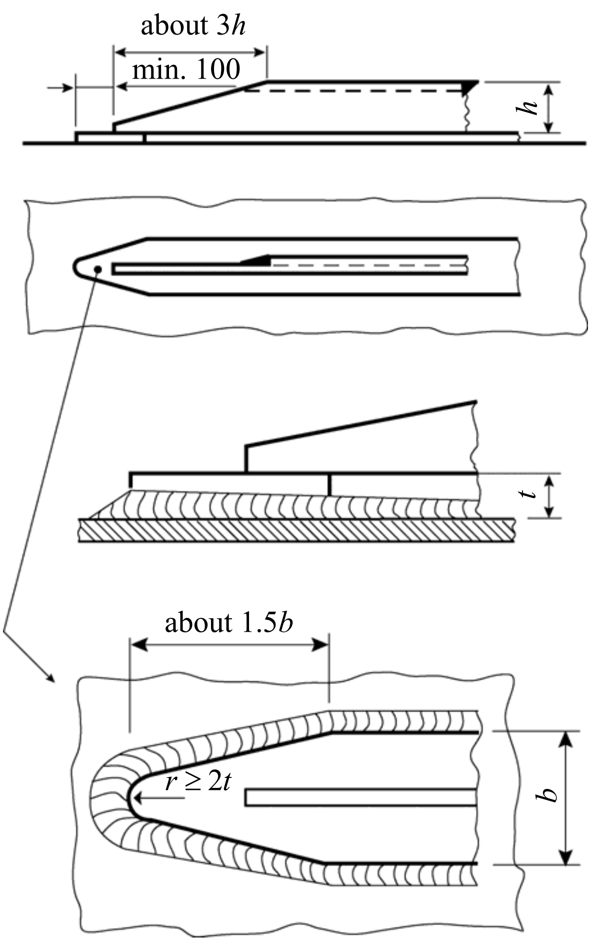

Figure 18: Example of bilge keel arrangement

7. Double Side structure in cargo hold area

RCN 1 to July 2010 version (effective from 1July 2012)

7.1 Application

7.1.1

The requirement of this article applies to longitudinally or transversely framed side structure.

The transversely framed side structures are built with transverse frames possibly supported by horizontal side girders.

The longitudinally framed side structures are built with longitudinal ordinary stiffeners supported by vertical primary supporting members.

The side within the hopper and topside tanks is, in general, to be longitudinally framed. It may be transversely framed when this is accepted for the double bottom and the deck according to [6.1.2] and [9.1.1], respectively.

7.2 Design principles

7.2.1

Where the double side space is void, the structural members bounding this space are to be structurally designed as a water ballast tank according to Ch 6. In such case the corresponding air pipe is considered as extending 0.76 m above the freeboard deck at side.

For corrosion addition, the space is still considered as void space.

7.3 Structural arrangement

7.3.1 General

Double side structures are to be thoroughly stiffened by providing web frames and side stringers within the double hull.

Continuity of the inner side structures, including stringers, is to be ensured within and beyond the cargo area. Scarfing brackets are a possible means.

7.3.2 Primary supporting member spacing

For transverse framing system, the spacing of transverse side primary supporting members is, in general, to be not greater than 3 frame spaces.

Greater spacing may be accepted depending on the results of the analysis carried out according to Ch 7 for the primary supporting members in the cargo holds.

The vertical distance between horizontal primary members of the double side is not to exceed 6 m, unless the appropriate structural members complying with the requirements for safe access are provided.

7.3.3 Primary supporting member fitting

Transverse side primary supporting members are to be fitted in line with web frames in topside and hopper tanks. However where it is not practicable for top side web frames, large brackets are to be fitted in the topside space in line with double side web frames

Transverse bulkheads in double side space are to be arranged in line with the cargo hold transverse bulkheads.

Vertical primary supporting members are to be fitted in way of hatch end beams.

Unless otherwise specified, horizontal side girders are to be fitted aft of the collision bulkhead up to $0.2L$ aft of the fore end, in line with fore peak girders.

7.3.4 Transverse ordinary stiffeners

The transverse ordinary stiffeners of the shell and the inner side are to be continuous or fitted with bracket end connections within the height of the double side. The transverse ordinary stiffeners are to be effectively connected to stringers. At their upper and lower ends, opposing shell and inner side transverse ordinary stiffeners and supporting stringer plates are to be connected by brackets.

7.3.5 Longitudinal ordinary stiffeners

The longitudinal side shell and inner side ordinary stiffeners, where fitted, are to be continuous within the length of the parallel part of cargo hold area and are to be fitted with brackets in way of transverse bulkheads aligned with cargo hold bulkheads. They are to be effectively connected to transverse web frames of the double side

structure. For the side longitudinal and ordinary stiffeners of inner skin out of parallel part of cargo hold area, special attention is to be paid for a structural continuity.

7.3.6 Sheer strake

The width of the sheer strake is to be not less than the value obtained, in m, from the following formula:

$$b = 0.715 + 0.425L / 100$$

The sheer strake may be either welded to the stringer plate or rounded.

If the shear strake is rounded, its radius, in mm, is to be not less than $17t_s$, where t_s is the net thickness, in mm, of the sheer strake.

The fillet weld at the connection of the welded sheer strake and deck plate may be either full penetration or deep penetration weld.

The upper edge of the welded sheer strake is to be rounded smooth and free of notches. Fixtures such as bulwarks, eye plates are not to be directly welded on the upper edge of sheer strake, except in fore and aft parts.

Longitudinal seam welds of rounded sheer strake are to be located outside the bent area at a distance not less than 5 times the maximum net thicknesses of the sheer strake.

The transition from a rounded sheer strake to an angled sheer strake associated with the arrangement of superstructures at the ends of the ship is to be carefully designed so as to avoid any discontinuities.

7.3.7 Plating connection

At the locations where the inner hull plating and the inner bottom plating are connected, attention is to be paid to the structural arrangement so as not to cause stress concentration.

Knuckles of the inner side are to be adequately stiffened by ordinary stiffeners or equivalent means, fitted in line with the knuckle.

The connections of hopper tank plating with inner hull and with inner bottom are to be supported by a primary supporting member.

7.4 Longitudinally framed double side

7.4.1 General

Adequate continuity of strength is to be ensured in way of breaks or changes in the width of the double side.

7.5 Transversely framed double side

7.5.1 General

Transverse frames of side and inner side may be connected by means of struts. Struts are generally to be connected to transverse frames by means of vertical brackets.

8. Single side structure in cargo hold area

RCN 1 to July 2010 version (effective from 1July 2012)

8.1 Application

8.1.1

This article applies to the single side structure with transverse framing.

If single side structure is supported by transverse or longitudinal primary supporting members, the requirements in [7] above apply to these primary supporting members as regarded to ones in double side skin.

8.2 General arrangement

8.2.1

Side frames are to be arranged at every frame space.

If air pipes are passing through the cargo hold, they are to be protected by appropriate measures to avoid a mechanical damage.

8.3 Side frames

8.3.1 General

Frames are to be built-up symmetrical sections with integral upper and lower brackets and are to be arranged with soft toes.

The side frame flange is to be curved (not knuckled) at the connection with the end brackets. The radius of curvature is not to be less than r, in mm, given by:

$$r = \frac{0.4 b_f^2}{t_f + t_C}$$

where:

t_C : Corrosion addition, in mm, specified in Ch 3, Sec 3

b_f and t_f : Flange width and net thickness of the curved flange, in mm. The end of the flange is to be sniped.

In ships less than 190 m in length, mild steel frames may be asymmetric and fitted with separate brackets. The face plate or flange of the bracket is to be sniped at both ends. Brackets are to be arranged with soft toes.

The dimensions of side frames are defined in Fig 19.

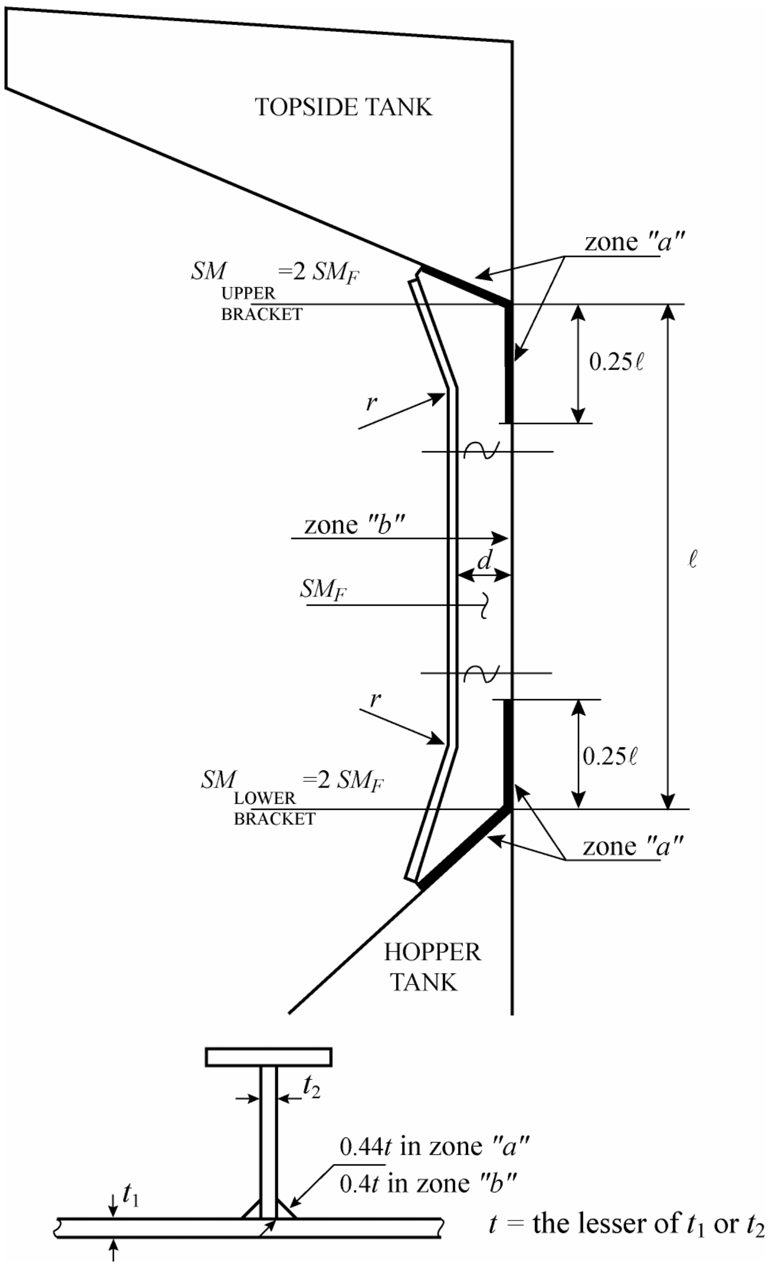

Figure 19: Dimensions of side frames

8.4 Upper and lower brackets

8.4.1

The face plates or flange of the brackets is to be sniped at both ends.

Brackets are to be arranged with soft toes.

The as-built thickness of the brackets is to be not less than the as-built thickness of the side frame webs to which they are connected.

8.4.2

The dimensions (in particular the height and length) of the lower brackets and upper brackets are to be not less than those shown in Fig 20.

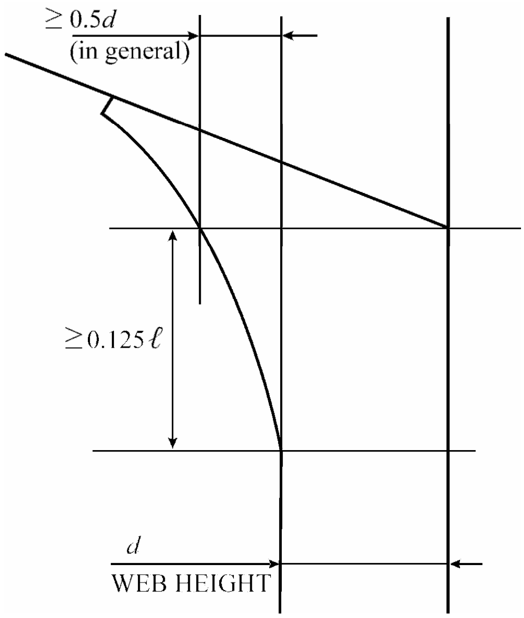

Figure 20: Dimensions of lower and upper brackets

8.5 Tripping brackets

8.5.1

In way of the foremost hold and in the holds of **BC-A** ships, side frames of asymmetrical section are to be fitted with tripping brackets at every two frames, as shown in Fig 21.

The as-built thickness of the tripping brackets is to be not less than the as-built thickness of the side frame webs to which they are connected.

Double continuous welding is to be adopted for the connections of tripping brackets with side shell frames and plating.

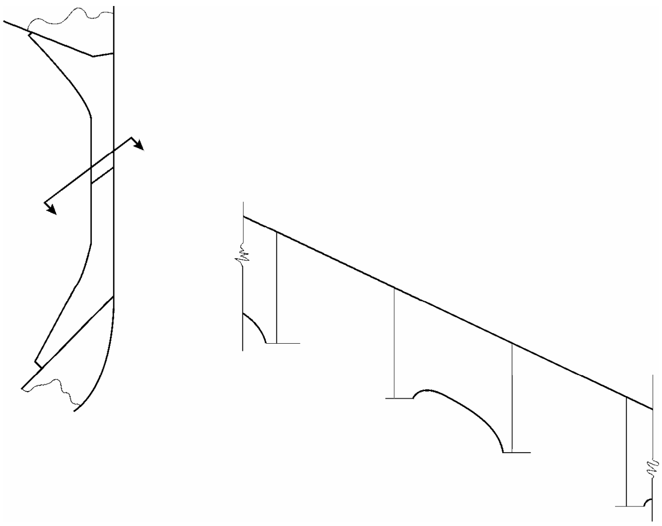

Figure 21: Tripping brackets to be fitted in way of foremost hold

8.6 Support structure

8.6.1

Structural continuity with the lower and upper end connections of side frames is to be ensured within hopper and topside tanks by connecting brackets as shown in Fig 22. The brackets are to be stiffened against buckling according to [5.6.2].

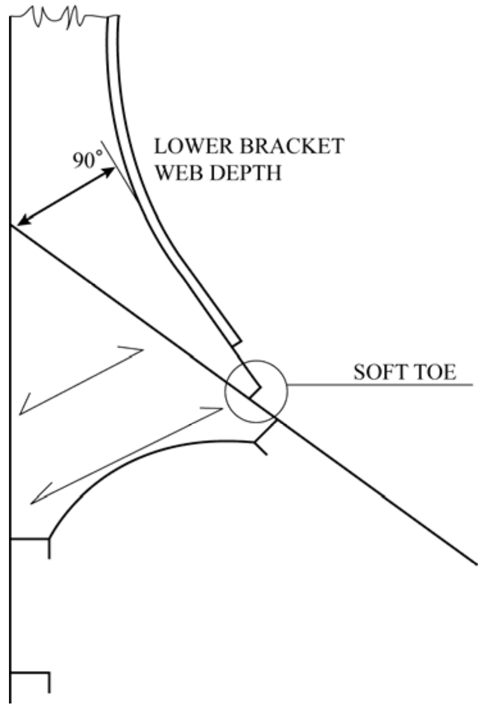

Figure 22: Example of support structure for lower end

9. Deck structure

9.1 Application

9.1.1

The deck outside the line of hatches and the topside tank sloping plates are to be longitudinally framed. Within the line of hatches, other arrangement than longitudinal framing may be considered provided that adequate structural continuity is ensured.

9.2 General arrangement

9.2.1

The spacing of web frames in topside tanks is generally to be not greater than 6 frame spaces.

Greater spacing may be accepted by the Society, on a case-by-case basis, depending on the results of the analysis carried out according to Ch 7.

9.2.2

The deck supporting structure is to be made of ordinary stiffeners longitudinally or transversely arranged, supported by primary supporting members.

9.2.3 Deck between hatches

Inside the line of openings, a transversely framed structure is to be generally adopted for the cross deck structures. Hatch end beams and cross deck beams are to be adequately supported by girders and extended outward to the second longitudinal from the hatch side girders towards the deck side. Where this is impracticable, intercostal stiffeners are to be fitted between the hatch side girder and the second longitudinal.

If the extension of beams outward to the second longitudinal is not achievable, structural checks of the structure are to be performed in compliance with the requirements in Ch.7 or by means deemed appropriate by the Society.

Smooth connection of the strength deck at side with the deck between hatches is to be ensured by a plate of intermediate thickness.

RCN 1 to July 2010 version (effective from 1July 2012)

9.2.4 Topside tank structures

Topside tank structures are to extend as far as possible within the machinery space and are to be adequately tapered.

Where a double side primary supporting member is fitted outside the plane of the topside tank web frame, a large bracket is to be fitted in line with.

9.2.5 Stringer plate

The width of the stringer plate is to be not less than the value obtained, in m, from the following formula:

$$b = 0.35 + 0.5L / 100$$

Rounded stringer plate, where adopted, are to have a radius complying with the requirements in [7.3.6].

9.2.6

Adequate continuity of strength by providing proper overlapping of structures and adequate scarphing members is to be ensured in way of:

- stepped strength deck
- changes in the framing system

9.2.7

Deck supporting structures under deck machinery, cranes, king post and equipment such as towing equipment, mooring equipment, etc., are to be adequately stiffened.

9.2.8

Pillars or other supporting structures are to be generally fitted under heavy concentrated loads.

9.2.9

A suitable stiffening arrangement is considered in way of the ends and corners of deckhouses and partial superstructures.

9.2.10 Connection of hatch end beams with deck structures

The connection of hatch end beams with deck structures is to be properly ensured by fitting inside the topside tanks additional web frames or brackets.

9.2.11 Construction of deck plating

Hatchways or other openings on decks are to have rounded corners, and compensation is to be suitably provided.

9.3 Longitudinally framed deck

9.3.1 General

Deck longitudinals within the parallel part of cargo hold area except within the line of hatch openings are to be continuous in way of deck transverses and transverse bulkheads. For the deck longitudinals out of parallel part of cargo hold area, other arrangements may be considered, provided adequate continuity of longitudinal strength is ensured.

Connections at ends of longitudinal stiffeners are to ensure a sufficient strength to bending and shear.

9.4 Transversely framed deck

9.4.1 General

Where the deck structure is transversely framed, deck beams or deck transverse stiffeners are to be fitted at each frame.

Transverse beams or deck transverse stiffeners are to be connected to side structure or frames by brackets.

9.5 Hatch supporting structures

9.5.1

Hatch side girders and hatch end beams of reinforced scantlings are to be fitted in way of cargo hold openings.

9.5.2

The connection of hatch end beams to web frames is to be ensured. Hatch end beams are to be aligned with transverse web frames in topside tanks.

(RCN 2, effective from 1 July 2008)

9.5.3

Clear of openings, adequate continuity of strength of longitudinal hatch coamings is to be ensured by under deck girders.

At hatchway corners, deck girders or their extension parts provided under deck in line with hatch coamings and hatch end beams are to be effectively connected so as to maintain the continuity in strength.

(RCN 2, effective from 1 July 2008)

9.5.4

For ships with holds designed for loading/discharging by grabs and having the additional class notation GRAB[X], wire rope grooving in way of cargo holds openings is to be prevented by fitting suitable protection such as half-round bar on the hatch side girders (i.e. upper portion of top side tank plates)/hatch end beams in cargo hold and upper portion of hatch coamings.

RCN 2 to July 2008 version (effective from 1 July 2010)

9.6 Openings in the strength deck

9.6.1 General

Openings in the strength deck are to be kept to a minimum and spaced as far as practicable from one another and from the breaks of effective superstructures. Openings are to be cut as far as practicable from hatchway corners, hatch side coamings and side shell platings.

9.6.2 Small opening location

Openings are generally to be cut outside the limits as shown in Fig 23 in dashed area, defined by:

- the bent area of a rounded sheer strake, if any, or the side shell
- $e = 0.25(B - b)$ from the edge of opening
- $c = 0.07\ell + 0.1b$ or $0.25b$, whichever is greater

where:

b : Width, in m, of the hatchway considered, measured in the transverse direction. (see Fig 23)

ℓ : Width, in m, in way of the corner considered, of the cross deck strip between two consecutive hatchways, measured in the longitudinal direction. (see Fig 23).

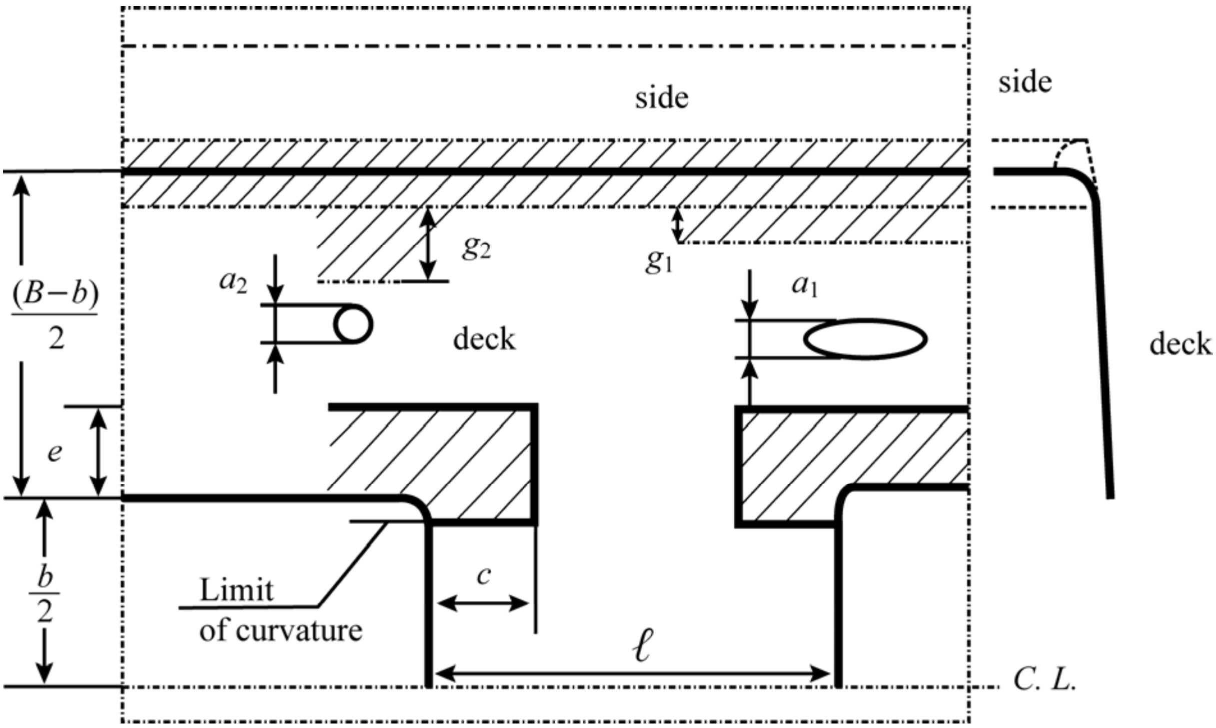

Figure 23: Position of openings in strength deck

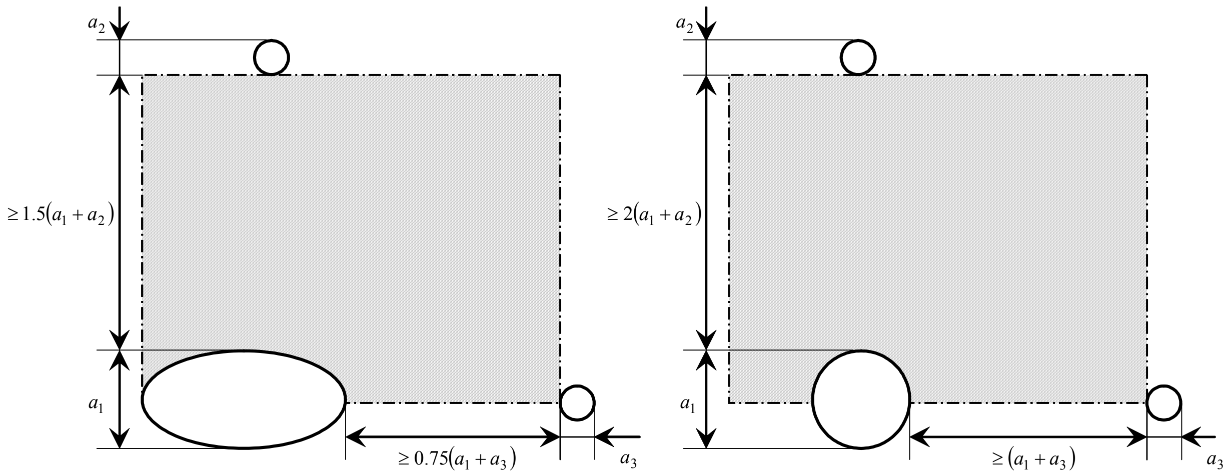

Figure 24: Elliptical and circular openings in strength deck

Moreover the transverse distance between these limits and openings or between openings together is not to be less than the followings:

- Transverse distance between the above limits and openings or between hatchways and openings as shown in Fig 23:
  - $g_2 = 2a_2$ for circular openings
  - $g_1 = a_1$ for elliptical openings
- Transverse distance between openings as shown in Fig 24:
  - $2(a_1 + a_2)$ for circular openings
  - $1.5(a_1 + a_2)$ for elliptical openings

  where

  a_1 : Transverse dimension of elliptical openings, or diameter of circular openings, as the case may be

  a_2 : Transverse dimension of elliptical openings, or diameter of circular openings, as the case may be

  a_3 : Longitudinal dimension of elliptical openings, or diameter of circular openings, as the case may be
- Longitudinal distance between openings is not to be less than the followings:
  - $(a_1 + a_3)$ for circular openings
  - $0.75(a_1 + a_3)$ for elliptical openings and for an elliptical opening in line with a circular one.

If the opening arrangements do not comply with these requirements, the longitudinal strength assessment in accordance with Ch 5 is to be carried out by subtracting such opening areas.

9.6.3 Corner of hatchways

For hatchways located within the cargo area, insert plates, whose thickness is to be determined according to the formula given after, are generally to be fitted in way of corners where the plating cut-out has a circular profile.

The radius of circular corners is to be not less than 5% of the hatch width, where a continuous longitudinal deck girder is fitted below the hatch coaming.

Corner radius, in the case of the arrangement of two or more hatchways athwartship, is considered by the Society on a case by case basis.

For hatchways located within the cargo area, insert plates are, in general, not required in way of corners where the plating cut-out has an elliptical or parabolic profile and the half axes of elliptical openings, or the half lengths of the parabolic arch, are not less than:

- 1/20 of the hatchway width or 600 mm, whichever is the lesser, in the transverse direction
- twice the transverse dimension, in the fore and aft direction.

Where insert plates are required, their net thickness is to be obtained, in mm, from the following formula:

$$t_{INS} = (0.8 + 0.4b / l)\, t$$

Corrigenda 2 to July 2012 version (effective from 1 July 2012)

without being taken less than t or greater than $1.6t$

where:

ℓ : Width, in m, in way of the corner considered, of the cross deck strip between two consecutive hatchways, measured in the longitudinal direction (see Fig 23)

b : Width, in m, of the hatchway considered, measured in the transverse direction (see Fig 23)

t : Actual net thickness, in mm, of the deck at the side of the hatchways.

For the extreme corners of end hatchways, the thickness of insert plates is to be 60% greater than the actual thickness of the adjacent deck plating. A lower thickness may be accepted by the Society on the basis of calculations showing that stresses at hatch corners are lower than permissible values.

Where insert plates are required, the arrangement is shown in Fig 25, in which d_1, d_2, d_3 and d_4 are to be greater than the ordinary stiffener spacing.

For hatchways located outside the cargo area, a reduction in the thickness of the insert plates in way of corners may be considered by the Society on a case by case basis.

For ships having length L of 150 m or above, the corner radius, the thickness and the extent of insert plate may be determined by the results of a direct strength assessment according to Ch 7, Sec 2 and Sec 3, including buckling check and fatigue strength assessment of hatch corners according to Ch 8, Sec 5.

(RCN 2, effective from 1 July 2008)

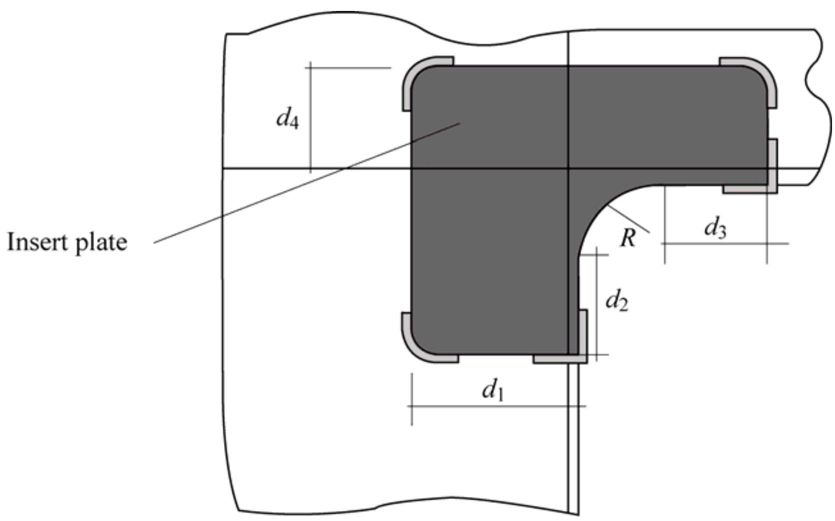

Figure 25: Hatch corner insert plate

10. Bulkhead structure

10.1 Application

10.1.1

The requirements of this article apply to longitudinal and transverse bulkhead structures which may be plane or corrugated.

10.1.2 Plane bulkheads

Plane bulkheads may be horizontally or vertically stiffened.

Horizontally framed bulkheads are made of horizontal ordinary stiffeners supported by vertical primary supporting members.

Vertically framed bulkheads are made of vertical ordinary stiffeners which may be supported by horizontal girders.

10.2 General

10.2.1

The web height of vertical primary supporting members of bulkheads may be gradually tapered from bottom to deck.

10.2.2

The net thickness of the after peak bulkhead plating in way of the stern tube is to be increased by at least 60% of other part of after peak bulkhead plating

10.3 Plane bulkheads

10.3.1 General

Where a bulkhead does not extend up to the uppermost continuous deck, suitable strengthening is to be provided in the extension of the bulkhead.

Bulkheads are to be stiffened in way of the deck girders.

The bulkhead stiffener webs of hopper and topside tank watertight bulkheads are required to be aligned with the webs of longitudinal stiffeners of sloping plates of inner hull.

A primary supporting member is to be provided in way of any vertical knuckle in longitudinal bulkheads. The distance between the knuckle and the primary supporting member is to be taken not greater than 70 mm. When the knuckle is not vertical, it is to be adequately stiffened by ordinary stiffeners or equivalent means, fitted in line with the knuckle.

Plate floors are to be fitted in the double bottom in line with the plate transverse bulkhead.

10.3.2 End connection of ordinary stiffeners

The crossing of ordinary stiffeners through a watertight bulkhead is to be watertight.

In general, end connections of ordinary stiffeners are to be bracketed. If bracketed end connections cannot be applied due to hull lines, etc., they are to be terminated on transverse headers between adjacent longitudinal or if

not possible, sniped ends may be accepted, provided the scantling of ordinary stiffeners and corresponding plating are modified accordingly.

10.3.3 Sniped end of ordinary stiffener

Sniped ends are not allowed on bulkheads subject to hydrostatic pressure. Where sniped ordinary stiffeners are fitted, the snipe angle is not to be greater than 30 degrees, and their ends are to be extended as far as practicable to the boundary of the bulkhead.

10.3.4 Bracketed ordinary stiffeners

Where bracketed ordinary stiffeners are fitted, the arm lengths of end brackets of ordinary stiffeners, as shown in Figs 26 and 27, are to be not less than the following values, in mm:

- for arm length a:
  - brackets of horizontal stiffeners and bottom bracket of vertical stiffeners:
    $a = 100\ell$
  - upper bracket of vertical stiffeners:
    $a = 80\ell$
- for arm length b, the greater of

  $b = 80\{(w + 20)/t\}^{0.5}$ and

  $b = \alpha p s \ell / t$

where:

ℓ : Span, in m, of the stiffener measured between supports

w : Net section modulus, in cm^3, of the stiffener

t : Net thickness, in mm, of the bracket

p : Design pressure, in kN/m^2, calculated at mid-span

α : Coefficient equal to:

$\alpha = 4.9$ for tank bulkheads

$\alpha = 3.6$ for watertight bulkheads.

The connection between the stiffener and the bracket is to be such that the net section modulus of the connection is not less than that of the stiffener.

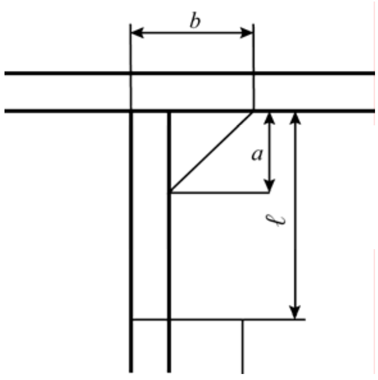

Figure 26: Bracket at upper end of ordinary stiffener on plane bulkhead

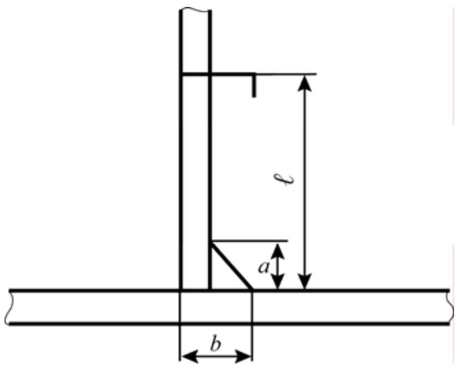

Figure 27: Bracket at lower end of ordinary stiffener on plane bulkhead

10.4 Corrugated bulkheads

10.4.1 General

For ships of 190 m of length L and above, the transverse vertically corrugated watertight bulkheads are to be fitted with a lower stool, and generally with an upper stool below deck. For ships less than 190 m in length L, corrugations may extend from inner bottom to deck provided the global strength of hull structures are satisfactorily proved for ships having ship length L of 150 m and above by DSA as required by Ch 7 of the Rules.

10.4.2 Construction

The main dimensions a, R, c, d, t, φ and s_C of corrugated bulkheads are defined in Fig 28.

The bending radius is not to be less than the following values, in mm:

$R = 3.0t$

where :

t : As-built thickness, in mm, of the corrugated plate.

The corrugation angle φ shown in Fig 28 is to be not less than 55°.

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When welds in a direction parallel to the bend axis are provided in the zone of the bend, the welding procedures are to be submitted to the Society for approval.

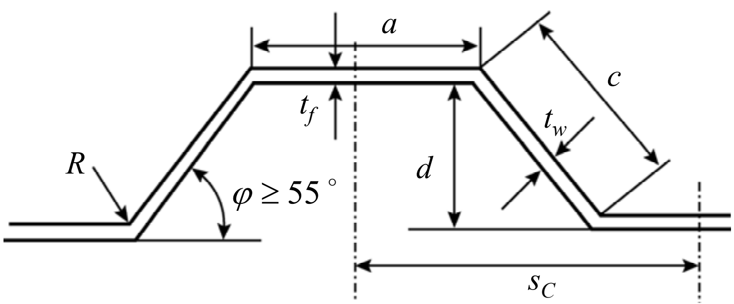

Figure 28: Dimensions of a corrugated bulkhead

10.4.3 Actual section modulus of corrugations

The net section modulus of a corrugation may be obtained, in cm^3, from the following formula:

$$w = \left[\frac{d(3at_f + ct_w)}{6} \right] 10^{-3}$$

where:

t_f, t_w : Net thickness of the plating of the corrugation, in mm, shown in Fig 28

d, a, c : Dimensions of the corrugation, in mm, shown in Fig 28.

Where the web continuity is not ensured at ends of the bulkhead, the net section modulus of a corrugation is to be obtained, in cm^3, from the following formula:

$$w = 0.5\, a\, t_f\, d \cdot 10^{-3}$$

10.4.4 Span of corrugations

The span ℓ_C of the corrugations is to be taken as the distance shown in Fig 29.

For the definition of ℓ_C, the internal end of the upper stool is not to be taken more than a distance from the deck at the centre line equal to:

- 3 times the depth of corrugation, in general
- 2 times the depth of corrugation, for rectangular stool

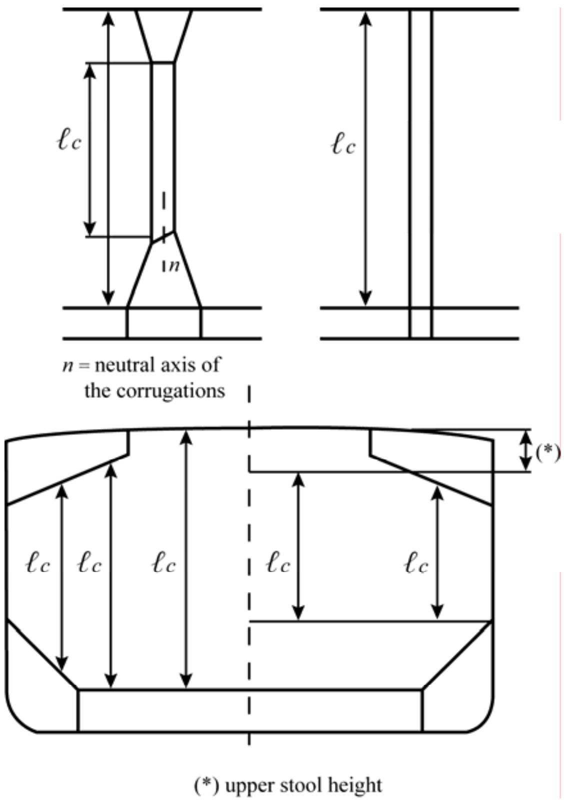

Figure 29: Span of the corrugations

10.4.5 Structural arrangements

The strength continuity of corrugated bulkheads is to be ensured at the ends of corrugations.

Where corrugated bulkheads are cut in way of primary supporting members, attention is to be paid to ensure correct alignment of corrugations on each side of the primary member.

Where vertically corrugated transverse bulkheads or longitudinal bulkheads are welded on the inner bottom plate, floors or girders are to be fitted in way of flanges of corrugations, respectively.

In general, the first vertical corrugation connected to the boundary structures is to have a width not smaller than typical width of corrugation flange. *RCN 1 to July 2008 version (effective from 1 July 2009)*

10.4.6 Bulkhead stools

Plate diaphragms or web frames are to be fitted in bottom stools in way of the double bottom longitudinal girders or plate floors, as the case may be.

Brackets or deep webs are to be fitted to connect the upper stool to the deck transverse or hatch end beams, as the case may be. *RCN 1 to July 2008 version (effective from 1 July 2009)*

10.4.7 Lower stool

The lower stool, when fitted, is to have a height in general not less than 3 times the depth of the corrugations. The ends of stool side ordinary stiffeners, when fitted in a vertical plane, are to be attached to brackets at the upper and lower ends of the stool.

The distance d from the edge of the stool top plate to the surface of the corrugation flange is to be in accordance with Fig 30.

The stool bottom is to be installed in line with double bottom floors or girders as the case may be, and is to have a width not less than 2.5 times the mean depth of the corrugation.

The stool is to be fitted with diaphragms in line with the longitudinal double bottom girders or floors as the case may be, for effective support of the corrugated bulkhead. Scallops in the brackets and diaphragms in way of the connections to the stool top plate are to be avoided.

Where corrugations are cut at the lower stool, corrugated bulkhead plating is to be connected to the stool top plate by full penetration welds. The stool side plating is to be connected to the stool top plate and the inner bottom plating by either full penetration or deep penetration welds. The supporting floors are to be connected to the inner bottom by either full penetration or deep penetration weld.

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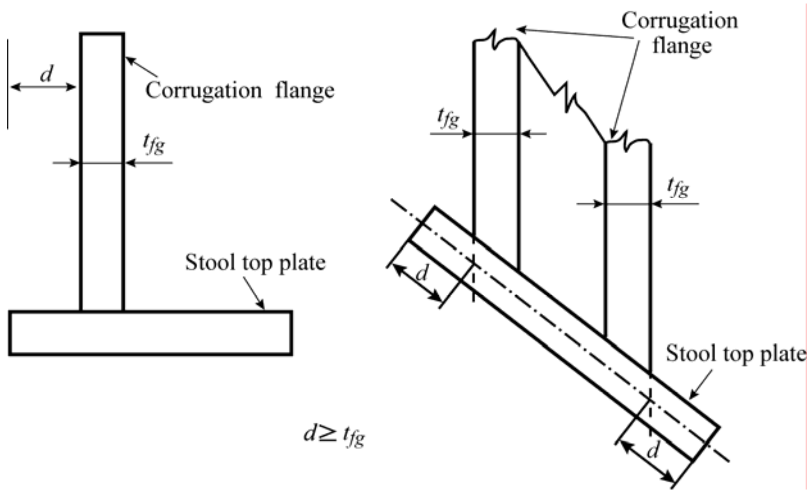

Figure 30: Permitted distance, *d*, from the edge of the stool top plate to the surface of the corrugation flange

10.4.8 Upper stool

The upper stool, when fitted, is to have a height in general between two and three times the depth of corrugations. Rectangular stools are to have a height in general equal to twice the depth of corrugations, measured from the deck level and at the hatch side girder.

The upper stool of transverse bulkhead is to be properly supported by deck girders or deep brackets between the adjacent hatch end beams.

The width of the upper stool bottom plate is generally to be the same as that of the lower stool top plate. The stool top of non-rectangular stools is to have a width not less than twice the depth of corrugations.

The ends of stool side ordinary stiffeners when fitted in a vertical plane, are to be attached to brackets at the upper and lower end of the stool.

The stool is to be fitted with diaphragms in line with and effectively attached to longitudinal deck girders extending to the hatch end coaming girders or transverse deck primary supporting members as the case may be, for effective support of the corrugated bulkhead.

Scallops in the brackets and diaphragms in way of the connection to the stool bottom plate are to be avoided.

RCN 1 to July 2008 version (effective from 1 July 2009)

10.4.9 Alignment

At deck, if no upper stool is fitted, two transverse or longitudinal reinforced beams as the case may be, are to be fitted in line with the corrugation flanges.

At bottom, if no lower stool is fitted, the corrugation flanges are to be in line with the supporting floors or girders.

The weld of corrugations and floors or girders to the inner bottom plating are to be full penetration ones.

The cut-outs for connections of the inner bottom longitudinals to double bottom floors are to be closed by collar plates. The supporting floors or girders are to be connected to each other by suitably designed shear plates.

Stool side plating is to be aligned with the corrugation flanges. Lower stool side vertical stiffeners and their brackets in the stool are to be aligned with the inner bottom structures as longitudinals or similar, to provide appropriate load transmission between these stiffening members.

Lower stool side plating is not to be knuckled anywhere between the inner bottom plating and the stool top plate.

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10.4.10 Effective width of the compression flange

The effective width of the corrugation flange in compression to be considered for the strength check of the bulkhead is to be obtained, in m, from the following formula:

$$b_{ef} = C_E a$$

where:

C_E : Coefficient to be taken equal to:

$$C_E = \frac{2.25}{\beta} - \frac{1.25}{\beta^2} \qquad \text{for } \beta > 1.25$$

$$C_E = 1.0 \qquad \text{for } \beta \le 1.25$$

β : Coefficient to be taken equal to:

$$\beta = 10^3 \frac{a}{t_f} \sqrt{\frac{R_{eH}}{E}}$$

a : Width, in m, of the corrugation flange (see Fig 28)

t_f : Net flange thickness, in mm.

10.4.11 Effective shedder plates

Effective shedder plates are those which:

- are not knuckled
- are welded to the corrugations and the lower stool top plate according to Ch 11
- are fitted with a minimum slope of 45°, their lower edge being in line with the lower stool side plating
- have thickness not less than 75% of that required for the corrugation flanges
- have material properties not less than those required for the flanges.

10.4.12 Effective gusset plate

Effective gusset plates are those which:

- are in combination with shedder plates having thickness, material properties and welded connections as requested for shedder plates in [10.4.11],
- have a height not less than half of the flange width,
- are fitted in line with the lower stool side plating,
- are welded to the lower stool top plate, corrugations and shedder plates according to Ch 11,
- have thickness and material properties not less than those required for the flanges.

10.4.13

(void) *RCN 1 to July 2008 version (effective from 1 July 2009)*

Figure 31: (void) *RCN 1 to July 2008 (effective from 1 July 2009)*

Figure 32: (void) *RCN 1 to July 2008 (effective from 1 July 2009)*

Figure 33: (void) *RCN 1 to July 2008 (effective from 1 July 2009)*

Figure 34: (void) *RCN 1 to July 2008 (effective from 1 July 2009)*

Figure 35: (void) *RCN 1 to July 2008 (effective from 1 July 2009)*

10.4.14

(void) *RCN 1 to July 2008 version (effective from 1 July 2009)*

10.4.15

(void) *RCN 1 to July 2008 version (effective from 1 July 2009)*

10.5 Non-tight bulkheads

10.5.1 Non-tight bulkheads not acting as pillars

Non-tight bulkheads not acting as pillars are to be provided with bulkhead stiffeners with a maximum spacing equal to:

- 0.9 m, for transverse bulkheads
- two frame spacings, with a maximum of 1.5 m, for longitudinal bulkheads.

The net thickness of bulkhead stiffener, in mm, is not to be less than the value obtained from the following formula:

$t = 3 + 0.015\, L_2$

where:

L_2 : Rule length L, but to be taken not greater than 300 m

The depth of bulkhead stiffener of flat bar type is in general not to be less than 1/12 of stiffener length. A smaller depth of stiffener may be accepted based on calculations showing compliance with Ch 6 Sec 2 [2.3.1], Ch 6 Sec 2 [4] and Ch 6 Sec 3 [4].

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10.5.2 Non-tight bulkheads acting as pillars

Non-tight bulkheads acting as pillars are to be provided with bulkhead stiffeners with a maximum spacing equal to:

- two frame spacings, when the frame spacing does not exceed 0.75 m,
- one frame spacing, when the frame spacing is greater than 0.75 m.

Each vertical stiffener, in association with a width of plating equal to 35 times the plating net thickness or 1/12 of stiffener length, whichever is the smaller, is to comply with the applicable requirements in Ch 6, Sec 2, for the load being supported.

In the case of non-tight bulkheads supporting longitudinally framed decks, vertical girders are to be provided in way of deck transverse.

10.6 Watertight bulkheads of trunks and tunnels

10.6.1

Ref. SOLAS Ch. II-1, Part B, Reg. 19.1

Watertight trunks, tunnels, duct keels and ventilators are to be of the same strength as watertight bulkheads at corresponding levels. The means used for making them watertight, and the arrangements adopted for closing openings in them, are to be to the satisfaction of the Society.

11. Pillars

11.1 General

11.1.1

Pillars are to be fitted, as far as practicable, in the same vertical line. If not possible, effective means are to be provided for transmitting their loads to the supports below.

11.1.2

Pillars are to be provided in line with the double bottom girder or as close thereto as practicable, and the structure above and under the pillars is to be of sufficient strength to provide effective distribution of the load. Where pillars connected to the inner bottom are not located in way of the intersection of floors and girders, partial floors or girders or equivalent structures suitable to support the pillars are to be arranged.

11.1.3

Pillars provided in tanks are to be of solid or open section type. Pillars located in spaces intended for products which may produce explosive gases are to be of open section type.

11.1.4 Connections

Heads and heels of pillars are to be secured by thick doubling plates and brackets as necessary. Where the pillars are likely to be subjected to tensile loads such as those in tanks, the head and heel of pillars are to be efficiently secured to withstand the tensile loads and the doubling plates replaced by insert plate.

In general, the net thickness of doubling plates is to be not less than 1.5 times the net thickness of the pillar.

Pillars are to be attached at their heads and heels by continuous welding.

Chapter 4

Design Loads

Appendix 2 Standard Loading Conditions for Direct Strength Analysis

Appendix 3 Standard Loading Conditions for Fatigue Assessment

Section 1 – GENERAL

1. General

1.1

1.1.1

The equivalent design wave (EDW) method is used to set the design loads which include lateral loads normal to plating and hull girder loads in still water and in waves.

1.1.2

External hydrostatic pressure and internal static pressure due to cargo and ballast are considered as lateral loads in still water. External hydrodynamic pressure and internal inertial pressure due to cargo and ballast are considered as lateral loads in waves.

1.1.3

Still water vertical shear force and bending moment, wave-induced vertical shear force and bending moment and wave-induced horizontal bending moment are considered as the hull girder loads.

1.1.4

The stresses due to the lateral loads in waves and the hull girder loads in waves are to be combined using load combination factors determined for each equivalent design wave.

Section 2 – SHIP MOTIONS AND ACCELERATIONS

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

a_0 : Acceleration parameter, taken equal to:

$$a_0 = f_p\left(1.58 - 0.47C_B\right)\left(\frac{2.4}{\sqrt{L}} + \frac{34}{L} - \frac{600}{L^2}\right)$$

T_R : Roll period, in s, defined in [2.1.1]

θ : Single roll amplitude, in deg, defined in [2.1.1]

T_P : Pitch period, in s, defined in [2.2.1]

Φ : Single pitch amplitude, in deg, defined in [2.2.1]

f_p : Coefficient corresponding to the probability level, taken equal to:

$f_p = 1.0$ for strength assessments corresponding to the probability level of 10^{-8}

$f_p = 0.5$ for strength assessments corresponding to the probability level of 10^{-4}

1. General

1.1

1.1.1

Ship motions and accelerations are assumed to be periodic. The motion amplitudes, defined by the formulae in this Section, are half of the crest to trough amplitudes.

1.1.2

As an alternative to the formulae in this Section, the Society may accept the values of ship motions and accelerations derived from direct calculations or obtained from model tests, when justified on the basis of the ship's characteristics and intended service. In general, the values of ship motions and accelerations to be determined are those which can be reached with a probability level of 10^{-8} or 10^{-4}. In any case, the model tests or the calculations, including the assumed sea scatter diagrams and spectra, are to be submitted to the Society for approval.

2. Ship absolute motions and accelerations

2.1 Roll

2.1.1

The roll period T_R, in s, and the single roll amplitude θ, in deg, are given by:

$$T_R = \frac{2.3k_r}{\sqrt{GM}}$$

$$\theta = \frac{9000\left(1.25 - 0.025T_R\right)f_p k_b}{\left(B + 75\right)\pi}$$

where:

k_b : Coefficient taken equal to:

$k_b = 1.2$ for ships without bilge keel

$k_b = 1.0$ for ships with bilge keel

k_r : Roll radius of gyration, in m, in the considered loading condition. When k_r is not known, the values indicated in Tab 1 may be assumed.

GM : Metacentric height, in m, in the considered loading condition. When GM is not known, the values indicated in Tab 1 may be assumed.

Table 1: Values of k_r and GM *RCN 1 to July 2008 version (effective from 1 July 2009)*

Loading condition		k_r	GM
Full load condition	Alternate or homogeneous loading	$0.35B$	$0.12B$
	Steel coil loading	$0.42B$	$0.24B$
Normal ballast condition		$0.45B$	$0.33B$
Heavy ballast condition		$0.40B$	$0.25B$

2.2 Pitch

2.2.1

The pitch period T_P, in s, and the single pitch amplitude Φ, in deg, are given by:

$$T_P = \sqrt{\frac{2\pi\lambda}{g}}$$

$$\Phi = f_p \frac{960}{L} \sqrt[4]{\frac{V}{C_B}}$$

where:

$$\lambda = 0.6\left(1 + \frac{T_{LC}}{T_S}\right)L$$

2.3 Heave

2.3.1

The vertical acceleration due to heave, in m/s^2, is given by:

$$a_{heave} = a_0 g$$

2.4 Sway

2.4.1

The transverse acceleration due to sway, in m/s^2, is given by:

$$a_{sway} = 0.3 a_0 g$$

2.5 Surge

2.5.1

The longitudinal acceleration due to surge, in m/s^2, is given by:

$a_{surge} = 0.2 a_0 g$

3. Ship relative accelerations

3.1 General

3.1.1

At any point, the accelerations in X, Y and Z directions are the acceleration components which result from the ship absolute motions and accelerations defined in [2.1] to [2.5].

3.2 Accelerations

3.2.1

The reference values of the longitudinal, transverse and vertical accelerations at any point are obtained from the following formulae:

- In longitudinal direction:

  $a_X = C_{XG} g \sin \Phi + C_{XS} a_{surge} + C_{XP} a_{pitch\,x}$

- In transverse direction:

  $a_Y = C_{YG} g \sin \theta + C_{YS} a_{sway} + C_{YR} a_{roll\,y}$

- In vertical direction:

  $a_Z = C_{ZH} a_{heave} + C_{ZR} a_{roll\,z} + C_{ZP} a_{pitch\,z}$

where:

C_{XG}, C_{XS}, C_{XP}, C_{YG}, C_{YS}, C_{YR}, C_{ZH}, C_{ZR} and C_{ZP} : Load combination factors defined in Ch 4, Sec 4, [2.2]

$a_{pitch\,x}$: Longitudinal acceleration due to pitch, in m/s^2

$$a_{pitch\,x} = \Phi \frac{\pi}{180} \left(\frac{2\pi}{T_P} \right)^2 R$$

$a_{roll\,y}$: Transverse acceleration due to roll, in m/s^2

$$a_{roll\,y} = \theta \frac{\pi}{180} \left(\frac{2\pi}{T_R} \right)^2 R$$

$a_{roll\,z}$: Vertical acceleration due to roll, in m/s^2

$$a_{roll\,z} = \theta \frac{\pi}{180} \left(\frac{2\pi}{T_R} \right)^2 y$$

$a_{pitch\,z}$: Vertical acceleration due to pitch, in m/s^2

$$a_{pitch\,z} = \Phi \frac{\pi}{180} \left(\frac{2\pi}{T_P} \right)^2 \left| (x - 0.45L) \right|$$

where $\left| (x - 0.45L) \right|$ is to be taken not less than $0.2L$

R = $z - \min\left(\frac{D}{4} + \frac{T_{LC}}{2}, \frac{D}{2} \right)$

x, y, z : X, Y and Z co-ordinates, in m, of any point considered with respect to the reference co-ordinate system defined in Ch 1, Sec 4

Section 3 – HULL GIRDER LOADS

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

x : X co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system

f_p : Coefficient corresponding to the probability, defined in Ch 4, Sec 2.

1. General

1.1 Sign conventions of bending moments and shear forces

1.1.1

Absolute values are to be taken for bending moments and shear forces introduced in this Section. The sign of bending moments and shear forces is to be considered according to Sec 4, Tab 3. The sign conventions of vertical bending moments, horizontal bending moments and shear forces at any ship transverse section are as shown in Fig 1, namely:

- the vertical bending moments M_{SW} and M_{WV} are positive when they induce tensile stresses in the strength deck (hogging bending moment) and are negative in the opposite case (sagging bending moment)
- the horizontal bending moment M_{WH} is positive when it induces tensile stresses in the starboard and is negative in the opposite case.
- the vertical shear forces Q_{SW}, Q_{WV} are positive in the case of downward resulting forces preceding and upward resulting forces following the ship transverse section under consideration, and is negative in the opposite case.

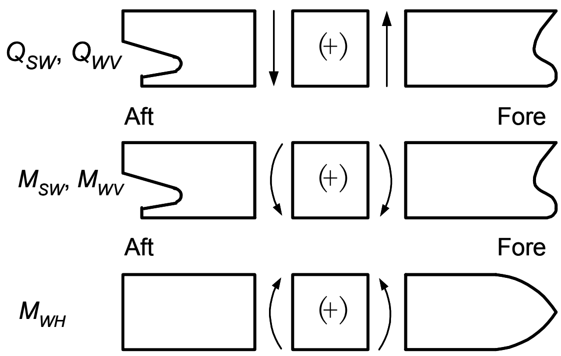


Figure 1: Sign conventions for shear forces Q_{SW}, Q_{WV} and bending moments M_{SW}, M_{WV} and M_{WH}

2. Still water loads

2.1 General

2.1.1

In general the vertical still water bending moment and the shear force of the individual loading condition is to be applied. The shipbuilder has to submit for each of the loading condition defined in Ch 4, Sec 7 a longitudinal strength calculation.

The values of still water vertical bending moment and shear force are to be treated as the upper limits with respect to hull girder strength.

In general, the design cargo and ballast loading conditions, based on amount of bunker, fresh water and stores at departure and arrival, are to be considered for the M_{SW} and Q_{SW} calculations. Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted in addition to those for departure and arrival conditions. Also, where any ballasting and/or deballasting is intended during voyage, calculations of the intermediate condition just before and just after ballasting and/or deballasting any ballast tank are to be submitted and where approved included in the loading manual for guidance.

2.1.2 Partially filled ballast tanks in ballast loading conditions

Ballast loading conditions involving partially filled peak and/or other ballast tanks at departure, arrival or during intermediate conditions are not permitted to be used as design conditions unless:

- design stress limits are satisfied for all filling levels between empty and full, and
- for **BC-A** and **BC-B** ships, longitudinal strength of hull girder in flooded condition according to Ch 5, Sec 1, [2.1.3] is complied with for all filling levels between empty and full.

To demonstrate compliance with all filling levels between empty and full, it will be acceptable if, in each condition at departure, arrival, and where required by [2.1.1], any intermediate condition, the tanks intended to be partially filled are assumed to be:

- empty
- full
- partially filled at intended level

Where multiple tanks are intended to be partially filled, all combinations of empty, full or partially filled at intended level for those tanks are to be investigated.

(RCN 2, effective from 1 July 2008)

2.1.3 Partially filled ballast tanks in cargo loading conditions

In cargo loading conditions, the requirement in [2.1.2] applies to the peak tanks only.

2.1.4 Sequential ballast water exchange

Requirements of [2.1.2] and [2.1.3] are not applicable to ballast water exchange using the sequential method.

(RCN 2, effective from 1 July 2008)

2.2 Still water bending moment

2.2.1

The design still water bending moments $M_{SW,H}$ and $M_{SW,S}$ at any hull transverse section are the maximum still water bending moments calculated, in hogging and sagging conditions, respectively, at that hull transverse section for the loading conditions, as defined in [2.1.1]. Greater values may be considered if defined by the Designer.

2.2.2

If the design still water bending moments are not defined, at a preliminary design stage, at any hull transverse section, the longitudinal distributions shown in Fig 2 may be considered.

In Fig 2, M_{SW} is the design still water bending moment amidships, in hogging or sagging conditions, whose values are to be taken not less than those obtained, in kN.m, from the following formulae:

- hogging conditions:

$$M_{SW,H} = 175CL^2B(C_B + 0.7)10^{-3} - M_{WV,H}$$

- sagging conditions:

$$M_{SW,S} = 175CL^2B(C_B + 0.7)10^{-3} - M_{WV,S}$$

where $M_{WV,H}$ and $M_{WV,S}$ are the vertical wave bending moments, in kN.m, defined in [3.1].

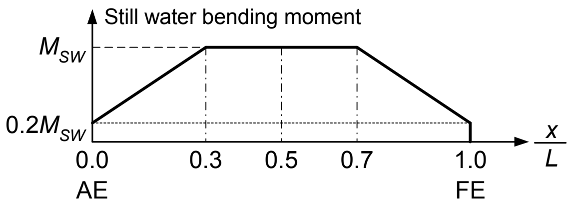


Figure 2: Preliminary still water bending moment distribution

2.3 Still water shear force

2.3.1

The design still water shear force Q_{SW} at any hull transverse section is the maximum positive or negative shear force calculated, at that hull transverse section, for the loading conditions, as defined in [2.1.1]. Greater values may be considered if defined by the Designer.

2.4 Still water bending moment and still water shear force in flooded condition

2.4.1

The still water bending moments $M_{SW,F}$, in hogging and sagging conditions, and the still water shear force $Q_{SW,F}$, in flooded condition are to be determined for the flooding scenario considering each cargo hold individually flooded up to the equilibrium waterline.

This means that double side spaces may not be considered flooded, and the cargo holds may not be considered completely flooded, but only up to the equilibrium waterline.

2.4.2

To calculate the weight of ingressed water, the following assumptions are to be made:

a) The permeability of empty cargo spaces and volume left in loaded cargo spaces above any cargo is to be taken as 0.95.

b) Appropriate permeabilities and bulk densities are to be used for any cargo carried. For iron ore, a minimum permeability of 0.3 with a corresponding bulk density of 3.0 t/m^3 is to be used. For cement, a minimum permeability of 0.3 with a corresponding bulk density of 1.3 t/m^3 is to be used. In this respect, "permeability" for solid bulk cargo means the ratio of the floodable volume between the particles, granules or any larger pieces of the cargo, to the gross volume of the bulk cargo.

For packed cargo conditions (such as steel mill products), the actual density of the cargo should be used with a permeability of zero.

2.4.3

To quantify the effects of ingressed water on the hull girder still water bending moments and still water shear forces, specific calculations are to be carried out. The loading conditions on which the design of the ship has been based are to be considered and, for each of them, the cargo holds are to be considered as being individually flooded up to the equilibrium waterline. The still water bending moments and still water shear forces are therefore to be calculated for any combination of considered loading conditions and flooded cargo holds.

3. Wave loads

3.1 Vertical wave bending moments

3.1.1 Intact condition

The vertical wave bending moments in intact condition at any hull transverse section are obtained, in kN.m, from the following formulae:

- hogging conditions:

$$M_{WV,H} = 190 F_M f_p C L^2 B C_B 10^{-3}$$

- sagging conditions:

$$M_{WV,S} = 110 F_M f_p C L^2 B (C_B + 0.7) 10^{-3}$$

where:

F_M : Distribution factor defined in Tab 1 (see also Fig 3).

Table 1: Distribution factor F_M

Hull transverse section location	Distribution factor F_M
$0 \le x < 0.4L$	$2.5\frac{x}{L}$
$0.4L \le x \le 0.65L$	1.0
$0.65L < x \le L$	$2.86\left(1-\frac{x}{L}\right)$

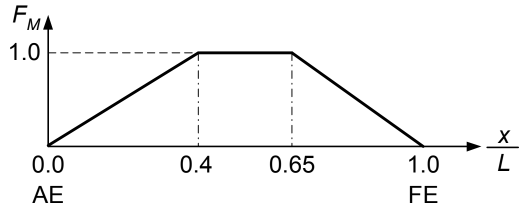


Figure 3: Distribution factor F_M

3.1.2 Flooded condition

The vertical wave bending moments in flooded condition at any hull transverse section are obtained, in kN.m, from the following formula:

$$M_{WV,F} = 0.8 M_{WV}$$

where M_{WV} is defined in [3.1.1].

3.1.3 Harbour condition

The vertical wave bending moments in harbour condition at any hull transverse section are obtained, in kN.m, from the following formula:

$$M_{WV,P} = 0.4 M_{WV}$$

where M_{WV} is defined in [3.1.1].

3.2 Vertical wave shear force

3.2.1 Intact condition

The vertical wave shear force in intact condition at any hull transverse section is obtained, in kN, from the following formula:

$$Q_{WV} = 30 F_Q f_p CLB(C_B + 0.7)10^{-2}$$

where:

F_Q : Distribution factor defined in Tab 2 for positive and negative shear forces (see also Fig 4).

Table 2: Distribution factor F_Q

Hull transverse section location	Distribution factor F_Q	
	Positive wave shear force	Negative wave shear force
$0 \le x < 0.2L$	$4.6A\dfrac{x}{L}$	$4.6\dfrac{x}{L}$
$0.2L \le x \le 0.3L$	$0.92A$	0.92
$0.3L < x < 0.4L$	$(9.2A-7)\left(0.4-\dfrac{x}{L}\right)+0.7$	$2.2\left(0.4-\dfrac{x}{L}\right)+0.7$
$0.4L \le x \le 0.6L$	0.7	0.7
$0.6L < x < 0.7L$	$3\left(\dfrac{x}{L}-0.6\right)+0.7$	$(10A-7)\left(\dfrac{x}{L}-0.6\right)+0.7$
$0.7L \le x \le 0.85L$	1	A
$0.85L < x \le L$	$6.67\left(1-\dfrac{x}{L}\right)$	$6.67A\left(1-\dfrac{x}{L}\right)$
Note : $A = \dfrac{190C_B}{110(C_B+0.7)}$		

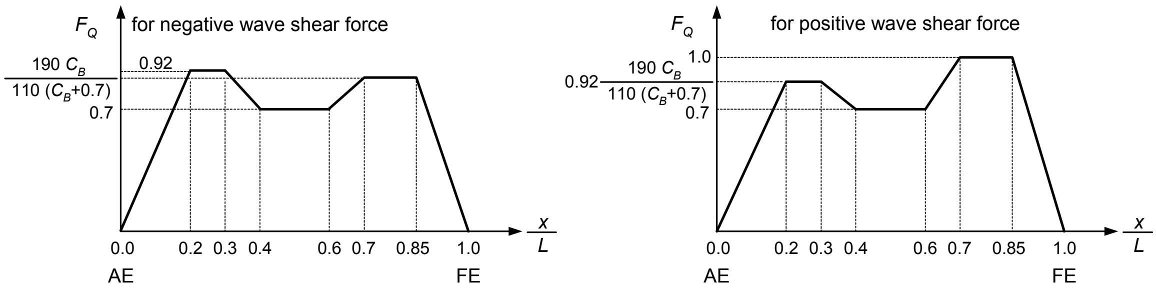


Figure 4: Distribution factor F_Q

3.2.2 Flooded condition

The vertical wave shear force in flooded condition at any hull transverse section are obtained, in kN, from the following formula:

$$Q_{WV,F} = 0.8Q_{WV}$$

where Q_{WV} is defined in [3.2.1].

3.2.3 Harbour condition

The vertical wave shear force in harbour condition at any hull transverse section are obtained, in kN, from the following formula:

$$Q_{WV,P} = 0.4Q_{WV}$$

where Q_{WV} is defined in [3.2.1].

3.3 Horizontal wave bending moment

3.3.1

The horizontal wave bending moment at any hull transverse section, in kN.m, is given by:

$$M_{WH} = (0.3 + \frac{L}{2000}) F_M f_p C L^2 T_{LC} C_B$$

where F_M is the distribution factor defined in [3.1.1].

3.4 Wave torsional moment

3.4.1

The wave torsional moment at any hull transverse section, in kN.m, is given by:

$$M_{WT} = f_p (|M_{WT1}| + |M_{WT2}|)$$

where:

$$M_{WT1} = 0.4 \cdot C \sqrt{\frac{L}{T}} \cdot B^2 D \cdot C_B \cdot F_{T1}$$

$$M_{WT2} = 0.22 C L B^2 C_B \cdot F_{T2}$$

$F_{T1,} F_{T2}$: Distribution factors, defined as follows:

$$F_{T1} = \sin\left(\frac{2\pi x}{L}\right)$$

$$F_{T2} = \sin^2\left(\frac{\pi x}{L}\right)$$

Section 4 – LOAD CASES

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

a_{surge}, $a_{pitch\,x}$, a_{sway}, $a_{roll\,y}$, a_{heave}, $a_{roll\,z}$, $a_{pitch\,z}$: Components of accelerations, defined in Ch 4, Sec 2.

1. General

1.1 Application

1.1.1

The load cases described in this section are those to be used for:

- the local strength analysis of plating and ordinary stiffeners and primary supporting members according to the applicable requirements of Ch 6, Sec 1, Ch 6, Sec 2 and Ch 6, Sec 4 respectively,
- the direct strength analysis of structural members, according to the applicable requirements of Ch 7,
- the fatigue check of structural details, according to the applicable requirements of Ch 8.

1.1.2

For the local strength analysis and for the direct strength analysis, the load cases are the mutually exclusive load cases H1, H2, F1, F2, R1, R2, P1 and P2 described in [2].

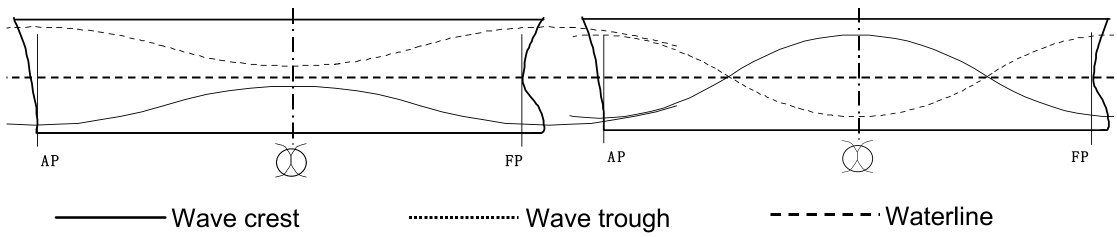
1.2 Equivalent design wave

1.2.1

Regular waves that generate response values equivalent to the long-term response values of the load components considered being predominant to the structural members are set as Equivalent Design Waves (EDWs). They consist of:

- regular waves when the vertical wave bending moment becomes maximum in head sea (EDW “H”)
- regular waves when the vertical wave bending moment becomes maximum in following sea (EDW “F”)
- regular waves when the roll motion becomes maximum (EDW “R”)
- regular waves when the hydrodynamic pressure at the waterline becomes maximum (EDW “P”)

The definitions of wave crest and wave trough in the EDW “H” and EDW “F” are given in Fig 1. The definitions of weather side down and weather side up for the EDW “R” and EDW “P” are given in Fig 2.



(a) for EDW “H” (b) for EDW ”F”

Figure 1: Definition of wave crest and wave trough for EDWs “H” and “F”

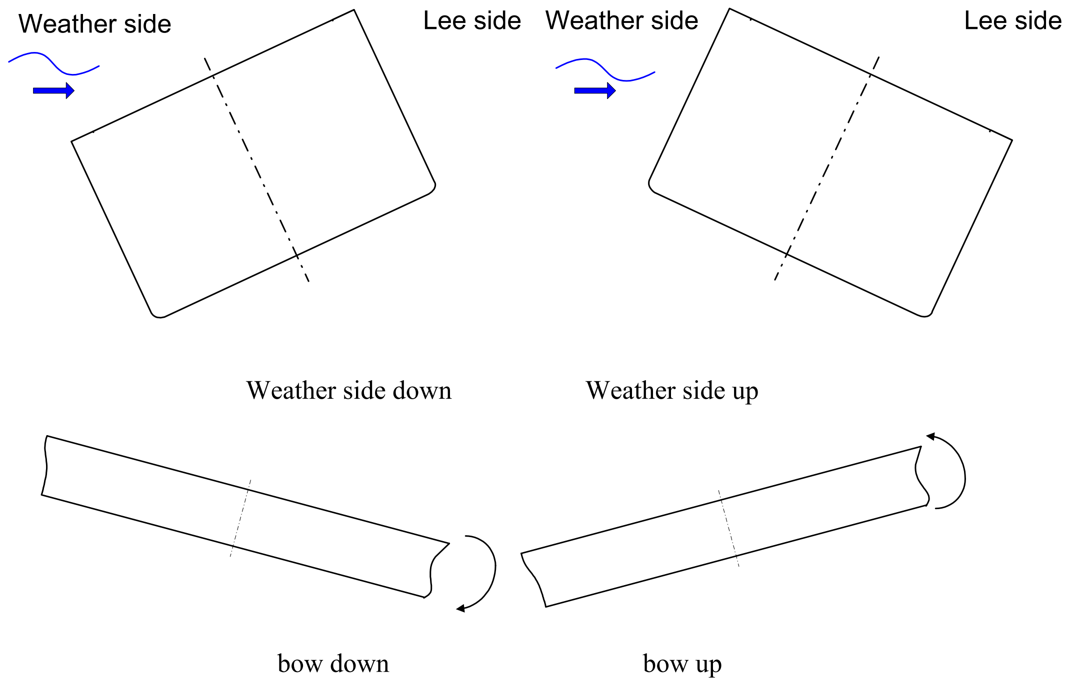


Figure 2: Definitions of ship motion

2. Load cases

2.1 General

2.1.1

The load cases corresponding to the Equivalent Design Waves (EDWs) are defined in Tab 1. The corresponding hull girder loads and motions of the ship are indicated in Tab 2. If the ship structure or the ship loading condition is not symmetrical with respect to the centreline plane of ship, the load cases (R1, R2, P1 and P2) corresponding to the beam conditions in which the encounter wave comes from the starboard (in this case the starboard is the weather side), should be also included in the structural strength assessment.

Table 1: Definition of load cases

Load case	H1	H2	F1	F2	R1	R2	P1	P2
EDW	"H"		"F"		"R"		"P"	
Heading	Head		Follow		Beam (Port: weather side)		Beam (Port: weather side)	
Effect	Max. Bending Moment		Max. Bending Moment		Max. Roll		Max. Ext. Pressure	
	Sagging	Hogging	Sagging	Hogging	(+)	(-)	(+)	(-)

Table 2: Reference hull girder loads and motions of ship

<table>
<tr><th>Load case</th><th>H1</th><th>H2</th><th>F1</th><th>F2</th><th>R1</th><th>R2</th><th>P1</th><th>P2</th></tr>
<tr><td>Vert. BM & SF</td><td colspan="2">Yes</td><td colspan="2">Yes</td><td colspan="2">-</td><td colspan="2">Yes</td></tr>
<tr><td>Hor. BM</td><td colspan="2">-</td><td colspan="2">-</td><td colspan="2">Yes</td><td colspan="2">-</td></tr>
<tr><td>Heave</td><td>Down</td><td>Up</td><td>-</td><td>-</td><td>Down</td><td>Up</td><td>Down</td><td>Up</td></tr>
<tr><td>Pitch</td><td>Bow down</td><td>Bow up</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Roll</td><td>-</td><td>-</td><td>-</td><td>-</td><td>Stbd up</td><td>Stbd down</td><td>Stbd up</td><td>Stbd down</td></tr>
<tr><td>Surge</td><td>Stern</td><td>Bow</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Sway</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>Port</td><td>Stbd</td></tr>
</table>

2.2 Load combination factors

2.2.1

The hull girder loads and the acceleration components to be considered in each load case H1, H2, F1, F2, R1, R2, P1 and P2 are to be obtained by multiplying the reference value of each component by the relevant load combination factor LCF defined in Tab 3.

2.2.2

The still water vertical bending moment is to be added to the hull girder loads in waves, calculated with load combination factors.

2.2.3

The internal loads are the sum of static pressures or forces induced by the weights carried, including those carried on decks, and of inertial pressures or forces induced by the accelerations on these weights and calculated with load combination factors.

Table 3: Load combination factors LCF

	LCF	H1	H2	F1	F2	R1	R2	P1	P2
M_{WV}	C_{WV}	-1	1	-1	1	0	0	$0.4-\dfrac{T_{LC}}{T_S}$	$\dfrac{T_{LC}}{T_S}-0.4$
Q_{WV}	C_{QW} (1)	-1	1	-1	1	0	0	$0.4-\dfrac{T_{LC}}{T_S}$	$\dfrac{T_{LC}}{T_S}-0.4$
M_{WH}	C_{WH}	0	0	0	0	$1.2-\dfrac{T_{LC}}{T_S}$	$\dfrac{T_{LC}}{T_S}-1.2$	0	0
a_{surge}	C_{XS}	-0.8	0.8	0	0	0	0	0	0
$a_{pitch\ x}$	C_{XP}	1	-1	0	0	0	0	0	0
$g\sin\Phi$	C_{XG}	1	-1	0	0	0	0	0	0
a_{sway}	C_{YS}	0	0	0	0	0	0	1	-1
$a_{roll\ y}$	C_{YR}	0	0	0	0	1	-1	0.3	-0.3
$g\sin\theta$	C_{YG}	0	0	0	0	1	-1	0.3	-0.3
a_{heave}	C_{ZH}	$0.6\dfrac{T_{LC}}{T_S}$	$-0.6\dfrac{T_{LC}}{T_S}$	0	0	$\dfrac{\sqrt{L}}{40}$	$-\dfrac{\sqrt{L}}{40}$	1	-1
$a_{roll\ z}$	C_{ZR}	0	0	0	0	1	-1	0.3	-0.3
$a_{pitch\ z}$	C_{ZP}	1	-1	0	0	0	0	0	0

(1) The LCF for C_{QW} is only used for the aft part of midship section. The inverse value of it should be used for the forward part of the midship section.

Section 5 – EXTERNAL PRESSURES

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

L_2 : Rule length L, but to be taken not greater than 300 m

C : Wave coefficient, as defined in Ch 1, Sec 4, [2.3.1]

λ : Wave length, in m, corresponding to the load case, defined in [1.3.1], [1.4.1], and [1.5.1]

f_p : Coefficient corresponding to the probability, defined in Ch 4, Sec 2

T_{LCi} : Draught in the considered cross section, in m, in the considered loading condition

B_i : Moulded breadth at the waterline, in m, in the considered cross section

x, y, z : X, Y and Z co-ordinates, in m, of the load point with respect to the reference co-ordinate system defined in Ch 1, sec 4.

1. External sea pressures on side shell and bottom

1.1 General

1.1.1

The total pressure p at any point of the hull, in kN/m^2, to be obtained from the following formula is not to be negative:

$$p = p_S + p_W$$

Where:

p_S : Hydrostatic pressure defined in [1.2]

p_W : Wave pressure equal to the hydrodynamic pressure defined in [1.3], [1.4] or [1.5], as the case may be, and corrected according to [1.6]

1.2 Hydrostatic pressure

1.2.1

The hydrostatic pressure p_S at any point of the hull, in kN/m^2, corresponding to the draught in still water is obtained, for each loading condition, from the formulae in Tab 1 (see also Fig 1).

Table 1: Hydrostatic pressure p_S

Location	Hydrostatic pressure, p_S, in kN/m^2
Points at and below the waterline ($z \le T_{LCi}$)	$\rho g(T_{LCi} - z)$
Points above the waterline ($z > T_{LCi}$)	0

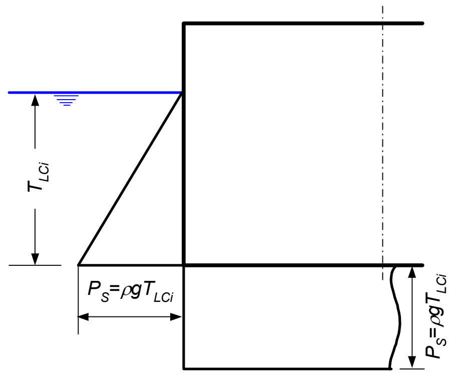


Figure 6: Hydrostatic pressure p_S

1.3 Hydrodynamic pressures for load cases H1, H2, F1 and F2

1.3.1

The hydrodynamic pressures p_H and p_F, for load cases H1, H2, F1 and F2, at any point of the hull below the waterline are to be obtained, in kN/m^2, from Tab 2.

The distribution of pressure p_{F2} is schematically given in Fig 2.

Table 2: Hydrodynamic pressures for load cases H1, H2, F1 and F2

Load case	Hydrodynamic pressure, in kN/m^2
H1	$p_{H1} = - k_\ell \, k_p \, p_{HF}$
H2	$p_{H2} = k_\ell \, k_p \, p_{HF}$
F1	$p_{F1} = - p_{HF}$
F2	$p_{F2} = p_{HF}$

where:

$$p_{HF} = 3 f_p f_{nl} C \sqrt{\frac{L+\lambda-125}{L}} \left(\frac{z}{T_{LCi}} + \frac{|2y|}{B_i} + 1 \right); \quad \text{with } \frac{|2y|}{B_i} \le 1.0 \text{ and } z \text{ is to be taken not greater than } T_{LCi}$$

f_{nl} : Coefficient considering nonlinear effect, taken equal to:

$f_{nl} = 0.9$ for the probability level of 10^{-8}

$f_{nl} = 1.0$ for the probability level of 10^{-4}

k_ℓ : Amplitude coefficient in the longitudinal direction of the ship, taken equal to:

$$k_\ell = 1 + \frac{12}{C_B} \left(1 - \sqrt{\frac{|2y|}{B}} \right) \left| \frac{x}{L} - 0.5 \right|^3 \qquad \text{for } 0.0 \le x/L \le 0.5$$

$$k_\ell = 1 + \frac{6}{C_B} \left(3 - \frac{|4y|}{B} \right) \left| \frac{x}{L} - 0.5 \right|^3 \qquad \text{for } 0.5 \le x/L \le 1.0$$

k_p : Phase coefficient in the longitudinal direction of the ship, taken equal to:

$$k_p = \left(1.25 - \frac{T_{LC}}{T_S} \right) \cos\left(\frac{2\pi |x - 0.5L|}{L} \right) - \frac{T_{LC}}{T_S} + 0.25$$, for local strength analysis in conditions other than full load condition, for direct strength analysis and for fatigue strength assessments

$k_p = -1.0$, for local strength analysis in full load condition

λ : Wave length, in m, taken equal to:

$$\lambda = 0.6\left(1+\frac{T_{LC}}{T_S}\right)L$$ for load cases H1 and H2

$$\lambda = 0.6\left(1+\frac{2}{3}\frac{T_{LC}}{T_S}\right)L$$ for load cases F1 and F2

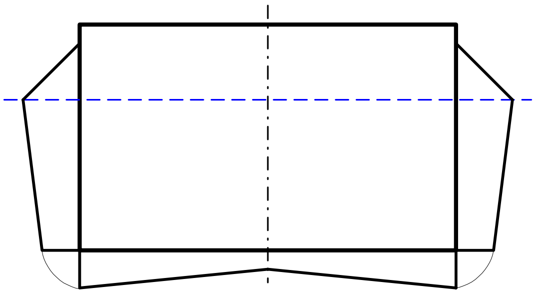


Figure 7: Distribution of hydrodynamic pressure p_{F2} at midship

1.4 Hydrodynamic pressures for load cases R1 and R2

1.4.1

The hydrodynamic pressures p_R, for load cases R1 and R2, at any point of the hull below the waterline are to be obtained, in kN/m^2, from the following formulae. The distribution of pressure p_{R1} is schematically given in Fig 3.

$$p_{R1} = f_{nl}\left(10y\sin\theta + 0.88 f_p C\sqrt{\frac{L+\lambda-125}{L}}\left(\frac{|2y|}{B}+1\right)\right)$$

$$p_{R2} = -p_{R1}$$

where:

f_{nl} : Coefficient considering nonlinear effect, taken equal to:

$f_{nl} = 0.8$ for the probability level of 10^{-8}

$f_{nl} = 1.0$ for the probability level of 10^{-4}

$$\lambda = \frac{g}{2\pi}T_R^2$$

y : Y co-ordinate of the load point, in m, taken positive on the portside.

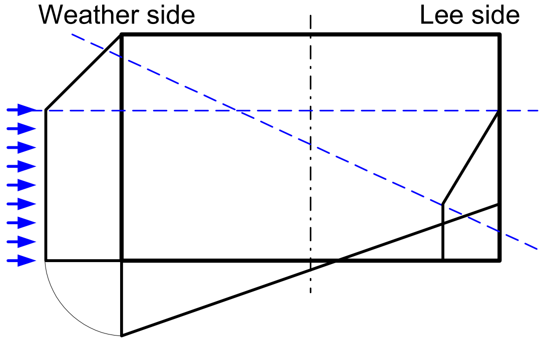


Figure 8: Distribution of hydrodynamic pressure p_{R1} at midship

1.5 Hydrodynamic pressures for load cases P1 and P2

1.5.1

The hydrodynamic pressures p_P, for the load cases P1 and P2, at any point of the hull below the waterline are to be obtained, in kN/m^2, from Tab 3. The distribution of pressure p_{P1} is schematically given in Fig 4.

Table 3: Hydrodynamic pressures for load cases P1 and P2

Load case	Hydrodynamic pressure, in kN/m^2	
	weather side	lee side
P1	$p_{P1} = p_P$	$p_{P1} = p_P/3$
P2	$p_{P2} = -\,p_P$	$p_{P2} = -\,p_P/3$

where:

$$p_P = 4.5 f_p f_{nl} C \sqrt{\frac{L+\lambda-125}{L}}\left(2\frac{|z|}{T_{LCi}} + 3\frac{|2y|}{B}\right)$$

f_{nl} : Coefficient considering nonlinear effect, taken equal to:

$f_{nl} = 0.65$ for the probability level of 10^{-8}

$f_{nl} = 1.0$ for the probability level of 10^{-4}

$$\lambda = \left(0.2 + 0.4\frac{T_{LC}}{T_S}\right)L$$

y : Y co-ordinate of the load point, in m, as defined in [1.4.1]

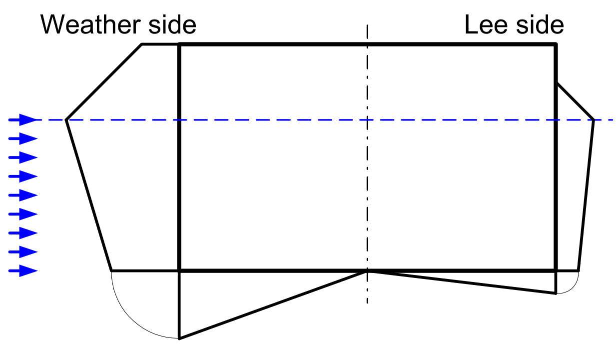


Figure 9: Distribution of hydrodynamic pressure p_{P1} at midship

1.6 Correction to hydrodynamic pressures

1.6.1

For the positive hydrodynamic pressure at the waterline (in load cases H1, H2, F2, R1, R2 and P1), the hydrodynamic pressure $P_{W,C}$ at the side above waterline is given (see Fig 5), in kN/m^2, by:

- $p_{W,C} = p_{W,WL} + \rho g (T_{LCi} - z)$ for $T_{LCi} \le z \le h_W + T_{LCi}$
- $p_{W,C} = 0$ for $z \ge h_W + T_{LCi}$

where:

$p_{W,WL}$: positive hydrodynamic pressure at the waterline for the considered load case

$$h_W = \frac{p_{W,WL}}{\rho g}$$

1.6.2

For the negative hydrodynamic pressure at the waterline (in load cases H1, H2, F1, R1, R2, and P2), the hydrodynamic pressure $P_{W,C}$, under the waterline is given (see Fig 5), in kN/m², by:

$p_{W,C} = p_W$, without being taken less than $\rho g(z-T_{LCi})$

where

p_W : Negative hydrodynamic pressure under the waterline for the considered load case

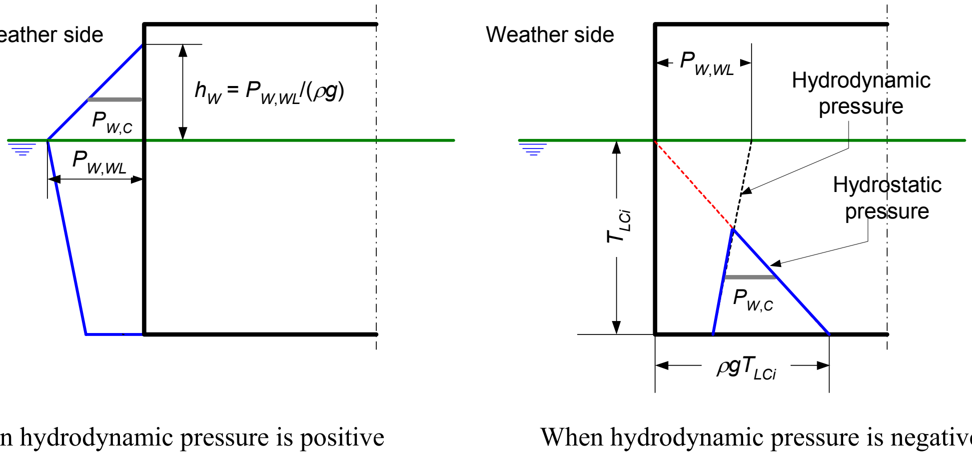


Figure 10: Correction to hydrodynamic pressure

2. External pressures on exposed decks

2.1 General

2.1.1

The external pressures on exposed decks are to be applied for the local scantling check of the structures on exposed deck but not applied for fatigue strength assessment.

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If a breakwater is fitted on the exposed deck, no reduction in the external pressures defined in [2.2] and [2.3] is allowed for the area of the exposed deck located aft of the breakwater.

2.2 Load cases H1, H2, F1 and F2

2.2.1

The external pressure p_D, for load cases H1, H2, F1 and F2, at any point of an exposed deck is to be obtained, in kN/m², from the following formula:

$$p_D = \varphi p_W$$

where:

p_W : Pressure obtained from the formulae in Tab 4

φ : Coefficient defined in Tab 5.

Table 4: Pressures on exposed decks for H1, H2, F1 and F2

Location	Pressure p_W, in kN/m^2	
	$L_{LL} \geq 100$ m	$L_{LL} < 100$ m
$0 \leq x_{LL}/L_{LL} \leq 0.75$	34.3	$14.9 + 0.195\, L_{LL}$
$0.75 < x_{LL}/L_{LL} < 1$	$34.3 + (14.8 + a(L_{LL} - 100))\left(4\dfrac{x_{LL}}{L_{LL}} - 3\right)$	$12.2 + \dfrac{L_{LL}}{9}\left(5\dfrac{x_{LL}}{L_{LL}} - 2\right) + 3.6\dfrac{x_{LL}}{L_{LL}}$

where:

a : Coefficient taken equal to:
$a = 0.0726$ for Type B freeboard ships
$a = 0.356$ for Type B-60 or Type B-100 freeboard ships.

x_{LL}: X coordinate of the load point measured from the aft end of the freeboard length L_{LL}.

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Table 5: Coefficient for pressure on exposed decks

Exposed deck location	φ
Freeboard deck	1.00
Superstructure deck, including forecastle deck	0.75
1st tier of deckhouse	0.56
2nd tier of deckhouse	0.42
3rd tier of deckhouse	0.32
4th tier of deckhouse	0.25
5th tier of deckhouse	0.20
6th tier of deckhouse	0.15
7th tier of deckhouse and above	0.10

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2.3 Load cases R1, R2, P1 and P2

2.3.1

The external pressure p_D, for load cases R1, R2, P1 and P2, at any point of an exposed deck is to be obtained, in kN/m^2, from the following formula:

$$p_D = 0.4\,\varphi p_W$$

where:

p_W : Hydrodynamic pressure at side of the exposed deck for the load cases P1, P2 , R1 and R2, in kN/m^2, can be determined by [1.6] at the z co-ordinate. p_W is to be taken greater one of the hydrodynamic pressures $p_{W,C}$ at both sides of the exposed deck (portside and starboard), and is not to be taken less than zero.

φ : Coefficient defined in Tab 5.

2.4 Load carried on exposed deck

2.4.1 Pressure due to distributed load

If a distributed load is carried on an exposed deck, the static pressure p_S corresponding to this load is to be defined by the Designer and, in general, is not to be taken less than 10 kN/m^2.

The total pressure p due to this load is to be considered not simultaneously to the pressures defined in [2.2] and [2.3]. It is to be taken equal, in kN/m^2, to the greater value obtained from the following formulae:

$$p = p_S + p_W$$

$$p = p_D$$

where:

p_S : Static pressure due to the distributed load carried, if any

p_W : Dynamic pressure due to the distributed load carried, in kN/m^2, taken equal to:

$$p_W = \frac{a_Z}{g} p_S$$

a_Z : Vertical acceleration at the centre of gravity of the distributed load carried for the load case considered, in m/s^2, obtained by the formulae defined in Ch 4, Sec 2, [3.2]

p_D : Pressure for the exposed deck, for the load case considered, as defined in [2.2.1] and [2.3.1].

2.4.2 Concentrated forces due to unit load

If a unit load is carried on an exposed deck, the static and dynamic forces due to the unit load carried are considered.

The total force F due to this load is to be considered not simultaneously to the pressures defined in [2.2] and [2.3]. It is to be taken, in kN, equal to value obtained from the following formula:

$$F = F_S + F_W$$

where:

F_S : Static force due to the unit load carried, in kN, taken equal to:

$$F_S = m_U g$$

F_W : Dynamic force due to unit load carried, in kN, taken equal to:

$$F_W = m_U a_Z$$

m_U : Mass of the unit load carried, in t

a_Z : Vertical acceleration at the centre of gravity of the unit load carried for the load case considered, in m/s^2, obtained by the formulae defined in Ch 4, Sec 2, [3.2].

3. External pressures on superstructure and deckhouses

3.1 Exposed decks

3.1.1

External pressures on exposed decks of superstructures and deckhouses are to be obtained according to [2].

3.2 Exposed wheel house tops

3.2.1

The lateral pressure for exposed wheel house tops, in kN/m^2, is not to be taken less than:

$$p = 12.5$$

3.3 Sides of superstructures

3.3.1

The lateral pressure for sides of superstructures, in kN/m^2, is to be obtained from the following formula:

$$p_{SI} = 2.1 C f_p c_F \left(C_B + 0.7\right) \frac{20}{10 + z - T}$$

f_p : Probability factor, taken equal to:

$f_p = 1.0$ for plate panels

$f_p = 0.75$ for ordinary stiffeners and primary supporting members

c_F : Distribution factor according to Tab 6.

Table 6: Distribution factor c_F

Location	c_F
$0 \le \frac{x}{L} < 0.2$	$1.0 + \frac{5}{C_B}\left(0.2 - \frac{x}{L}\right)$, without taking x/L less than 0.1
$\frac{x}{L} \ge 0.2$	1.0

3.4 End bulkheads of superstructure and deckhouse walls

3.4.1

The lateral pressure, in kN/m^2, for determining the scantlings is to be obtained from the greater of the following formulae:

$$p_A = nc\left[bC - (z - T)\right]$$

$$p_A = p_{A\min}$$

where:

n : Coefficient defined in Tab 7, depending on the tier level.

The lowest tier is normally that tier which is directly situated above the uppermost continuous deck to which the depth D is to be measured. However, where the actual distance ($D - T$) exceeds the minimum non-corrected tabular freeboard according to ILLC as amended by at least one standard superstructure height as defined in Ch 1, Sec 4, [3.18.1], this tier may be defined as the 2nd tier and the tier above as the 3rd tier

c : Coefficient taken equal to:

$$c = 0.3 + 0.7 \frac{b_1}{B_1}$$

For exposed parts of machinery casings, c is not to be taken less than 1.0

b_1 : Breadth of deckhouse at the position considered

B_1 : Actual maximum breadth of ship on the exposed weather deck at the position considered.

b_1 / B_1 is not to be taken less than 0.25

b : Coefficient defined in Tab 8

x : X co-ordinate, in m, of the calculation point for the bulkhead considered. When determining sides of a deckhouse, the deckhouse is to be subdivided into parts of approximately equal length, not exceeding $0.15L$ each, and x is to be taken as the X co-ordinate of the centre of each part considered.

z : Z co-ordinate, in m, of the midpoint of stiffener span, or to the middle of the plate field

ℓ : Span, in m, to be taken as the superstructure height or deckhouse height respectively, and not less than 2.0 m

$p_{A\min}$: Minimum lateral pressure, in kN/m^2, defined in Tab 9.

Table 7: Coefficient *n*

Type of bulkhead	Location	*n*
Unprotected front	Lowest tier	$20+\frac{L_2}{12}$
	Second tier	$10+\frac{L_2}{12}$
	Third tier and above	$5+\frac{L_2}{15}$
Protected front	All tiers	$5+\frac{L_2}{15}$
Sides	All tiers	$5+\frac{L_2}{15}$
Aft end	Abaft amidships	$7+\frac{L_2}{100}-8\frac{x}{L_2}$
	Forward of amidships	$5+\frac{L_2}{100}-4\frac{x}{L_2}$

Table 8: Coefficient *b*

Location of bulkhead	*b*
$\frac{x}{L}<0.45$	$1.0+\left(\frac{\frac{x}{L}-0.45}{C_B+0.2}\right)^2$
$\frac{x}{L}\geq 0.45$	$1.0+1.5\left(\frac{\frac{x}{L}-0.45}{C_B+0.2}\right)^2$
Where: C_B : Block coefficient with $0.6\leq C_B\leq 0.8$. When determining scantlings of aft ends forward of amidships, C_B need not be taken less than 0.8.	

Table 9: Minimum lateral pressure p_{Amin}

	p_{Amin}, in kN/m^2	
L	**Lowest tier of unprotected fronts**	**Elsewhere (1)**
$90 < L \le 250$	$25 + \dfrac{L}{10}$	$12.5 + \dfrac{L}{20}$
$L > 250$	50	25
(1) For the 4th tier and above, $p_{A\min}$ is to be taken equal to 12.5 kN/m^2.		

4. Pressure in bow area

4.1 Bow flare area pressure

4.1.1

The bow pressure, in kN/m^2, to be considered for the reinforcement of the bow flare area is to be obtained from the following formula:

$$p_{FB} = K\left(p_S + p_W\right)$$

where:

p_S, p_W : Hydrostatic pressure and maximum hydrodynamic pressures among load cases H, F, R and P at considered point of the hull in normal ballast condition. Minimum ballast draught in ballast condition T_B defined in Ch 1, Sec 4, [2.1.1] is to be considered as T_{LCi} for the calculation of hydrostatic pressure and hydrodynamic pressures.

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K : Coefficient taken equal to:

$$K = \frac{c_{FL}\left(0.2V + 0.6\sqrt{L}\right)^2}{42C\left(C_B + 0.7\right)\left(1 + \dfrac{20}{C_B}\left(\dfrac{x}{L} - 0.7\right)^2\right)}\left(10 + z - T_B\right) \text{ to be taken not less than 1.0}$$

c_{FL} : Coefficient taken equal to:

$c_{FL} = 0.8$ in general

$c_{FL} = \dfrac{0.4}{1.2 - 1.09\sin\alpha}$ where the flare angle α is greater than 40°

Where, the flare angle α at the load calculation point is to be measured in plane of the frame between a vertical line and the tangent to the side shell plating. (see Fig 7)

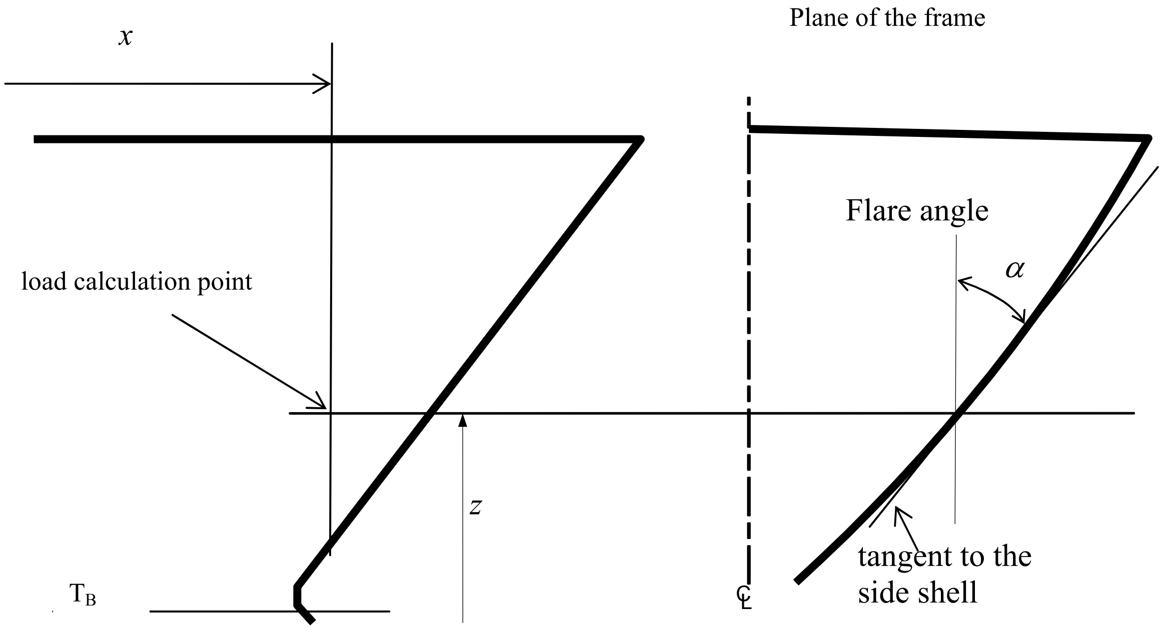


Figure 7: The definition of the flare angle

4.2 Design bottom slamming pressure

4.2.1

The bottom slamming pressure, in kN/m², to be considered for the reinforcement of the flat bottom forward is to be obtained from the following formula:

- $p_{SL} = 162 c_1 c_{SL} \sqrt{L}$ for $L \le 150$m
- $p_{SL} = 1984 c_1 c_{SL} (1.3 - 0.002L)$ for $L > 150$m

where:

c_1 : Coefficient taken equal to:

$$c_1 = 3.6 - 6.5 \left(\frac{T_{BFP}}{L} \right)^{0.2}$$, to be taken not greater than 1.0

T_{BFP} : Smallest design ballast draught, in m, defined at forward perpendicular for normal ballast conditions. Where the sequential method for ballast water exchange is intended to be applied, T_{BFP} is to be considered for the sequence of exchange.

c_{SL} : Distribution factor taken equal to(see Fig 6):

$$c_{SL} = 0 \qquad \text{for } \frac{x}{L} \le 0.5$$

$$c_{SL} = \frac{\frac{x}{L} - 0.5}{c_2} \qquad \text{for } 0.5 < \frac{x}{L} \le 0.5 + c_2$$

$c_{SL} = 1.0$ for $0.5 + c_2 < \dfrac{x}{L} \le 0.65 + c_2$

$c_{SL} = 0.5\left(1 + \dfrac{1 - \dfrac{x}{L}}{0.35 - c_2}\right)$ for $\dfrac{x}{L} > 0.65 + c_2$

c_2 : Coefficient taken equal to:

$c_2 = 0.33C_B + \dfrac{L}{2500}$, to be taken not greater than 0.35.

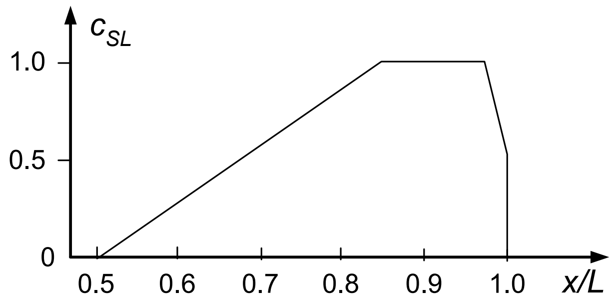


Figure 6: Distribution factor c_{SL}

4.2.2

It is the Master's responsibility to observe, among others, the weather conditions and the draught at forward perpendicular during water ballast exchange operations, in particular when the forward draught during these operations is less than T_{BFP}.

The above requirement and the draught T_{BFP} is to be clearly indicated in the operating manuals.

5. External pressures on hatch covers

5.1 General

5.1.1

If a specific load is carried on a hatch cover, the pressure is to be obtained according to [2.4].

5.2 Wave pressure

5.2.1

The pressure at any point of the hatch cover is to be obtained according to [2.2.1], considering φ equal to 1.0.

However, when the hatchway is located at least one superstructure standard height, as defined in Ch 1, Sec 4, [3.18], higher than the freeboard deck, the pressure p_W may be taken equal to 34.3 kN/m^2.

Section 6 – INTERNAL PRESSURES AND FORCES

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

ρ_C : Density of the dry bulk cargo, in t/m^3, taken equal to:

- the value given in Tab 1 for ships having a length L of 150 m and above
- the maximum density from the loading manual for ships having a length L less than 150 m

Table 1: Density of dry bulk cargo

Type of loading	Density	
	BC-A, BC-B	**BC-C**
Cargo hold loaded up to the upper deck	max(M_H/V_H, 1.0)	1.0
Cargo hold not loaded up to the upper deck	3.0 **(1)**	-
(1) Except otherwise specified by the designer.		

ρ_L : Density of internal liquid, in t/m^3, taken equal to 1.025 when internal liquid is ballast water

M_H : The actual cargo mass in a cargo hold corresponding to a homogeneously loaded condition at maximum draught, in t

V_H : Volume, in m^3, of cargo hold excluding the volume enclosed by hatch coaming

K_C : Coefficient taken equal to:

$K_C = \cos^2\alpha + (1 - \sin\psi)\sin^2\alpha$ for inner bottom, hopper tank, transverse and longitudinal bulkheads, lower stool, vertical upper stool, inner side and side shell:

$K_C = 0$ for top side tank, upper deck and sloped upper stool:

α : Angle, in deg, between panel considered and the horizontal plane

ψ : Assumed angle of repose, in deg, of bulk cargo (considered drained and removed); in the absence of more precise evaluation, the following values may be taken:

$\psi = 30°$ in general

$\psi = 35°$ for iron ore

$\psi = 25°$ for cement

h_C : Vertical distance, in m, from the inner bottom to the upper surface of bulk cargo, as defined in [1.1.1] or [1.1.2]

h_{DB} : Height, in m, of the double bottom in the centreline

h_{LS} : Mean height, in m, of the lower stool, measured from the inner bottom

z_{TOP} : Z co-ordinate, in m, of the top of the tank, in upright condition

z_{BO} : Z co-ordinate, in m, of the top of the overflow pipe

a_X : Longitudinal acceleration at the centre of gravity of the hold or tank considered, in m/s^2, obtained by the formulae defined in Ch 4, Sec 2, [3.2]

a_Y : Transverse acceleration at the centre of gravity of the hold or tank considered, in m/s^2, obtained by the formulae defined in Ch 4, Sec 2, [3.2]

a_Z : Vertical acceleration at the centre of gravity of the hold or tank considered, in m/s^2, obtained by the formulae defined in Ch 4, Sec 2, [3.2]

B_H : Mean breadth of the cargo hold, in m

b_{IB} : Breadth of inner bottom, in m, as defined on Fig 2

D_1 : Distance, in m, from the base line to the freeboard deck at side amidships

s_C : Spacing of corrugations, in m; see Ch 3, Sec 6, Fig 28

x, y, z : X, Y and Z co-ordinates, in m, of the load point with respect to the reference co-ordinate system defined in Ch 1, Sec 4. y is to be taken positive on the weather side

x_G, y_G, z_G : X, Y and Z co-ordinates, in m, of the centre of gravity of the hold or tank considered with respect to the reference co-ordinate system defined in Ch 1, Sec 4

d_{AP} : Distance from the top of air pipe to the top of compartment, in m, taken equal to:

$d_{AP} = z_{BO} - z_{TOP}$

1. Lateral pressure due to dry bulk cargo

1.1 Dry bulk cargo upper surface

1.1.1

When the dry bulk cargo density is such that the cargo hold is loaded to the top of hatch coaming, the upper surface of the dry bulk cargo is an equivalent horizontal surface to be determined in considering the same loaded cargo volume in the considered hold bounded by the side shell or inner hull, as the case may be.

For holds of cylindrical shape, the equivalent horizontal surface of the dry bulk cargo may be taken at a distance h_C, in m, above the inner bottom obtained from the following formula (see Fig 1):

$$h_C = h_{HPU} + h_0$$

where:

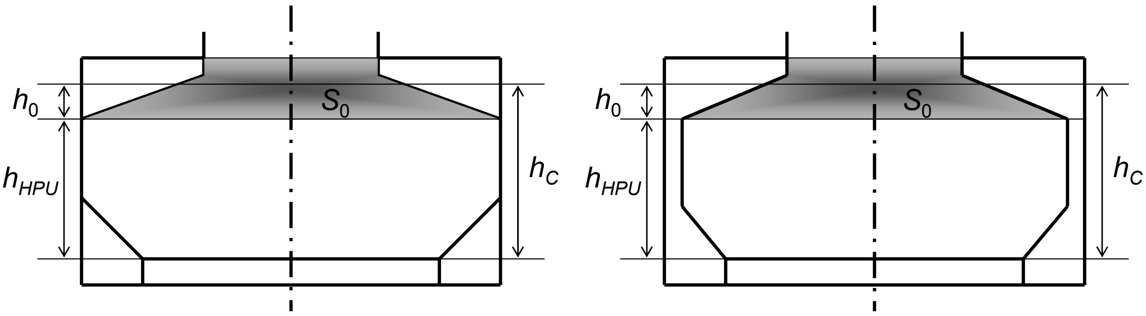
$$h_0 = \frac{S_A}{B_H}$$

$$S_A = S_0 + \frac{V_{HC}}{\ell_H}$$

h_{HPU} : Vertical distance, in m, between inner bottom and lower intersection of top side tank and side shell or inner side, as the case may be, as defined in Fig 1

S_0 : Shaded area, in m^2, above the lower intersection of top side tank and side shell or inner side, as the case may be, and up to the upper deck level, as defined in Fig 1

V_{HC} : Volume, in m^3, enclosed by the hatch coaming.



Single side bulk carrier Double side bulk carrier

Figure 1: Definitions of h_C, h_0, h_{HPU} and S_0

1.1.2

When the dry bulk cargo density is such that the cargo hold is not loaded up to the upper deck, the upper surface of the dry bulk cargo is considered as having a plane surface of width $B_H/2$ in the centreline and inclined parts with an angle equal to half the angle of repose ($\psi/2$) at sides, and is to be determined in considering the same loaded cargo volume in the considered hold, taken equal to M / ρ_C.

For holds of cylindrical shape, the upper surface of the dry bulk cargo may be taken at a distance h_C, in m, above the inner bottom obtained from the following formula (see Fig 2):

$$h_C = h_{HPL} + h_1 + h_2$$

where:

h_{HPL} : Vertical distance, in m, between inner bottom and upper intersection of hopper tank and inner side, as defined in Fig 2. h_{HPL} is to be taken equal to 0 if there is no hopper tank.

h_1 : Vertical distance, in m, obtained from the following formula, see Fig 2.

$$h_1 = \frac{M}{\rho_C \cdot B_H \ell_H} - \frac{B_H + b_{IB}}{2B_H} h_{HPL} - \frac{3}{16} B_H \tan\frac{\psi}{2} + \frac{V_{TS}}{B_H \ell_H}$$

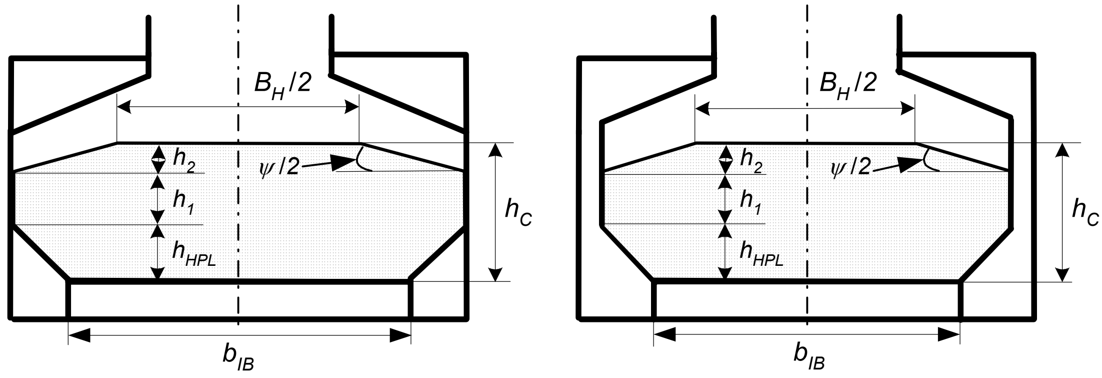
M : Mass, in t, of the bulk cargo to be considered, as defined in Ch 4 Sec 7

V_{TS} : Total volume, in m^3, of transverse stools at bottom of transverse bulkheads within the concerned cargo hold length ℓ_H. This volume excludes the part of hopper tank passing through the transverse bulkhead.

h_2 : Bulk cargo upper surface, in m, depending on y, given by:

$$h_2 = \frac{B_H}{4}\tan\frac{\psi}{2}\text{, if } 0 \le |y| \le \frac{B_H}{4}$$

$$h_2 = \left(\frac{B_H}{2} - |y|\right)\tan\frac{\psi}{2}\text{, if } \frac{B_H}{4} \le |y| \le \frac{B_H}{2}$$



Single side bulk carrier Double side bulk carrier

Figure 2: Definitions of h_C, h_1, h_2 and h_{HPL}

For holds of non-cylindrical shape, and in case of prescriptive rule requirements, the upper surface of the bulk cargo may be taken at the upper deck level with a density of dry bulk cargo equal to M/V_H.

1.2 Dry bulk cargo pressure in still water

1.2.1

The dry bulk cargo pressure in still water p_{CS}, in kN/m^2, is given by:

$$p_{CS} = \rho_C g K_C \left(h_C + h_{DB} - z\right)$$

1.3 Inertial pressure due to dry bulk cargo

1.3.1

The inertial pressure induced by dry bulk cargo p_{CW}, in kN/m^2, for each load case is given by the following formulae.

- for load case H: $p_{CW} = \rho_C \left[0.25 a_X \left(x - x_G\right) + K_C\, a_Z \left(h_C + h_{DB} - z\right)\right]$
- for load case F: $p_{CW} = 0$
- for load cases R and P: $p_{CW} = \rho_C \left[0.25 a_Y \left(y - y_G\right) + K_C\, a_Z \left(h_C + h_{DB} - z\right)\right]$

$(x\text{-}x_G)$ is to be taken as $0.25\ell_H$ in the load case H1 or $-0.25\ell_H$ in the load case H2 for local strength by Ch 6 and fatigue check for longitudinal stiffeners by Ch 8.

The total pressure ($p_{CS} + p_{CW}$) is not to be negative.

1.4 Shear load due to dry bulk cargo

1.4.1

In order to evaluate the total force in the vertical direction, shear load due to dry bulk cargo acting along sloping plates in way of bilge hopper tank and lower stool is to be considered.

The shear load due to dry bulk cargo acting along the sloping members in still water $p_{CS\text{-}S}$ (positive down to inner bottom plating), in kN/m^2, is given by:

$$p_{CS-S} = \rho_C g \frac{(1-K_C)(h_C + h_{DB} - z)}{\tan\alpha}$$

The shear load due to dry bulk cargo acting along the sloping members in waves p_{CW-S} (positive down to inner bottom plating), in kN/m^2, is given by:

- for load cases H, R and P: $p_{CW-S} = \rho_C a_Z \dfrac{(1-K_C)(h_C + h_{DB} - z)}{\tan\alpha}$
- for load case F: $p_{CW-S} = 0$

1.4.2

In order to evaluate the total force in the longitudinal and transverse directions, shear load due to dry bulk cargo in way of inner bottom plating is to be considered.

The shear load due to dry bulk cargo in the longitudinal direction in waves p_{CW-S} (positive forward), in kN/m^2, is given by:

- for load case H: $p_{CW-S} = 0.75\rho_C a_X h_C$
- for load cases F, R and P: $p_{CW-S} = 0$

The shear load due to dry bulk cargo in the transverse direction in waves p_{CW-S} (positive weather side), in kN/m^2, is given by:

- for load cases R and P: $p_{CW-S} = 0.75\rho_C a_Y h_C$
- for load cases H and F: $p_{CW-S} = 0$

2. Lateral pressure due to liquid

2.1 Pressure due to liquid in still water

2.1.1

The liquid pressure in still water p_{BS}, in kN/m^2, is given by the greater of the following values:

$$p_{BS} = \rho_L g(z_{TOP} - z + 0.5d_{AP})$$

$$p_{BS} = \rho_L g(z_{TOP} - z) + 100P_{PV}$$

where:

P_{PV} : Setting pressure, in bar, of safety valves to be considered if any

For local strength assessments, the static pressure p_{BS} is to be taken not less than 25 kN/m^2.

2.1.2

When checking ballast water exchange operations by means of the flow through method, the static pressure p_{BS} for local strength assessments and direct strength analysis by Ch 7 is to be not less than:

$$p_{BS} = \rho_L g(z_{TOP} - z + d_{AP}) + 25$$

Additional calculation may be required where piping or pumping arrangements may lead to a higher pressure.

2.1.3

For fatigue strength assessment, the liquid pressure in still water p_{BS}, in kN/m², is given by the following formula.

$$p_{BS} = \rho_L g(z_{TOP} - z)$$

If the p_{BS} is negative, p_{BS} is to be taken equal to 0.

Where the considered load point is located in the fuel oil, other oils or fresh water tanks, liquids are assumed to be fulfilled up to the half height of the tanks and z_{TOP} is taken to the Z coordinate of the liquid surface at the upright condition.

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2.2 Inertial pressure due to liquid

2.2.1

The inertial pressure due to liquid p_{BW}, in kN/m^2, for each load case is given as follows. When checking ballast water exchange operations by means of the flow through method, the inertial pressure due to ballast water is not to be considered for local strength assessments and direct strength analysis.

- for load case H: $p_{BW} = \rho_L \left[a_Z (z_{TOP} - z) + a_X (x - x_B)\right]$

  $(x\text{-}x_B)$ is to be taken as $0.75\ell_H$ in the load case H1 or $-0.75\ell_H$ in the load case H2 for local strength by Ch 6 and fatigue check for longitudinal stiffeners by Ch 8
- for load case F: $p_{BW} = 0$
- for load cases R and P: $p_{BW} = \rho_L \left[a_Z (z_B - z) + a_Y (y - y_B)\right]$

where:

x_B : X co-ordinate, in m, of the aft end of the tank when the bow side is downward, or of the fore end of the tank when the bow side is upward, as defined in Fig 3

y_B : Y co-ordinate, in m, of the tank top located at the most lee side when the weather side is downward, or of the most weather side when the weather side is upward, as defined in Fig 3

z_B : Z co-ordinate of the following point:

- for completely filled spaces: the tank top
- for ballast hold: the top of the hatch coaming

The reference point B is defined as the upper most point after rotation by the angle φ between the vertical axis and the global acceleration vector $\vec{A}_G$ shown in Fig 3. φ is obtained from the following formulae:

- load cases H1 and H2:

$$\varphi = \tan^{-1}\left(\frac{|a_X|}{g\cos\Phi + a_Z}\right)$$

- load cases R1(P1) and R2(P2):

$$\varphi = \tan^{-1}\left(\frac{|a_Y|}{g\cos\theta + a_Z}\right)$$

where:

θ : Single roll amplitude, in deg, defined in Ch4, Sec 2, [2.1.1]

Φ : Single pitch amplitude, in deg, defined in Ch4, Sec 2, [2.2.1]

The total pressure $(p_{BS} + p_{BW})$ is not to be negative.

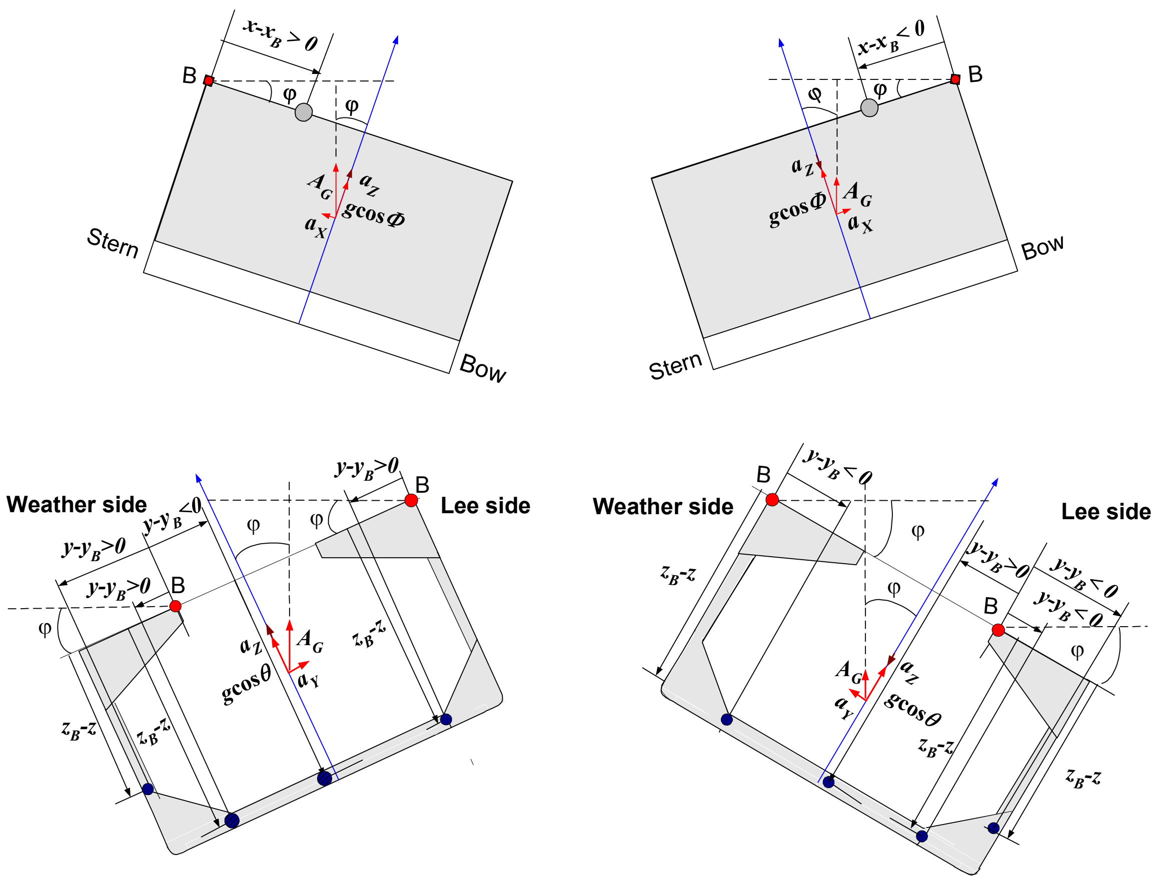

Figure 3: Definition of x_B and y_B

3. Lateral pressures and forces in flooded condition

3.1 Application

3.1.1

The lateral pressures to be considered in flooded condition are indicated in:

- [3.2] in general cases
- [3.3] for the particular case of transverse corrugated bulkheads
- [3.4] for the particular case of double bottom

3.2 General

3.2.1

The pressure p_F to be considered as acting on plating (excluding bottom and side shell plating) which constitute boundaries of compartments not intended to carry liquids is to be obtained, in kN/m^2, from the following formula:

$$p_F = \rho g\left(1 + 0.6\frac{a_Z}{g}\right)(z_F - z)\text{, without being less than } gd_0$$

where:

z_F : Z co-ordinate, in m, of the freeboard deck at side in way of the transverse section considered. Where the results of damage stability calculations are available, the deepest equilibrium waterline may be considered in lieu of the freeboard deck; in this case, the Society may require transient conditions to be taken into account

d_0 : Distance, in m, to be taken equal to:

$d_0 = 0.02L$ for $90 \text{ m} \leq L < 120$ m

$d_0 = 2.4$ for $L \geq 120$ m

3.3 Transverse vertically corrugated watertight bulkheads

3.3.1 Application

Each cargo hold is to be considered individually flooded.

3.3.2 General

The loads to be considered as acting on each bulkhead are those given by the combination of those induced by cargo loads with those induced by the flooding of one hold adjacent to the bulkhead under examination. In any case, the pressure due to the flooding water alone is to be considered.

The most severe combinations of cargo induced loads and flooding loads are to be used for the check of the scantlings of each bulkhead, depending on the loading conditions included in the loading manual:

- homogeneous loading conditions
- non-homogeneous loading conditions,

considering the individual flooding of both loaded and empty holds.

For the purpose of this item, homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling ratio, evaluated for each hold, does not exceed 1.20, to be corrected for different cargo densities.

Non-homogeneous part loading conditions associated with multiport loading and unloading operations for homogeneous loading conditions need not be considered according to these requirements.

The specified design load limits for the cargo holds are to be represented by loading conditions defined by the Designer in the loading manual.

For the purpose of this item, holds carrying packed cargoes are to be considered as empty.

Unless the ship is intended to carry, in non-homogeneous conditions, only iron ore or cargo having bulk density equal to or greater than 1.78 t/m^3, the maximum mass of cargo which may be carried in the hold is also to be considered to fill that hold up to the upper deck level at centreline.

3.3.3 Flooding level

The flooding level z_F is the distance, in m, measured vertically from the base line with the ship in the upright position, and equal to:

- in general:
  - D_1 for the foremost transverse corrugated bulkhead
  - $0.9D_1$ for other bulkheads;

where the ship is to carry cargoes having bulk density less than 1.78 t/m^3 in non-homogeneous loading conditions, the following values may be assumed:

  - $0.95D_1$ for the foremost transverse corrugated bulkhead
  - $0.85D_1$ for other bulkheads
- for ships less than 50000 t deadweight with type B freeboard:
  - $0.95D_1$ for the foremost transverse corrugated bulkhead
  - $0.85D_1$ for other bulkheads;

where the ship is to carry cargoes having bulk density less than 1.78 t/m^3 in non-homogeneous loading conditions, the following values may be assumed:

  - $0.9D_1$ for the foremost transverse corrugated bulkhead
  - $0.8D_1$ for other bulkheads.

3.3.4 Pressures and forces on a corrugation in non-flooded bulk cargo loaded holds

At each point of the bulkhead, the pressure is to be obtained, in kN/m^2, from the following formula:

$$p_B = \rho_C g(h_C + h_{DB} - z)\tan^2\left(45 - \frac{\psi}{2}\right)$$

The force acting on a corrugation is to be obtained, in kN, from the following formula:

$$F_B = \rho_C g s_C \frac{(h_C - h_{LS})^2}{2}\tan^2\left(45 - \frac{\psi}{2}\right)$$

3.3.5 Pressures and forces on a corrugation in flooded bulk cargo loaded holds

Two cases are to be considered, depending on the values of z_F and h_C (see [3.3.3] and [1.1]):

- First case, when $z_F \geq h_C + h_{DB}$

  At each point of the bulkhead located at a distance between z_F and $h_C + h_{DB}$ from the base line, the pressure, in kN/m^2, is to be obtained from the following formula:

  $p_{B,F} = \rho\, g\, (z_F - z)$

  At each point of the bulkhead located at a distance lower than $h_C + h_{DB}$ from the base line, the pressure, in kN/m^2, is to be obtained from the following formula:

  $$p_{B,F} = \rho g(z_F - z) + [\rho_C - \rho(1 - perm)]g(h_C + h_{DB} - z)\tan^2\left(45 - \frac{\psi}{2}\right)$$

  where *perm* is the permeability of cargo, to be taken as 0.3 for iron ore, coal cargoes and cement.

  The force acting on a corrugation is to be obtained, in kN, from the following formula:

  $$F_{B,F} = s_C\left[\rho g\frac{(z_F - h_C - h_{DB})^2}{2} + \frac{\rho g(z_F - h_C - h_{DB}) + (p_{B,F})_{LE}}{2}(h_C - h_{LS})\right]$$

  where $(p_{B,F})_{LE}$ is the pressure $p_{B,F}$, in kN/m^2, calculated at the lower edge of the corrugation.

- Second case, when $z_F < h_C + h_{DB}$

  At each point of the bulkhead located at a distance between z_F and $h_C + h_{DB}$ from the base line, the pressure is to be obtained, in kN/m^2, from the following formula:

  $$p_{B,F} = \rho_C g(h_C + h_{DB} - z)\tan^2\left(45 - \frac{\psi}{2}\right)$$

  At each point of the bulkhead located at a distance lower than z_F from the base line, the pressure is to be obtained, in kN/m^2, from the following formula:

$$p_{B,F} = \rho g(z_F - z) + \left[\rho_C(h_C + h_{DB} - z) - \rho(1 - perm)(z_F - z)\right]g \tan^2\left(45 - \frac{\psi}{2}\right)$$

where *perm* is the permeability of cargo, to be taken as 0.3 for iron ore, coal cargoes and cement.

The force acting on a corrugation is to be obtained, in kN, from the following formula:

$$F_{B,F} = s_C\left[\rho_C g\frac{(h_C + h_{DB} - z_F)^2}{2}\tan^2\left(45 - \frac{\psi}{2}\right)\right] + s_C\left[\frac{\rho_C g(h_C + h_{DB} - z_F)\tan^2\left(45 - \frac{\psi}{2}\right) + (p_{B,F})_{LE}}{2}(z_F - h_{DB} - h_{LS})\right]$$

where $(p_{B,F})_{LE}$ is the pressure $p_{B,F}$, in kN/m^2, calculated at the lower edge of the corrugation.

3.3.6 Pressures and forces on a corrugation in flooded empty holds

At each point of the bulkhead, the still water pressure induced by the flooding to be considered is to be obtained, in kN/m^2, from the following formula:

$$p_F = \rho\, g\, (z_F - z)$$

The force acting on a corrugation is to be obtained, in kN, from the following formula:

$$F_F = s_C \rho g \frac{(z_F - h_{DB} - h_{LS})^2}{2}$$

3.3.7 Resultant pressures and forces

Resultant pressures and forces to be calculated for homogeneous and non-homogeneous loading conditions are to be obtained according to the following formulae:

- Homogeneous loading conditions

At each point of the bulkhead structures, the resultant pressure to be considered for the scantlings of the bulkhead is to be obtained, in kN/m^2, from the following formula:

$$p = p_{B,F} - 0.8 p_B$$

The resultant force acting on a corrugation is to be obtained, in kN, from the following formula:

$$F = F_{B,F} - 0.8\, F_B$$

where:

p_B : Pressure in the non-flooded holds, in kN/m^2, to be obtained as specified in [3.3.4]

$p_{B,F}$: Pressure in the flooded holds, in kN/m^2, to be obtained as specified in [3.3.5]

$F_{B,F}$: Force acting on a corrugation in the flooded holds, in kN, to be obtained as specified in [3.3.5].

F_B : Force acting on a corrugation in non-flooded holds, in kN, to be obtained as specified in [3.3.4].

- Non-homogeneous loading conditions

At each point of the bulkhead structures, the resultant pressure to be considered for the scantlings of the bulkhead is to be obtained, in kN/m^2, by the following formula:

$$p = p_{B,F}$$

The resultant force acting on a corrugation is to be obtained, in kN, by the following formula:

$$F = F_{B,F}$$

where:

$p_{B,F}$: Pressure in the flooded holds kN/m^2, to be obtained as specified in [3.3.5]

$F_{B,F}$: Force acting on a corrugation in the flooded holds kN/m^2, to be obtained as specified in [3.3.5].

3.4 Double bottom

3.4.1 Application

Each cargo hold is to be considered individually flooded.

3.4.2 General

The loads to be considered as acting on the double bottom are those given by the external sea pressures and the combination of the cargo loads with those induced by the flooding of the hold which the double bottom belongs to.

The most severe combinations of cargo induced loads and flooding loads are to be used, depending on the loading conditions included in the loading manual:

- homogeneous loading conditions
- non-homogeneous loading conditions
- packed cargo conditions (such as in the case of steel mill products).

For each loading condition, the maximum dry bulk cargo density to be carried is to be considered in calculating the allowable hold loading.

3.4.3 Flooding level

The flooding level z_F is the distance, in m, measured vertically from the base line with the ship in the upright position, and equal to:

- for ships less than 50000 t deadweight with type B freeboard:
  - $0.95D_1$ for the foremost hold
  - $0.85D_1$ for other holds;
- for other ships:
  - D_1 for the foremost hold
  - $0.9D_1$ for other holds;

4. Testing lateral pressure

4.1 Still water pressures

4.1.1

The total pressure to be considered as acting on plates and stiffeners subject to tank testing is obtained, in kN/m^2, from the following formula:

$$p_{ST} = 10(z_{ST} - z)$$

where:

z_{ST} : Testing load height, in m, as defined in Tab 2.

Table 2: Testing load height

Compartment or structure to be tested	Testing load height, in m
Double bottom tanks	The greater of the following: $z_{ST} = z_{TOP} + d_{AP}$ $z_{ST} = z_{ml}$
Hopper side tanks, topside tanks, double side tanks, fore and after peaks used as tank, cofferdams	The greater of the following: $z_{ST} = z_{TOP} + d_{AP}$ $z_{ST} = z_{TOP} + 2.4$
Tank bulkheads, deep tanks, fuel oil bunkers	The greater of the following: $z_{ST} = z_{TOP} + d_{AP}$ $z_{ST} = z_{TOP} + 2.4$ $z_{ST} = z_{TOP} + 10p_{PV}$
Ballast hold	The greater of the following: $z_{ST} = z_{TOP} + d_{AP}$ $z_{ST} = z_h + 0.9$
Fore and aft peak not used as tank	The greater of the following: $z_{ST} = z_F$ $z_{ST} = z_{ml}$
Watertight doors below freeboard deck	$z_{ST} = z_{fd}$
Chain locker (if aft of collision bulkhead)	$z_{ST} = z_{TOP}$
Independent tanks	The greater of the following: $z_{ST} = z_{TOP} + d_{AP}$ $z_{ST} = z_{TOP} + 0.9$
Ballast ducts	Testing load height corresponding to ballast pump maximum pressure

where:

z_{ml} : Z co-ordinate, in m, of the bulkhead deck at side.

z_h : Z co-ordinate, in m, of the top of hatch coaming.

z_F : As defined in [3.2.1].

z_{fd} : Z co-ordinate, in m, of the freeboard deck.

p_{PV} : Setting pressure, in bar, of safety valves.

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Section 7 – LOADING CONDITIONS

Symbols

M_H : The actual cargo mass in a cargo hold corresponding to a homogeneously loaded condition at maximum draught, in t

M_{Full} : The cargo mass in a cargo hold corresponding to cargo with virtual density (homogenous mass / hold cubic capacity, minimum 1.0 t/m^3) filled to the top of the hatch coaming, in t.

$$M_{Full} = V_{Full} \cdot \max(M_H / V_H, 1.0)$$

M_{Full} is in no case to be less than M_H

M_{HD} : The maximum cargo mass allowed to be carried in a cargo hold according to design loading condition(s) with specified holds empty at maximum draught, in t

V_{Full} : Volume, in m^3, of the cargo hold including the volume enclosed by the hatch coaming

V_H : Volume, in m^3, defined in Ch 4, Sec 6

T_{HB} : Deepest ballast draught, in m.

1. Application

1.1 Ships having a length *L* less than 150 m

1.1.1

The severest loading conditions from the loading manual, midship section drawing or otherwise specified by the Designer are to be considered for the longitudinal strength according to Ch 5, Sec 1 and for the local strength check of plating, ordinary stiffeners and primary supporting members according to Ch 6.

1.2 Ships having a length *L* of 150 m and above

1.2.1

The requirements in [2] to [4] are applicable to ships having a length *L* of 150 m and above.

1.2.2

These requirements are not intended to prevent any other loading conditions to be included in the loading manual for which calculations are to be submitted. It is not intended to replace in any way the required loading manual/instrument.

1.2.3

The maximum loading condition draught is to be taken as the moulded summer load line draught.

1.2.4

The loading conditions listed in [2] are to be applied for the check of longitudinal strength as required by Ch 5, Sec 1, the check of local strength by Ch 6, the direct strength analysis by Ch 7, for capacity and disposition of ballast tanks and stability purposes. The loading conditions listed in [3] are to be applied for the check of local strength. The loading conditions listed in [4] are to be applied for direct strength analysis.

1.2.5
In operation, a bulk carrier may be loaded differently from the design loading conditions specified in the loading manual, provided longitudinal and local strength as defined in the loading manual and onboard loading instrument and applicable stability requirements are not exceeded.

2. General

2.1 Design loading conditions - General

2.1.1
For the determination of the maximum cargo mass in cargo holds, the condition corresponding to the ship being loaded at maximum draught with 50% of consumables is to be considered.

2.1.2 BC-C
Homogeneous cargo loaded condition where the cargo density corresponds to all cargo holds, including hatchways, being 100% full at maximum draught with all ballast tanks empty.

2.1.3 BC-B
As required for **BC-C**, plus:

Homogeneous cargo loaded condition with cargo density 3.0 t/m^3, and the same filling ratio (cargo mass/hold cubic capacity) in all cargo holds at maximum draught with all ballast tanks empty.

In cases where the cargo density applied for this design loading condition is less than 3.0 t/m^3, the maximum density of the cargo that the ship is allowed to carry is to be indicated with the additional service feature **{maximum cargo density *x.y* t/m^3}**.

2.1.4 BC-A
As required for **BC-B**, plus:

At least one cargo loaded condition with specified holds empty, with cargo density 3.0 t/m^3, and the same filling ratio (cargo mass/hold cubic capacity) in all loaded cargo holds at maximum draught with all ballast tanks empty.

The combination of specified empty holds is to be indicated with the additional service feature **{holds *a*, *b*, ... may be empty}**.

In such cases where the design cargo density applied is less than 3.0 t/m^3, the maximum density of the cargo that the ship is allowed to carry is to be indicated within the additional service feature **{holds *a*, *b*, ... may be empty with maximum cargo density *x.y* t/m^3}**.

2.2 Applicable ballast conditions

2.2.1 Ballast tank capacity and disposition
All bulk carriers are to have ballast tanks of sufficient capacity and so disposed to at least fulfill the following requirements.

Normal ballast condition

Normal ballast condition is a ballast (no cargo) condition where:

- the ballast tanks may be full, partially full or empty. Where ballast tanks are partially full, the conditions in Ch 4, Sec 3 are to be complied with
- any cargo hold or holds adapted for the carriage of water ballast at sea are to be empty
- the propeller is to be fully immersed, and
- the trim is to be by the stern and is not to exceed $0.015L_{BP}$.

In the assessment of the propeller immersion and trim, the draughts at the forward and after perpendiculars may be used.

Heavy ballast condition

Heavy ballast condition is a ballast (no cargo) condition where:

- the ballast tanks may be full, partially full or empty. Where ballast tanks are partially full, the conditions in Ch 4, Sec 3 are to be complied with
- at least one cargo hold adapted for carriage of water ballast at sea is to be full
- the propeller immersion I/D is to be at least 60 %, where:
  I = Distance from propeller centerline to the waterline
  D = Propeller diameter
- the trim is to be by the stern and is not to exceed $0.015L_{BP}$
- the moulded forward draught in the heavy ballast condition is not to be less than the smaller of $0.03L_{BP}$ or 8 m.

2.2.2 Strength requirements

All bulk carriers are to meet the following strength requirements:

Normal ballast condition:

- the structures of bottom forward are to be strengthened in accordance with the Rules against slamming for the condition of [2.2.1] for normal ballast condition at the lightest forward draught,
- the longitudinal strength requirements according to Ch 4, Sec 3 are to be met for the condition of [2.2.1] for normal ballast condition, and
- in addition, the longitudinal strength requirements according to Ch 4, Sec 3 are to be met with all ballast tanks 100% full.

Heavy ballast condition:

- the longitudinal strength requirements according to Ch 4, Sec 3 are to be met for the condition of [2.2.1] for heavy ballast condition
- in addition, the longitudinal strength requirements according to Ch 4, Sec 3 are to be met with all ballast tanks 100% full and one cargo hold adapted and designated for the carriage of water ballast at sea, where provided, 100% full, and

- where more than one hold is adapted and designated for the carriage of water ballast at sea, it will not be required that two or more holds be assumed 100% full simultaneously in the longitudinal strength assessment, unless such conditions are expected in the heavy ballast condition. Unless each hold is individually investigated, the designated heavy ballast hold and any/all restrictions for the use of other ballast hold(s) are to be indicated in the loading manual.

2.3 Departure and arrival conditions

2.3.1

Unless otherwise specified, each of the design loading conditions defined in [2.1] and [2.2] is to be investigated for the arrival and departure conditions as defined as follows:

- Departure condition : with bunker tanks not less than 95% full and other consumables 100%
- Arrival condition : with 10% of consumables

3. Design loading conditions for local strength

3.1 Definitions

3.1.1

The maximum allowable or minimum required cargo mass in a cargo hold, or in two adjacently loaded holds, is related to the net load on the double bottom. The net load on the double bottom is a function of draft, cargo mass in the cargo hold, as well as the mass of fuel oil and ballast water contained in double bottom tanks.

3.2 Applicable general conditions

3.2.1

Any cargo hold is to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at maximum draught.

3.2.2

Any cargo hold is to be capable of carrying minimum 50% of M_H, with all double bottom tanks in way of the cargo hold being empty, at maximum draught.

3.2.3

Any cargo hold is to be capable of being empty, with all double bottom tanks in way of the cargo hold being empty, at the deepest ballast draught.

3.3 Additional conditions applicable except when additional service feature {no MP} is assigned

3.3.1

Any cargo hold is to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of maximum draught.

3.3.2

Any cargo hold is to be capable of being empty with all double bottom tanks in way of the cargo hold being empty, at 83% of maximum draught.

3.3.3

Any two adjacent cargo holds are to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of the maximum draught. This requirement to the mass of cargo and fuel oil in double bottom tanks in way of the cargo hold applies also to the condition where the adjacent hold is filled with ballast, if applicable.

3.3.4

Any two adjacent cargo holds are to be capable of being empty, with all double bottom tanks in way of the cargo hold being empty, at 75% of maximum draught.

3.4 Additional conditions applicable for BC-A only

3.4.1

Cargo holds, which are intended to be empty at maximum draught, are to be capable of being empty with all double bottom tanks in way of the cargo hold also being empty.

3.4.2

Cargo holds, which are intended to be loaded with high density cargo, are to be capable of carrying M_{HD} plus 10% of M_H, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom being empty in way of the cargo hold, at maximum draught.
In operation the maximum allowable cargo mass shall be limited to M_{HD}.

3.4.3

Any two adjacent cargo holds which according to a design loading condition may be loaded with the next holds being empty, are to be capable of carrying 10% of M_H in each hold in addition to the maximum cargo load according to that design loading condition, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at maximum draught.
In operation the maximum allowable mass shall be limited to the maximum cargo load according to the design loading conditions.

3.5 Additional conditions applicable for ballast hold(s) only

3.5.1

Cargo holds, which are designed as ballast water holds, are to be capable of being 100% full of ballast water including hatchways, with all double bottom tanks in way of the cargo hold being 100% full, at any heavy ballast draught. For ballast holds adjacent to topside wing, hopper and double bottom tanks, it shall be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty.

3.6 Additional conditions applicable during loading and unloading in harbour only

3.6.1

Any single cargo hold is to be capable of holding the maximum allowable seagoing mass at 67% of maximum draught, in harbour condition.

3.6.2

Any two adjacent cargo holds are to be capable of carrying M_{Full}, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of maximum draught, in harbour condition.

3.6.3

At reduced draught during loading and unloading in harbour, the maximum allowable mass in a cargo hold may be increased by 15% of the maximum mass allowed at the maximum draught in sea-going condition, but shall not exceed the mass allowed at maximum draught in the sea-going condition. The minimum required mass may be reduced by the same amount.

3.7 Hold mass curves

3.7.1

Based on the design loading criteria for local strength, as given in [3.2] to [3.6] except [3.5.1], hold mass curves are to be included in the loading manual and the loading instrument, showing maximum allowable and minimum required mass as a function of draught in sea-going condition as well as during loading and unloading in harbour. Hold mass curves are to be calculated according to Ch 4, App 1.

3.7.2

At other draughts than those specified in the design loading conditions, the maximum allowable and minimum required mass is to be adjusted for the change in buoyancy acting on the bottom. Change in buoyancy is to be calculated using water plane area at each draught.

Hold mass curves for each single hold, as well as for any two adjacent holds, are to be included in the loading manual and the loading instrument.

4. Design loading conditions for direct strength analysis

4.1 Loading patterns

4.1.1

The loading patterns applicable to types of bulk carriers with various service feature notations are summarized in Tab 1, which are to be considered in direct strength analysis in accordance with [2] and [3].

Table 1: Applicable loading patterns according to additional service features

No.	Loading pattern	Ref.	BC-			BC-, (no MP)		
			A	B	C	A	B	C
1	Full load in homogeneous condition	3.2.1	x	x	x	x	x	x
2	Slack load	3.2.2	x	x	x	x	x	x
3	Deepest ballast	3.2.3	x	x	x	x	x	x
4	Multiport -1	3.3.1	x	x	x			
5	Multiport -2	3.3.2	x	x	x			
6	Multiport -3	3.3.3	x	x	x			
7	Multiport -4	3.3.4	x	x	x			
8	Alternate load	3.4.1&.2	x			x		
9	Alternate block load	3.4.3	x			x		
10	Heavy ballast	3.5.1	x	x	x	x	x	x
11	Harbour condition -1	3.6.1				x	x	x
12	Harbour condition -2	3.6.2				x	x	x

4.1.2

Other loading conditions from the loading manual, which are not covered in Tab 1, if any, are also to be considered.

4.2 Still water bending moment and shear force

4.2.1

Load cases defined in Sec 4 are to be considered for each loading pattern given in Tab 1. The still water vertical bending moment provided in Tab 2 and the still water vertical shear force provided in Tab 3 are to be used for each combination of loading pattern and load case.

4.2.2

If one loading condition in the loading manual has a still water vertical bending moment more severe than the value in Tab 2 for the corresponding loading pattern, the value in Tab 2 for this loading pattern is to be replaced with the value from the loading manual.

4.3 Application

4.3.1

The minimum required loading conditions for direct strength analysis, including vertical shear force analysis, are defined in Ch 4, App 2.

4.3.2

The standard loading conditions for fatigue assessment are defined in Ch 4, App 3.

Table 2: Vertical still water bending moment

		Loading pattern				
		Full load in homogeneous condition	**Slack load**	**Multiport**	**Heavy ballast (Ballast hold)**	**Harbour condition**
			Alternate load	Alternate block load		
			Normal ballast	Deepest ballast		
Load case	H1	$0.5M_{SW,S}$	0	$M_{SW,S}$	$M_{SW,S}$	
	H2	$0.5M_{SW,H}$	$M_{SW,H}$	$M_{SW,H}$	0	
	F1	$0.5\ M_{SW,S}$	0	$M_{SW,S}$	$M_{SW,S}$	
	F2	$0.5M_{SW,H}$	$M_{SW,H}$	$M_{SW,H}$	0	
	R1	$0.5\ M_{SW,S}$	0	$M_{SW,S}$	$M_{SW,S}$	---
		$0.5M_{SW,H}$	$M_{SW,H}$	$M_{SW,H}$	0	
	R2	$0.5\ M_{SW,S}$	0	$M_{SW,S}$	$M_{SW,S}$	
		$0.5M_{SW,H}$	$M_{SW,H}$	$M_{SW,H}$	0	
	P1	$0.5\ M_{SW,S}$	0	$M_{SW,S}$	$M_{SW,S}$	
	P2	$0.5M_{SW,H}$	$M_{SW,H}$	$M_{SW,H}$	0	
	Static	---				$M_{SW,P,S}$
						$M_{SW,P,H}$

where:

$M_{SW,H}$: Allowable still water vertical bending moment in hogging condition for seagoing condition

$M_{SW,S}$: Allowable still water vertical bending moment in sagging condition for seagoing condition

$M_{SW,P,H}$: Allowable still water vertical bending moment in hogging condition for harbour condition

$M_{SW,P,S}$: Allowable still water vertical bending moment in sagging condition for harbour condition

Table 3: Vertical still water shear force

		Loading pattern				
		Full load in homogeneous condition	**Alternate load (BC-A)**	**Multiport (BC-B and BC-C)**	**Heavy ballast (Ballast hold)**	**Heavy ballast (Except for ballast hold)**
Load case	H1	---	Q_{SW}	Q_{SW}	Q_{SW}	---
	H2	---	Q_{SW}	Q_{SW}	Q_{SW}	---
	F1	---	Q_{SW}	Q_{SW}	Q_{SW}	---
	F2	---	Q_{SW}	Q_{SW}	Q_{SW}	---

where:

Q_{SW} : Allowable still water shear force at the position of the considered transverse bulkhead

Section 8 - LOADING MANUAL AND LOADING INSTRUMENT

1. General

1.1 All ships

1.1.1

An approved loading manual is to be supplied on board for all ships.

In addition, an approved loading instrument is to be supplied for all ships.

The loading instrument is ship specific onboard equipment and the results of the calculations are only applicable to the ship for which it has been approved.

An approved loading instrument may not replace an approved loading manual.

1.2 Ships equal to or greater than 150 m in length *L*

1.2.1

BC-A, **BC-B**, and **BC-C** ships are to be provided with an approved loading manual and an approved computer-based loading instrument, in accordance with the applicable requirements of this Section.

A guidance for loading and unloading sequences is given in [5].

2. Loading manual

2.1 Definitions

2.1.1 All ships

A loading manual is a document which describes:

- the loading conditions on which the design of the ship has been based, including permissible limits of still water bending moment and shear force. The conditions specified in the ballast water exchanging procedure and dry docking procedure are to be included in the loading manual.
- the results of the calculations of still water bending moments and shear forces
- the allowable local loading for the structure (hatch covers, decks, double bottom, etc.).

2.1.2 Ships equal to or greater than 150 m in length *L*

In addition to [2.1.1], for **BC-A**, **BC-B** and **BC-C** ships, the loading manual is also to describe:

- envelope results and permissible limits of still water bending moments and shear forces in the hold flooded condition according to Ch 5, Sec 1
- the cargo hold(s) or combination of cargo holds that might be empty at full draught. If no cargo hold is allowed to be empty at full draught, this is to be clearly stated in the loading manual
- maximum allowable and minimum required mass of cargo and double bottom contents of each hold as a function of the draught at mid-hold position

- maximum allowable and minimum required mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds. This mean draught may be calculated by averaging the draught of the two mid-hold positions
- maximum allowable tank top loading together with specification of the nature of the cargo for cargoes other than bulk cargoes
- maximum allowable load on deck and hatch covers. If the ship is not approved to carry load on deck or hatch covers, this is to be clearly stated in the loading manual
- maximum rate of ballast change together with the advice that a load plan is to be agreed with the terminal on the basis of the achievable rates of change of ballast.

2.2 Conditions of approval

2.2.1 All ships

The approved loading manual is to be based on the final data of the ship. The manual is to include the design (cargo and ballast) loading conditions, subdivided into departure and arrival conditions as appropriate, upon which the approval of the hull scantlings is based.

In the case of modifications resulting in changes to the main data of the ship, a new approved loading manual is to be issued.

2.2.2 Ships equal to or greater than 150 m in length *L*

In addition to [2.2.1], for **BC-A**, **BC-B** and **BC-C** ships, the following loading conditions, subdivided into departure and arrival conditions as appropriate, are also to be included in the loading manual:

- homogeneous light and heavy cargo loading conditions at maximum draught
- alternate light and heavy cargo loading conditions at maximum draught, where applicable
- ballast conditions. For ships having ballast holds adjacent to topside wing, hopper and double bottom tanks, it shall be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty
- short voyage conditions where the ship is to be loaded to maximum draught but with limited amount of bunkers
- multiple port loading / unloading conditions
- deck cargo conditions, where applicable
- typical loading sequences where the ship is loaded from commencement of cargo loading to reaching full deadweight capacity, for homogeneous conditions, relevant part load conditions and alternate conditions where applicable. Typical unloading sequences for these conditions are also to be included. The typical loading / unloading sequences are also to be developed to not exceed applicable strength limitations. The typical loading sequences are also to be developed paying due attention to loading rate and the deballasting capability. Tab 1 contains, as guidance only, an example of a Loading Sequence Summary Form
- typical sequences for change of ballast at sea, where applicable.

2.3 Language

2.3.1

The loading manual is to be prepared in a language understood by the users. If this language is not English, a translation into English is to be included.

3. Loading instrument

3.1 Definitions

3.1.1 All ships

A loading instrument is an instrument which is either analog or digital and by means of which it can be easily and quickly ascertained that, at specified read-out points, the still water bending moments, shear forces, in any load or ballast condition, do not exceed the specified permissible values.

3.1.2 Ships equal to or greater than 150 m in length *L*

For **BC-A**, **BC-B** and **BC-C** ships, the loading instrument is an approved digital system as defined in [3.1.1]. In addition to [3.1.1], it is also to ascertain as applicable that:

- the mass of cargo and double bottom contents in way of each hold as a function of the draught at mid-hold position
- the mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds
- the still water bending moment and shear forces in the hold flooded conditions

do not exceed the specified permissible values.

3.2 Conditions of approval

3.2.1 All ships

The loading instrument is subject to approval, which is to include:

- verification of type approval, if any
- verification that the final data of the ship have been used
- acceptance of number and position of all read-out points
- acceptance of relevant limits for read-out points
- checking of proper installation and operation of the instrument on board, under agreed test conditions, and that a copy of the operation manual is available.

3.2.2 Ships equal to or greater than 150 m in length *L*

In addition, for **BC-A**, **BC-B** and **BC-C** ships, the approval is also to include, as applicable:

- acceptance of hull girder bending moment limits for all read-out points
- acceptance of hull girder shear force limits for all read-out points
- acceptance of limits for the mass of cargo and double bottom contents of each hold as a function of draught
- acceptance of limits for the mass of cargo and double bottom contents in any two adjacent holds as a function of draught.

3.2.3
In the case of modifications implying changes in the main data of the ship, the loading instrument is to be modified accordingly and approved.

3.2.4
An operational manual is always to be provided for the loading instrument.

The operation manual and the instrument output are to be prepared in a language understood by the users. If this language is not English, a translation into English is to be included.

3.2.5
The operation of the loading instrument is to be verified upon installation under the agreed test conditions. It is to be checked that the agreed test conditions and the operation manual for the instrument are available on board.

4. Annual and class renewal survey

4.1 General

4.1.1
At each annual and class renewal survey, it is to be checked that the approved loading manual is available on board.

4.1.2
The loading instrument is to be checked for accuracy at regular intervals by the ship's Master by applying test loading conditions.

4.1.3
At each class renewal survey this checking is to be done in the presence of the Surveyor.

5. Guidance for loading/unloading sequences

5.1 General

5.1.1
The typical loading/unloading sequences shall be developed paying due attention to the loading/unloading rate, the ballasting/deballasting capacity and the applicable strength limitations.

5.1.2
The shipbuilder will be required to prepare and submit for approval typical loading and unloading sequences.

5.1.3
The typical loading sequences as relevant should include:

- alternate light and heavy cargo load condition
- homogeneous light and heavy cargo load condition
- short voyage condition where the ship is loaded to maximum draught but with limited bunkers
- multiple port loading/unloading condition

- deck cargo condition
- block loading.

5.1.4
The loading/unloading sequences may be port specific or typical.

5.1.5
The sequence is to be built up step by step from commencement of cargo loading to reaching full deadweight capacity. Each time the loading equipment changes position to a new hold defines a step. Each step is to be documented and submitted to the Society. In addition to longitudinal strength, the local strength of each hold is to be considered.

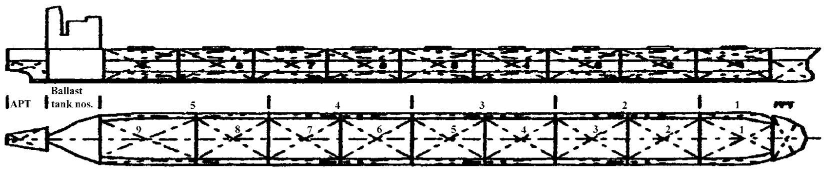
5.1.6
For each loading condition a summary of all steps is to be included. This summary is to highlight the essential information for each step such as:

- how much cargo is filled in each hold during the different steps,
- how much ballast is discharged from each ballast tank during the different steps,
- the maximum still water bending moment and shear at the end of each step,
- the ship's trim and draught at the end of each step.

Table 1: Guidance on Typical Loading Sequence Summary Form

LOADING/UNLOADING SEQUENCE SUMMARY FORM

Vessel name	Voyage No.	Condition	Yard	Id. Number



Port (specific or typical) :	Condition at commencement of loading/discharging	
Total mass of cargo to be loaded/discharged :	Condition at end of loading/discharging	
Dock water density (t/m3) :	Maximum Loading/discharging rate :	Average Loading/discharging rate :
Number of loaders/dischargers :	Maximum Ballasting/Deballasting rate :	Average Ballasting/Deballasting rate :

Hold No.			7	6	5	4	3	2	1
Volume of Hold,Vh(m^3)									
Height of hold,h(m)									

Note : During each pour it has to be controlled that allowable limits for hull girder shear force, bending moments and mass in holds are not exceeded. Loading/discharging operations may have to be paused to allow for ballasting/deballasting in order to keep actual values within limits.

Hold content at commencement of loading/discharging

Cargo mass									
Density (t/m^3)									
Grade									

Ballasting contents at commencement of loading/discharging

Wings or peaks	APT	No. B.T.	No. B.T.	No. B.T.	No. B.T.	No. B.T.	No. B.T.	No. B.T.	FPT
Upper									
Lower/Peaks									

Commencement of loading/discharging (sea)

Taft (m)	Trim (m)	Tfwd (m)	Maximum S.F.(%)	Maximum B.M.(%)

CARGO OPERATIONS

Pour No. / Grade	Hold	Hold	Hold 7	Hold 6	Hold 5	Hold 4	Hold 3	Hold 2	Hold 1
1									
2									
3									
4									
5									
6									
7									
8									

BALLASTING OPERATIONS

Upper Lower/Peak	APT	No. B.T.	No. B.T.	No. B.T.	No. B.T.	No. B.T.	No. B.T.	No. B.T.	FPT
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									

Values at end of pour (from harbour to sea)

Taft (m)	Trim (m)	Tfwd (m)	Maximum S.F.(%)	Maximum B.M.(%)

Total cargo onboard (t) : Remaining cargo to be loaded (t) : Total amount of bunkers onboard (t) :

Draft Survey n-1									
Draft Survey n									

Upper									
Lower/Peak									
Upper									
Lower/Peak									

Hold content at end of loading/discharging

Cargo mass									

Total mass loaded /discharged (t)		

Ballasting contents at end of loading/discharging

Wings or peaks	APT	Ball.no.5	Ball.no.4	Hold no.6	Ball.no.3	Hold no.4	Ball.no.2	Ball.no.1	FPT
Upper									
Lower/Peaks									

Values at end of loading/discharging (sea)

Taft (m)	Trim (m)	Tfwd (m)	Maximum S.F.(%)	Maximum B.M.(%)

Maximum occuring values among all conditions above

Net load on Double Bottom										tons/m^2
Net load in two adjacent holds										tons

Net load on double bottom = $(Mh/V) * h \cdot T$ (t/m^2)
where : Mh = Mass in hold + mass in DB (t)
V = Total volume of hold (m^3)
h = height of hold from inner bottom to top of coaming (m)
T = draught (m)

Approved by : ____________________

Date : ____________________

Appendix 1 – HOLD MASS CURVES

Symbols

h : Vertical distance from the top of inner bottom plating to the lowest point of the upper deck plating at the ship's centreline, in m.

h_a : Vertical distance from the top of inner bottom plating to the lowest point of the upper deck plating at the ship's centreline of the aft cargo hold in a block loading, in m.

h_f : Vertical distance from the top of inner bottom plating to the lowest point of the upper deck plating at the ship's centreline of the fore cargo hold in a block loading, in m.

M_H : As defined in Ch 4, Sec 7

M_{Full} : As defined in Ch 4, Sec 7

M_{HD} : As defined in Ch 4, Sec 7

M_D : The maximum cargo mass given for each cargo hold, in t

M_{BLK} : The maximum cargo mass in a cargo hold according to the block loading condition in the loading manual, in t

T_{HB} : As defined in Ch 4, Sec 7

T_i : Draught in loading condition No. i, at mid-hold position of cargo hold length ℓ_H , in m

V_H : As defined in Ch 4, Sec 6

V_f and V_a: Volume of the forward and after cargo hold excluding volume of the hatchway part, in m^3.

$T_{\min}$: $0.75T_S$ or draught in ballast conditions with the two adjacent cargo holds empty, whichever is greater, in m.

Σ : The sum of masses of two adjacent cargo holds

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1. General

1.1 Application

1.1.1

The requirements of this Appendix apply to ships of 150 m in length L and above.

1.1.2

This Appendix describes the procedure to be used for determination of:

- the maximum and minimum mass of cargo in each cargo hold as a function of the draught at mid-hold position of cargo hold
- the maximum and minimum mass of cargo in any two adjacent holds as a function of the mean draught in way of these holds.

1.1.3

Results of these calculations are to be included in the reviewed loading manual which has also to indicate the maximum permissible mass of cargo at scantling draught in each hold or in any two adjacent holds, as obtained from the design review.

1.1.4

The following notice on referring to the maximum permissible and the minimum required mass of cargo is to be described in loading manual.

Where ship engages in a service to carry such hot coils or heavy cargoes that have some adverse effect on the local strength of the double bottom and that the loading is not described as cargo in loading manual, the maximum permissible and the minimum required mass of cargo are to be considered specially.

2. Maximum and minimum masses of cargo in each hold

2.1 Maximum permissible mass and minimum required masses of single cargo hold in seagoing condition

2.1.1 General

The cargo mass curves of single cargo hold in seagoing condition are defined in [2.1.2] to [2.1.5]. However if the ship structure is checked for more severe loading conditions than the ones considered in Ch 4, Sec 7, [3.7.1], the minimum required cargo mass and the maximum allowable cargo mass can be based on those corresponding loading conditions.

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2.1.2 BC-A ship not having {No MP} assigned

- For loaded holds

  The maximum permissible mass ($W_{\max}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

  $$W_{\max}(T_i) = M_{HD} + 0.1M_H - 1.025V_H \frac{(T_S - T_i)}{h}$$

  However, $W_{\max}(T_i)$ is no case to be greater than $M_{HD.}$

  The minimum required cargo mass ($W_{\min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

  $W_{\min}(T_i) = 0$ for $T_i \le 0.83T_S$

  $W_{\min}(T_i) = 1.025V_H \dfrac{(T_i - 0.83T_S)}{h}$ for $T_S \ge T_i > 0.83T_S$

- For empty holds which can be empty at the maximum draught

  The maximum permissible mass ($W_{\min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

  $W_{\max}(T_i) = M_{Full}$ for $T_S \ge T_i \ge 0.67T_S$

  $W_{\max}(T_i) = M_{Full} - 1.025V_H \dfrac{(0.67T_S - T_i)}{h}$ for $T_i < 0.67T_S$

The minimum required mass ($W_{\min}(T_i)$) is obtained, in t, by the following formula:

$W_{\min}(T_i) = 0$ for $T_i \le T_S$

Examples for mass curve of loaded cargo hold and cargo hold which can be empty at the maximum draught for **BC-A** ships not having {No MP} assigned are shown in Fig 1.

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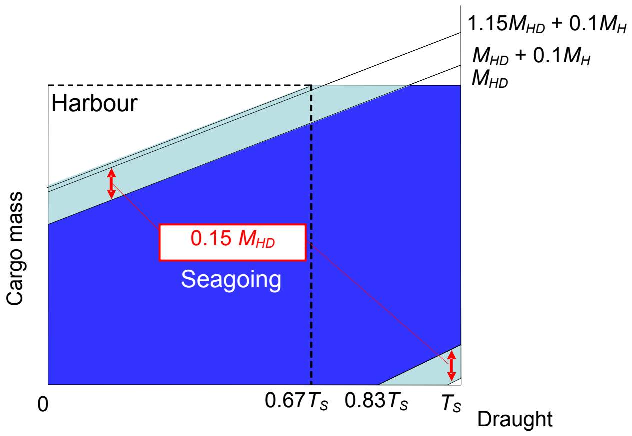
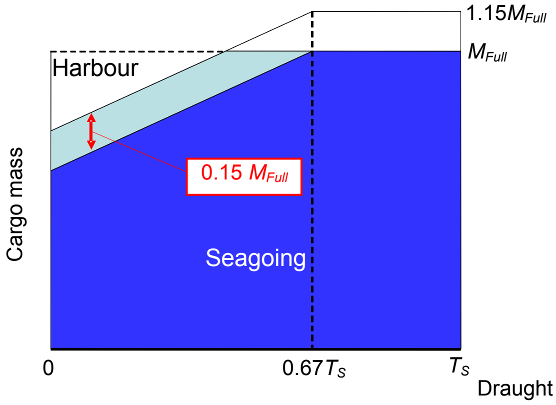


(a) Loaded hold



b) Cargo hold which can be empty at the maximum draught

Figure 1: Example of mass curve for BC-A ships not having {No MP} assigned

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2.1.3 BC-A ship having {No MP} assigned

- For loaded holds

The maximum permissible mass ($W_{\max}(T_i)$) at various draughts (T_i) is the same specified in [2.1.2].

The minimum required mass ($W_{\min}(T_i)$) is obtained, in t, by the following formulae:

$W_{\min}(T_i) = 0$ for $T_i \le T_{HB}$

$W_{\min}(T_i) = 1.025 V_H \dfrac{(T_i - T_{HB})}{h}$ for $T_S \ge T_i > T_{HB}$ or

$W_{\min}(T_i) = 0.5 M_H - 1.025 V_H \dfrac{(T_S - T_i)}{h} \ge 0$ for $T_S \ge T_i$

- For empty hold which can be empty at the maximum draught

The maximum permissible mass ($W_{\max}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\max}(T_i) = M_{Full} - 1.025 V_H \frac{(T_S - T_i)}{h}$$

The minimum required cargo mass ($W_{\min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$W_{\min}(T_i) = 0$ for $T_i \le T_S$

Examples for mass curve of cargo hold for **BC-A** ships, having {No MP} assigned are shown in Fig 2.

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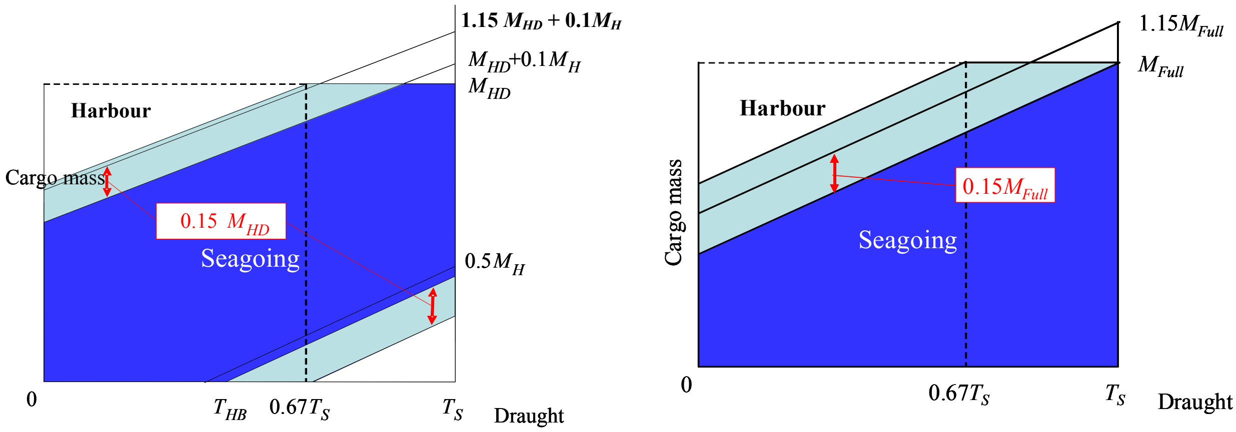

(a) Loaded hold (b) Cargo hold which can be empty at the maximum draught

Figure 2: Example of mass curve for BC-A ships having {No MP} assigned

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2.1.4 BC-B and BC-C ships not having {No MP} assigned

The maximum permissible mass ($W_{\max}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\max}(T_i) = M_{Full} \qquad \text{for } T_S \geq T_i \geq 0.67T_S$$

$$W_{\max}(T_i) = M_{Full} - 1.025V_H \frac{(0.67T_S - T_i)}{h} \qquad \text{for } T_i < 0.67T_S$$

The minimum required cargo mass ($W_{\min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \qquad \text{for } T_i \leq 0.83T_S$$

$$W_{\min}(T_i) = 1.025V_H \frac{(T_i - 0.83T_S)}{h} \qquad \text{for } T_S \geq T_i > 0.83T_S$$

Example for mass curve of cargo hold for BC-B and BC-C ships is shown in Fig. 3.

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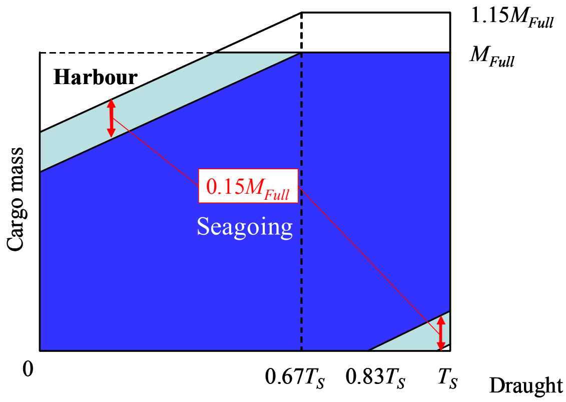

Figure 3: Example of mass curve for BC-B and BC-C ships not having {No MP} assigned

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2.1.5 BC-B and BC-C ships having {No MP} assigned

The maximum permissible mass ($W_{\max}(T_i)$) at various draughts T_i is obtained, in t, by the following formulae:

$$W_{\max}(T_i) = M_{Full} - 1.025V_H \frac{(T_S - T_i)}{h}$$

The minimum required cargo mass ($W_{\min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$W_{\min}(T_i) = 0$ for $T_i \le T_{HB}$

$W_{\min}(T_i) = 1.025V_H \frac{(T_i - T_{HB})}{h}$ for $T_S \ge T_i > T_{HB}$ or

$W_{\min}(T_i) = 0.5M_H - 1.025V_H \frac{(T_S - T_i)}{h}$ for $T_S \ge T_i$

$W_{\min}(T_i) \ge 0.0$

Example for mass curve of cargo hold for **BC-B** or **BC-C** ships with {No MP} is shown in Fig 4.

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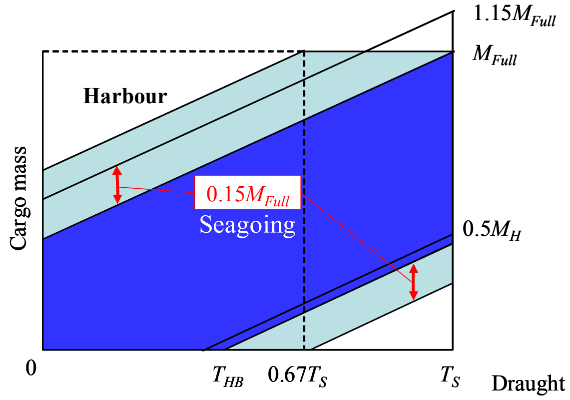

Figure 4: Example of mass curve for BC-B and BC-C ships having {No MP} assigned

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2.2 Maximum permissible mass and minimum required masses of single cargo hold in harbour condition

2.2.1 General

The cargo mass curves of single cargo hold in harbour condition are defined in [2.2.2]. However if the ship structure is checked for more severe loading conditions than ones considered in Ch 4, Sec 7, [3.7.1], the minimum required cargo mass and the maximum allowable cargo mass can be based on those corresponding loading conditions.

RCN 2 to July 2008 version (effective from 1 July 2010)

2.2.2 All ships

The maximum permissible cargo mass and the minimum required cargo mass corresponding to draught for loading/unloading conditions in harbour may be increased or decreased by 15% of the maximum permissible mass at the maximum draught for the cargo hold in seagoing condition. However, maximum permissible mass is in no case to be greater than the maximum permissible cargo mass at designed maximum load draught for each cargo hold.

2.2.3 BC-A ship not having {No MP} assigned

The maximum permissible mass ($W_{max}(T_i)$) at various draughts T_i in harbour condition is also to be checked by the following formulae in addition to the requirements in [2.1.2]:

For loaded hold

$W_{max}(T_i) = M_{HD}$ for $T_i \geq 0.67T_S$

$W_{max}(T_i) = M_{HD} + 0.1M_H - 1.025V_H \dfrac{0.67T_S - T_i}{h}$ for $T_i < 0.67T_S$

RCN 2 to July 2008 version (effective from 1 July 2010)

2.2.4 BC-A ship having {No MP} assigned

The maximum permissible mass ($W_{max}(T_i)$) at various draughts T_i in harbour condition is also to be checked by the following formulae in addition to the requirements in [2.1.3]:

For empty hold which can be empty at the maximum draught

$W_{max}(T_i) = M_{Full}$ for $T_S \geq T_i \geq 0.67T_S$

$W_{max}(T_i) = M_{Full} - 1.025V_H \dfrac{(0.67T_S - T_i)}{h}$ for $T_i < 0.67T_S$

RCN 2 to July 2008 version (effective from 1 July 2010)

2.2.5 BC-B and BC-C ships having {No MP} assigned

The maximum permissible mass $W_{max}(T_i)$ at various draughts T_i in harbour condition is also to be checked by the following formulae in addition to the requirements in [2.2.2]:

$W_{max}(T_i) = M_{Full}$ for $T_S \geq T_i \geq 0.67T_S$

$W_{max}(T_i) = M_{Full} - 1.025V_H \dfrac{(0.67T_S - T_i)}{h}$ for $T_i < 0.67T_S$

RCN 2 to July 2008 version (effective from 1 July 2010)

3. Maximum and minimum masses of cargo of two adjacent holds

3.1 Maximum permissible mass and minimum required masses of two adjacent holds in seagoing condition

3.1.1 General

The cargo mass curves of two adjacent cargo holds in seagoing condition are defined in [3.1.2] and [3.1.3]. However if the ship structure is checked for more severe loading conditions than ones considered in Ch 4, Sec 7, [3.7.1], the minimum required cargo mass and the maximum allowable cargo mass can be based on those corresponding loading conditions.

RCN 2 to July 2008 version (effective from 1 July 2010)

3.1.2 BC-A ships with "Block loading" and not having {No MP} assigned

The maximum permissible mass ($W_{max}(T_i)$) at various draughts (T_i) is obtained, in t, by the greater of the following formulae:

$$W_{max}(T_i) = \sum (M_{BLK} + 0.1M_H) - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_s - T_i) \qquad \text{or}$$

$$W_{max}(T_i) = \sum M_{Full} - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(0.67T_s - T_i)$$

However, $W_{max}(T_i)$ is no case to be greater than $\sum M_{BLK}$.

The minimum required cargo mass ($W_{min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \qquad \text{for} \quad T_i \le 0.75T_S$$

$$W_{\min}(T_i) = 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_i - 0.75T_S) \qquad \text{for} \quad T_S \ge T_i > 0.75T_S$$

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3.1.2 bis BC-A ships with "Block loading" and having {No MP} assigned

The maximum permissible mass $W_{\max}(T_i)$ at various draughts T_i is obtained, in t, by the following formula:

$$W_{\max}(T_i) = \sum(M_{BLK} + 0.1M_H) - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_s - T_i)$$

However, $W_{\max}(T_i)$ is no case to be greater than $\sum M_{BLK}$.

The minimum required cargo mass $W_{\min}(T_i)$ at various draughts T_i is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \qquad \text{for} \quad T_i \le T_{HB}$$

$$W_{\min}(T_i) = 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_i - T_{HB}) \qquad \text{for} \quad T_S \ge T_i > T_{HB}$$

Examples for mass curve of cargo hold for BC-A with block loading ships are shown in Fig 5.

RCN 2 to July 2008 version (effective from 1 July 2010)

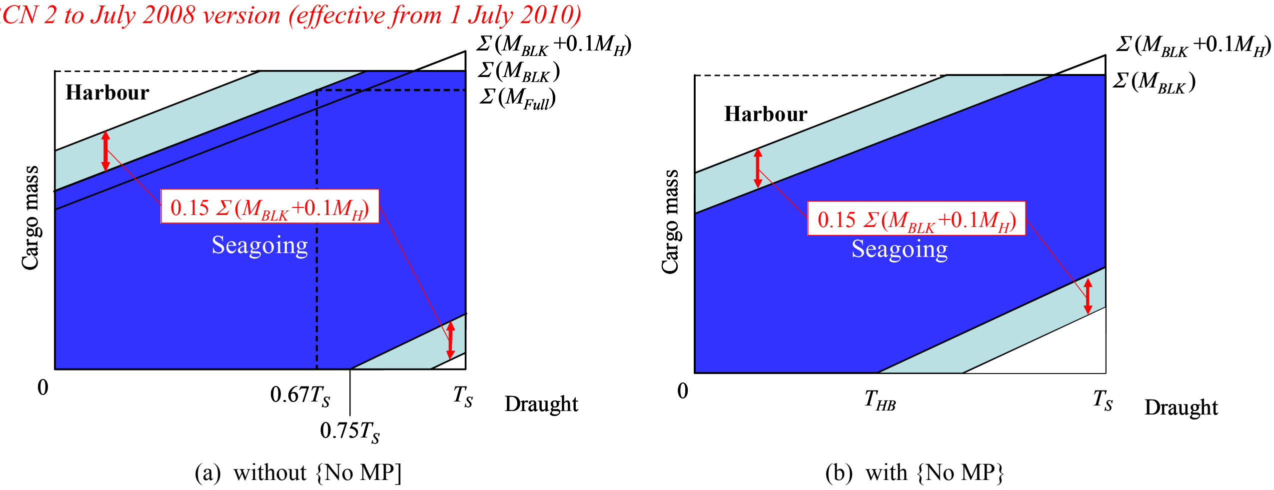

Figure 5: Example of mass curve for BC-A ships with "Block loading"

RCN 2 to July 2008 version (effective from 1 July 2010)

3.1.3 (void)

(void)

RCN 2 to July 2008 version (effective from 1 July 2010)

3.1.4 BC-A ships without "Block loading" and BC-B, BC-C ships, not having {No MP} assigned

The maximum permissible mass $W_{\max}(T_i)$ at various draughts T_i is obtained, in t, by the following formulae:

$$W_{\max}(T_i) = \sum M_{Full} \qquad \text{for} \quad T_S \ge T_i \ge 0.67T_S$$

$$W_{\max}(T_i) = \sum M_{Full} - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(0.67T_S - T_i) \qquad \text{for} \quad T_i < 0.67T_S$$

The minimum required cargo mass $W_{\min}(T_i)$ at various draughts T_i is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \qquad \text{for} \quad T_i \le 0.75T_S$$

$$W_{\min}(T_i) = 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_i - 0.75T_S) \qquad \text{for} \quad T_S \ge T_i > 0.75T_S$$

RCN 2 to July 2008 version (effective from 1 July 2010)

3.1.5 BC-A ships without "Block loading" and BC-B, BC-C ships, having {No MP} assigned

The maximum permissible mass $W_{max}(T_i)$ at various draughts T_i is obtained, in t, by the following formulae:

$$W_{\max}(T_i) = \sum M_{Full} - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_S - T_i) \qquad \text{for} \quad T_i < T_S$$

The minimum required cargo mass $W_{min}(T_i)$ at various draughts T_i is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \qquad \text{for} \quad T_i \le T_{HB}$$

$$W_{\min}(T_i) = 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_i - T_{HB}) \qquad \text{for} \quad T_S \ge T_i > T_{HB}$$

Examples for mass curve of cargo hold for **BC-A** without block loading and **BC-B** or **BC-C** are shown in Fig 6.

RCN 2 to July 2008 version (effective from 1 July 2010)

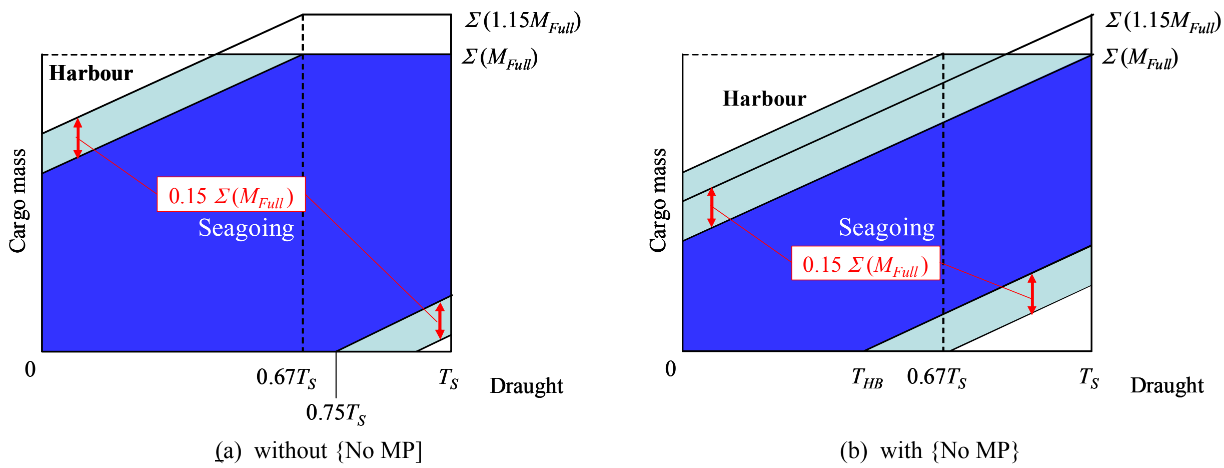

Figure 6: Example of mass curve for BC A-ship without block loading and BC-B or BC-C ships

RCN 2 to July 2008 version (effective from 1 July 2010)

3.2 Maximum permissible mass and minimum required masses of two adjacent cargo holds in harbour condition

3.2.1 General

The cargo mass curves of two adjacent cargo holds in harbour condition are defined in [3.2.2]. However if the ship structure is checked for more severe loading conditions than ones considered in Ch 4, Sec 7, [3.7.1], the minimum required cargo mass and the maximum allowable cargo mass can be based on those corresponding loading conditions.

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3.2.2 All ships

The maximum permissible cargo mass and minimum required cargo mass corresponding to draught for loading/unloading conditions in harbour may be increased or decreased by 15% of the maximum permissible mass at the maximum draught for the cargo hold in seagoing condition. However, maximum permissible mass is in no case to be greater than the maximum permissible cargo mass at designed maximum load draught for each cargo hold.

3.2.3 BC-A ships with “Block loading” and having {No MP} assigned

The maximum permissible mass ($W_{max}(T_i)$) at various draughts T_i in harbour condition is also to be checked by the following formulae in addition to the requirements in [3.1.2 bis]:

$$W_{\max}(T_i) = \sum M_{Full} - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(0.67T_S - T_i)$$

$$W_{\max}(T_i) \le \sum M_{BLK}$$

RCN 2 to July 2008 version (effective from 1 July 2010)

3.2.4 BC-A ships without “Block loading” and BC-B, BC-C ships, having {No MP} assigned

The maximum permissible mass ($W_{max}(T_i)$) at various draughts T_i in harbour condition is also to be checked by the following formulae in addition to the requirements in [3.1.5]:

$$W_{\max}(T_i) = \sum M_{Full} \qquad \text{for} \quad T_S \ge T_i \ge 0.67T_S$$

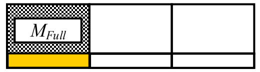
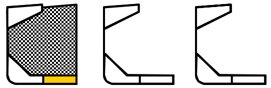
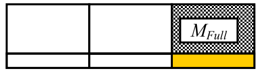
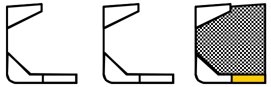
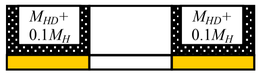
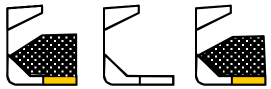
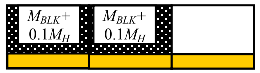
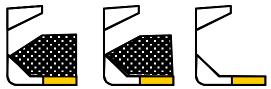
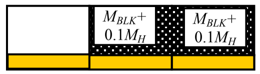
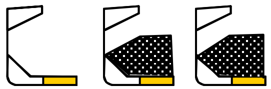
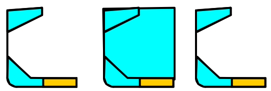
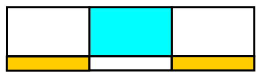
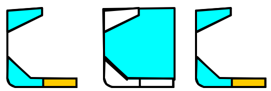
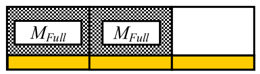
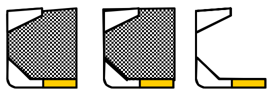
$$W_{\max}(T_i) = \sum M_{Full} - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(0.67T_S - T_i) \qquad \text{for} \quad T_i < 0.67T_S$$

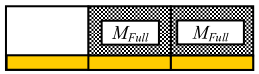
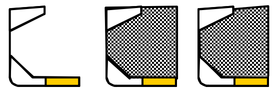
RCN 2 to July 2008 version (effective from 1 July 2010)

Appendix 2 – STANDARD LOADING CONDITION FOR DIRECT STRENGTH ANALYSIS

Table 1: Bending moment analysis applicable to empty hold in alternate condition of BC-A (mid-hold is empty hold)

No.	Description [a]	Draught	Loading Pattern	Aft	Mid	Fore	Load Case (Design Wave) / Still water vertical bending moment [b]				Remarks (see below)
1	Full Load ([2.1.3])	T_S	M_H M_H M_H				P1 / $0.5M_{SW,S}$				1), 2)
2	Full Load ([3.2.1])	T_S	M_{Full} M_{Full} M_{Full}				P1 / $0.5M_{SW,S}$				1), 3)
3	Slack Load ([3.2.2])	T_S	50%M_H M_{Full} M_{Full}				P1 / 0				3)
4	Slack Load ([3.2.2])	T_S	M_{Full} M_{Full} 50%M_H				P1 / 0				3)
5	Deepest Ballast ([3.2.3])	T_{HB}					R1 / $M_{SW,H}$	R1 / $M_{SW,S}$	P1 / $M_{SW,S}$		4), 5)
6	Multi Port -3 ([3.3.3])	$0.67T_S$	M_{Full} M_{Full}				H1 / $M_{SW,S}$				3), 6)
7	Multi Port -3 ([3.3.3])	$0.67T_S$	M_{Full} M_{Full}				H1 / $M_{SW,S}$				3), 6)

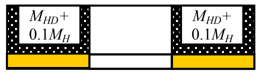
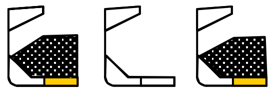
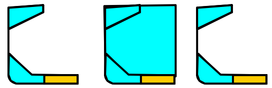
No.	Description [a)]	Draught	Loading Pattern	Aft	Mid	Fore	Load Case (Design Wave) Still water vertical bending moment [b)]				Remarks (see below)
8	Multi Port -4 ([3.3.4])	$0.75T_S$					F2 $M_{SW,H}$	P1 $M_{SW,S}$			3), 6)
9	Multi Port -4 ([3.3.4])	$0.75T_S$					F2 $M_{SW,H}$	P1 $M_{SW,S}$			3), 6)
10	Alternate Load ([3.4.1])	T_S					F2 $M_{SW,H}$	P1 0			2)
11	Alt-Block Load ([3.4.3])	T_S					H1 $M_{SW,S}$	F2 $M_{SW,H}$	P1 $M_{SW,S}$		2), 8), 9), 10)
12	Alt-Block Load ([3.4.3])	T_S					H1 $M_{SW,S}$	F2 $M_{SW,H}$	P1 $M_{SW,S}$		2), 8), 9), 10)
13	Heavy Ballast ([3.5.1])	$T_{HB}(min)$					H1 $M_{SW,S}$	R1 0	R1 $M_{SW,S}$		11),12)
14	Heavy Ballast	$T_{HB}(min)$					R1 0	R1 $M_{SW,S}$			11), 12), 13)
15	Harbour Condition -2 ([3.6.2])	$0.67T_S$					--- $M_{SW,P,H}$	--- $M_{SW,P,S}$			3), 14), 15)

No.	Description a)	Draught	Loading Pattern	Aft Mid Fore	Load Case (Design Wave) Still water vertical bending moment b)				Remarks (see below)
16	Harbour Condition -2 ([3.6.2])	$0.67T_S$			---	---			3), 14), 15)
					$M_{SW,P,H}$	$M_{SW,P,S}$			

a) Referred paragraph number corresponds to loading pattern prescribed in Ch 4, Sec 7.
b) $M_{SW,H}$, $M_{SW,S}$: Allowable still water vertical bending moment for seagoing condition, hogging or sagging respectively
$M_{SW,P,H}$, $M_{SW,P,S}$: Allowable still water vertical bending moment for harbour condition, hogging or sagging respectively

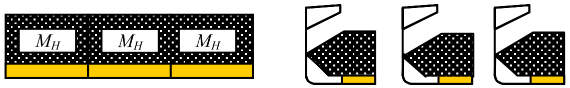
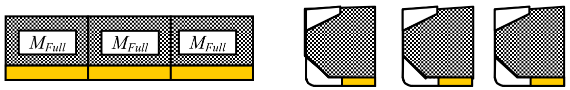
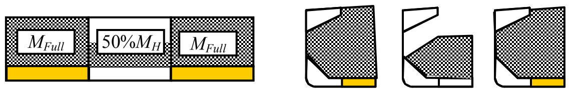
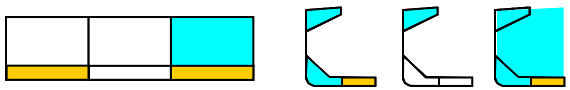
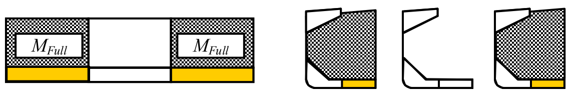
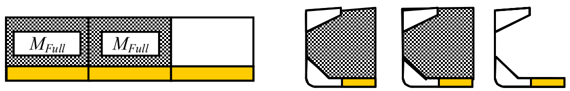
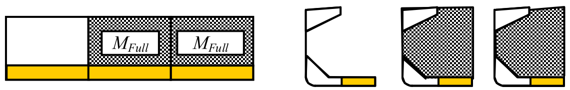
Remarks
1) Single loading pattern in M_{Full} with cargo density of 3.0 t/m^3 can be analyzed in lieu of these two loading patterns.
2) Cargo density 3.0 t/m^3 is to be used for calculation of dry cargo pressure in principle.
3) M_H/V_H or 1.0 t/m^3, whichever is greater, is to be used as cargo density for calculation of dry cargo pressure.
4) In case of no ballast hold, normal ballast condition with assuming $M_{SW,S} = 0$ is to be analyzed.
5) Position of ballast hold is to be adjusted as appropriate.
6) This condition is not required when {**no MP**} notation is assigned.
7) For vertical shear force analysis, maximum shear force ($Q_{SW} + Q_{WV}$) with reduced vertical bending moment ($0.8M_{SW} + 0.65C_{WV}M_{WV}$) is to be considered.
8) This condition is only required when such a condition is prepared in the loading manual.
9) "M_{BLK}" is maximum cargo mass according to the design loading condition in the loading manual.
10) Actual still water vertical bending moment, as given in the loading manual, may be used in stead of design value.
11) This condition is to be considered for the empty hold which is assigned as ballast hold if any.
12) Minimum draught among heavy ballast conditions is to be used in principle.
13) This condition is not required when such a condition is explicitly prohibited in the loading manual.
14) This condition is to be analyzed when {**no MP**} notation is assigned.
15) External sea pressures and internal pressures can be considered as static.

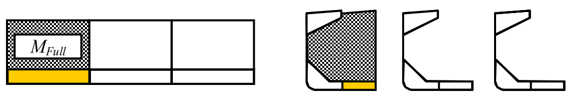
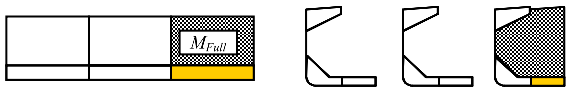
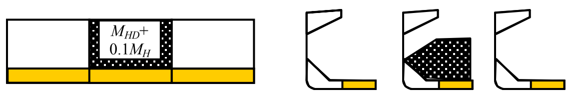
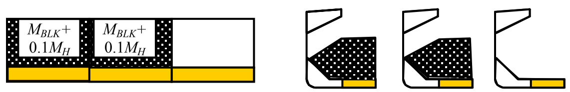
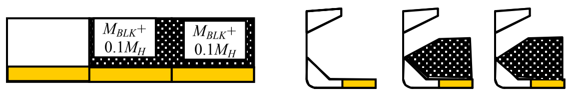
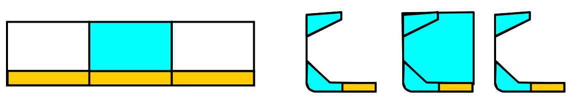
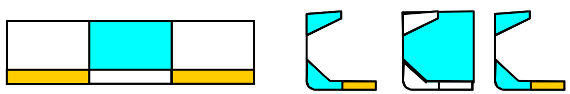
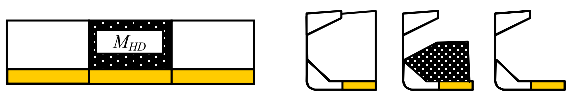
Table 2: Shear force analysis applicable to empty hold of BC-A (mid-hold is empty hold)

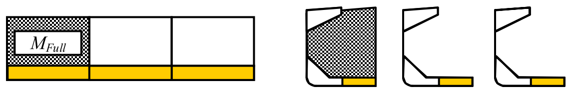
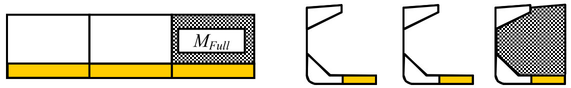
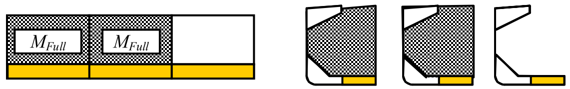
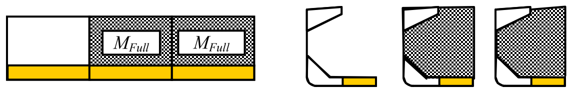
No.	Description [a]	Draught	Loading Pattern	Aft Mid Fore	Load Case (Design Wave) / Still water vertical bending moment [b] / Still water shear force				Remarks (see Table 1 above)
10SF	Alternate Load ([3.4.1])	T_S			F2				2), 7)
					$0.8M_{SW,H}$				
					Q_{SW}				
13SF	Heavy Ballast ([3.5.1])	$T_{HB}(min)$			H1				7), 11), 12)
					$0.8M_{SW,S}$				
					Q_{SW}				

a) Referred paragraph number corresponds to loading pattern prescribed in Ch 4, Sec 7.
b) $M_{SW,H}$, $M_{SW,S}$: Allowable still water vertical bending moment for seagoing condition, hogging or sagging respectively

Table 3: Bending moment analysis applicable to loaded hold in alternate condition of BC-A (mid-hold is loaded hold)

No.	Description a)	Draught	Loading Pattern	Aft	Mid	Fore	Load Case (Design Wave) / Still water vertical bending moment b)				Remarks (see below)
1	Full Load ([2.1.3])	T_S	 M_H M_H M_H				P1				1), 2)
							$0.5M_{SW,S}$				
2	Full Load ([3.2.1])	T_S	 M_{Full} M_{Full} M_{Full}				P1				1), 3)
							$0.5M_{SW,S}$				
3	Slack Load ([3.2.2])	T_S	 M_{Full} $50\%M_H$ M_{Full}				P1				3)
							0				
4	Deepest Ballast ([3.2.3])	T_{HB}					R1	R1	P1		4), 5)
							$M_{SW,H}$	$M_{SW,S}$	$M_{SW,S}$		
5	Multi Port -2 ([3.3.2])	$0.83T_S$	 M_{Full} M_{Full}				F2	P1			3), 6)
							$M_{SW,H}$	$M_{SW,S}$			
6	Multi Port -3 ([3.3.3])	$0.67T_S$	 M_{Full} M_{Full}				P1				3), 6)
							$M_{SW,S}$				
7	Multi Port -3 ([3.3.3])	$0.67T_S$	 M_{Full} M_{Full}				P1				3), 6)
							$M_{SW,S}$				

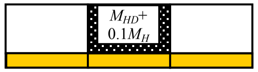
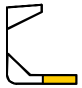
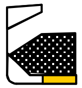
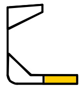
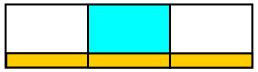
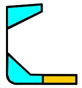
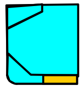
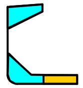
No.	Description [a)]	Draught	Loading Pattern	Aft	Mid	Fore	Load Case (Design Wave)				Remarks (see below)
							Still water vertical bending moment [b)]				
8	Multi Port -4 ([3.3.4])	$0.75T_S$					F2 $M_{SW,H}$	R1 $M_{SW,H}$	R1 $M_{SW,S}$	P1 $M_{SW,S}$	3), 6)
9	Multi Port -4 ([3.3.4])	$0.75T_S$					F2 $M_{SW,H}$	R1 $M_{SW,H}$	R1 $M_{SW,S}$	P1 $M_{SW,S}$	3), 6)
10	Alternate Load ([3.4.2])	T_S					F2 $M_{SW,H}$	P1 0			2)
11	Alt-Block Load ([3.4.3])	T_S					H1 $M_{SW,S}$	F2 $M_{SW,H}$	P1 $M_{SW,S}$		2), 8), 9), 10)
12	Alt-Block Load ([3.4.3])	T_S					H1 $M_{SW,S}$	F2 $M_{SW,H}$	P1 $M_{SW,S}$		2), 8), 9), 10)
13	Heavy Ballast ([3.5.1])	$T_{HB}(min)$					H1 $M_{SW,S}$	R1 0	R1 $M_{SW,S}$		11),12)
14	Heavy Ballast	$T_{HB}(min)$					R1 0	R1 $M_{SW,S}$			11), 12), 13)
15	Harbour Condition -1 ([3.6.1])	$0.67T_S$					--- $M_{SW,P,H}$	--- $M_{SW,P,S}$			2), 15)

No.	Description [a)]	Draught	Loading Pattern (Aft, Mid, Fore)	Load Case (Design Wave) Still water vertical bending moment [b)]				Remarks (see below)
16	Harbour Condition -1 ([3.6.1])	$0.67T_S$		--- $M_{SW,P,H}$	--- $M_{SW,P,S}$			3), 14), 15)
17	Harbour Condition -1 ([3.6.1])	$0.67T_S$		--- $M_{SW,P,H}$	--- $M_{SW,P,S}$			3), 14), 15)
18	Harbour Condition -2 ([3.6.2])	$0.67T_S$		--- $M_{SW,P,H}$	--- $M_{SW,P,S}$			3), 14), 15)
19	Harbour Condition -2 ([3.6.2])	$0.67T_S$		--- $M_{SW,P,H}$	--- $M_{SW,P,S}$			3), 14), 15)

a) Referred paragraph number corresponds to loading pattern prescribed in Ch 4, Sec 7.
b) $M_{SW,H}$, $M_{SW,S}$: Allowable still water vertical bending moment for seagoing condition, hogging or sagging respectively
$M_{SW,P,H}$, $M_{SW,P,S}$: Allowable still water vertical bending moment for harbour condition, hogging or sagging respectively

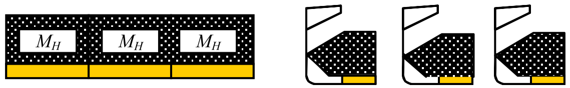
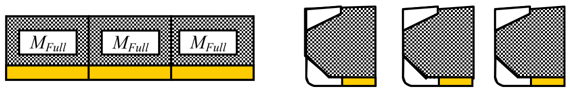
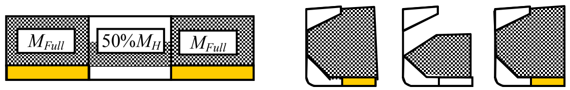
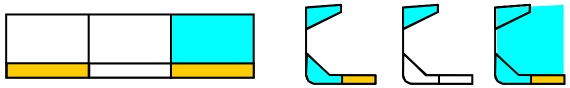
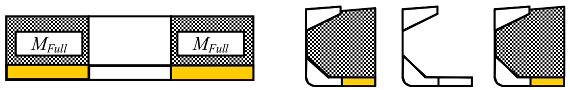
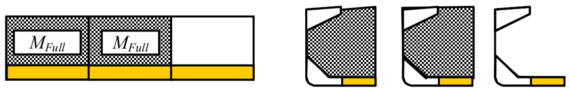
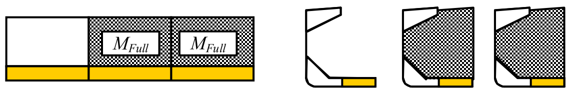
Remarks
1) Single loading pattern in M_{Full} with cargo density of 3.0 t/m^3 can be analyzed in lieu of these two loading patterns.
2) Cargo density 3.0 t/m^3 is to be used for calculation of dry cargo pressure in principle.
3) M_H/V_H or 1.0 t/m^3, whichever is greater, is to be used as cargo density for calculation of dry cargo pressure.
4) In case of no ballast hold, normal ballast condition with assuming $M_{SW,S} = 0$ is to be analyzed.
5) Position of ballast hold is to be adjusted as appropriate.
6) This condition is not required when {**no MP**} notation is assigned.
7) For vertical shear force analysis, maximum shear force ($Q_{SW} + Q_{WV}$) with reduced vertical bending moment ($0.8M_{SW} + 0.65C_{WV}M_{WV}$) is to be considered.
8) This condition is only required when such a condition is prepared in the loading manual.
9) "M_{BLK}" is maximum cargo mass according to the design loading condition in the loading manual.
10) Actual still water vertical bending moment, as given in the loading manual, may be used in stead of design value.
11) This condition is to be considered for the loaded hold which is assigned as ballast hold if any.
12) Minimum draught among heavy ballast conditions is to be used in principle.
13) This condition is not required when such a condition is explicitly prohibited in the loading manual.
14) This condition is to be analyzed when {**no MP**} notation is assigned.
15) External sea pressures and internal pressures can be considered as static.

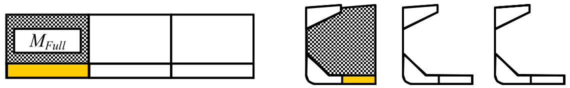
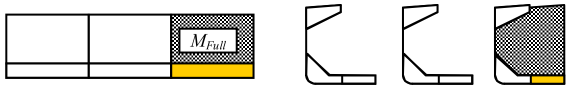
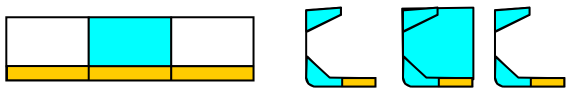
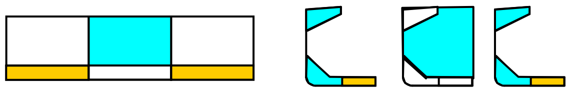
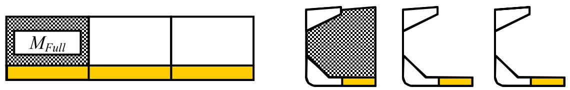
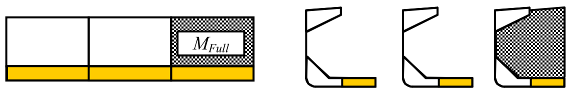
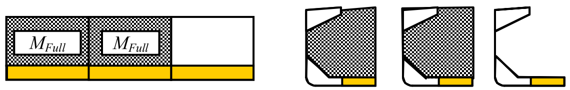
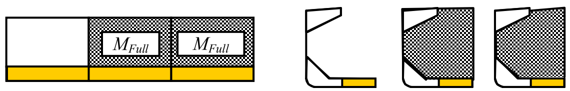
Table 4: Shear force analysis applicable to loaded hold of BC-A (mid-hold is loaded hold)

<table>
<tr><th rowspan="3">No.</th><th rowspan="3">Description [a)]</th><th rowspan="3">Draught</th><th rowspan="3">Loading Pattern</th><th rowspan="3">Aft</th><th rowspan="3">Mid</th><th rowspan="3">Fore</th><th colspan="4">Load Case (Design Wave)</th><th rowspan="3">Remarks (see Table 3 above)</th></tr>
<tr><th colspan="4">Still water vertical bending moment [b)]</th></tr>
<tr><th colspan="4">Still water shear force</th></tr>
<tr><td rowspan="3">10SF</td><td rowspan="3">Alternate Load ([3.4.2])</td><td rowspan="3">T_S</td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td><td>F2</td><td></td><td></td><td></td><td rowspan="3">2), 7)</td></tr>
<tr><td>$0.8M_{SW,H}$</td><td></td><td></td><td></td></tr>
<tr><td>Q_{SW}</td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">13SF</td><td rowspan="3">Heavy Ballast ([3.5.1])</td><td rowspan="3">$T_{HB}(min)$</td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td><td>H1</td><td></td><td></td><td></td><td rowspan="3">7), 11), 12)</td></tr>
<tr><td>$0.8M_{SW,S}$</td><td></td><td></td><td></td></tr>
<tr><td>Q_{SW}</td><td></td><td></td><td></td></tr>
</table>

a) Referred paragraph number corresponds to loading pattern prescribed in Ch 4, Sec 7.
b) $M_{SW,H}$, $M_{SW,S}$: Allowable still water vertical bending moment for seagoing condition, hogging or sagging respectively

Table 5: Bending moment analysis applicable to BC-B and BC-C

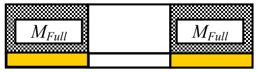
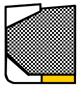
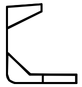
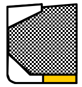
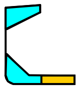
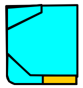
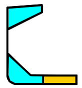
No.	Description [a]	Draught	Loading Pattern / Aft / Mid / Fore	Load Case (Design Wave) Still water vertical bending moment [b]				Remarks (see below)
1	Full Load ([2.1.3])	T_S		P1 $0.5M_{SW,S}$				1), 2), 3)
2	Full Load ([3.2.1])	T_S		P1 $0.5M_{SW,S}$				2), 4)
3	Slack Load ([3.2.2])	T_S		P1 0				4)
4	Deepest Ballast ([3.2.3])	T_{HB}		R1 $M_{SW,H}$	R1 $M_{SW,S}$	P1 $M_{SW,S}$	F2 $M_{SW,H}$	5), 6), 14)
5	Multi Port -2 ([3.3.2])	$0.83T_S$		F2 $M_{SW,H}$	P1 $M_{SW,S}$			4), 7)
6	Multi Port -3 ([3.3.3])	$0.67T_S$		P1 $M_{SW,S}$				4), 7)
7	Multi Port -3 ([3.3.3])	$0.67T_S$		P1 $M_{SW,S}$				4), 7)

No.	Description [a]	Draught	Loading Pattern / Aft / Mid / Fore	Load Case (Design Wave) Still water vertical bending moment [b]				Remarks (see below)
8	Multi Port -4 ([3.3.4])	$0.75T_S$		F2 $M_{SW,H}$	R1 $M_{SW,H}$	R1 $M_{SW,S}$	P1 $M_{SW,S}$	4), 7)
9	Multi Port -4 ([3.3.4])	$0.75T_S$		F2 $M_{SW,H}$	R1 $M_{SW,H}$	R1 $M_{SW,S}$	P1 $M_{SW,S}$	4), 7)
10	Heavy Ballast ([3.5.1])	$T_{HB}(min)$		H1 $M_{SW,S}$	R1 0	R1 $M_{SW,S}$		9), 10)
11	Heavy Ballast	$T_{HB}(min)$		R1 0	R1 $M_{SW,S}$			9), 10), 11)
12	Harbour Condition -1 ([3.6.1])	$0.67T_S$		--- $M_{S,P}(+)$	--- $M_{S,P}(-)$			4), 12),13)
13	Harbour Condition -1 ([3.6.1])	$0.67T_S$		--- $M_{S,P}(+)$	--- $M_{S,P}(-)$			4), 12), 13)
14	Harbour Condition -2 ([3.6.2])	$0.67T_S$		--- $M_{S,P}(+)$	--- $M_{S,P}(-)$			4), 12), 13)
15	Harbour Condition -2 ([3.6.2])	$0.67T_S$		--- $M_{S,P}(+)$	--- $M_{S,P}(-)$			4), 12), 13)

a) Referred paragraph number corresponds to loading pattern prescribed in Ch 4, Sec 7.
b) $M_{SW,H}$, $M_{SW,S}$: Allowable still water vertical bending moment for seagoing condition, hogging or sagging respectively
$M_{SW,P,H}$, $M_{SW,P,S}$: Allowable still water vertical bending moment for harbour condition, hogging or sagging respectively

Remarks
1) Applicable to **BC-B** only.
2) For **BC-B** single loading pattern in M_{Full} with cargo density of 3.0 t/m^3 can be analyzed in lieu of these two loading patterns.
3) Cargo density 3.0 t/m^3 is to be used for calculation of dry cargo pressure in principle.
4) M_H/V_H or 1.0 t/m^3, whichever is greater, is to be used as cargo density for calculation of dry cargo pressure.
5) In case of no ballast hold, normal ballast condition with assuming $M_{SW,S} = 0$ is to be analyzed.
6) Position of ballast hold is to be adjusted as appropriate.
7) This condition is not required when {**no MP**} notation is assigned.
8) For vertical shear force analysis, maximum shear force ($Q_{SW} + Q_{WV}$) with reduced vertical bending moment ($0.8M_{SW} + 0.65C_{WV}M_{WV}$) is to be considered.
9) This condition is to be considered for the cargo hold which is assigned as ballast hold if any.
10) Minimum draught among heavy ballast conditions is to be used in principle.
11) This condition is not required when such a condition is explicitly prohibited in the loading manual.
12) This condition is to be analyzed when {**no MP**} notation is assigned.
13) External sea pressures and internal pressures can be considered as static.
14) Load case F2 is to be analyzed when {**no MP**} notation is assigned.

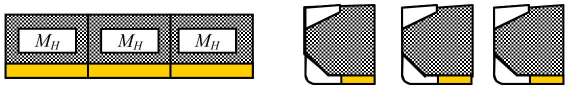
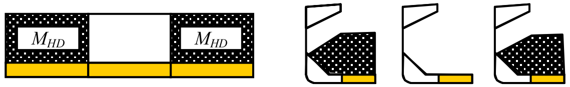
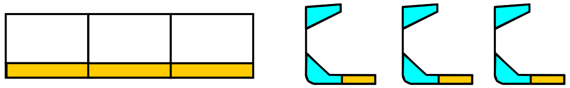
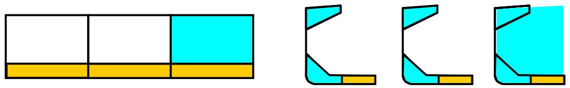
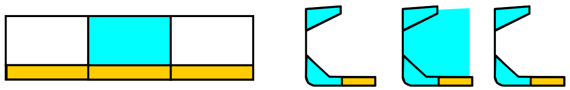
Table 6: Shear force analysis applicable to BC-B and BC-C

No.	Description [a]	Draught	Loading Pattern	Aft	Mid	Fore	Load Case (Design Wave) / Still water vertical bending moment [b] / Still water shear force				Remarks (see Table 5 above)
5SF	Multi Port -2 ([3.3.2])	$0.83T_S$					F2				4), 7), 8)
							$0.8M_{SW,H}$				
							Q_{SW}				
10SF	Heavy Ballast ([3.5.1])	$T_{HB}(min)$					H1				8), 9), 10)
							$0.8M_{SW,S}$				
							Q_{SW}				

a) Referred paragraph number corresponds to loading pattern prescribed in Ch 4, Sec 7.
b) $M_{SW,H}$, $M_{SW,S}$: Allowable still water vertical bending moment for seagoing condition, hogging or sagging respectively

Appendix 3 - STANDARD LOADING CONDITION FOR FATIGUE ASSESSMENT

Table 1: Fatigue Assessment applicable to empty hold in alternate condition of BC-A (mid-hold is empty hold)

No.	Description	Draught [a)]	Loading pattern / Aft / Mid / Fore	Load case (Design wave)				Still water vertical bending moment [b)]	Remarks (see below)
1	Full Load	T		H1	F1	R1	P1	$M_{S,(1)}$	1)
				H2	F2	R2	P2		
2	Alternate Load	T		H1	F1	R1	P1	$M_{S,(2)}$	2)
				H2	F2	R2	P2		
3	Normal Ballast	T_{NB}		H1	F1	R1	P1	$M_{S,(3)}$	
				H2	F2	R2	P2		
4	Heavy Ballast	T_{HB}		H1	F1	R1	P1	$M_{S,(4)}$	3)
				H2	F2	R2	P2		
				H1	F1	R1	P1	$M_{S,(4)}$	4)
				H2	F2	R2	P2		

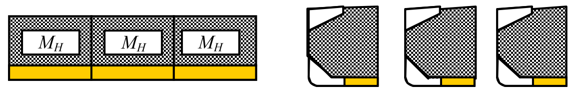
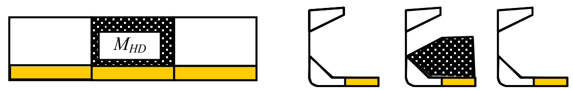
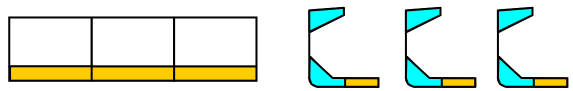
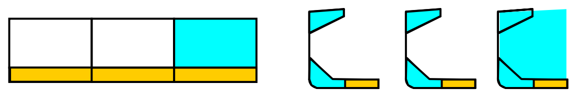
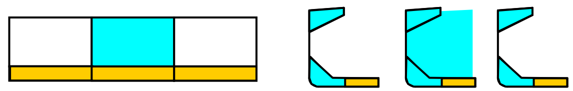
a) T : Moulded draught, T_{NB} : Draught at normal ballast condition, T_{HB} : Draught at heavy ballast condition

b) $M_{S,(1)}$, $M_{S,(2)}$, $M_{S,(3)}$, $M_{S,(4)}$: Still water vertical bending moment as defined in [3.2.2] of Ch 8, Sec 3

Remarks

1) M_H/V_H is to be used as cargo density for calculation of dry cargo pressure.
2) Cargo density 3.0 t/m^3 is to be used for calculation of dry cargo pressure in principle.
3) This condition is to be applied only for the empty hold which is not assigned as ballast hold. Position of ballast hold is to be adjusted as appropriate.
4) This condition is to be applied only for the empty hold which is assigned as ballast hold.

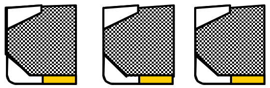
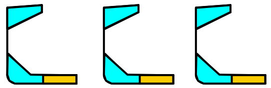
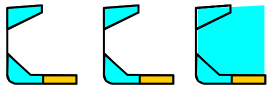
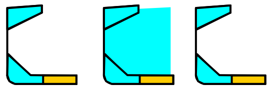
Table 2: Fatigue Assessment applicable to loaded hold in alternate condition of BC-A (mid-hold is loaded hold)

No.	Description	Draught [a)]	Loading pattern / Aft Mid Fore	Load case (Design wave)				Still water vertical bending moment [b)]	Remarks (see below)
1	Full Load	T		H1	F1	R1	P1	$M_{S,(1)}$	1)
				H2	F2	R2	P2		
2	Alternate Load	T		H1	F1	R1	P1	$M_{S,(2)}$	2)
				H2	F2	R2	P2		
3	Normal Ballast	T_{NB}		H1	F1	R1	P1	$M_{S,(3)}$	
				H2	F2	R2	P2		
4	Heavy Ballast	T_{HB}		H1	F1	R1	P1	$M_{S,(4)}$	3)
				H2	F2	R2	P2		
				H1	F1	R1	P1	$M_{S,(4)}$	4)
				H2	F2	R2	P2		

a) T : Moulded draught, T_{NB} : Draught at normal ballast condition, T_{HB} : Draught at heavy ballast condition
b) $M_{S,(1)}$, $M_{S,(2)}$, $M_{S,(3)}$, $M_{S,(4)}$: Still water vertical bending moment as defined in [3.2.2] of Ch 8, Sec 3

Remarks
1) M_H/V_H is to be used as cargo density for calculation of dry cargo pressure.
2) Cargo density 3.0 t/m^3 is to be used for calculation of dry cargo pressure in principle.
3) This condition is to be applied only for the loaded hold which is not assigned as ballast hold. Position of ballast hold is to be adjusted as appropriate.
4) This condition is to be applied only for the loaded hold which is assigned as ballast hold.

Table 3: Fatigue Assessment applicable to BC-B, BC-C

No.	Description	Draught a)	Loading pattern	Aft Mid Fore	Load case (Design wave)				Still water vertical bending moment b)	Remarks (see below)
1	Full Load	T			H1	F1	R1	P1	$M_{S,(1)}$	1)
					H2	F2	R2	P2		
2	Normal Ballast	T_{NB}			H1	F1	R1	P1	$M_{S,(3)}$	
					H2	F2	R2	P2		
3	Heavy Ballast	T_{HB}			H1	F1	R1	P1	$M_{S,(4)}$	2)
					H2	F2	R2	P2		
					H1	F1	R1	P1	$M_{S,(4)}$	3)
					H2	F2	R2	P2		

a) T : Moulded draught, T_{NB} : Draught at normal ballast condition, T_{HB} : Draught at heavy ballast condition
b) $M_{S,(1)}$, $M_{S,(2)}$, $M_{S,(3)}$, $M_{S,(4)}$: Still water vertical bending moment as defined in [3.2.2] of Ch 8, Sec 3

Remarks
1) M_H/V_H is to be used as cargo density for calculation of dry cargo pressure.
2) This condition is to be applied only for the mid-hold which is not assigned as ballast hold. Position of ballast hold is to be adjusted as appropriate.
3) This condition is to be applied only for the mid-hold which is assigned as ballast hold.

Chapter 5

Hull Girder Strength

Section 1 - YIELDING CHECK

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

M_{SW} : Design still water bending moment in intact condition, in kN.m, at the hull transverse section considered, defined in Ch 4, Sec 3, [2.2]:

$M_{SW} = M_{SW,H}$ in hogging conditions

$M_{SW} = M_{SW,S}$ in sagging conditions

M_{WV} : Vertical wave bending moment in intact condition, in kN.m, at the hull transverse section considered, defined in Ch 4, Sec 3, [3.1]

$M_{SW,F}$: Still water bending moment, in kN.m, in flooded conditions, at the hull transverse section under consideration, to be calculated according to Ch 4, Sec 3

$M_{WV,F}$: Vertical wave bending moment, in kN.m, in flooded conditions, at the hull transverse section under consideration, , to be calculated according to Ch 4, Sec 3

$M_{WV,P}$: Vertical wave bending moment, in kN.m, in harbour conditions, at the hull transverse section under consideration, to be calculated according to Ch 4, Sec 3

M_{WH} : Horizontal wave bending moment, in kN.m, at the hull transverse section considered, defined in Ch 4, Sec 3, [3.3]

Q_{SW} : Design still water shear force in intact condition, in kN, at the hull transverse section considered, defined in Ch 4, Sec 3, [2.3]

Q_{WV} : Vertical wave shear force in intact condition, in kN, at the hull transverse section considered, defined in Ch 4, Sec 3, [3.2]

$Q_{SW,F}$: Still water shear force, in kN, in flooded conditions, at the hull transverse section under consideration, to be calculated according to Ch 4, Sec 3

$Q_{WV,F}$: Vertical wave shear force, in kN, in flooded conditions, at the hull transverse section under consideration, to be calculated according to Ch 4, Sec 3

$Q_{WV,P}$: Vertical wave shear force, in kN, in harbour conditions, at the hull transverse section under consideration, to be calculated according to Ch 4, Sec 3

k : Material factor, as defined in Ch 1, Sec 4, [2.2.1]

x : X co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4]

z : Z co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4]

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section defined in [1.2], with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4]

V_D : Vertical distance, in m, defined in [1.4.2]

I_Y : Net moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis, to be calculated according to [1.5]

I_Z : Net moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis, to be calculated according to [1.5]

S : Net first moment, in m^3, of the hull transverse section, to be calculated according to [1.6]

Z_A : Net section modulus, in m^3, at any point of the hull transverse section, to be calculated according [1.4.1]

Z_{AB}, Z_{AD} : Net section moduli, in m^3, at bottom and deck, respectively, to be calculated according to [1.4.2]

C : Wave parameter defined in Ch 1, Sec 4, [2.3.1]

$\sigma_{1,ALL}$: Allowable normal stress, in N/mm^2, defined in [3.1.1]

$\tau_{1,ALL}$: Allowable shear stress, in N/mm^2, defined in [3.2.1]

ρ : Sea water density, taken equal to 1.025 t/m^3.

1. Strength characteristics of the hull girder transverse sections

1.1 General

1.1.1

This Article specifies the criteria for calculating the hull girder strength characteristics to be used for the checks in [2] to [5], in association with the hull girder loads specified in Ch 4, Sec 3.

1.2 Hull girder transverse sections

1.2.1 General

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder longitudinal strength, i.e. all continuous longitudinal members below and including the strength deck defined in [1.3], taking into account the requirements in [1.2.2] to [1.2.9].

These members are to be considered as having (see also Ch 3, Sec 2) net offered scantlings based on gross offered thickness reduced by $0.5t_C$, when the hull girder strength characteristics are used for:

- the hull girder yielding check according to [2] to [5]
- the ultimate strength check in Ch 5, Sec 2
- the calculation of the hull girder stresses for the strength checks of plating, ordinary stiffeners and primary supporting members according to Ch 6.

1.2.2 Continuous trunks and continuous longitudinal hatch coamings

Continuous trunks and continuous longitudinal hatch coamings may be included in the hull girder transverse sections, provided they are effectively supported by longitudinal bulkheads or primary supporting members.

1.2.3 Longitudinal ordinary stiffeners or girders welded above the strength deck

Longitudinal ordinary stiffeners or girders welded above the strength deck (including the deck of any trunk fitted as specified in [1.2.2]) are to be included in the hull girder transverse sections.

1.2.4 Longitudinal girders between hatchways, supported by longitudinal bulkheads

Where longitudinal girders, effectively supported by longitudinal bulkheads, are fitted between hatchways, the sectional area of these longitudinal girders are to be included in the hull girder transverse.

1.2.5 Longitudinal bulkheads with vertical corrugations

Longitudinal bulkheads with vertical corrugations are not to be included in the hull girder transverse sections.

1.2.6 Members in materials other than steel

Where a member contributing to the longitudinal strength is made in material other than steel with a Young's modulus E equal to 2.06 10^5 N/mm^2, the steel equivalent sectional area that may be included in the hull girder transverse sections is obtained, in m^2, from the following formula:

$$A_{SE} = \frac{E}{2.06 \cdot 10^5} A_M$$

where:

A_M : Sectional area, in m^2, of the member under consideration.

1.2.7 Large openings

Large openings are:

- elliptical openings exceeding 2.5 m in length or 1.2 m in breadth
- circular openings exceeding 0.9 m in diameter.

Large openings and scallops, where scallop welding is applied, are always to be deducted from the sectional areas included in the hull girder transverse sections.

1.2.8 Small openings

Smaller openings than those in [1.2.7] in one transverse section in the strength deck or bottom area need not be deducted from the sectional areas included in the hull girder transverse sections, provided that:

$$\Sigma b_S \le 0.06(B - \Sigma b)$$

where:

Σb_S : Total breadth of small openings, in m, in the strength deck or bottom area at the transverse section considered, determined as indicated in Fig 1

Σb : Total breadth of large openings, in m, at the transverse section considered, determined as indicated in Fig 1.

Where the total breadth of small openings Σb_S does not fulfil the above criteria, only the excess of breadth is to be deducted from the sectional areas included in the hull girder transverse sections.

1.2.9 Lightening holes, draining holes and single scallops

Lightening holes, draining holes and single scallops in longitudinals need not be deducted if their height is less than $0.25 h_w$, without being greater than 75 mm, where h_w is the web height, in mm.

Otherwise, the excess is to be deducted from the sectional area or compensated.

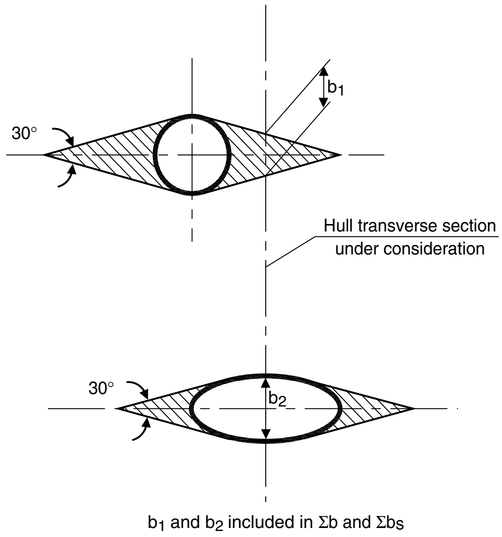


Figure 1: Calculation of Σb and Σb_S

1.3 Strength deck

1.3.1

The strength deck is, in general, the uppermost continuous deck.

In the case of a superstructure or deckhouses contributing to the longitudinal strength, the strength deck is the deck of the superstructure or the deck of the uppermost deckhouse.

1.3.2

A superstructure extending at least 0.15L within 0.4L amidships may generally be considered as contributing to the longitudinal strength.

For other superstructures and for deckhouses, their contribution to the longitudinal strength is to be assessed on a case by case basis, to evaluate their percentage of participation to the longitudinal strength.

1.4 Section modulus

1.4.1

The section modulus at any point of a hull transverse section is obtained, in m^3, from the following formula:

$$Z_A = \frac{I_Y}{|z - N|}$$

1.4.2

The section moduli at bottom and at deck are obtained, in m^3, from the following formulae:

- at bottom:

$$Z_{AB} = \frac{I_Y}{N}$$

- at deck:

  $$Z_{AD} = \frac{I_Y}{V_D}$$

  where:

  V_D : Vertical distance, in m, taken equal to:

  - in general:

    $$V_D = z_D - N$$

    where:

    z_D : Z co-ordinate, in m, of strength deck at side, defined in [1.3], with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4]

  - if continuous trunks or hatch coamings are taken into account in the calculation of I_Y, as specified in [1.2.2]:

    $$V_D = (z_T - N)\left(0.9 + 0.2\frac{y_T}{B}\right) \geq z_D - N$$

    where:

    y_T, z_T : Y and Z co-ordinates, in m, of the top of continuous trunk or hatch coaming with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4]; y_T and z_T are to be measured for the point which maximises the value of V_D

  - if longitudinal ordinary stiffeners or girders welded above the strength deck are taken into account in the calculation of I_Y, as specified in [1.2.3], V_D is to be obtained from the formula given above for continuous trunks and hatch coamings. In this case, y_T and z_T are the Y and Z co-ordinates, in m, of the top of the longitudinal stiffeners or girders with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4].

1.5 Moments of inertia

1.5.1

The moments of inertia I_Y and I_Z, in m^4, are those, calculated about the horizontal and vertical neutral axes, respectively, of the hull transverse sections defined in [1.2].

1.6 First moment

1.6.1

The first moment S, in m^3, at a level z above the baseline is that, calculated with respect to the horizontal neutral axis, of the portion of the hull transverse sections defined in [1.2] located above the z level.

2. Hull girder stresses

2.1 Normal stresses

2.1.1 General

The normal stresses in a member made in material other than steel with a Young's modulus E equal to 2.06 10^5 N/mm^{2,} included in the hull girder transverse sections as specified in [1.2.6], are obtained from the following formula:

$$\sigma_1 = \frac{E}{2.06 \cdot 10^5} \sigma_{1S}$$

where:

σ_{1S} : Normal stress, in N/mm^2, in the member under consideration, calculated according to [2.1.2] and [2.1.3] considering this member as having the steel equivalent sectional area A_{SE} defined in [1.2.6].

2.1.2 Normal stresses induced by vertical bending moments

The normal stresses induced by vertical bending moments are obtained, in N/mm^2, from the following formulae:

- at any point of the hull transverse section, located below z_{VD} , where $z_{VD} = V_D + N$:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_A} 10^{-3}$$

- at bottom:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_{AB}} 10^{-3}$$

- at deck:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_{AD}} 10^{-3}$$

2.1.3 Normal stresses in flooded conditions of BC-A or BC-B ships

This requirement applies to **BC-A** or **BC-B** ships, in addition to [2.1.2].

The normal stresses, in the flooded conditions specified in Ch 4, Sec 3, are to be obtained at any point, in N/mm^2, from the following formula:

$$\sigma_1 = \frac{M_{SW,F} + M_{WV,F}}{Z_A} 10^{-3}$$

2.2 Shear stresses

2.2.1 General

The shear stresses induced by vertical shear forces Q_{SW} and Q_{WV} in intact condition and, for **BC-A** and **BC-B** ships by vertical shear forces $Q_{SW,F}$ and $Q_{WV,F}$ in flooded condition are normally to be obtained through direct analyses.

When they are combined, vertical shear forces Q_{SW} and Q_{WV} in intact condition are to be taken with the same sign. The same is to be applied also for combination of vertical shear forces $Q_{SW,F}$ and $Q_{WV,F}$ in flooded condition.

The shear force correction ΔQ_C is to be taken into account, in accordance with [2.2.2]. The shear force correction need not to be considered at the fore end of foremost hold and aft end of aftermost hold.

As an alternative to this procedure, the shear stresses induced by the vertical shear forces Q_{SW} and Q_{WV} in intact condition and, for **BC-A** and **BC-B** ships by the vertical shear forces $Q_{SW,F}$ and $Q_{WV,F}$ in flooded condition may be obtained through the simplified procedure in [2.2.2] and [2.2.3] respectively.

2.2.2 Simplified calculation of shear stresses induced by vertical shear forces

The shear stresses induced by the vertical shear forces in the calculation point are obtained, in N/mm^2, from the following formula:

$$\tau_1 = \left(Q_{SW} + Q_{WV} - \varepsilon \Delta Q_C\right)\frac{S}{I_Y t}\delta$$

where:

t : Minimum net thickness, in mm, of side and inner side plating, as applicable according to Tab 1

δ : Shear distribution coefficient defined in Tab 1

$\varepsilon = \mathrm{sgn}\left(Q_{SW}\right)$

ΔQ_C : Shear force correction (see Fig 2) at the section considered. The shear force correction is to be considered independently forward and aft of the transverse bulkhead for the hold considered. The shear force correction takes into account, when applicable, the portion of loads transmitted by the double bottom girders to the transverse bulkheads:

RCN 1 to July 2008 version (effective from 1 July 2009)

- for ships with any non-homogeneous loading conditions, such as alternate hold loading conditions and heavy ballast conditions carrying ballast in hold(s):

$$\Delta Q_C = \alpha\left|\frac{M}{B_H \ell_H} - \rho T_{LC,mh}\right| \text{ for each non-homogenous loading condition}$$

RCN 1 to July 2008 version (effective from 1July 2009)

- for other ships and homogenous loading conditions: *RCN 1 to July 2008 version (effective from 1 July 2009)*

  $\Delta Q_C = 0$

$\varphi = 1.38 + 1.55\frac{\ell_0}{b_0}$, to be taken not greater than 3.7

$$\alpha = g\frac{\ell_0 b_0}{2 + \varphi\frac{\ell_0}{b_0}}$$

ℓ_0, b_0 : Length and breadth, respectively, in m, of the flat portion of the double bottom in way of the hold considered; b_0 is to be measured on the hull transverse section at the middle of the hold

ℓ_H : Length, in m, of the hold considered, measured between the middle of the transverse corrugated bulkheads depth

B_H : Ship's breadth, in m, measured at the level of inner bottom on the hull transverse section at the middle of the hold considered

M : Mass, in t, in the considered section.

- Adjacent cargo hold is loaded in a non homogenous loading condition for the condition under consideration

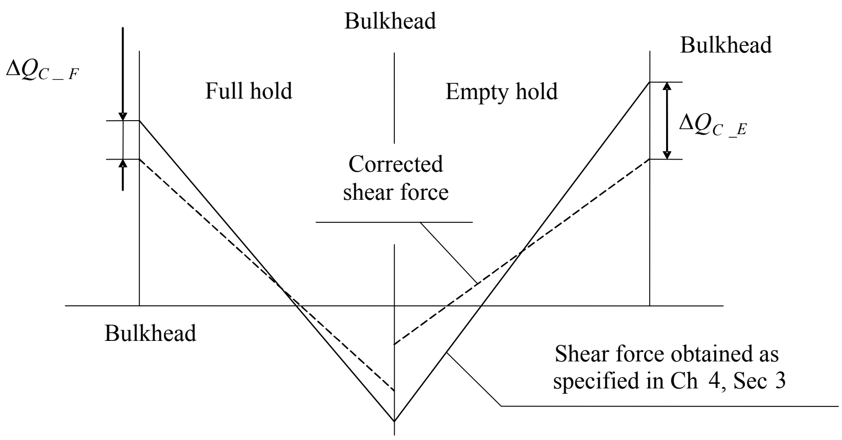
  M is to include the total mass in the hold and the mass of water ballast in double bottom tank, bounded by side girders in way of hopper tank plating or longitudinal bulkhead.

- Other cases

  M is the total mass in the hold.

  RCN 1 to July 2008 version (effective from 1July 2009)

$T_{LC,mh}$: Draught, in m, measured vertically on the hull transverse section at the middle of the hold considered, from the moulded baseline to the waterline in the loading condition considered.



ΔQ_{C_F} : shear force correction for the hull load
ΔQ_{C_E} : shear force correction for the empty hold

RCN 1 to July 2008 version (effective from 1 July 2009)

Figure 2: Shear force correction ΔQ_C

Table 1: Shear stresses induced by vertical shear forces

Ship typology	Location	*t*, in mm	δ
Single side skin construction	Sides	t_S	0,5
Double side skin construction	Sides	t_S	$0.5(1-\phi)$
	Inner sides	t_{IS}	0.5ϕ

where:

t_S, t_{IS} : Minimum net thicknesses, in mm, of side and inner side, respectively

t_{SM}, t_{ISM} : Mean net thicknesses, in mm, over all the strakes of side and inner side , respectively. They are calculated as $\Sigma(\ell_i\, t_i) / \Sigma\ell_i$, where ℓ_i and t_i are the length, in m, and the net thickness, in mm, of the i[th] strake of side and inner side.

ϕ : Coefficient taken equal to: $\phi = 0.275 + 0.25\dfrac{t_{ISM}}{t_{SM}}$

RCN 1 to July 2010 version (effective from 1July 2012)

2.2.3 Shear stresses in flooded conditions of BC-A or BC-B ships

This requirement applies to **BC-A** or **BC-B** ships, in addition to [2.2.1] and [2.2.2].

The shear stresses, in the flooded conditions specified in Ch 4, Sec 3, are to be obtained at the calculation point, in N/mm², from the following formula:

$$\tau_1 = \left(Q_{SW,F} + Q_{WV,F} - \varepsilon \Delta Q_C\right)\frac{S}{I_Y t}\delta$$

$$\varepsilon = \operatorname{sgn}(Q_{SW,F})$$

ΔQ_C : Shear force correction, to be calculated according to [2.2.2], where the mass of the ingressed water is to be added to M, and where the draught $T_{LC,mh}$ is to be measured up to the equilibrium waterline.

RCN 1 to July 2008 version (effective from 1 July 2009)

t : Net thickness, in mm, of the side plating.

3. Checking criteria

3.1 Normal stresses

3.1.1

It is to be checked that the normal stresses σ_1 calculated according to [2.1.2] and, when applicable, [2.1.3] are in compliance with the following formula:

$$\sigma_1 \le \sigma_{1,ALL}$$

where:

$\sigma_{1,ALL}$: Allowable normal stress, in N/mm², obtained from the following formulae:

$$\sigma_{1,ALL} = \frac{130}{k} \quad \text{for} \quad \frac{x}{L} \le 0.1$$

$$\sigma_{1,ALL} = \frac{190}{k} - \frac{1500}{k}\left(\frac{x}{L} - 0.3\right)^2 \quad \text{for} \quad 0.1 < \frac{x}{L} < 0.3$$

$$\sigma_{1,ALL} = \frac{190}{k} \quad \text{for} \quad 0.3 \le \frac{x}{L} \le 0.7$$

$$\sigma_{1,ALL} = \frac{190}{k} - \frac{1500}{k}\left(\frac{x}{L} - 0.7\right)^2 \quad \text{for} \quad 0.7 < \frac{x}{L} < 0.9$$

$$\sigma_{1,ALL} = \frac{130}{k} \quad \text{for} \quad \frac{x}{L} \ge 0.9$$

3.2 Shear stresses

3.2.1

It is to be checked that the shear stresses τ_1 calculated according to [2.2.1] or [2.2.2] and, when applicable, [2.2.3] are in compliance with the following formula:

$$\tau_1 \le \tau_{1,ALL}$$

where:

$\tau_{1,ALL}$: Allowable shear stress, in N/mm²:

$$\tau_{1,ALL} = 120/k$$

4. Section modulus and moment of inertia

4.1 General

4.1.1

The requirements in [4.2] to [4.5] provide the minimum hull net girder section modulus, complying with the checking criteria indicated in [3], and the midship net section moment of inertia required to ensure sufficient hull girder rigidity.

4.1.2

The k material factors are to be defined with respect to the materials used for the bottom and deck members contributing to the longitudinal strength according to [1]. When material factors for higher strength steels are used, the requirements in [4.5] apply.

4.2 Section modulus within 0.4*L* amidships

4.2.1

The net section moduli Z_{AB} and Z_{AD} at the midship section are to be not less than the value obtained, in m^3, from the following formula:

- $Z_{R,MIN} = 0.9CL^2 B\left(C_B + 0.7\right)k\,10^{-6}$

4.2.2

In addition, the net section moduli Z_{AB} and Z_{AD} within 0.4L amidships are to be not less than the value obtained, in m^3, from the following formula:

- $Z_R = \dfrac{M_{SW}+M_{WV}}{\sigma_{1,ALL}} 10^{-3}$
- in addition, for **BC-A** and **BC-B** ships:

  $Z_R = \dfrac{M_{SW,F}+M_{WV,F}}{\sigma_{1,ALL}} 10^{-3}$

4.2.3

Where the total breadth Σb_S of small openings, as defined in [1.2.8], is deducted from the sectional areas included in the hull girder transverse sections, the values $Z_{R,MIN}$ and Z_R defined in [4.2.1] or [4.2.2] may be reduced by 3%.

4.2.4

Scantlings of members contributing to the longitudinal strength (see [1]), based on the section modulus requirement in [4.2.1], are to be maintained within 0.4L amidships.

4.3 Section modulus outside 0.4*L* amidships

4.3.1

The net section moduli Z_{AB} and Z_{AD} outside 0.4L amidships are to be not less than the value obtained, in m^3, from the following formula:

- $Z_R = \frac{M_{SW}+M_{WV}}{\sigma_{1,ALL}}10^{-3}$
- in addition, for **BC-A** and **BC-B** ships:

  $Z_R = \frac{M_{SW,F}+M_{WV,F}}{\sigma_{1,ALL}}10^{-3}$

4.3.2

Scantlings of members contributing to the hull girder longitudinal strength (see [1]) may be gradually reduced, outside 0.4*L* amidships, to the minimum required for local strength purposes at fore and aft parts, as specified in Ch 9, Sec 1 or Ch 9, Sec 2, respectively.

4.4 Midship section moment of inertia

4.4.1

The net midship section moment of inertia about its horizontal neutral axis is to be not less than the value obtained, in m^4, from the following formula:

$$I_{YR} = 3Z'_{R,MIN}L \cdot 10^{-2}$$

where $Z'_{R,MIN}$ is the required net midship section modulus $Z_{R,MIN}$, in m^3, calculated as specified in [4.2.1] but assuming $k = 1$.

4.5 Extent of higher strength steel

4.5.1

When a material factor for higher strength steel is used in calculating the required section modulus at bottom or deck according to [4.2] or [4.3], the relevant higher strength steel is to be adopted for all members contributing to the longitudinal strength (see [1]), at least up to a vertical distance, in m, obtained from the following formulae:

- above the baseline (for section modulus at bottom):

  $V_{HB} = \frac{\sigma_{1B} - k\sigma_{1,ALL}}{\sigma_{1B} + \sigma_{1D}} z_D$

- below a horizontal line located at a distance V_D (see [1.4.2]) above the neutral axis of the hull transverse section (for section modulus at deck):

  $V_{HD} = \frac{\sigma_{1D} - k\sigma_{1,ALL}}{\sigma_{1B} + \sigma_{1D}} \left(N + V_D\right)$

where:

σ_{1B}, σ_{1D} : Normal stresses, in N/mm^2, at bottom and deck, respectively, calculated according to [2.1]

z_D : Z co-ordinate, in m, of the strength deck defined in [1.3], with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4]

4.5.2

The higher strength steel is to extend in length at least throughout 0.4*L* amidships where it is required for strength purposes according to the provision of the present Rules.

5. Permissible still water bending moment and shear force

5.1 Permissible still water bending moment and shear force in intact condition

5.1.1 Permissible still water bending moment

The permissible still water bending moment at any hull transverse section in intact condition, in hogging or sagging conditions, is the value M_{SW} considered in the hull girder section modulus calculation according to [4.2] and [4.3].

In the case of structural discontinuities in the hull transverse sections, the distribution of permissible still water bending moments is considered on a case by case basis.

5.1.2 Permissible still water shear force - Direct calculation

Where the shear stresses are obtained through calculation analyses according to [2.2.1], the permissible positive or negative still water shear force in intact condition at any hull transverse section is obtained, in kN, from the following formula:

$$Q_P = \varepsilon |Q_T| - Q_{WV}$$

where:

$$\varepsilon = \mathrm{sgn}(Q_{SW})$$

Q_T : Shear force, in kN, which produces a shear stress $\tau = 120/k$ N/mm^2 in the most stressed point of the hull net transverse section, taking into account the shear force correction ΔQ_C in accordance with [2.2.2].

A lower value of the permissible still water shear force may be considered, if requested by the Shipbuilder.

5.1.3 Permissible still water shear force - Simplified calculation

Where the shear stresses are obtained through the simplified procedure in [2.2.2], the permissible positive or negative still water shear force in intact condition at any hull transverse section is obtained, in kN, from the following formula:

$$Q_P = \varepsilon \left(\frac{120}{k\delta} \frac{I_Y t}{S} + \Delta Q_C \right) - Q_{WV}$$

where:

$$\varepsilon = \mathrm{sgn}(Q_{SW})$$

δ : Shear distribution coefficient defined in Tab 1

t : Minimum net thickness, in mm, of side and inner side plating, as applicable according to Tab 1

ΔQ_C : Shear force corrections defined in [2.2.2], to be considered independently forward and aft of the transverse bulkhead.

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A lower value of the permissible still water shear force may be considered, if requested by the Shipbuilder.

5.2 Permissible still water bending moment and shear force in harbour conditions

5.2.1 Permissible still water bending moment

The permissible still water bending moment at any hull transverse section in harbour conditions, in hogging or sagging conditions, is obtained, in kN.m, from the following formula:

$$M_{P,P} = M_{SW} + M_{WV} - M_{WV,P}$$

A lower value of the permissible still water bending moment in harbour conditions may be considered, if requested by the Shipbuilder.

5.2.2 Permissible still water shear force

The permissible positive or negative still water shear force at any hull transverse section, in harbour conditions, is obtained, in kN, from the following formula:

$$Q_{P,P} = \varepsilon Q_P + Q_{WV} - Q_{WV,P}$$

where:

$\varepsilon = \mathrm{sgn}(Q_{SW})$

Q_P : Permissible still water shear force during navigation, in kN, to be calculated according to [5.1.3].

A lower value of the permissible still water shear force in harbour conditions may be considered, if requested by the Shipbuilder.

5.3 Permissible still water bending moment and shear force in flooded condition

5.3.1 Permissible still water bending moment

The permissible still water bending moment at any hull transverse section in flooded condition, in hogging or sagging conditions, is the value $M_{SW,F}$ considered in the hull girder section modulus calculation according to [4.2] and [4.3].

In the case of structural discontinuities in the hull transverse sections, the distribution of permissible still water bending moments is considered on a case by case basis.

5.3.2 Permissible still water shear force - Direct calculation

Where the shear stresses are obtained through calculation analyses according to [2.2.1], the permissible positive or negative still water shear force in flooded condition at any hull transverse section is obtained, in kN, from the following formula:

$$Q_{P,F} = \varepsilon |Q_T| - Q_{WV,F}$$

where:

$\varepsilon = \mathrm{sgn}(Q_{SW,F})$

Q_T : Shear force, in kN, which produces a shear stress $\tau = 120/k$ N/mm^2 in the most stressed point of the hull net transverse section, taking into account the shear force correction ΔQ_C in accordance with [2.2.2].

5.3.3 Permissible still water shear force - Simplified calculation

Where the shear stresses are obtained through the simplified procedure in [2.2.2], the permissible positive or negative still water shear force in flooded condition at any hull transverse section is obtained, in kN, from the following formula:

$$Q_{P,F} = \varepsilon\left(\frac{120}{k\delta}\frac{I_Y t}{S} + \Delta Q_C\right) - Q_{WV,F}$$

where:

$\varepsilon = \mathrm{sgn}(Q_{SW})$

δ : Shear distribution coefficient defined in Tab 1

t : Minimum net thickness, in mm, of side and inner side plating, as applicable according to Tab 1

ΔQ_C : Shear force correction, to be calculated according to [2.2.2], where the mass M is to include the mass of the ingressed water in the hold considered and the draught T_{LC} is to be measured up to the equilibrium waterline.

Section 2 - ULTIMATE STRENGTH CHECK

1. Application

1.1 General

1.1.1

The requirements of this Section apply to ships equal to or greater than 150 m in length L.

2. Hull girder ultimate strength check

2.1 Hull girder loads

2.1.1 Bending moment

The bending moment M in sagging and hogging conditions, to be considered in the ultimate strength check of the hull girder, is to be obtained, in kN.m, in intact, flooded and harbour conditions, from the following formula:

$M = M_{SW} + \gamma_W M_{WV}$

where:

M_{SW}, $M_{SW,F}$, $M_{SW,P}$: Design still water bending moment, in kN.m, in sagging and hogging conditions at the hull transverse section considered, to be calculated respectively in intact (M_{SW}), flooded ($M_{SW,F}$) and harbour ($M_{SW,P}$) conditions

M_{WV}, $M_{WV,F}$, $M_{WV,P}$: Vertical wave bending moment, in kN.m, in sagging and hogging conditions at the hull transverse section considered, defined in Ch 4, Sec 3, respectively in intact (M_{WV}), flooded ($M_{WV,F}$) and harbour ($M_{WV,P}$) conditions

γ_W : Safety factor on wave hull girder bending moments, taken equal to:

$\gamma_W = 1.20$

2.2 Hull girder bending moment

2.2.1 Curve *M*- χ

The ultimate bending moment capacities of a hull girder transverse section, in hogging and sagging conditions, are defined as the maximum values of the curve of bending moment capacity M versus the curvature χ of the transverse section considered (see Fig 1).

The curvature χ is positive for hogging condition and negative for sagging condition.

The curve M-χ is to be obtained through an incremental-iterative procedure, according to the criteria specified in App 1.

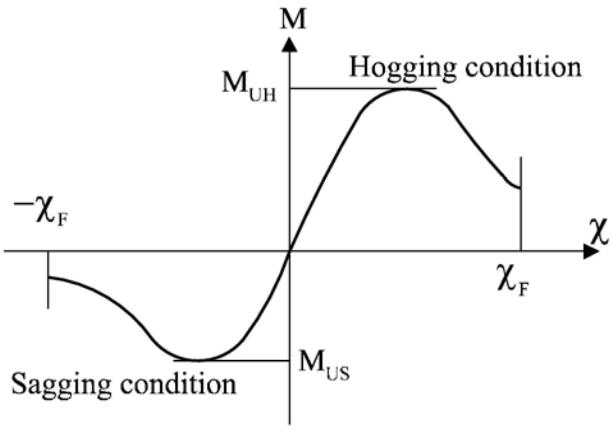

Figure 1: Curve bending moment capacity *M* versus curvature χ

2.2.2 Hull girder transverse sections

The hull girder transverse sections are constituted by the elements contributing to the hull girder longitudinal strength, considered with their net offered scantlings according to Ch 3, Sec 2, [3.2.4].

2.3 Checking criteria

2.3.1

It is to be checked that the hull girder ultimate bending capacity at any hull transverse section is in compliance with the following formula:

$$M \leq \frac{M_U}{\gamma_R}$$

where:

M_U : Ultimate bending moment capacity of the hull transverse section considered, calculated with net offered scantlings based on gross offered thickness reduced by 0.5 t_C, in kN.m:

$M_U = M_{UH}$ in hogging conditions

$M_U = M_{US}$ in sagging conditions

M_{UH} : Ultimate bending moment capacity in hogging conditions, in kN.m, defined in [2.2.1]

M_{US} : Ultimate bending moment capacity in sagging conditions, in kN.m, defined in [2.2.1]

M : Bending moment, in kN.m, defined in [2.1.1] for the ship in intact, flooded and harbour conditions

γ_R : Safety factor taken equal to 1.10

Appendix 1 - HULL GIRDER ULTIMATE STRENGTH

Symbols

For symbols not defined in this Appendix, refer to Ch 1, Sec 4.

I_Y : Moment of inertia, in m^4, of the hull transverse section around its horizontal neutral axis, to be calculated according to Ch 5, Sec 1, [1.5.1]

Z_{AB}, Z_{AD} : Section moduli, in m^3, at bottom and deck, respectively, defined in Ch 5, Sec 1, [1.4.2].

R_{eHs} : Minimum yield stress, in N/mm², of the material of the considered stiffener.

R_{eHp} : Minimum yield stress, in N/mm², of the material of the considered plate.

A_s : Net sectional area, in cm², of stiffener, without attached plating

A_p : Net sectional area, in cm², of attached plating

1. Hull girder ultimate strength check

1.1 Introduction

1.1.1

This Appendix provides the criteria for obtaining the curve M-χ and the ultimate longitudinal bending moment capacity M_U that are to be calculated according to the simplified incremental-iterative approach, as specified in [2.1].

2. Criteria for the calculation of the curve *M*-χ

2.1 Simplified method based on a incremental-iterative approach

2.1.1 Procedure

The curve M-χ is to be obtained by means of an incremental-iterative approach, summarised in the flow chart in Fig 1.

In this approach, the ultimate hull girder bending moment capacity M_U is defined as the peak value of the curve with vertical bending moment M versus the curvature χ of the ship cross section as shown in Fig 1**.** The curve is to be obtained through an incremental-iterative approach.

Each step of the incremental procedure is represented by the calculation of the bending moment M_i which acts on the hull transverse section as the effect of an imposed curvature χ_i.

For each step, the value χ_i is to be obtained by summing an increment of curvature $\Delta\chi$ to the value relevant to the previous step χ_{i-1}.This increment of curvature corresponds to an increment of the rotation angle of the hull girder transverse section around its horizontal neutral axis.

This rotation increment induces axial strains ε in each hull structural element, whose value depends on the position of the element. In hogging condition, the structural elements above the neutral axis are lengthened, while the elements below the neutral axis are shortened. Vice-versa in sagging condition.

The stress σ induced in each structural element by the strain ε is to be obtained from the load-end shortening curve σ-ε of the element, which takes into account the behaviour of the element in the non-linear elasto-plastic domain.

The distribution of the stresses induced in all the elements composing the hull transverse section determines, for each step, a variation of the neutral axis position, since the relationship σ-ε is non-linear. The new position of the neutral axis relevant to the step considered is to be obtained by means of an iterative process, imposing the equilibrium among the stresses acting in all the hull elements.

Once the position of the neutral axis is known and the relevant stress distribution in the section structural elements is obtained, the bending moment of the section M_i around the new position of the neutral axis, which corresponds to the curvature χ_i imposed in the step considered, is to be obtained by summing the contribution given by each element stress.

The main steps of the incremental-iterative approach described above are summarised as follows (see also Fig 1):

Step 1 Divide the transverse section of hull into stiffened plate elements.

Step 2 Define stress-strain relationships for all elements as shown in Tab 1

Step 3 Initialize curvature χ_1 and neutral axis for the first incremental step with the value of incremental curvature (curvature that induces a stress equal to 1% of yield strength in strength deck) as:

$$\chi_1 = \Delta\chi = \frac{0.01\dfrac{R_{eH}}{E}}{z_D - N}$$

where:

z_D : Z co-ordinate, in m, of strength deck at side, with respect to reference co-ordinate defined in Ch 1, Sec 4, [4]

Step 4 Calculate for each element the corresponding strain $\varepsilon_i = \chi\,(z_i - z_{NA})$ and the corresponding stress σ_i

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Step 5 Determine the neutral axis z_{NA_cur} at each incremental step by establishing force equilibrium over the whole transverse section as:

$\Sigma A_i\ \sigma_i = \Sigma A_j\ \sigma_j$ (i-th element is under compression, j-th element under tension)

Step 6 Calculate the corresponding moment by summing the contributions of all elements as:

$$M_U = \sum \sigma_{Ui} A_i \left|\left(z_i - z_{NA\_cur}\right)\right|$$

Step 7 Compare the moment in the current incremental step with the moment in the previous incremental step. If the slope in M-χ relationship is less than a negative fixed value, terminate the process and define the peak value of M_U. Otherwise, increase the curvature by the amount of $\Delta\chi$ and go to **Step 4**.

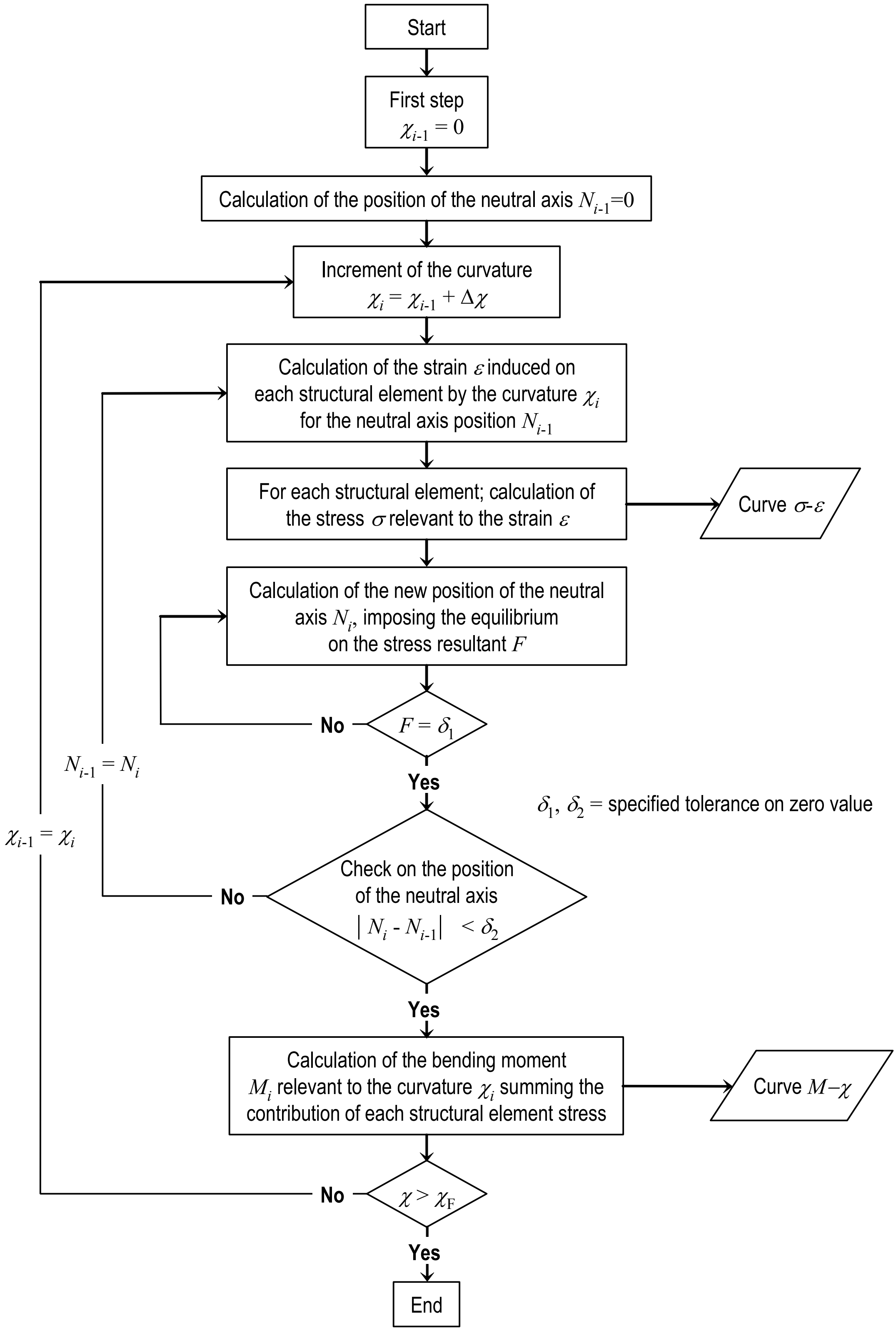

Figure 1: Flow chart of the procedure for the evaluation of the curve *M*-χ

2.1.2 Assumption

In applying the procedure described in [2.1.1], the following assumptions are generally to be made:

- the ultimate strength is calculated at hull transverse sections between two adjacent transverse webs.

- the hull girder transverse section remains plane during each curvature increment.
- the hull material has an elasto-plastic behaviour.
- the hull girder transverse section is divided into a set of elements, which are considered to act independently.

  These elements are:
  – transversely framed plating panels and/or ordinary stiffeners with attached plating, whose structural behaviour is described in [2.2.1]
  – hard corners, constituted by plating crossing, whose structural behaviour is described in [2.2.2].
- according to the iterative procedure, the bending moment M_i acting on the transverse section at each curvature value χ_i is obtained by summing the contribution given by the stress σ acting on each element. The stress σ, corresponding to the element strain ε, is to be obtained for each curvature increment from the non-linear load-end shortening curves σ- ε - of the element.

  These curves are to be calculated, for the failure mechanisms of the element, from the formulae specified in [2.2]. The stress σ is selected as the lowest among the values obtained from each of the considered load-end shortening curves σ- ε.
- The procedure is to be repeated until the value of the imposed curvature reaches the value χ_F, in m^{-1}, in hogging and sagging condition, obtained from the following formula:

  $$\chi_F = \pm 0.003 \frac{M_Y}{EI_Y}$$

  where:

  M_Y : the lesser of the values M_{Y1} and M_{Y2}, in kN.m:

  $M_{Y1} = 10^3\, R_{eH}\, Z_{AB}$

  $M_{Y2} = 10^3\, R_{eH}\, Z_{AD}$

If the value χ_F is not sufficient to evaluate the peaks of the curve M-χ, the procedure is to be repeated until the value of the imposed curvature permits the calculation of the maximum bending moments of the curve.

2.1.3 Modeling of the hull girder cross section

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder ultimate strength.

Sniped stiffeners are also to be modeled imaginarily, taking account that they doesn't contribute to the hull girder strength.

The structural members are categorized into an ordinary stiffener element, a stiffened plate element or a hard corner element.

The plate panel including web plate of girder or side stringer is idealized into either a stiffened plate element, an attached plate of an ordinary stiffener element or a hard corner element.

The plate panel is categorized into the following two kinds:

- longitudinally stiffened panel of which the longer side is in the longitudinal direction, and
- transversely stiffened panel of which the longer side is in the perpendicular direction to the longitudinal direction.

- Hard corner element

  Hard corner elements are sturdier elements composing the hull girder transverse section, which collapse mainly according to an elasto-plastic mode of failure (material yielding); they are generally constituted by two plates not lying in the same plane.

  The extent of a hard corner element from the point of intersection of the plates is taken equal to $20t_p$ on transversely stiffened panel and to $0.5s$ on a longitudinally stiffened panel. (see Fig 6)

  where:

  t_p : Gross offered thickness of the plate, in mm

  s : Spacing of the adjacent longitudinal stiffener, in m

  Bilge, sheer strake-deck stringer elements, girder-deck connections and face plate-web connections on large girders are typical hard corners.

- Ordinary stiffener element

  The ordinary stiffener constitutes an ordinary stiffener element together with the attached plate.

  The attached plate width is in principle:

  - equal to the mean spacing of the ordinary stiffener when the panels on both sides of the stiffener are longitudinally stiffened, or

  - equal to the width of the longitudinally stiffened panel when the panel on one side of the stiffener is longitudinally stiffened and the other panel is of the transversely stiffened. (See Fig.6)

- Stiffened plate element

  The plate between ordinary stiffener elements, between an ordinary stiffener element and a hard corner element or between hard corner elements is to be treated as a stiffened plate element. (See Fig. 6)

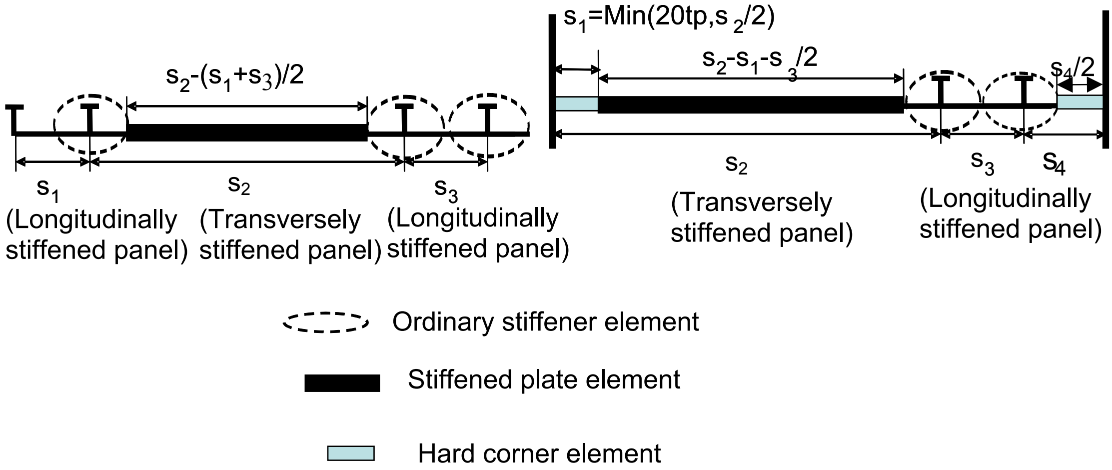

Figure 6: Extension of the breadth of the attached plating and hard corner element

The typical examples of modeling of hull girder section are illustrated in Figs 7 and 8.

Notwithstanding the foregoing principle these figures are to be applied to the modeling in the vicinity of upper deck, sheer strake and hatch side girder.

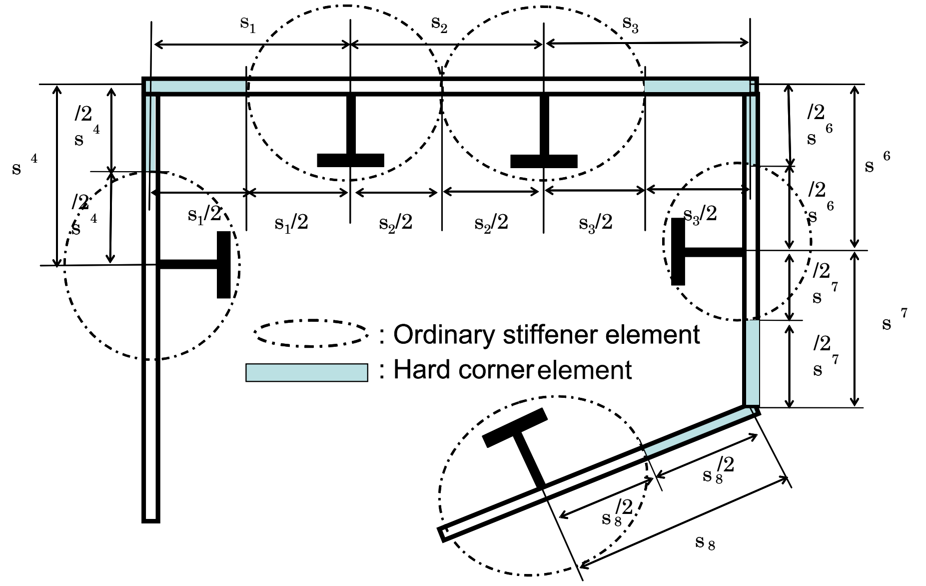

Figure 7: Extension of the breadth of the attached plating and hard corner element

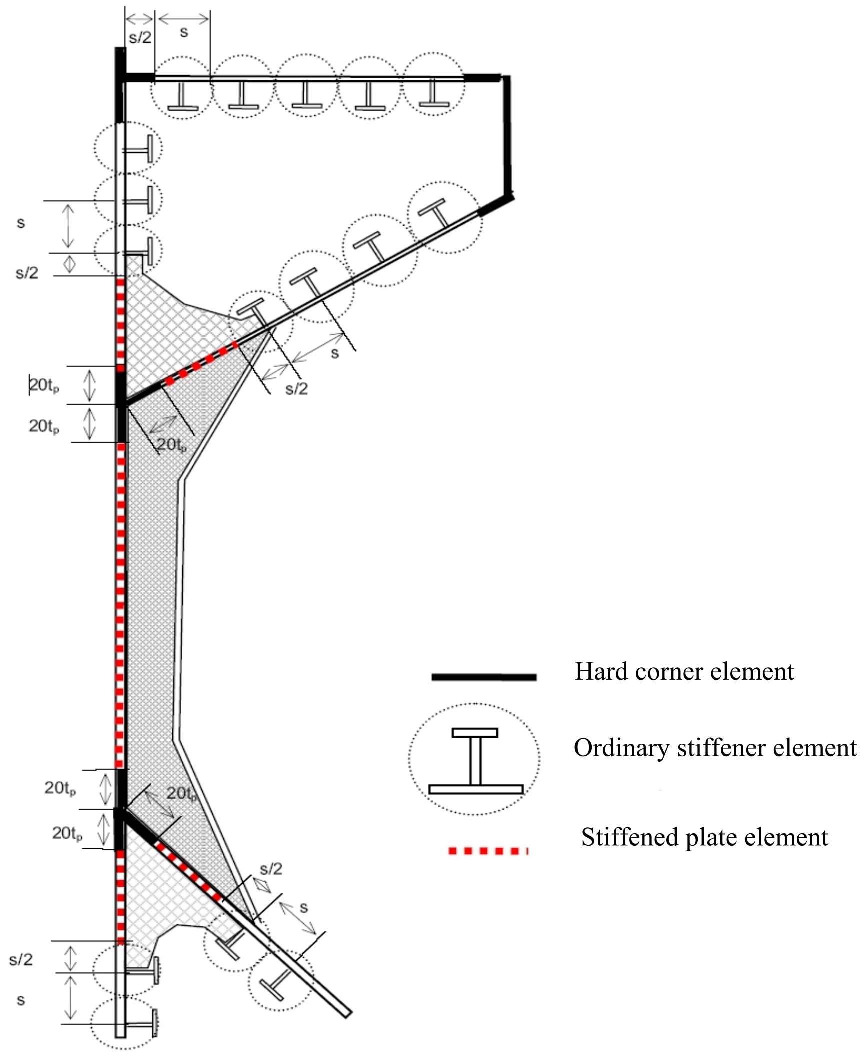

Figure 8: Examples of the configuration of stiffened plate elements, ordinary stiffener elements and hard corner elements on a hull section

(Note)

(1) In case of the knuckle point as shown in Fig 9, the plating area adjacent to knuckles in the plating with an angle greater than 30 degrees is defined as a hard corner. The extent of one side of the corner is taken equal to $20t_p$ on transversely framed panels and to $0.5s$ on longitudinally framed panels from the knuckle point.

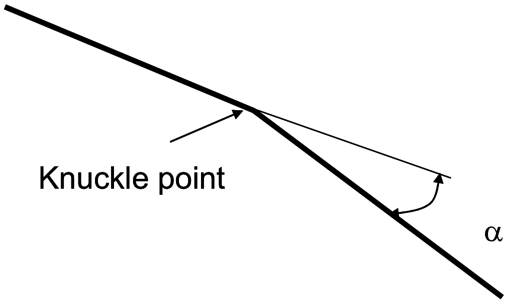

Figure 9: The case of plating with knuckle point

(2) Where the plate members are stiffened by non-continuous longitudinal stiffeners, the non-continuous stiffeners are considered only as dividing a plate into various elementary plate panels.

(3) Where the opening is provided in the stiffened plate element, the openings are to be considered in accordance with Ch 5, Sec 1, [1.2.7], [1.2.8] and [1.2.9].

(4) Where attached plating is made of steels having different thicknesses and/or yield stresses, an average thickness and/or average yield stress obtained from the following formula are to be used for the calculation.

$$t = \frac{t_1 s_1 + t_2 s_2}{s}, \qquad R_{eHp} = \frac{R_{eHp1} t_1 s_1 + R_{eHp2} t_2 s_2}{ts}$$

Where,

R_{eHp1}, R_{eHp2}, t_1, t_2, s_1, s_2 and s are shown in Fig 10.

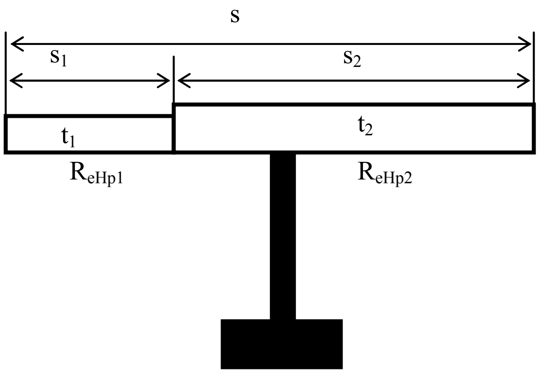

Figure 10: Element with different thickness and yield strength

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2.2 Load-end shortening curves σ-ε

2.2.1 Stiffened plate element and ordinary stiffener element

Stiffened plate element and ordinary stiffener element composing the hull girder transverse sections may collapse following one of the modes of failure specified in Tab 1.

- Where the plate members are stiffened by non-continuous longitudinal stiffeners, the stress of the element is to be obtained in accordance with [2.2.3] to [2.2.7], taking into account the non-continuous longitudinal stiffener.

  In calculating the total forces for checking the hull girder ultimate strength, the area of non-continuous longitudinal stiffener is to be assumed as zero.
- Where the opening is provided in the stiffened plate element, the considered area of the stiffened plate element is to be obtained by deducting the opening area from the plating in calculating the total forces for checking the hull girder ultimate strength. The consideration of the opening is in accordance with the requirement in Ch 5, Sec 1, [1.2.7] to [1.2.9].
- For stiffened plate element, the effective breadth of plate for the load shortening portion of the stress-strain curve is to be taken as full plate breadth, i.e. to the intersection of other plate or longitudinal stiffener – not from the end of the hard corner element nor from the attached plating of ordinary stiffener element, if any. In calculating the total forces for checking the hull girder ultimate strength, the area of the stiffened plate element is to be taken between the hard corner element and the ordinary stiffener element or between the hard corner elements, as applicable.

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Table 1: Modes of failure of stiffened plate element and ordinary stiffener element

Element	Mode of failure	Curve σ–ε defined in
Lengthened stiffened plate element or ordinary stiffener element	Elasto-plastic collapse	[2.2.3]
Shortened ordinary stiffener element	Beam column buckling Torsional buckling Web local buckling of flanged profiles Web local buckling of flat bars	[2.2.4] [2.2.5] [2.2.6] [2.2.7]
Shortened stiffened plate element	Plate buckling	[2.2.8]

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2.2.2 Hard corner element

The relevant load-end shortening curve σ-ε is to be obtained for lengthened and shortened hard corners according to [2.2.3].

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2.2.3 Elasto-plastic collapse of structural elements

The equation describing the load-end shortening curve σ-ε for the elasto-plastic collapse of structural elements composing the hull girder transverse section is to be obtained from the following formula, valid for both positive (shortening) and negative (lengthening) strains (see Fig 2):

$\sigma = \Phi R_{eHA}$

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where:

R_{eHA} : Equivalent minimum yield stress, in N/mm², of the considered element, obtained by the following formula

$$R_{eHA} = \frac{R_{eHp} A_p + R_{eHs} A_s}{A_p + A_s}$$

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Φ : Edge function, equal to:

$\Phi = -1$ for $\varepsilon < -1$

$\Phi = \varepsilon$ for $-1 \leq \varepsilon \leq 1$

$\Phi = 1$ for $\varepsilon > 1$

ε : Relative strain, equal to:

$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_Y}$$

ε_E : Element strain

ε_Y : Strain at yield stress in the element, equal to:

$$\varepsilon_Y = \frac{R_{eHA}}{E}$$

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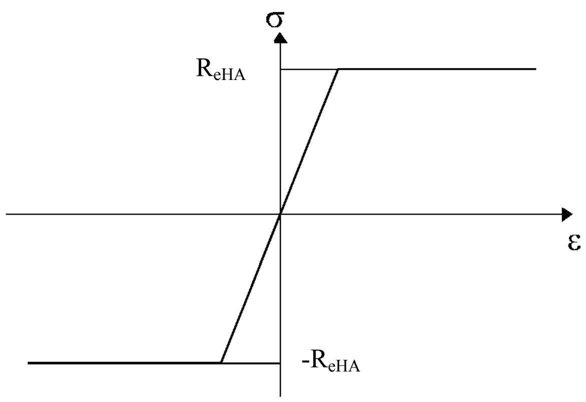

Figure 2: Load-end curve σ-ε for elasto plastic collapse

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2.2.4 Beam column buckling

The equation describing the load-end shortening curve σ_{CR1}-ε for the beam column buckling of ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula (see Fig 3):

$$\sigma_{CR1} = \Phi \sigma_{C1} \frac{A_s + A_{pE}}{A_s + A_p}$$

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where:

Φ : Edge function defined in [2.2.3]

σ_{C1} : Critical stress, in N/mm^2, equal to:

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon} \qquad \text{for } \sigma_{E1} \le \frac{R_{eHB}}{2}\varepsilon$$

$$\sigma_{C1} = R_{eHB}\left(1 - \frac{R_{eHB}\,\varepsilon}{4\,\sigma_{E1}}\right) \qquad \text{for } \sigma_{E1} > \frac{R_{eHB}}{2}\varepsilon$$

R_{eHB} : Equivalent minimum yield stress, in N/mm², of the considered element, obtained by the following formula

$$R_{eHB} = \frac{R_{eHp}A_{pE1}l_{pE} + R_{eHs}A_s l_{sE}}{A_{pE1}l_{pE} + A_s l_{sE}}$$

A_{pEl} : Effective area, in cm², equal to

$A_{pEl} = 10 b_{E1} t_p$

l_{pE} : Distance, in mm, measured from the neutral axis of the stiffener with attached plate of width b_{el} to the bottom of the attached plate

l_{sE} : Distance, in mm, measured from the neutral axis of the stiffener with attached plating of width b_{El} to the top of the stiffener

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ε : Relative strain defined in [2.2.3]

σ_{E1} : Euler column buckling stress, in N/mm^2, equal to:

$$\sigma_{E1} = \pi^2 E \frac{I_E}{A_E l^2} 10^{-4}$$

I_E : Net moment of inertia of ordinary stiffeners, in cm^4, with attached shell plating of width b_{E1}

b_{E1} : Effective width, in m, of the attached shell plating, equal to:

$$b_{E1} = \frac{s}{\beta_E} \qquad \text{for } \beta_E > 1.0$$

$$b_{E1} = s \qquad \text{for } \beta_E \le 1.0$$

$\beta_E = 10^3 \frac{s}{t_p}\sqrt{\frac{\varepsilon R_{eHp}}{E}}$ *RCN 1 to July 2008 version (effective from 1 July 2009)*

A_{pE} : Net sectional area, in cm^2, of attached shell plating of width b_E, equal to:

$A_{pE} = 10 b_E t_p$

b_E : Effective width, in m, of the attached shell plating, equal to:

$$b_E = \left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2}\right)s \qquad \text{for } \beta_E > 1.25$$

$$b_E = s \qquad \text{for } \beta_E \le 1.25$$

(RCN 1, effective from 1 April 2008)

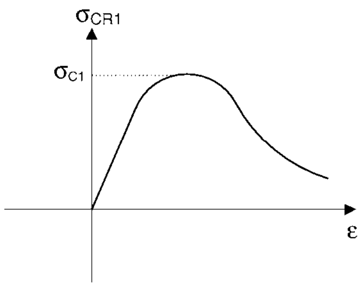


Figure 3: Load-end shortening curve σ_{CR1}-ε for beam column buckling

2.2.5 Torsional buckling

The equation describing the load-end shortening curve σ_{CR2}-ε for the flexural-torsional buckling of ordinary stiffeners composing the hull girder transverse section is to be obtained according to the following formula (see Fig 4).

$$\sigma_{CR2} = \Phi \frac{A_S \sigma_{C2} + A_p \sigma_{CP}}{A_S + A_p}$$

RCN 1 to July 2008 version (effective from 1 July 2009)

where:

Φ : Edge function defined in [2.2.3]

σ_{C2} : Critical stress, in N/mm^2, equal to:

$$\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon} \qquad \text{for } \sigma_{E2} \le \frac{R_{eHs}}{2}\varepsilon$$

$$\sigma_{C2} = R_{eHs}\left(1 - \frac{R_{eHs}\,\varepsilon}{4\sigma_{E2}}\right) \qquad \text{for } \sigma_{E2} > \frac{R_{eHs}}{2}\varepsilon$$

RCN 1 to July 2008 version (effective from 1 July 2009)

σ_{E2} : Euler torsional buckling stress, in N/mm^2, defined in Ch 6, Sec 3, [4.3]

ε : Relative strain defined in [2.2.3]

σ_{CP} : Buckling stress of the attached plating, in N/mm^2, equal to:

$$\sigma_{CP} = \left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2}\right) R_{eHp} \qquad \text{for } \beta_E > 1.25$$

$$\sigma_{CP} = R_{eHp} \qquad \text{for } \beta_E \le 1.25$$

RCN 1 to July 2008 version (effective from 1 July 2009)

β_E : Coefficient defined in [2.2.4]

(RCN 1, effective from 1 April 2008)

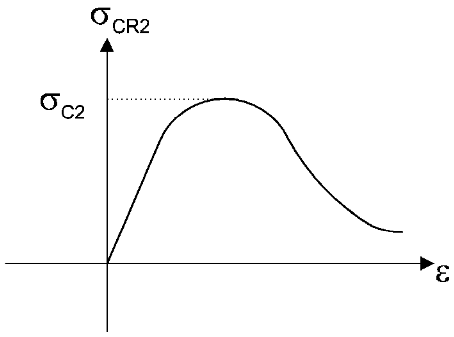


Figure 4: Load-end shortening curve σ_{CR2}-ε for flexural-torsional buckling

2.2.6 Web local buckling of ordinary stiffeners made of flanged profiles

The equation describing the load-end shortening curve σ_{CR3}-ε for the web local buckling of flanged ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi \frac{10^3 b_E t_p R_{eHp} + (h_{we} t_w + b_f t_f) R_{eHs}}{10^3 s t_p + h_w t_w + b_f t_f}$$

RCN 1 to July 2008 version (effective from 1 July 2009)

where

Φ : Edge function defined in [2.2.3]

b_E : Effective width, in m, of the attached shell plating, defined in [2.2.4]

h_{we} : Effective height, in mm, of the web, equal to:

$$h_{we} = \left(\frac{2.25}{\beta_w} - \frac{1.25}{\beta_w^2} \right) h_w \qquad \text{for } \beta_w > 1.25$$

$$h_{we} = h_w \qquad \text{for } \beta_w \le 1.25$$

$$\beta_w = \frac{h_w}{t_w} \sqrt{\frac{\varepsilon R_{eHs}}{E}}$$

RCN 1 to July 2008 version (effective from 1 July 2009)

ε : Relative strain defined in [2.2.3]

2.2.7 Web local buckling of ordinary stiffeners made of flat bars

The equation describing the load-end shortening curve σ_{CR4}-ε for the web local buckling of flat bar ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula (see Fig 5):

$$\sigma_{CR4} = \Phi \frac{A_P \sigma_{CP} + A_s \sigma_{C4}}{A_p + A_s}$$

RCN 1 to July 2008 version (effective from 1 July 2009)

where:

Φ : Edge function defined in [2.2.3]

σ_{CP} : Buckling stress of the attached plating, in N/mm^2, defined in [2.2.5]

σ_{C4} : Critical stress, in N/mm^2, equal to:

$$\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon} \qquad \text{for } \sigma_{E4} \le \frac{R_{eHs}}{2}\varepsilon$$

$$\sigma_{C4} = R_{eHs}\left(1 - \frac{R_{eHs}\,\varepsilon}{4\sigma_{E4}}\right) \qquad \text{for } \sigma_{E4} > \frac{R_{eHs}}{2}\varepsilon$$

RCN 1 to July 2008 version (effective from 1 July 2009)

σ_{E4} : Local Euler buckling stress, in N/mm^2, equal to:

$$\sigma_{E4} = 160000\left(\frac{t_w}{h_w}\right)^2$$

ε : Relative strain defined in [2.2.3].

(RCN 1, effective from 1 April 2008)

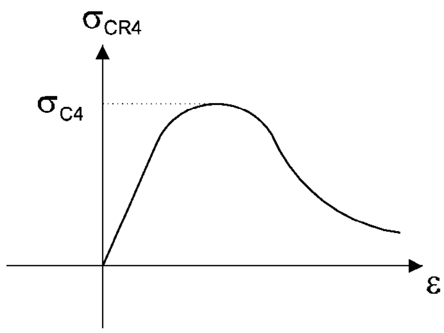


Figure 5: Load-end shortening curve σ_{CR4}-ε for web local buckling

2.2.8 Plate buckling

The equation describing the load-end shortening curve σ_{CR5}-ε for the buckling of transversely stiffened panels composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR5} = \min\begin{cases} R_{eHp}\,\Phi \\ \Phi R_{eHp}\left[\dfrac{s}{\ell}\left(\dfrac{2.25}{\beta_E} - \dfrac{1.25}{\beta_E^2}\right) + 0.1\left(1 - \dfrac{s}{\ell}\right)\left(1 + \dfrac{1}{\beta_E^2}\right)^2\right] \end{cases}$$

RCN 1 to July 2008 version (effective from 1 July 2009)

where:

Φ : Edge function defined in [2.2.3].

$$\beta_E = 10^3\,\frac{s}{t_p}\sqrt{\frac{\varepsilon R_{eHp}}{E}}$$

RCN 1 to July 2008 version (effective from 1 July 2009)

s : plate breadth, in m, taken as the spacing between the ordinary stiffeners.

ℓ : longer side of the plate, in m.

(RCN 1, effective from 1 April 2008)

Chapter 6

Hull Scantlings

Section 1 - PLATING

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

I_Y : Net moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis, to be calculated according to Ch 5, Sec 1, [1.5], on gross offered thickness reduced by $0.5t_C$ for all structural members

I_Z : Net moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis, to be calculated according to Ch 5, Sec 1, [1.5], on gross offered thickness reduced by $0.5t_C$ for all structural members

N : Z co-ordinate with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4], in m, of the centre of gravity of the hull net transverse section, defined in Ch 5, Sec 1, [1.2], considering gross offered thickness reduced by $0.5t_C$ for all structural members

t : Net thickness, in mm, of a plate panel.

p_S, p_W : Still water and wave pressure, in kN/m^2, in intact conditions, defined in [3.1.2]

p_F : Pressure, in kN/m^2, in flooded conditions, defined in [3.1.3]

p_T : Pressure, in kN/m^2, in testing conditions, defined in [3.1.4]

σ_X : Normal stress, in N/mm^2, defined in [3.1.5]

ℓ : Length, in m, of the longer side of the elementary plate panel, measured along the chord

s : Length, in m, of the shorter side of the elementary plate panel, measured along the chord at mid-span of ℓ

c_a : Coefficient of aspect ratio of the plate panel, equal to:

$$c_a = 1.21\sqrt{1 + 0.33\left(\frac{s}{\ell}\right)^2} - 0.69\frac{s}{\ell}$$, to be taken not greater than 1.0

c_r : Coefficient of curvature of the panel, equal to:

$$c_r = 1 - 0.5\frac{s}{r}$$, to be taken not less than 0.4

r : Radius of curvature, in m.

1. General

1.1 Application

1.1.1

The requirements of this Section apply for the strength check of plating subjected to lateral pressure and, for plating contributing to the longitudinal strength, to in-plane hull girder normal stress.

In addition, the buckling check of platings and stiffened panels is to be carried out according to Ch 6, Sec 3.

1.2 Net thicknesses

1.2.1

As specified in Ch 3, Sec 2, all thicknesses referred to in this Section are net, i.e. they do not include any corrosion addition.

The gross thicknesses are obtained as specified in Ch 3, Sec 2, [3].

1.2.2

The net thickness, in mm, of each plating is given by the greatest of the net thicknesses calculated for each load calculation point, as defined in [1.5.1], representative of the considered plating (see Tab 1). The geometry to be considered is that of the elementary plate panel related to the load calculation point.

1.3 Pressure combination

1.3.1 Elements of the outer shell

The still water and wave lateral pressures are to be calculated considering independently the following cases:

- the still water and wave external sea pressures
- the still water and wave internal pressure considering the compartment adjacent to the outer shell as being loaded. If the compartment adjacent to the outer shell is intended to carry liquids, this still water and wave internal pressures are to be reduced from the corresponding still water and wave external sea pressures.

1.3.2 Elements other than those of the outer shell

The still water and wave lateral pressures to be considered as acting on an element which separates two adjacent compartments are those obtained considering the two compartments individually loaded.

1.4 Elementary plate panel

1.4.1

The elementary plate panel (EPP) is the smallest unstiffened part of plating between stiffeners.

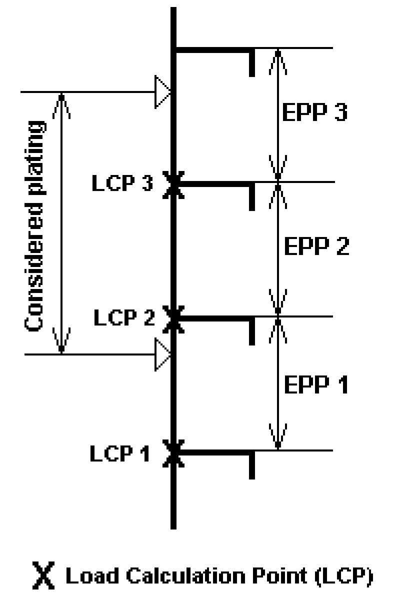
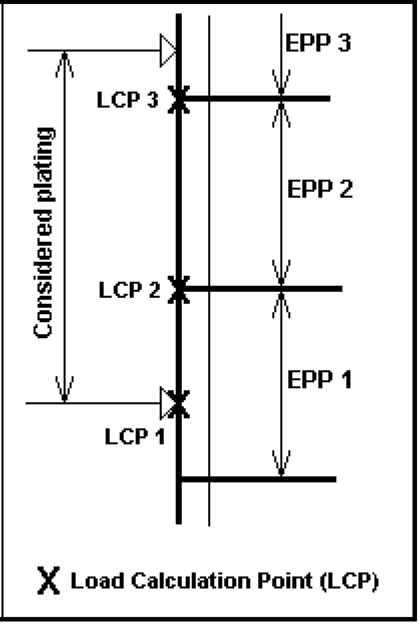
1.5 Load calculation point

1.5.1

Unless otherwise specified, lateral pressure and hull girder stresses are to be calculated:

- for longitudinal framing, at the lower edge of the elementary plate panel (see Tab 1) or, in the case of horizontal plating, at the point of minimum y-value among those of the elementary plate panel considered, as the case may be
- for transverse framing, at the lower edge of the elementary plate panel or at the lower edge of the strake (see Tab 1) or, in the case of horizontal plating, at the point of minimum y-value among those of the elementary plate panel considered, as the case may be.

Table 1: Load calculation points

Longitudinally stiffened plating	Transversely stiffened plating
	

2. General requirements

2.1 Corrugated bulkhead

2.1.1

Unless otherwise specified, the net plating thickness of a corrugated bulkhead is to be not less than that obtained for a plate panel with s equal to the greater of a and c, where a and c are defined in Fig 1.

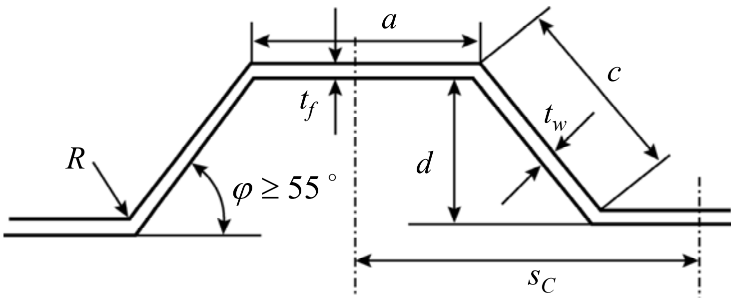


Figure 1: Corrugated bulkhead

2.2 Minimum net thicknesses

2.2.1

The net thickness of plating is to be not less than the values given in Tab 2.

In addition, in the cargo area, the net thickness of side shell plating, from the normal ballast draught to $0.25T_S$ (minimum 2.2 m) above T_S, is to be not less than the value obtained, in mm, from the following formula:

$$t = 28(s + 0.7)\frac{(BT_S)^{0.25}}{\sqrt{R_{eH}}}$$

Table 2: Minimum net thickness of plating

Plating	Minimum net thickness, in mm
Keel	$7.5 + 0.03L$
Bottom, inner bottom	$5.5 + 0.03L$
Weather strength deck and trunk deck, if any	$4.5 + 0.02L$
Side shell, bilge	$0.85L^{1/2}$
Inner side, hopper sloping plate and topside sloping plate	$0.7L^{1/2}$
Transverse and longitudinal watertight bulkheads	$0.6L^{1/2}$
Wash bulkheads	6.5
Accommodation deck	5.0

2.3 Bilge plating

2.3.1

The net thickness of the longitudinally framed bilge plating, in mm, is to be not less than the value obtained from [3.2].

2.3.2

The net thickness of the transversely framed bilge plating, in mm, is to be not less than the value obtained from the following formula:

$$t = 0.76\left[\left(p_S + p_W\right)s_b\right]^{0.4} R^{0.6} k^{0.5}$$

where :

R : Bilge radius, in m

s_b : Spacing of floors or transverse bilge brackets, in m.

2.3.3

The net thickness of the bilge plating is to be not less than the actual net thicknesses of the adjacent 2 m width bottom or side plating, whichever is the greater.

2.4 Keel plating

2.4.1

The net thickness of the keel plating is to be not less than the actual net thicknesses of the adjacent 2 m width bottom plating.

2.5 Sheerstrake

2.5.1 Welded sheerstrake

The net thickness of a welded sheerstrake is to be not less than the actual net thicknesses of the adjacent 2 m width side plating, taking into account higher strength steel corrections if needed.

2.5.2 Rounded sheerstrake

The net thickness of a rounded sheerstrake is to be not less than the actual net thickness of the adjacent deck plating.

2.5.3 Net thickness of the sheerstrake in way of breaks of effective superstructures

The net thickness of the sheerstrake is to be increased in way of breaks of effective superstructures occurring within 0.5*L* amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is not to be less than 40% of the net thickness of sheerstrake, but need not exceed 4.5 mm.

Where the breaks of superstructures occur outside 0.5*L* amidships, the increase in net thickness may be reduced to 30%, but need not exceed 2.5 mm.

2.5.4 Net thickness of the sheerstrake in way of breaks of non-effective superstructures

The net thickness of the sheerstrake is to be increased in way of breaks of non-effective superstructures occurring within 0.6*L* amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 15%, but need not exceed 4.5 mm.

2.6 Stringer plate

2.6.1 General

The net thickness of the stringer plate is to be not less than the actual net thickness of the adjacent deck plating.

2.6.2 Net thickness of the stringer plate in way of breaks of long superstructures

The net thickness of the stringer plate is to be increased in way of breaks of long superstructures occurring within 0.5*L* amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is not to be less than 40% of the net thickness of stringer plate, but need not exceed 4.5 mm.

Where the breaks of superstructures occur outside 0.5*L* amidships, the increase in net thickness may be reduced to 30%, but need not exceed 2.5 mm.

2.6.3 Net thickness of the stringer plate in way of breaks of short superstructures

The net thickness of the stringer plate is to be increased in way of breaks of short superstructures occurring within 0.6*L* amidships, over a length of about one sixth of the ship breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 15%, but need not exceed 4.5 mm.

2.7 Inner bottom loaded by steel coils on a wooden support

2.7.1 General

The net thickness of inner bottom, bilge hopper sloping plate and inner hull for ships intended to carry steel coils is to comply with [2.7.2] to [2.7.4].

The provision is determined by assuming Fig 2 as the standard means of securing steel coils.

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(Insert Fig 2- Inner bottom loaded by steel coils)

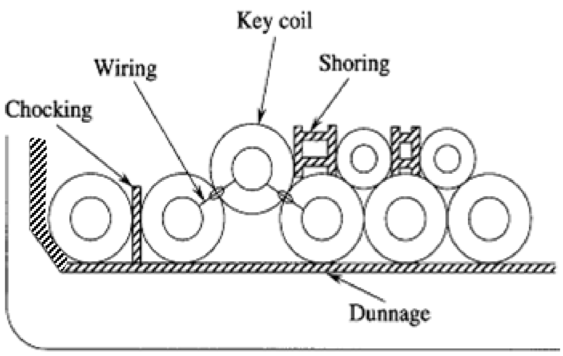

Figure 2: Inner bottom loaded by steel coils

2.7.1 bis1 Accelerations

In order to calculate the accelerations, the following coordinates are to be used for the centre of gravity.

$x_{G-sc} = 0.75\,\ell_H$ forward of aft bulkhead, where the hold of which the mid position is located forward from 0,45L from A.E.

$x_{G-sc} = 0.75\,\ell_H$ afterward of fore bulkhead, where the hold of which the mid position is located afterward from 0,45L from A.E.

$$y_{G-sc} = \varepsilon \frac{B_h}{4}$$

$$z_{G-sc} = h_{DB} + \left\{1 + (n_1 - 1)\frac{\sqrt{3}}{2}\right\}\frac{d_{sc}}{2}$$

where:

ε : 1.0 when a port side structural member is considered, or -1.0 when a starboard side structural member is considered.

B_h : breadth in m, at the mid of the hold, of the cargo hold at the level of connection of bilge hopper plate with side shell or inner hull

d_{sc} : diameter of steel coils, in m

h_{DB} : height of inner bottom, in m

ℓ_H : Cargo hold length, in m

Vertical acceleration a_Z, in m/s², are to be calculated by the formulae defined in Ch 4, Sec 2, [3.2] and tangential acceleration a_R due to roll, in m/s², is to be calculated by the following formula.

$$a_R = \theta \frac{\pi}{180}\left(\frac{2\pi}{T_R}\right)^2 \sqrt{y_{G\_SC}{}^2 + R^2}$$

where:

θ, T_R and R: as defined in Ch 4, Sec 2, [3.2].

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2.7.2 Inner bottom plating

The net thickness of plating of longitudinally framed inner bottom is to be not less than the value obtained, in mm, from the following formula:

$$t = K_1\sqrt{\frac{\{g(\cos(C_{ZP}\Phi)\cos(C_{ZR}\theta)) + a_z\}F}{\lambda_P R_Y}}$$

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where:

K_1 : Coefficient taken equal to:

$$K_1 = \sqrt{\frac{1.7s\ell K_2 - 0.73s^2K_2^2 - (\ell - \ell')^2}{2\ell'(2s + 2\ell K_2)}}$$

a_z : Vertical acceleration, in m/s², defined in [2.7.1 bis1]

Φ : Single pitch amplitude, in deg, defined in Ch 4, Sec 2, [2.2]

θ : Single roll amplitude, in deg, defined in Ch 4, Sec 2, [2.1]

C_{ZP}, C_{ZR} : Load combination factor defined in Ch 4, Sec 4, [2.2]

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F : Force, in kg, taken equal to:

$$F = K_S\frac{Wn_1n_2}{n_3} \qquad \text{for } n_2 \le 10 \text{ and } n_3 \le 5$$

$$F = K_S n_1 W\frac{l}{l_S} \qquad \text{for } n_2 > 10 \text{ or } n_3 > 5$$

RCN 1 to July 2008 version (effective from 1 July 2009)

λ_P : Coefficient defined in Tab 6

K_S : Coefficient taken equal to:

$K_S = 1.4$ when steel coils are lined up in one tier with a key coil

$K_S = 1.0$ in other cases

W : Mass of one steel coil, in kg

n_1 : Number of tiers of steel coils

n_2 : Number of load points per elementary plate panel (See Figs.3 and 4)

When $n_3 \le 5$, n_2 can be obtained from Tab 3 according to the values of n_3 and ℓ / ℓ_S

RCN 1 to July 2008 version (effective from 1 July 2009)

n_3 : Number of dunnages supporting one steel coil

ℓ_S : Length of a steel coil, in m

K_2 : Coefficient taken equal to:

$$K_2 = -\frac{s}{\ell} + \sqrt{\left(\frac{s}{\ell}\right)^2 + 1.37\left(\frac{\ell}{s}\right)^2\left(1 - \frac{\ell'}{\ell}\right)^2 + 2.33}$$

ℓ' : Distance, in m, between outermost load points per elementary plate panel in ship length (See Figs.3 and 4). When $n_2 \leq 10$ and $n_3 \leq 5$, ℓ' can be obtained from Tab 4 according to the values of ℓ, ℓ_s, n_2 and n_3. When $n_2 > 10$ or $n_3 > 5$, ℓ' is to be taken equal to ℓ.

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2.7.3 Bilge hopper sloping plate and inner hull plate *RCN 1 to July 2008 version (effective from 1 July 2009)*

The net thickness of plating of longitudinally framed bilge hopper sloping plate and inner hull is to be not less than the value obtained, in mm, from the following formula:

$$t = K_1\sqrt{\frac{a_{hopper}F'}{\lambda_P R y}}$$

RCN 1 to July 2008 version (effective from 1 July 2009)

where:

K_1 : Coefficient defined in [2.7.2]

θ_h : Angle, in deg, between inner bottom plate and bilge hopper sloping plate or inner hull plate

RCN 1 to July 2008 version (effective from 1 July 2009)

$$a_{hopper} = -C_{YR}a_R\sin\left(\tan^{-1}\left|\frac{y_{G\_SC}}{R}\right| - \theta_h\right) + g\cos(\theta_h - C_{YG}\theta)\cos(C_{XG}\Phi) + C_{YS}a_{sway}\sin\theta_h$$

RCN 1 to July 2008 version (effective from 1 July 2009)

a_R : tangential acceleration defined in [2.7.1 bis1].

a_{sway} : Transverse acceleration due to sway, in m/s², defined in Ch 4, Sec 2, [2.4]

C_{XG}, C_{YS}, C_{YR}, C_{YG} : Load combination factors defined in Ch 4, Sec 4, [2.2]

y_{G}_sc : Centre of gravity in transverse direction, in m, defined in [2.7.1 bis1]

R : Coefficient defined in Ch 4, Sec 2, [3.2.1]

F' : Force, in kg, taken equal to:

$$F' = \frac{Wn_2C_k}{n_3} \quad \text{for } n_2 \leq 10 \text{ and } n_3 \leq 5$$

$$F' = C_kW\frac{l}{l_s} \quad \text{for } n_2 > 10 \text{ or } n_3 > 5$$

RCN 1 to July 2008 version (effective from 1 July 2009)

λ_P : Coefficient defined in Tab 6

W, n_2, n_3, Φ and θ : As defined in [2.7.2]

C_k : Coefficient taken equal to:

$C_k = 3.2$ when steel coils are lined up two or more tier, or when steel coils are lined up one tier and key coil is located second or third from bilge hopper sloping plate or inner hull plate

$C_k = 2.0$ for other cases

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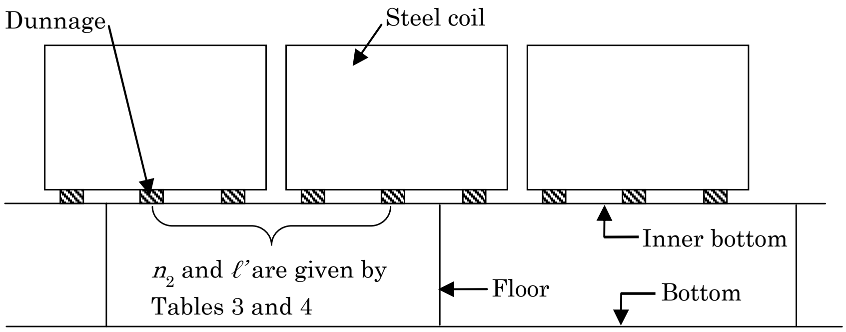

Figure 3: Loading condition of steel coils (example of n_2 = 4, n_3 = 3)

RCN 1 to July 2008 version (effective from 1 July 2009)

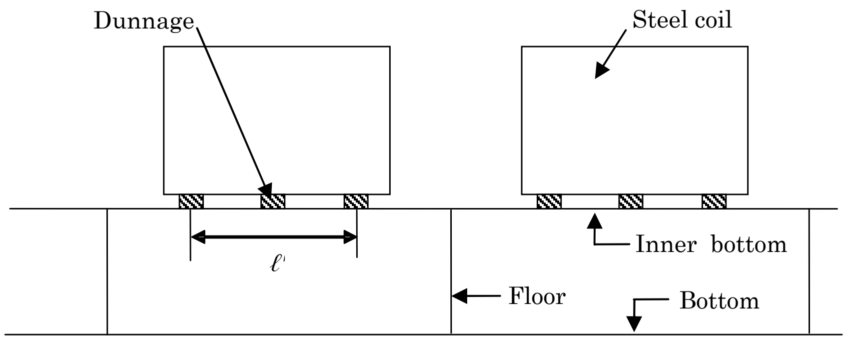

Figure 4: Loading condition of steel coils (Example of n_2 = 3, n_3 = 3)

RCN 1 to July 2008 version (effective from 1 July 2009)

2.7.4

(void) *RCN 1 to July 2008 version (effective from 1 July 2009)*

Table 3: Number n_2 of load points per elementary plate panel

n_2	$n_3 = 2$	$n_3 = 3$	$n_3 = 4$	$n_3 = 5$
1	$0 < \frac{\ell}{\ell_S} \leq 0.5$	$0 < \frac{\ell}{\ell_S} \leq 0.33$	$0 < \frac{\ell}{\ell_S} \leq 0.25$	$0 < \frac{\ell}{\ell_S} \leq 0.2$
2	$0.5 < \frac{\ell}{\ell_S} \leq 1.2$	$0.33 < \frac{\ell}{\ell_S} \leq 0.67$	$0.25 < \frac{\ell}{\ell_S} \leq 0.5$	$0.2 < \frac{\ell}{\ell_S} \leq 0.4$
3	$1.2 < \frac{\ell}{\ell_S} \leq 1.7$	$0.67 < \frac{\ell}{\ell_S} \leq 1.2$	$0.5 < \frac{\ell}{\ell_S} \leq 0.75$	$0.4 < \frac{\ell}{\ell_S} \leq 0.6$
4	$1.7 < \frac{\ell}{\ell_S} \leq 2.4$	$1.2 < \frac{\ell}{\ell_S} \leq 1.53$	$0.75 < \frac{\ell}{\ell_S} \leq 1.2$	$0.6 < \frac{\ell}{\ell_S} \leq 0.8$
5	$2.4 < \frac{\ell}{\ell_S} \leq 2.9$	$1.53 < \frac{\ell}{\ell_S} \leq 1.87$	$1.2 < \frac{\ell}{\ell_S} \leq 1.45$	$0.8 < \frac{\ell}{\ell_S} \leq 1.2$
6	$2.9 < \frac{\ell}{\ell_S} \leq 3.6$	$1.87 < \frac{\ell}{\ell_S} \leq 2.4$	$1.45 < \frac{\ell}{\ell_S} \leq 1.7$	$1.2 < \frac{\ell}{\ell_S} \leq 1.4$
7	$3.6 < \frac{\ell}{\ell_S} \leq 4.1$	$2.4 < \frac{\ell}{\ell_S} \leq 2.73$	$1.7 < \frac{\ell}{\ell_S} \leq 1.95$	$1.4 < \frac{\ell}{\ell_S} \leq 1.6$
8	$4.1 < \frac{\ell}{\ell_S} \leq 4.8$	$2.73 < \frac{\ell}{\ell_S} \leq 3.07$	$1.95 < \frac{\ell}{\ell_S} \leq 2.4$	$1.6 < \frac{\ell}{\ell_S} \leq 1.8$
9	$4.8 < \frac{\ell}{\ell_S} \leq 5.3$	$3.07 < \frac{\ell}{\ell_S} \leq 3.6$	$2.4 < \frac{\ell}{\ell_S} \leq 2.65$	$1.8 < \frac{\ell}{\ell_S} \leq 2.0$
10	$5.3 < \frac{\ell}{\ell_S} \leq 6.0$	$3.6 < \frac{\ell}{\ell_S} \leq 3.93$	$2.65 < \frac{\ell}{\ell_S} \leq 2.9$	$2.0 < \frac{\ell}{\ell_S} \leq 2.4$

Table 4: Distance between load points in ship length direction per elementary plate panel of inner bottom

n_2	n_3			
	2	**3**	**4**	**5**
1	Actual breadth of dunnage			
2	$0.5\ell_S$	$0.33\ell_S$	$0.25\ell_S$	$0.2\ell_S$
3	$1.2\ell_S$	$0.67\ell_S$	$0.50\ell_S$	$0.4\ell_S$
4	$1.7\ell_S$	$1.20\ell_S$	$0.75\ell_S$	$0.6\ell_S$
5	$2.4\ell_S$	$1.53\ell_S$	$1.20\ell_S$	$0.8\ell_S$
6	$2.9\ell_S$	$1.87\ell_S$	$1.45\ell_S$	$1.2\ell_S$
7	$3.6\ell_S$	$2.40\ell_S$	$1.70\ell_S$	$1.4\ell_S$
8	$4.1\ell_S$	$2.73\ell_S$	$1.95\ell_S$	$1.6\ell_S$
9	$4.8\ell_S$	$3.07\ell_S$	$2.40\ell_S$	$1.8\ell_S$
10	$5.3\ell_S$	$3.60\ell_S$	$2.65\ell_S$	$2.0\ell_S$

3. Strength check of plating subjected to lateral pressure

3.1 Load model

3.1.1 General

The still water and wave lateral pressures induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the plating under consideration and the type of the compartments adjacent to it.

The plating which constitutes the boundary of compartments not intended to carry liquid (excluding bottom and side shell plating) is to be subjected to lateral pressure in flooded conditions.

The wave lateral pressures and hull girder loads are to be calculated, for the probability level of 10^{-8}, in the mutually exclusive load cases H1, H2, F1, F2, R1, R2, P1 and P2, as defined in Ch 4, Sec 4.

3.1.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure p_S includes:

- the hydrostatic pressure, defined in Ch 4, Sec 5, [1]
- the still water internal pressure, defined in Ch 4, Sec 6 for the various types of cargoes and for ballast.

Wave pressure p_W includes for each load case H1, H2, F1, F2, R1, R2, P1 and P2:

- the hydrodynamic pressure, defined in Ch 4, Sec 5, [1]
- the inertial pressure, defined in Ch 4, Sec 6 for the various types of cargoes and for ballast.

3.1.3 Lateral pressure in flooded conditions

The lateral pressure in flooded conditions p_F is defined in Ch 4, Sec 6, [3.2.1].

3.1.4 Lateral pressure in testing conditions

The lateral pressure p_T in testing conditions is taken equal to:

- $p_T = p_{ST} - p_S$ for bottom shell plating and side shell plating
- $p_T = p_{ST}$ otherwise,

where:

p_{ST} : Testing pressure defined in Ch 4, Sec 6, [4]

p_S : Pressure taken equal to:

- if the testing is carried out afloat: hydrostatic pressure defined in Ch 4, Sec 5, [1] for the draught T_1, defined by the Designer, at which the testing is carried out. If T_1 is not defined, the testing is considered as being not carried out afloat
- if the testing is not carried out afloat: $p_S = 0$

3.1.5 Normal stresses

The normal stress to be considered for the strength check of plating contributing to the hull girder longitudinal strength is the maximum value of σ_X between sagging and hogging conditions, when applicable, obtained, in N/mm^2, from the following formula:

$$\sigma_X = \left[C_{SW} \left| \frac{M_{SW}}{I_Y} \right| (z-N) + C_{WV} \left| \frac{M_{WV}}{I_Y} \right| (z-N) - C_{WH} \left| \frac{M_{WH}}{I_Z} \right| y \right] 10^{-3}$$

where:

M_{SW} : Permissible still water bending moments, in kN.m, in hogging or sagging as the case may be

M_{WV} : Vertical wave bending moment, in kN.m, in hogging or sagging as the case may be, as defined in Ch 4, Sec 3

M_{WH} : Horizontal wave bending moment, in kN.m, as defined in Ch 4, Sec 3

C_{SW} : Combination factor for each load case H1, H2, F1, F2, R1, R2, P1 and P2 and defined in Tab 5

C_{WV}, C_{WH} : Combination factors defined in Ch 4, Sec 4, [2.2] for each load case H1, H2, F1, F2, R1, R2, P1 and P2 and given in Tab 5.

Table 5: Combination factors C_{SW}, C_{WV} and C_{WH}

LC	Hogging			Sagging		
	C_{SW}	C_{WV}	C_{WH}	C_{SW}	C_{WV}	C_{WH}
H1	Not Applicable			-1	-1	0
H2	1	1	0	Not Applicable		
F1	Not Applicable			-1	-1	0
F2	1	1	0	Not Applicable		
R1	1	0	$1.2-\dfrac{T_{LC}}{T_S}$	-1	0	$1.2-\dfrac{T_{LC}}{T_S}$
R2	1	0	$\dfrac{T_{LC}}{T_S}-1.2$	-1	0	$\dfrac{T_{LC}}{T_S}-1.2$
P1	1	$0.4-\dfrac{T_{LC}}{T_S}$	0	-1	$0.4-\dfrac{T_{LC}}{T_S}$	0
P2	1	$\dfrac{T_{LC}}{T_S}-0.4$	0	-1	$\dfrac{T_{LC}}{T_S}-0.4$	0

3.2 Plating thickness

3.2.1 Intact conditions

The net thickness of laterally loaded plate panels is to be not less than the value obtained, in mm, from the following formula:

$$t = 15.8 c_a c_r s \sqrt{\frac{p_S + p_W}{\lambda_P R_Y}}$$

where:

λ_P : Coefficient defined in Tab 6

Table 6: Coefficient λ_P

Plating		Coefficient λ_P
Contributing to the hull girder longitudinal strength	Longitudinally framed plating	$0.95-0.45\left\|\dfrac{\sigma_X}{R_Y}\right\|$, without being taken greater than 0.9
	Transversely framed plating	$0.95-0.90\left\|\dfrac{\sigma_X}{R_Y}\right\|$, without being taken greater than 0.9
Not contributing to the hull girder longitudinal strength		0.9

3.2.2 Net thickness under flooded conditions excluding corrugations of transverse vertically corrugated bulkhead separating cargo holds

The plating which constitutes the boundary of compartments not intended to carry liquids (excluding bottom plating and side shell plating), and excluding corrugations of transverse vertically corrugated bulkhead separating cargo holds is to be checked in flooded conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 15.8 c_a c_r s \sqrt{\frac{p_F}{\alpha \lambda_P R_Y}}$$

where:

λ_P : Coefficient defined in Tab 6, determined by considering σ_X in flooded condition

α : Coefficient taken equal to:

α = 0.95 for the plating of collision bulkhead

α = 1.15 for the plating of other watertight boundaries of compartments.

3.2.3 Net thickness of corrugation of transverse vertically corrugated watertight bulkheads separating cargo holds for flooded conditions

The net plate thickness t, in mm, of transverse vertically corrugated watertight bulkheads separating cargo holds is to be not less than that obtained from the following formula:

$$t = 14.9 s \sqrt{\frac{1.05 p}{R_{eH}}}$$

p : pressure p_F or resultant pressure p, in kN/m^2, as defined in Ch 4, Sec 6 [3.3.6] and [3.3.7], respectively

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s : plate width, in m, to be taken equal to the width of the corrugation flange or web, whichever is greater

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For built-up corrugation bulkheads, when the thicknesses of the flange and web are different:

- the net thickness of the narrower plating is to be not less than that obtained, in mm, from the following formula:

  $$t_N = 14.9 s \sqrt{\frac{1.05 p}{R_{eH}}}$$

  s : plate width, in m, of the narrower plating.

  RCN 1 to July 2008 version (effective from 1 July 2009)

- the net thickness of the wider plating is not to be less than the greater of those obtained, in mm, from the following formulae:

  $$t_W = 14.9 s \sqrt{\frac{1.05 p}{R_{eH}}}$$

  $$t_W = \sqrt{\frac{462 s^2 p}{R_{eH}} - t_{NP}^2}$$

where:

t_{NP} : Actual net thickness of the narrower plating, in mm, to be not taken greater than:

$$t_{NP} = 14.9 s \sqrt{\frac{1.05 p}{R_{eH}}}$$

s : plate width, in m, to be taken equal to the width of the corrugation flange or web, whichever is greater.

The net thickness of the lower part of corrugations is to be maintained for a distance from the inner bottom (if no lower stool is fitted) or the top of the lower stool not less than $0.15\ell_C$, where ℓ_C is the span of the corrugations, in m, to be obtained according to Ch 3, Sec 6, [10.4.4]. The net thickness is also to comply with the requirements in [3.2.1], Sec 2, [3.6.1 & 3.6.2], and Sec 3, [6].

The net thickness of the middle part of corrugations is to be maintained for a distance from the deck (if no upper stool is fitted) or the bottom of the upper stool not greater than $0.3\ \ell_C$. The net thickness is also to comply with the requirements in [3.2.1] and Sec 2, [3.6.1 & 3.6.2].

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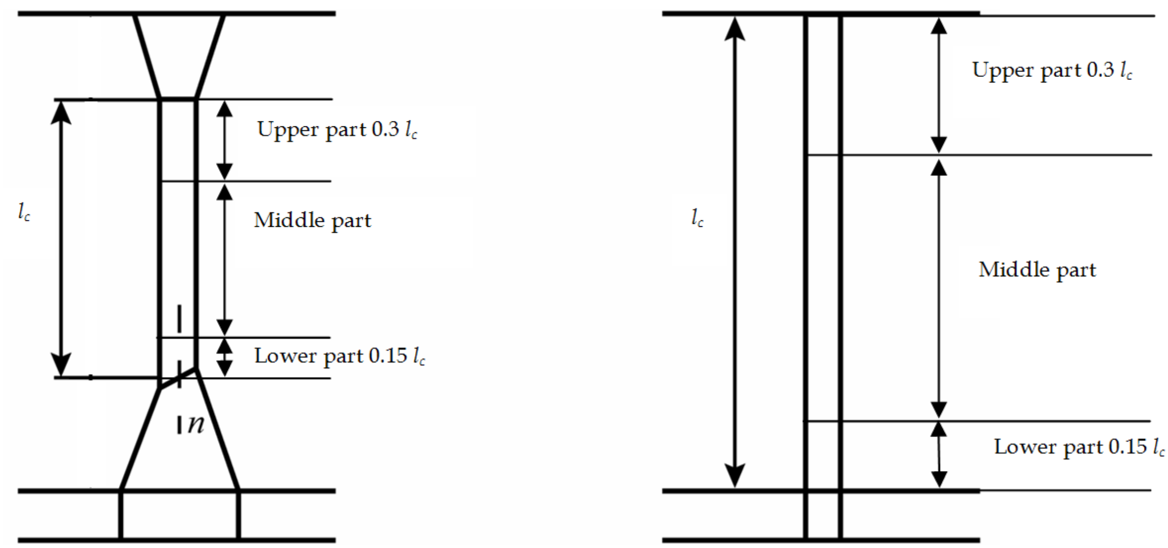

Figure 5: Parts of Corrugation

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3.2.3 bis1 Net thickness of lower stool and upper stool

The net thickness and material of the stool top plate of lower stool are to be not less those for the corrugated bulkhead plating above required by [3.2.3].

The net thickness and material of the upper portion of vertical or sloping stool side plating of lower stool within the depth equal to the corrugation flange width from the stool top are to be not less than the flange plate at the lower end of the corrugation required by [3.2.3], as applicable, whichever is the greater.

The net thickness and material of the stool bottom plate of upper stool are to be the same as those of the bulkhead plating required by [3.2.3], as applicable, whichever is the greater.

The net thickness of the lower portion of stool side plating is to not be less than 80% of the upper part of the bulkhead plating required by [3.2.3], as applicable, whichever is the greater, where the same material is used.

The net thickness of lower stool and upper stool are to be not less than those required by [3.2.1], [3.2.2] and [3.2.4].

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3.2.3 bis 2 Net thickness of supporting floors of corrugated bulkhead

The net thickness and material of the supporting floors and pipe tunnel beams of corrugated bulkhead, when no stool is fitted, are to be not less than those of the corrugation flanges required by [3.2.3].

When a lower stool is fitted, the net thickness of supporting floors are to be not less than that of the stool side plating required by the first sentence of [3.2.2].

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3.2.4 Testing Conditions

The plating of compartments or structures as defined in Ch 4, Sec 6, [4] is to be checked in testing conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 15.8 c_a c_r s \sqrt{\frac{p_T}{1.05 R_Y}}$$

Section 2 - ORDINARY STIFFENERS

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

L_2 : Rule length L, but to be taken not greater than 300 m

I_Y : Net moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis, to be calculated according to Ch 5, Sec 1, [1.5], on gross offered thickness reduced by $0.5t_C$ for all structural members

I_Z : Net moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis, to be calculated according to Ch 5, Sec 1, [1.5], on gross offered thickness reduced by $0.5t_C$ for all structural members

N : Z co-ordinate with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4], in m, of the centre of gravity of the hull net transverse section defined in Ch 5, Sec 1, [1.2], considering gross offered thickness reduced by $0.5t_C$ for all structural members

p_S, p_W : Still water and wave pressure, in kN/m^2, in intact conditions, defined in [3.1.2]

p_F : Pressure, in kN/m^2, in flooded conditions, defined in [3.1.3]

p_T : Pressure, in kN/m^2, in testing conditions, defined in [3.1.4]

σ_X : Normal stress, in N/mm^2, defined in [3.1.5]

s : Spacing, in m, of ordinary stiffeners, measured at mid-span along the chord

ℓ : Span, in m, of ordinary stiffeners, measured along the chord between the supporting members, see Ch 3, Sec 6, [4.2]

h_w : Web height, in mm

t_w : Net web thickness, in mm

b_f : Face plate width, in mm

t_f : Net face plate thickness, in mm

b_p : Width, in m, of the plating attached to the stiffener, for the yielding check, defined in Ch 3, Sec 6, [4.3]

w : Net section modulus, in cm^3, of the stiffener, with an attached plating of width b_p, to be calculated as specified in Ch 3, Sec 6, [4.4]

A_{sh} : Net shear sectional area, in cm^2, of the stiffener, to be calculated as specified in Ch 3, Sec 6, [4.4]

m : Coefficient taken equal to:

$m = 10$ for vertical stiffeners

$m = 12$ for other stiffeners

τ_a : Allowable shear stress, in N/mm^2, taken equal to:

$$\tau_a = \frac{R_Y}{\sqrt{3}}$$

1. General

1.1 Application

1.1.1

The requirements of this Section apply for the yielding check of ordinary stiffeners subjected to lateral pressure and, for ordinary stiffeners contributing to the hull girder longitudinal strength, to hull girder normal stresses.

The yielding check is also to be carried out for ordinary stiffeners subjected to specific loads, such as concentrated loads.

In addition, the buckling check of ordinary stiffeners is to be carried out according to Ch 6, Sec 3.

1.2 Net scantlings

1.2.1

As specified in Ch 3, Sec 2, all scantlings referred to in this Section are net, i.e. they do not include any corrosion addition.

The gross scantlings are obtained as specified in Ch 3, Sec 2, [3].

1.3 Pressure combination

1.3.1 Elements of the outer shell

The still water and wave lateral pressures are to be calculated considering independently the following cases:

- the still water and wave external sea pressures
- the still water and wave internal pressure considering the compartment adjacent to the outer shell as being loaded. If the compartment adjacent to the outer shell is intended to carry liquids, this still water and wave internal pressures are to be reduced from the corresponding still water and wave external sea pressures.

1.3.2 Elements other than those of the outer shell

The still water and wave lateral pressures to be considered as acting on an element which separates two adjacent compartments are those obtained considering the two compartments individually loaded.

1.4 Load calculation point

1.4.1 Horizontal stiffeners

Unless otherwise specified, lateral pressure and hull girder stress, if any, are to be calculated at mid-span of the ordinary stiffener considered.

1.4.2 Vertical stiffeners

The lateral pressure p is to be calculated as the maximum between the value obtained at mid-span and the value obtained from the following formula:

- $p = \dfrac{p_U + p_L}{2}$, when the upper end of the vertical stiffener is below the lowest zero pressure level
- $p = \dfrac{\ell_1}{\ell}\dfrac{p_L}{2}$, when the upper end of the vertical stiffener is at or above the lowest zero pressure level (see Fig 1)

where:

ℓ_1 : Distance, in m, between the lower end of vertical stiffener and the lowest zero pressure level

p_U, p_L : Lateral pressures at the upper and lower end of the vertical stiffener span ℓ, respectively.

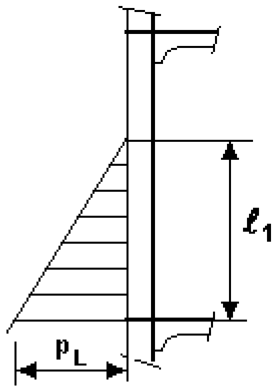

Figure 1: Definition of pressure for vertical stiffeners

2. General requirements

2.1 (void) *RCN 1 to July 2008 version (effective from 1 July 2009)*

2.1.1

(void) *RCN 1 to July 2008 version (effective from 1 July 2009)*

Figure 2: (void) *RCN 1 to July 2008 version (effective from 1 July 2009)*

2.2 Net thickness of web of ordinary stiffeners

2.2.1 Minimum net thickness of webs of ordinary stiffeners other than side frames of single side bulk carriers

The net thickness of the web of ordinary stiffeners, in mm, is to be not less than the greater of:

- $t = 3.0 + 0.015L_2$
- 40% of the net required thickness of the attached plating, to be determined according to Ch.6, Sec.1.

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2.2.2 Minimum net thickness of side frames of single side bulk carriers *RCN 1 to July 2008 version (effective from 1 July 2009)*

The net thickness of side frame webs within the cargo area, in mm, is to be not less than the value obtained from the following formula:

$t_{MIN} = 0.75\alpha(7 + 0.03L)$

where:

α : Coefficient taken equal to:

$\alpha = 1.15$ for the frame webs in way of the foremost hold

$\alpha = 1.00$ for the frame webs in way of other holds.

2.2.3 Maximum net thickness of web of ordinary stiffener

The net thickness of the web of ordinary stiffeners, in mm, is to be less than 2 times the net offered thickness of the attached plating. *RCN 1 to July 2008 version (effective from 1 July 2009)*

2.3 Net dimensions of ordinary stiffeners

2.3.1 Flat bar

The net dimensions of a flat bar ordinary stiffener (see Fig 3) are to comply with the following requirement:

$$\frac{h_w}{t_w} \le 20\sqrt{k}$$

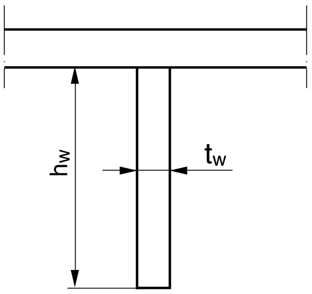

Figure 3: Net dimensions of a flat bar

2.3.2 T-section

The net dimensions of a T-section ordinary stiffener (see Fig 4) are to comply with the following requirements:

$$\frac{h_w}{t_w} \le 65\sqrt{k}$$

$$\frac{b_f}{t_f} \le 33\sqrt{k}$$

$$b_f t_f \ge \frac{h_w t_w}{6}$$

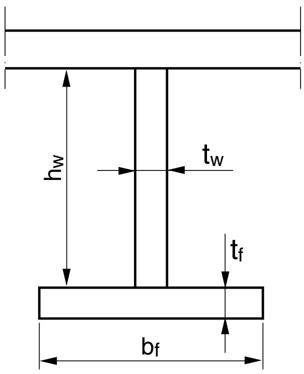

Figure 4: Net dimensions of a T-section

2.3.3 Angle

The net dimensions of an angle ordinary stiffener (see Fig 5) are to comply with the following requirements:

$$\frac{h_w}{t_w} \le 55\sqrt{k}$$

$$\frac{b_f}{t_f} \le 16.5\sqrt{k}$$

$$b_f t_f \ge \frac{h_w t_w}{6}$$

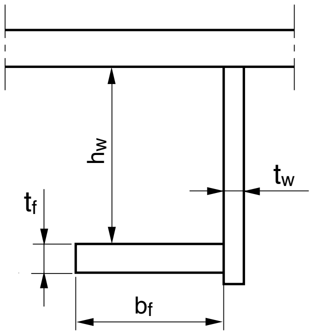

Figure 5: Net dimensions of an angle

2.4 Struts connecting ordinary stiffeners

2.4.1

The net sectional area A_{SR}, in cm^2, and the net moment of inertia I_{SR} about the main axes, in cm^4, of struts connecting ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$A_{SR} = \frac{p_{SR} s\ell}{20}$$

$$I_{SR} = \frac{0.75 s\ell (p_{SR1} + p_{SR2}) A_{ASR}\ \ell_{SR}^2}{47.2 A_{ASR} - s\ell (p_{SR1} + p_{SR2})}$$

where:

p_{SR} : Pressure to be taken equal to the greater of the values obtained, in kN/m^2, from the following formulae:

$$p_{SR} = 0.5(p_{SR1} + p_{SR2})$$

$$p_{SR} = p_{SR3}$$

p_{SR1} : External pressure in way of the strut, in kN/m^2, acting on one side, outside the compartment in which the strut is located

p_{SR2} : External pressure in way of the strut, in kN/m^2, acting on the opposite side, outside the compartment in which the strut is located

p_{SR3} : Internal pressure at mid-span of the strut, in kN/m^2, in the compartment in which the strut is located

ℓ : Span, in m, of ordinary stiffeners connected by the strut (see Ch 3, Sec 6, [4.2.3])

ℓ_{SR} : Length, in m, of the strut

A_{ASR} : Actual net sectional area, in cm^2, of the strut.

2.5 Ordinary stiffeners of inner bottom loaded by steel coils on a wooden support

2.5.1 General

The requirements of this sub-article apply to the ordinary stiffeners located on inner bottom plate, bilge hopper sloping plate and inner hull plate when loaded by steel coils on a wooden support (dunnage), as indicated in Fig 2 of Ch 6, Sec 1.

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2.5.2 Ordinary stiffeners located on inner bottom plating

The net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of single span ordinary stiffeners located on inner bottom plating are to be not less than the values obtained from the following formulae:

$$w = K_3 \frac{\left[g \cdot \cos(C_{ZP}\Phi) \cdot \cos(C_{ZR}\theta) + a_Z\right] \cdot F}{8.\lambda_S R_Y}$$

$$A_{SH} = \frac{5\left[g \cdot \cos(C_{ZP}\Phi) \cdot \cos(C_{ZR}\theta)) + a_Z\right] \cdot F}{\tau_a \sin\phi} 10^{-3}$$ *RCN 1 to July 2008 version (effective from 1 July 2009)*

where:

K_3 : Coefficient defined in Tab 1. When n_2 is greater than 10, K_3 is to be taken equal to $2\,\ell / 3$

a_Z : Vertical acceleration, in m/s^2, defined in Ch 6, Sec1, [2.7.1 bis1]

Φ : Single pitch amplitude, in deg, defined in Ch 4, Sec 2, [2.2]

θ : Single roll amplitude, in deg, defined in Ch 4, Sec 2, [2.1]

C_{ZP}, C_{ZR}: Load combination factor defined in Ch 4, Sec 4, [2.2]

F : Force, in kg, defined in Ch 6, Sec 1, [2.7.2]

λ_S : Coefficient defined in Tab 3

ϕ : Angle, in deg, defined in [3.2.3].

RCN 1 to July 2008 version (effective from 1 July 2009)

2.5.3 Ordinary stiffeners located on bilge hopper sloping plate or inner hull plate

The net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of single span ordinary stiffeners located on bilge hopper sloping plate and inner hull plate are to be not less than the values obtained from the following formulae:

$$w = K_3 \frac{a_{hopper} F'}{8\lambda_S R_Y}$$ *RCN 1 to July 2008 version (effective from 1 July 2009)*

$$A_{sh} = \frac{5 a_{hopper} F'}{\tau_a \sin\phi} 10^{-3}$$ *RCN 1 to July 2008 version (effective from 1 July 2009)*

where:

K_3 : Coefficient defined in Tab 1. When n_2>10, K_3 is taken equal to $2\ell/3$.

θ_h : Angle, in deg, between inner bottom plate and bilge hopper sloping plate or inner hull plate

a_{hopper} : Acceleration, in m/s², defined in Ch 6, Sec 1, [2.7.4]

F' : Force, in kg, defined in Ch 6, Sec 1, [2.7.3]

λ_S : Coefficient defined in Tab 3

ϕ : Angle, in deg, defined in [3.2.3]

ℓ' : Distance, in m, between outermost load points per elementary plate panel in ship length

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Table 1: Coefficient K_3

n_2	1	2	3	4	5	6	7	8	9	10
K_3	ℓ	$\ell-\frac{\ell'^2}{\ell}$	$\ell-\frac{2\ell'^2}{3\ell}$	$\ell-\frac{5\ell'^2}{9\ell}$	$\ell-\frac{\ell'^2}{2\ell}$	$\ell-\frac{7\ell'^2}{15\ell}$	$\ell-\frac{4\ell'^2}{9\ell}$	$\ell-\frac{3\ell'^2}{7\ell}$	$\ell-\frac{5\ell'^2}{12\ell}$	$\ell-\frac{11\ell'^2}{27\ell}$

2.5.4

(void) *RCN 1 to July 2008 version (effective from 1 July 2009)*

2.6 Deck ordinary stiffeners in way of launching appliances used for survival craft or rescue boat

2.6.1

The scantlings of deck ordinary stiffeners are to be determined by direct calculations.

2.6.2

The loads exerted by launching appliance are to correspond to the Safe Working Load of the launching appliance.

2.6.3

The combined stress, in N/mm², is not to exceed the smaller of:

$$\frac{100}{235}R_{eH} \text{ and } \frac{54}{235}R_m$$

where R_m is the ultimate tensile strength of the stiffener material, in N/mm².

3. Yielding check

3.1 Load model

3.1.1 General

The still water and wave lateral loads induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the ordinary stiffener under consideration and the type of the compartments adjacent to it.

Ordinary stiffeners located on plating which constitutes the boundary of compartments not intended to carry liquids (excluding those on bottom and side shell plating) are to be subjected to the lateral pressure in flooded conditions.

The wave lateral loads and hull girder loads are to be calculated, for the probability level of 10^{-8}, in the mutually exclusive load cases H1, H2, F1, F2, R1, R2, P1 and P2, as defined in Ch 4, Sec 4.

3.1.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure p_S includes:

- the hydrostatic pressure, defined in Ch 4, Sec 5, [1]
- the still water internal pressure, defined in Ch 4, Sec 6 for the various types of cargoes and for ballast.

Wave pressure p_W includes for each load case H1, H2, F1, F2, R1, R2, P1 and P2:

- the hydrodynamic pressure, defined in Ch 4, Sec 5, [1]
- the inertial pressure, defined in Ch 4, Sec 6 for the various types of cargoes and for ballast.

3.1.3 Lateral pressure in flooded conditions

The lateral pressure in flooded conditions p_F is defined in Ch 4, Sec 6, [3.2.1].

3.1.4 Lateral pressure in testing conditions

The lateral pressure p_T in testing conditions is taken equal to:

- $p_T = p_{ST} - p_S$ for bottom shell plating and side shell plating
- $p_T = p_{ST}$ otherwise,

where:

p_{ST} : Testing pressure defined in Ch 4, Sec 6, [4]

p_S : Pressure taken equal to:

- if the testing is carried out afloat: hydrostatic pressure defined in Ch 4, Sec 5, [1] for the draught T_1, defined by the Designer, at which the testing is carried out. If T_1 is not defined, the testing is considered as being not carried out afloat
- if the testing is not carried out afloat: $p_S = 0$

3.1.5 Normal stresses

The normal stress to be considered for the strength check of ordinary stiffeners contributing to the hull girder longitudinal strength is the maximum value of σ_X between sagging and hogging conditions, when applicable, obtained , in N/mm^2, from the following formula:

$$\sigma_X = \left[C_{SW} \left| \frac{M_{SW}}{I_Y} \right| (z - N) + C_{WV} \left| \frac{M_{WV}}{I_Y} \right| (z - N) - C_{WH} \left| \frac{M_{WH}}{I_Z} \right| y \right] 10^{-3}$$

where:

M_{SW} : Permissible still water bending moments, in kN.m, in hogging or sagging as the case may be

M_{WV} : Vertical wave bending moment, in kN.m, in hogging or sagging as the case may be, as defined in Ch 4, Sec 3

M_{WH} : Horizontal wave bending moment, in kN.m, as defined in Ch 4, Sec 3

C_{SW} : Combination factor for each load case H1, H2, F1, F2, R1, R2, P1 and P2 and defined in Tab 2

C_{WV}, C_{WH} : Combination factors defined in Ch 4, Sec 4, [2.2] for each load case H1, H2, F1, F2, R1, R2, P1 and P2 and given in Tab 2.

Table 2: Combination factors C_{SW}, C_{WV} and C_{WH}

LC	Hogging			Sagging		
	C_{SW}	C_{WV}	C_{WH}	C_{SW}	C_{WV}	C_{WH}
H1	Not Applicable			-1	-1	0
H2	1	1	0	Not Applicable		
F1	Not Applicable			-1	-1	0
F2	1	1	0	Not Applicable		
R1	1	0	$1.2-\frac{T_{LC}}{T_S}$	-1	0	$1.2-\frac{T_{LC}}{T_S}$
R2	1	0	$\frac{T_{LC}}{T_S}-1.2$	-1	0	$\frac{T_{LC}}{T_S}-1.2$
P1	1	$0.4-\frac{T_{LC}}{T_S}$	0	-1	$0.4-\frac{T_{LC}}{T_S}$	0
P2	1	$\frac{T_{LC}}{T_S}-0.4$	0	-1	$\frac{T_{LC}}{T_S}-0.4$	0

3.2 Strength criteria for single span ordinary stiffeners other than side frames of single side bulk carriers

3.2.1 Boundary conditions

The requirements of this sub-article apply to ordinary stiffeners considered as clamped at both ends.

For other boundary conditions, the yielding check is to be considered on a case by case basis.

3.2.2 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus in [3.2.3] to [3.2.7] is calculated as the average of the values required for all the stiffeners of the same group, but this average is to be taken not less than 90% of the maximum required value.

The same applies for the minimum net shear sectional area.

3.2.3 Net section modulus and net shear sectional area of single span ordinary stiffeners under intact conditions

The net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of single span ordinary stiffeners subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w=\frac{(p_S+p_W)s\ell^2}{m\lambda_S R_Y}10^3$$

$$A_{sh}=\frac{5(p_S+p_W)s\ell}{\tau_a \sin\phi}$$

where:

λ_S : Coefficient defined in Tab 3.

ϕ : Angle, in deg, between the stiffener web and the shell plate, measured at the middle of the stiffener span; the correction is to be applied when ϕ is less than 75 deg.

Table 3: Coefficient λ_S

Ordinary stiffener	Coefficient λ_S
Longitudinal stiffener ccontributing to the hull girder longitudinal strength	$1.2\left(1.0-0.85\left\|\frac{\sigma_X}{R_Y}\right\|\right)$, without being taken greater than 0.9
Other stiffeners	0.9

3.2.4 Net section modulus of corrugated bulkhead of ballast hold for ships having a length *L* less than 150m

The net section modulus w, in cm³, of corrugated bulkhead of ballast hold for ships having a length L less than 150m subjected to lateral pressure are to be not less than the values obtained from the following formula:

$$w = K\frac{(p_S + p_W)s_C\ell^2}{m\lambda_S R_Y}10^3$$

where:

K : Coefficient given in Tab 4 and 5, according to the type of end connection. When $d_H < 2.5d_0$, both section modulus per half pitch of corrugated bulkhead and section modulus of lower stool at inner bottom are to be calculated.

s_C : Half pitch length, in m, of the corrugation, defined in Ch 3, Sec 6, Fig 28

ℓ : Length, in m, between the supports, as indicated in Fig 6

λ_S : Coefficient defined in Tab 3.

The effective width of the corrugation flange in compression is to be considered according to Ch 3, Sec 6, [10.4.10] when the net section modulus of corrugated bulkhead is calculated.

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Table 4: Values of *K*, in case $d_H \geq 2.5d_0$

Upper end support		
Supported by girders	Welded directly to deck	Welded to stool efficiently supported by ship structure
1.25	1.00	0.83

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Table 5: Values of *K*, in case $d_H < 2.5d_0$

Section modulus of	Upper end support		
	Supported by girders	Connected to deck	Connected to stool
Corrugated bulkhead	0.83	0.71	0.65
Stool at bottom	0.83	1.25	1.13

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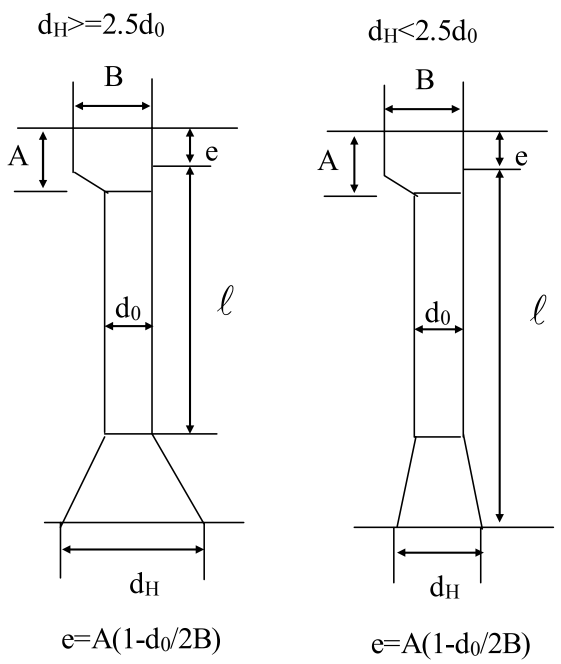

Figure 6: Measurement of ℓ

3.2.5 Net section modulus and net shear sectional area of single span ordinary stiffeners under flooded conditions excluding corrugations of transverse vertically corrugated bulkhead separating cargo holds

The net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of single span ordinary stiffeners excluding corrugations of transverse vertically corrugated bulkhead separating cargo holds subjected to flooding are to be not less than the values obtained from the following formulae:

$$w = \frac{p_F s \ell^2}{16 \alpha \lambda_S R_Y} 10^3$$

$$A_{sh} = \frac{5 p_F s \ell}{\alpha \tau_a \sin\phi}$$

where:

λ_s, ϕ : Coefficient and angle defined in [3.2.3], λ_s being determined by considering σ_X in flooded condition.

α : Coefficient taken equal to:

α = 0.95 for the ordinary stiffeners of collision bulkhead,

α = 1.15 for the ordinary stiffeners of other watertight boundaries of compartments.

without taken $\alpha\lambda_S$ greater than 1.0

3.2.6

(void) *RCN 1 to July 2008 version (effective from 1 July2009)*

3.2.7 Net section modulus and net shear sectional area of single span ordinary stiffeners under testing conditions

The net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of single span ordinary stiffeners subjected to testing are to be not less than the values obtained from the following formulae:

$$w = \frac{p_T s \ell^2}{1.05 m R_Y} 10^3$$

$$A_{sh} = \frac{5 p_T s \ell}{1.05 \tau_a \sin\phi}$$

where:

ϕ : Angle, in deg, defined in [3.2.3].

3.3 Strength criteria for side frames of single side bulk carriers

3.3.1 Net section modulus and net shear sectional area of side frames

The net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of side frames subjected to lateral pressure are to be not less, in the mid-span area, than the values obtained from the following formulae:

$$w = 1.125 \alpha_m \frac{(p_S + p_W) s \ell^2}{m \lambda_S R_Y} 10^3$$

$$A_{sh} = 1.1 \alpha_S \frac{5 (p_S + p_W) s \ell}{\tau_a \sin\phi} \left(\frac{\ell - 2\ell_B}{\ell} \right)$$

where:

α_m : Coefficient taken equal to:

$\alpha_m = 0.42$ for **BC-A** ships

$\alpha_m = 0.36$ for other ships

λ_S : Coefficient taken equal to 0.9

ℓ : Side frame span, in m, defined in Ch 3, Sec 6, Fig 19, to be taken not less than 0.25D

α_S : Coefficient taken equal to:

$\alpha_S = 1.1$ for side frames of holds specified to be empty in **BC-A** ships

$\alpha_S = 1.0$ for other side frames

ℓ_B : Lower bracket length, in m, defined in Fig 7

p_s, p_w : Still water and wave pressures, in kN/m², in intact conditions calculated as defined in [1.3] and [1.4.2]. *RCN 1 to July 2008 version (effective from 1 July 2009)*

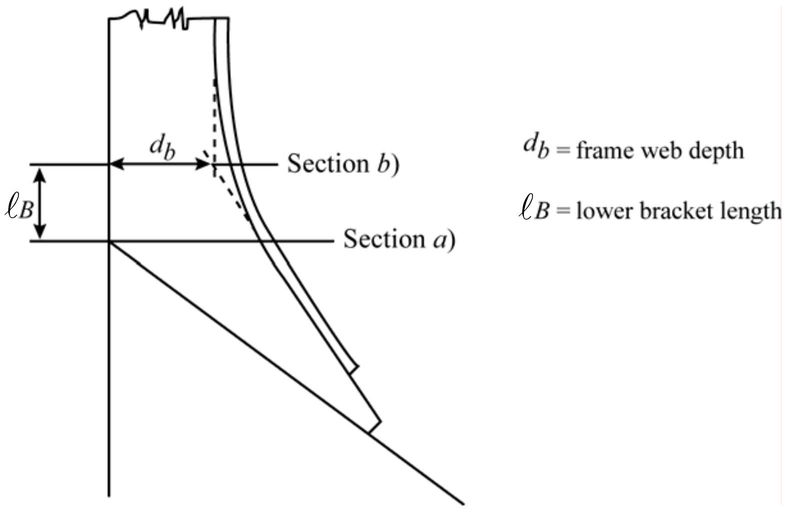

Figure 7: Side frame lower bracket length

In addition, for side frames of holds intended to carry ballast water in heavy ballast condition, the net section modulus w, in cm^3, and the net shear sectional area A_{sh} , in cm^2, all along the span are to be in accordance with [3.2.3], ℓ being the span of the side frame as defined in Ch.3, Sec.6, [4.2], with consideration to brackets at ends. *RCN 1 to July 2008 version (effective from 1 July 2009)*

3.3.2 Supplementary strength requirements

In addition to [3.3.1], the net moment of inertia, in cm^4, of the 3 side frames located immediately abaft the collision bulkhead is to be not less than the value obtained from the following formula:

$$I = 0.18\frac{(p_S + p_W)\ell^4}{n}$$

where:

ℓ : Side frame span, in m

n : Number of frames from the bulkhead to the frame in question, taken equal to 1, 2 or 3

As an alternative, supporting structures, such as horizontal stringers, are to be fitted between the collision bulkhead and a side frame which is in line with transverse webs fitted in both the topside tank and hopper tank, maintaining the continuity of forepeak stringers within the foremost hold.

3.3.3 Lower bracket of side frame

At the level of lower bracket as shown in Ch 3, Sec 6, Fig 19, the net section modulus of the frame and bracket, or integral bracket, with associated shell plating, is to be not less than twice the net section modulus w required for the frame mid-span area obtained from [3.3.1].

In addition, for holds intended to carry ballast water in heavy ballast condition, the net section modulus w, in cm^3, at the level of lower bracket is to be not less than twice the greater of the net section moduli obtained from [3.3.1] and [3.2.3]. *RCN 1 to July 2008 version (effective from 1 July2009)*

The net thickness t_{LB} of the frame lower bracket, in mm, is to be not less than the net thickness of the side frame web plus 1.5 mm.

Moreover, the net thickness t_{LB} of the frame lower bracket is to comply with the following formula:

- for symmetrically flanged frames: $\dfrac{h_{LB}}{t_{LB}} \le 87\sqrt{k}$
- for asymmetrically flanged frames : $\dfrac{h_{LB}}{t_{LB}} \le 73\sqrt{k}$

The web depth h_{LB} of lower bracket may be measured from the intersection between the sloped bulkhead of the hopper tank and the side shell plate, perpendicularly to the face plate of the lower bracket (see Ch 3, Sec 6, Fig 22).

For the 3 side frames located immediately abaft the collision bulkhead, whose scantlings are increased according to [3.3.2], when t_{LB} is greater than $1.73t_w$, the thickness t_{LB} may be taken as the value t'_{LB} obtained from the following formula:

$$t'_{LB} = \left(t_{LB}^2 t_w\right)^{1/3}$$

where t_w is the net thickness of the side frame web, in mm, corresponding to A_{sh} determined in accordance to [3.3.1].

The flange outstand is not to exceed $12k^{0.5}$ times the net flange thickness.

3.3.4 Upper bracket of side frame

At the level of upper bracket as shown in Ch 3, Sec 6, Fig 19, the net section modulus of the frame and bracket, or integral bracket, with associated shell plating, is to be not less than twice the net section modulus w required for the frame mid-span area obtained from [3.3.1].

In addition, for holds intended to carry ballast water in heavy ballast condition, the net section modulus w, in cm^3, at the level of upper bracket is not to be less than twice the greater of the net sections moduli obtained from [3.2.3] and [3.3.1].

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The net thickness t_{UB} of the frame upper bracket, in mm, is to be not less than the net thickness of the side frame web.

3.4 Upper and lower connections of side frames of single side bulk carriers

3.4.1

The section moduli of the:

- side shell and hopper tank longitudinals that support the lower connecting brackets,
- side shell and topside tank longitudinals that support the upper connecting brackets

are to be such that the following relationship is separately satisfied for each lower and upper connecting bracket (see also Ch 3, Sec 6, Fig 22):

$$\sum_n w_i d_i \ge \alpha_T \frac{(p_S + p_W)\ell^2 \ell_1^2}{16 R_Y}$$

where:

n : Number of the longitudinal stiffeners of side shell and hopper / topside tank that support the lower / upper end connecting bracket of the side frame, as applicable

w_i : Net section modulus, in cm^3, of the i-th longitudinal stiffener of the side shell or hopper / topside tank that support the lower / upper end connecting bracket of the side frame, as applicable

d_i : Distance, in m, of the above i-th longitudinal stiffener from the intersection point of the side shell and hopper /topside tank

ℓ_1 : Spacing, in m, of transverse supporting webs in hopper / topside tank, as applicable

R_y : Lowest value of equivalent yield stress, in N/mm^2, among the materials of the longitudinal stiffeners of side shell and hopper / topside tanks that support the lower / upper end connecting bracket of the side frame

α_T : Coefficient taken equal to:

α_T = 150 for the longitudinal stiffeners supporting the lower connecting brackets

α_T = 75 for the longitudinal stiffeners supporting the upper connecting brackets

ℓ : Side frame span, in m, as defined in [3.3.1]

p_s, p_w : Still water and wave pressures as those for the side frame.

3.4.2

The net connection area, A_i, in cm^2, of the bracket to the i-th longitudinal stiffener supporting the bracket is to be obtained from the following formula:

$$A_i = 0.4 \frac{w_i s}{\ell_1^2} \frac{k_{bkt}}{k_{lg,i}}$$

where:

w_i : Net section modulus, in cm^3, of the i-th longitudinal stiffener of the side or sloped bulkheads that support the lower or the upper end connecting bracket of the side frame, as applicable

ℓ_1 : As defined in [3.4.1]

k_{bkt} : Material factor for the bracket

$k_{lg,i}$: Material factor for the i-th longitudinal stiffener.

s : Frame spacing, in m

3.5 Strength criteria for multi-span ordinary stiffeners

3.5.1 Checking criteria

The maximum normal stress σ and shear stress τ in a multi-span ordinary stiffener, calculated according to [3.5.2], are to comply with the formulae in Tab 6.

Table 6: Checking criteria for multi-span ordinary stiffeners

Condition	Intact	Flooded	Testing
Normal stress	$\sigma \le \lambda_S R_Y$	$\sigma \le \alpha \lambda_S R_Y$	$\sigma \le 1.05 R_Y$
Shear stress	$\tau \le \tau_a$	$\tau \le \alpha \tau_a$	$\tau \le 1.05 \tau_a$
Note 1: λ_s : Coefficient defined in [3.2.3] α : Coefficient defined in [3.2.5]			

3.5.2 Multi-span ordinary stiffeners

The maximum normal stress σ and shear stress τ in a multi-span ordinary stiffener are to be determined by a direct calculation taking into account:

- the distribution of still water and wave pressure and forces, if any
- the number and position of intermediate supports (decks, girders, etc.)
- the condition of fixity at the ends of the stiffener and at intermediate supports
- the geometrical characteristics of the stiffener on the intermediate spans.

3.6 Scantlings of transverse vertically corrugated watertight bulkheads separating cargo holds for flooded conditions

3.6.1 Bending capacity and shear capacity of the corrugations of transverse vertically corrugated watertight bulkheads separating cargo holds

The bending capacity and the shear capacity of the corrugations of watertight bulkheads between separating cargo holds are to comply with the following formulae:

$$0.5W_{LE} + W_M \geq \frac{M}{0.95R_{eH}}10^3$$

$$\tau \leq \frac{R_{eH}}{2}$$

where:

M : Bending moment in a corrugation, to be obtained, in kNm, from the following formula:

$M = F\ell_C/8$

F : force F_F or resultant force F, in kN, to be calculated according to Ch 4, Sec 6, [3.3.6] and [3.3.7], respectively

ℓ_C : Span of the corrugations, in m, to be obtained according to [3.6.2]

W_{LE} : Net section modulus, in cm³, of one half pitch corrugation, to be calculated at the lower end of the corrugations according to [3.6.2], without being taken greater than the value obtained from the following formula:

$$W_{LE,M} = W_G + \left(\frac{Qh_G - 0.5h_G^2 s_C p_G}{R_{eH}}\right)10^3$$

W_G : Net section modulus, in cm³, of one half pitch corrugation, to be calculated in way of the upper end of shedder or gusset plates, as applicable, according to [3.6.2]

Q : Shear force at the lower end of a corrugation, to be obtained, in kN, from the following formula:

$Q = 0.8F$

h_G : Height, in m, of shedders or gusset plates, as applicable (see Fig 11 to Fig 15)

p_G : pressure p_F or resultant pressure p, in kN/m², to be calculated in way of the middle of the shedders or gusset plates, as applicable, according to Ch 4, Sec 6, [3.3.6] and [3.3.7], respectively

s_C : Spacing of the corrugations, in m, to be taken according to Ch3, Sec 6, Fig 28

W_M : Net section modulus in cm³ of one half pitch corrugation, to be calculated at the mid-span of corrugations according to [3.6.2] without being taken greater than $1.15W_{LE}$

τ : Shear stress in the corrugation, in N/mm², to be obtained from the following formula:

$$\tau = 10\frac{Q}{A_{sh}}$$

A_{sh} : Shear area, in cm², calculated according to the followings.

The shear area is to be reduced in order to account for possible non-perpendicular between the corrugation webs and flanges. In general, the reduced shear area may be obtained by multiplying the web sectional area by (sin φ), φ being the angle between the web and the flange (see Ch 3, Sec 6, Fig 28).

The actual net section modulus of corrugations is to be calculated according to [3.6.2].

The net section modulus of the corrugations upper part of the bulkhead, as defined in Sec 1, Fig 5, is not to be less than 75% of that of the middle part complying with this requirement and Sec 1, [3.2.1], corrected for different minimum yield stresses.

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3.6.2 Net section modulus at the lower end of the corrugations

a) The net section modulus at the lower end of the corrugations (Fig 11 to Fig 15) is to be calculated with the compression flange having an effective flange width b_{ef} not larger than that indicated in Ch 3, Sec 6, [10.4.10].

b) Webs not supported by local brackets

Except in case e), if the corrugation webs are not supported by local brackets below the stool top plate (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs 30% effective.

c) Effective shedder plates

Provided that effective shedder plates, as defined in Ch 3, Sec 6, [10.4.11] are fitted (see Fig 11 and Fig 12), when calculating the section modulus of corrugations at the lower end (cross-sections 1 in Fig 11 and Fig 12), the net area of flange plates may be increased by the value obtained, in cm², from the following formula:

$I_{SH} = 2.5a\sqrt{t_f t_{SH}}$ without being taken greater than $2.5at_f$,

where:

a : Width, in m, of the corrugation flange (Ch 3, Sec 6, Fig 28)

t_{SH} : Net shedder plate thickness, in mm

t_f : Net flange thickness, in mm.

d) Effective gusset plates

Provided that effective gusset plates, as defined in Ch 3, Sec 6, [10.4.12], are fitted (see Fig 13 to Fig15), when calculating the net section modulus of corrugations at the lower end (cross-sections 1 in Fig 13 to Fig 15), the area of flange plates may be increased by the value obtained, in cm², from the following formula:

$$I_G = 7h_G t_f$$

where:

h_G : Height, in m, of gusset plates (see Fig 13 to Fig 15) to be taken not greater than $(10/7)S_{GU}$

S_{GU} : Width, in m, of gusset plates

t_f : Net flange thickness, in mm

e) Sloping stool top plate

If the corrugation webs are welded to a sloping stool top plate which has an angle not less than 45º with the horizontal plane, the section modulus of the corrugations may be calculated considering the corrugation webs fully effective. For angles less than 45º, the effectiveness of the web may be obtained by linear interpolation between 30% for 0º and 100% for 45º.

Where effective gusset plates are fitted, when calculating the net section modulus of corrugations the net area of flange plates may be increased as specified in d) above. No credit may be given to shedder plates only.

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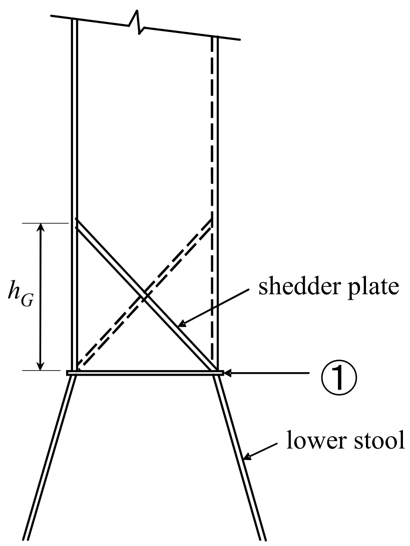

Figure 11: Symmetrical shedder plates

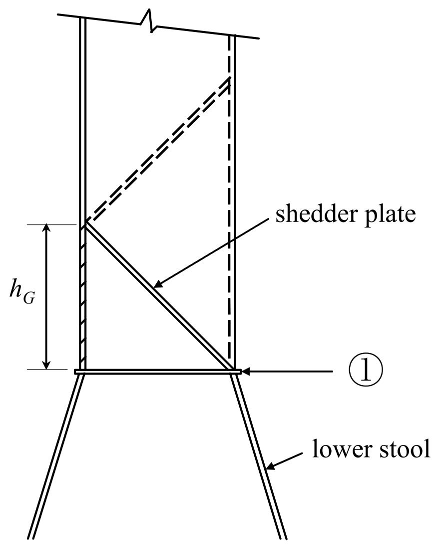

Figure 12: Asymmetrical shedder plates

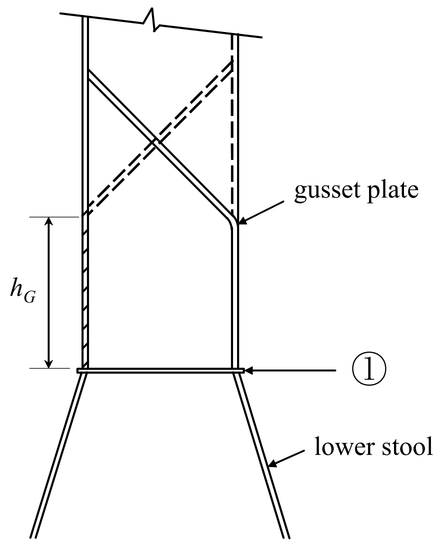

Figure 13: Symmetrical gusset/shedder plates

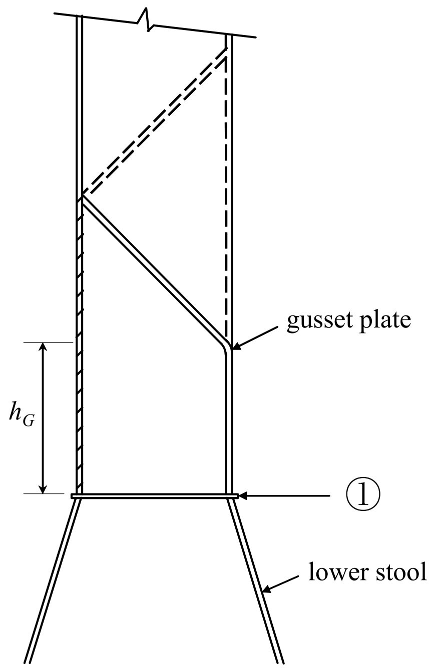

Figure 14: Asymmetrical gusset/shedder plates

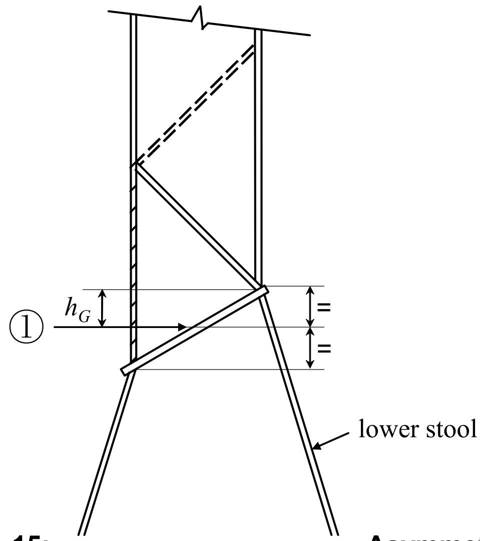

Figure 15: Asymmetrical gusset/shedder plates

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3.6.3 Stiffeners in lower stool and upper stool

The net section modulus of stiffeners in lower stool and upper stool is to be greater of the values obtained from the following formula or required by [3.2.5].

$$w = \frac{ps\ell^2}{16a\lambda_s R_Y}10^3$$

Where,

p : Pressure, in kN/m², as defined in Ch 4 Sec 6, [3.3.7]

a and λ_s : defined in [3.2.5]

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4. Web stiffeners of primary supporting members

4.1 Net scantlings

4.1.1

Where primary supporting member web stiffeners are welded to ordinary stiffener face plates, their net sectional area at the web stiffener mid-height is to be not less than the value obtained, in cm^2, from the following formula:

$$A = 0.1k_1 ps\ell$$

where:

k_1 : Coefficient depending on the web connection with the ordinary stiffener, to be taken as:

- $k_1 = 0.30$ for connections without collar plate (see Ch 3, Sec 6, Fig 8)
- $k_1 = 0.225$ for connections with a collar plate (see Ch 3, Sec 6, Fig 9)
- $k_1 = 0.20$ for connections with one or two large collar plates (see Ch 3, Sec 6, Fig 10 and 11)

p : Pressure, in kN/m^2, acting on the ordinary stiffener.

4.1.2

The net section modulus of web stiffeners of non-watertight primary supporting members is to be not less than the value obtained, in cm^3, from the following formula:

$$w = 2.5 s^2 t S_S^2$$

where:

s : Length, in m, of web stiffeners

t : Web net thickness, in mm, of the primary supporting member

S_S : Spacing, in m, of web stiffeners.

4.1.3 Connection ends of web stiffeners

Where the web stiffeners of primary supporting members are welded to ordinary stiffener face plates, the stress at ends of web stiffeners of primary supporting members in water ballast tanks, in N/mm^2, is to comply with the following formula when no bracket is fitted :

$$\sigma \le 175$$

where:

$$\sigma = K_{con} K_{longi} K_{stiff} \frac{\Delta\sigma}{\cos\theta}$$

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K_{con} : Coefficient considering stress concentration, taken equal to:

$K_{con} = 3.5$ for stiffeners in the double bottom or double side space (see Fig 8)

$K_{con} = 4.0$ for other cases (e.g. hopper tank, top side tank, etc.) (see Fig 8)

K_{longi} : Coefficient considering shape of cross section of the longitudinal, taken equal to:

$K_{longi} = 1.0$ for symmetrical profile of stiffener (e.g. T-section, flat bar)

$K_{longi} = 1.3$ for asymmetrical profile of stiffener (e.g. angle section, bulb profile)

K_{stiff} : Coefficient considering the shape of the end of the stiffener, taken equal to:

$K_{stiff} = 1.0$ for standard shape of the end of the stiffener (see Fig 9)

$K_{stiff} = 0.8$ for the improved shape of the end of the stiffener (see Fig 9)

θ : As given in Fig 10

$\Delta\sigma$: Stress range, in N/mm^2, transferred from longitudinals into the end of web stiffener, as obtained from the following formula:

$$\Delta\sigma = \frac{2W}{0.322h'\left[\left(A_{w1}/\ell_1\right)+\left(A_{w2}/\ell_2\right)\right]+A_{s0}}$$

W : Dynamic load, in N, as obtained from the following formula:

$$W = 1000\left(\ell - 0.5s\right)sp$$

p : Maximum inertial pressure due to liquid in the considered compartment where the web stiffener is located according to Ch 4 Sec 6 [2.2.1], in kN/m^2, of the probability level of 10^{-4}, calculated at mid-span of the ordinary stiffener

ℓ : Span of the longitudinal, in m

s : Spacing of the longitudinal, in m

A_{s0}, A_{w1}, A_{w2} : Geometric parameters as given in Fig 10, in mm^2

ℓ_1, ℓ_2 : Geometric parameters as given in Fig 10, in mm

h' : As obtained from following formula, in mm:

$$h' = h_s + h_0'$$

h_s : As given in Fig 10, in mm

h_0' : As obtained from the following formula, in mm

$$h_0' = 0.636b' \quad \text{for } b' \le 150$$

$$h_0' = 0.216b' + 63 \quad \text{for } 150 < b'$$

b' : Smallest breadth at the end of the web stiffener, in mm, as shown in Fig 9

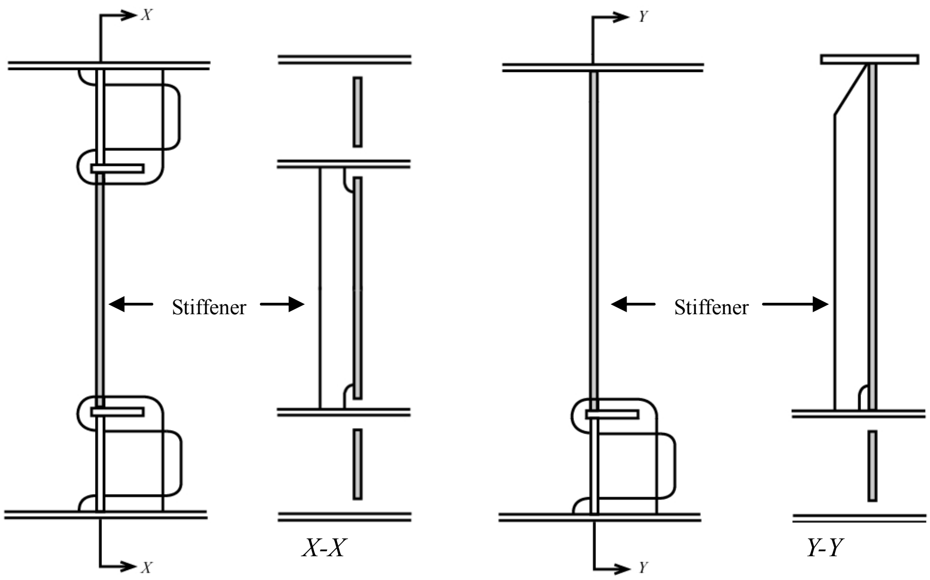


Figure 8: Web stiffeners fitted on primary supporting members

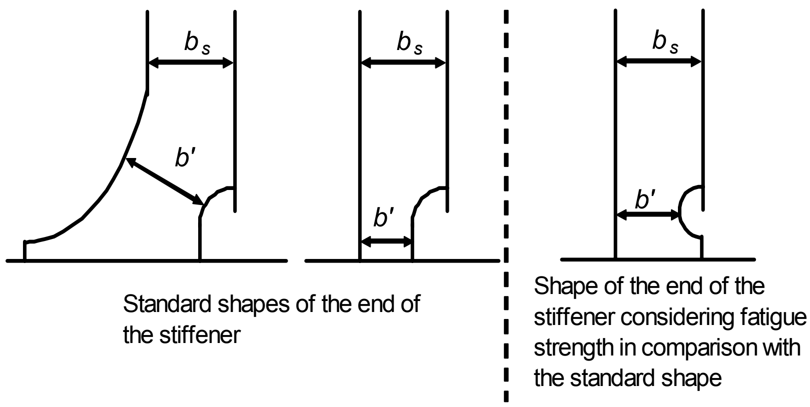
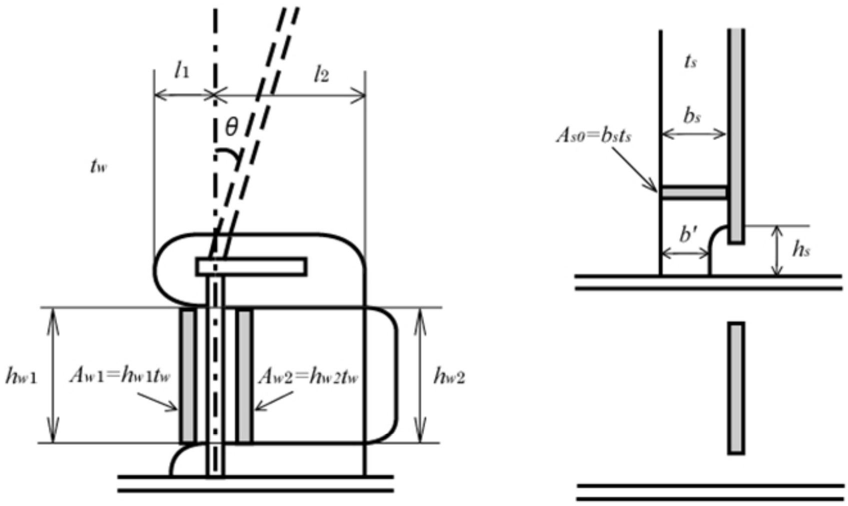


Figure 9: Shape of the end of the web stiffener



Note:

t_s: net thickness of the web stiffener, in *mm*.

t_w: net thickness of the collar plate, in *mm*.

Figure 10: Definitions of geometric parameters

Section 3 – BUCKLING & ULTIMATE STRENGTH OF ORDINARY STIFFENERS AND STIFFENED PANELS

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

In this section, compressive and shear stresses are to be taken positive, tension stresses are to be taken negative.

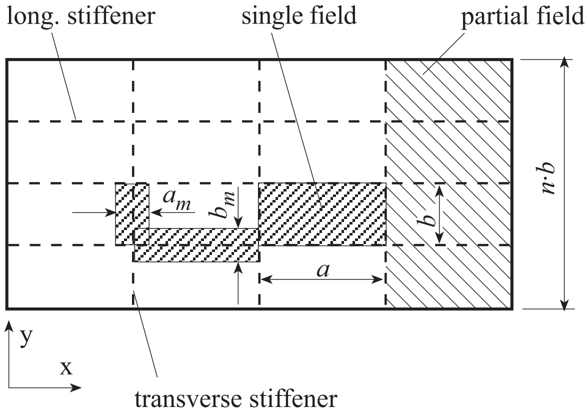
a : Length in mm of the longer side of the partial plate field in general or length in mm of the side of the partial plate field according Table 2, BLC 3 - 10

b : Length in mm of the shorter side of the partial plate field in general or length in mm of the side of the partial plate field according Table 2, BLC 3 - 10

α : Aspect ratio of elementary plate panel, taken equal to:

$$\alpha = \frac{a}{b}$$

n : Number of elementary plate panel breadths within the partial or total plate panel



longitudinal : stiffener in the direction of the length a
transverse : stiffener in the direction of the breath b

Figure 1: General arrangement of panel

t : Net plate thickness, in mm

σ_n : Normal stress resulting from hull girder bending, in N/mm^2

τ_{SF} : Shear stress induced by the shear forces as defined in [2.1.3], in N/mm^2

σ_x : Membrane stress in x-direction, in N/mm^2

σ_y : Membrane stress in y-direction, in N/mm^2

τ : Shear stress in the x-y plane, in N/mm^2

λ : Reference degree of slenderness, taken equal to:

$$\lambda = \sqrt{\frac{R_{eH}}{K\sigma_e}}$$

K : Buckling factor according to Tab 2 and Tab 3

Reference stress, to be the following for LC 1 and 2:

σ_e : Reference stress, taken equal to:

$$\sigma_e = 0.9E\left(\frac{t}{b'}\right)^2$$

b' : shorter side of elementary plate panel

Reference stress, to be the following for LC 3 through 10:

σ_e : Reference stress, taken equal to:

$$\sigma_e = 0.9E\left(\frac{t}{b}\right)^2$$

ψ : Edge stress ratio taken equal to:

$\psi = \sigma_2 / \sigma_1$

where:

σ_1 : maximum compressive stress

σ_2 : minimum compressive stress or tensile stress

S : Safety factor, taken equal to:

$S = 1.0$ except for the case mentioned below

$S = 1.1$ for structures which are exclusively exposed to local loads (e.g. hatch covers, foundations)

$S = 1.15$ for the ultimate strength in lateral buckling mode of longitudinal and transverse ordinary stiffeners of the hatchway coamings, sloping plating of the topside tanks and hopper tanks, inner bottom, inner side if any, side shell of single side skin construction and top and bottom stools of transverse bulkheads, assessed according to [4.2].

For constructions of aluminium alloys the safety factors are to be increased in each case by 0.1

F_1 : Correction factor for boundary condition of stiffeners on the longer side of elementary plate panels according to Tab 1. If the clamping is unequal on the longitudinal sides of the panel, the minimum value of the appropriate F_1-parameter has to be used.

Table 1: Correction factor F_1

	F_1 [(2)]	Edge stiffener
Stiffeners sniped at both ends	1.00	
Guidance values where both ends are effectively connected to adjacent structures [(1)]	1.05	Flat bar
	1.10	Bulb section
	1.21	Angle and tee-sections
	1.30	Girders of high rigidity (e.g. bottom transversers)

(1) Exact values may be determined by direct calculations.
(2) An average value of F_1 is to be used for plate panels having different edge stiffeners.

Corrigenda 1 to July 2012 version (effective from 1July 2012)

1. General

1.1

1.1.1

The requirements of this Section apply for the buckling check of structural members subjected to compressive stresses, shear stresses and lateral pressure.

1.1.2

The buckling checks have to be performed for the following elements:

a) according to requirements of [2], [3] and[4] and for all load cases as defined in Ch 4, Sec 4 in intact condition:
   - elementary plate panels and ordinary stiffeners in a hull transverse section analysis,
   - elementary plate panels modeled in FEM as requested in Ch 7.

b) according to requirements of [6] and only in flooded condition:
   - transverse vertically corrugated watertight bulkheads.

1.1.3

The boundary condition for elementary plate panels are to be considered as simply supported. If the boundary condition differs significantly from simple support, more appropriate boundary condition can be applied according to cases 3, 4 and 7 to 10 of Tab 2.

2. Application

2.1 Load model for hull transverse section analysis

2.1.1 General

The structural members at a considered hull transverse section are to be checked for buckling criteria under the combination of:

- the normal stress σ_n resulting from hull girder bending, as defined in [2.1.2]
- the shear stress τ_{SF} as defined in [2.1.3]
- the lateral pressure in intact condition applied on the members as the case may be.

The lateral pressures and hull girder loads are to be calculated, for the probability level of 10^{-8}, in the mutually exclusive load cases H1, H2, F1, F2, R1, R2, P1 and P2, as defined in Ch 4, Sec 4.

2.1.2 Normal stress σ_n

The normal stress σ_n to be considered for each of the mutually exclusive load cases as referred in [2.1.1] is the maximum compressive stress on the considered structural member according to the formulas given in Ch 6, Sec 1, [3.1.5] and Ch 6, Sec 2, [3.1.5], respectively for elementary plate panels and ordinary stiffeners.

For transverse ordinary stiffeners, the normal stress σ_n for each of the mutually exclusive load cases is the maximum compressive stress calculated at each end.

2.1.3 Shear stress

The shear stress τ_{SF} to be considered for each of the mutually exclusive load cases as referred in [2.1.1] is the shear stress induced by the shear forces, in kN, equal to:

$$Q = Q_{SW} + C_{QW} \, Q_{WV}$$

where:

Q_{SW} : Design still water shear force in intact condition, in kN, at the hull transverse section considered, defined in Ch 4, Sec 3, [2.3]

Q_{WV} : Vertical wave shear force in intact condition, in kN, at the hull transverse section considered, defined in Ch 4, Sec 3, [3.2]

C_{QW} : Load combination factor as defined in Ch 4, Sec 4, Tab 3

If the design still water shear force is not available at preliminary design stage, the following default value, in kN, may be used:

$$Q_{SW0} = 30 \, CLB(C_B + 0.7) 10^{-2}$$

2.1.4 Lateral pressure

The lateral pressure to be considered for the buckling check is defined in Ch 6, Sec 1, [3.1] for curved plate panel and in Ch 6, Sec 2, [3.1] for ordinary stiffeners.

The load calculation point for the curved plate panel is located at mid distance of the curved plate panel extremities along the curve.

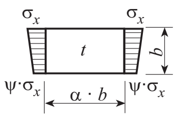
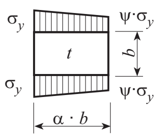
The load calculation point of ordinary stiffeners is defined in Ch 6, Sec 2, [1.4]

2.2 Application

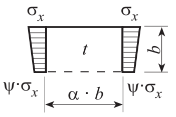
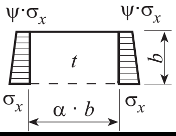
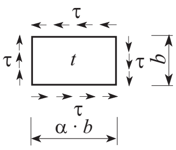
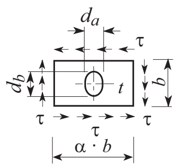
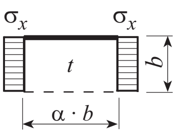
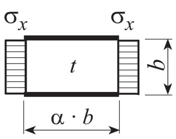
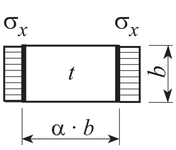
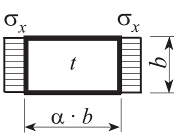
2.2.1

Application of the buckling and ultimate strength criterion is described in App 1.

Table 2: Buckling and reduction factors for plane elementary plate panels

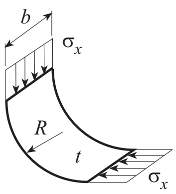
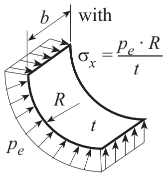
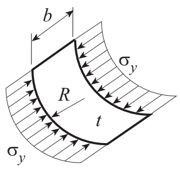
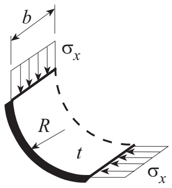
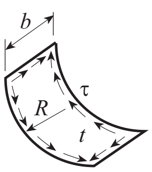
<table>
<tr><th>Buckling-Load Case</th><th>Edge stress ratio ψ</th><th>Asp. ratio $\alpha = a/b$</th><th>Buckling factor K</th><th>Reduction factor κ</th></tr>
<tr><td rowspan="3">1

</td><td>$1 \ge \psi \ge 0$</td><td rowspan="3">$\alpha \ge 1$</td><td>$K = \dfrac{8.4}{\psi + 1.1}$</td><td rowspan="3">$\kappa_x = 1$ for $\lambda \le \lambda_c$
$\kappa_x = c\left(\dfrac{1}{\lambda} - \dfrac{0.22}{\lambda^2}\right)$ for $\lambda > \lambda_c$
$c = (1.25 - 0.12\psi) \le 1.25$
$\lambda_c = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0.88}{c}}\right)$</td></tr>
<tr><td>$0 > \psi > -1$</td><td>$K = 7.63 - \psi(6.26 - 10\psi)$</td></tr>
<tr><td>$\psi \le -1$</td><td>$K = (1-\psi)^2 \cdot 5.975$</td></tr>
<tr><td rowspan="5">2

</td><td>$1 \ge \psi \ge 0$</td><td>$\alpha \ge 1$</td><td>$K = F_1\left(1 + \dfrac{1}{\alpha^2}\right)^2 \dfrac{2.1}{(\psi + 1.1)}$</td><td rowspan="5">$\kappa_y = c\left(\dfrac{1}{\lambda} - \dfrac{R + F^2(H - R)}{\lambda^2}\right)$
$c = (1.25 - 0.12\psi) \le 1.25$
$R = \lambda\left(1 - \dfrac{\lambda}{c}\right)$ for $\lambda < \lambda_c$
$R = 0.22$ for $\lambda \ge \lambda_c$
$\lambda_c = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0.88}{c}}\right)$
$F = \left(1 - \dfrac{\dfrac{K}{0.91} - 1}{\lambda_p^{\,2}}\right) \cdot c_1 \ge 0$
$\lambda_p^{\,2} = \lambda^2 - 0.5$ for $1 \le \lambda_p^{\,2} \le 3$
$c_1 = 1$, for σ_y due to direct loads
$c_1 = \left(1 - \dfrac{F_1}{\alpha}\right) \ge 0$, for σ_y due to bending (in general)
$c_1 = 0$, for σ_y due to bending in extreme load cases (e.g. wt. bulkheads)
$H = \lambda - \dfrac{2\lambda}{c\left(T + \sqrt{T^2 - 4}\right)} \ge R$
$T = \lambda + \dfrac{14}{15\lambda} + \dfrac{1}{3}$</td></tr>
<tr><td rowspan="2">$0 > \psi > -1$</td><td>$1 \le \alpha \le 1.5$</td><td>$K = F_1\left[\left(1 + \dfrac{1}{\alpha^2}\right)^2 \dfrac{2.1(1+\psi)}{1.1} - \dfrac{\psi}{\alpha^2}(13.9 - 10\psi)\right]$</td></tr>
<tr><td>$\alpha > 1.5$</td><td>$K = F_1\left[\left(1 + \dfrac{1}{\alpha^2}\right)^2 \dfrac{2.1(1+\psi)}{1.1} - \dfrac{\psi}{\alpha^2}(5.87 + 1.87\alpha^2 + \dfrac{8.6}{\alpha^2} - 10\psi)\right]$</td></tr>
<tr><td rowspan="2">$\psi \le -1$</td><td>$1 \le \alpha \le \dfrac{3(1-\psi)}{4}$</td><td>$K = F_1\left(\dfrac{1-\psi}{\alpha}\right)^2 \cdot 5.975$</td></tr>
<tr><td>$\alpha > \dfrac{3(1-\psi)}{4}$</td><td>$K = F_1\left[\left(\dfrac{1-\psi}{\alpha}\right)^2 \cdot 3.9675 + 0.5375\left(\dfrac{1-\psi}{\alpha}\right)^4 + 1.87\right]$</td></tr>
<tr><td colspan="3">Explanations for boundary conditions</td><td colspan="2">- - - - - plate edge free
——— plate edge simply supported
━━━ plate edge clamped</td></tr>
</table>

Note : The load cases as listed in Tab 2 are general cases. Each stress component (σ_x, σ_y) is to be understood in a local coordinates.

3 	$1 \geq \psi \geq 0$	$\alpha > 0$	$K = \frac{4\left(0.425 + \frac{1}{\alpha^2}\right)}{3\psi + 1}$	$\kappa_x = 1$ for $\lambda \leq 0.7$ $\kappa_x = \frac{1}{\lambda^2 + 0,51}$ for $\lambda > 0.7$
	$0 > \psi \geq -1$		$K = 4\left(0.425 + \frac{1}{\alpha^2}\right)(1+\psi) - 5\psi(1 - 3.42\psi)$	
4 	$1 \geq \psi \geq -1$	$\alpha > 0$	$K = \left(0.425 + \frac{1}{\alpha^2}\right)\frac{3-\psi}{2}$	
5 	===		$K = K_\tau \sqrt{3}$	$\kappa_\tau = 1$ for $\lambda \leq 0.84$ $\kappa_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$
		$\alpha \geq 1$	$K_\tau = \left[5.34 + \frac{4}{\alpha^2}\right]$	
		$0 < \alpha < 1$	$K_\tau = \left[4 + \frac{5.34}{\alpha^2}\right]$	
6 	===		$K = K'r$ $K' = K$ according to load case 5 r = Reductions factor r = $\left(1 - \frac{d_a}{a}\right)\left(1 - \frac{d_b}{b}\right)$ with $\frac{d_a}{a} \leq 0.7$ and $\frac{d_b}{b} \leq 0.7$	
7 	===	$\alpha \geq 1.64$	$K = 1.28$	$\kappa_x = 1$ for $\lambda \leq 0.7$ $\kappa_x = \frac{1}{\lambda^2 + 0.51}$ for $\lambda > 0.7$
		$\alpha < 1.64$	$K = \frac{1}{\alpha^2} + 0.56 + 0.13\alpha^2$	
8 	===	$\alpha \geq \frac{2}{3}$	$K = 6.97$	$\kappa_x = 1$ for $\lambda \leq 0.83$ $\kappa_x = 1,13\left[\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right]$ for $\lambda > 0.83$
		$\alpha < \frac{2}{3}$	$K = \frac{1}{\alpha^2} + 2.5 + 5\alpha^2$	
9 	===	$\alpha \geq 4$	$K = 4$	
		$4 > \alpha > 1$	$K = 4 + \left[\frac{4-\alpha}{3}\right]^4 \cdot 2.74$	
		$\alpha \leq 1$	$K = \frac{4}{\alpha^2} + 2.07 + 0.67\alpha^2$	
10 	===	$\alpha \geq 4$	$K = 6.97$	
		$4 > \alpha > 1$	$K = 6.97 + \left[\frac{4-\alpha}{3}\right]^4 \cdot 3.1$	
		$\alpha \leq 1$	$K = \frac{4}{\alpha^2} + 2.07 + 4\alpha^2$	
Explanations for boundary conditions		- - - - - plate edge free ——— plate edge simply supported ▬▬▬ plate edge clamped		

Note : The load cases as listed in Tab 2 are general cases. Each stress component (σ_x, σ_y) is to be understood in a local coordinates.

Table 3: Buckling and reduction factor for curved plate panel with R/t ≤ 2500 [1]

Buckling-Load Case	Aspect ratio b/R	Buckling factor K	Reduction factor κ
1a 	$\frac{b}{R} \le 1.63\sqrt{\frac{R}{t}}$	$K = \frac{b}{\sqrt{R\,t}} + 3\frac{(R\,t)^{0.175}}{b^{0.35}}$	$\kappa_x = 1$ for $\lambda \le 0.4$ [2] $\kappa_x = 1.274 - 0.686 \cdot \lambda$ for $0.4 < \lambda \le 1.2$ $\kappa_x = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$
1b with $\sigma_x = \frac{p_e \cdot R}{t}$  p_e = external pressure in [N/mm²]	$\frac{b}{R} > 1.63\sqrt{\frac{R}{t}}$	$K = 0.3\frac{b^2}{R^2} + 2.25\left(\frac{R^2}{b\,t}\right)^2$	
2 	$\frac{b}{R} \le 0.5\sqrt{\frac{R}{t}}$	$K = 1 + \frac{2}{3}\frac{b^2}{R\,t}$	$\kappa_y = 1$ for $\lambda \le 0.25$ [2] $\kappa_y = 1.233 - 0.933 \cdot \lambda$ for $0.25 < \lambda \le 1$ $\kappa_y = 0.3/\lambda^3$ for $1 < \lambda \le 1.5$ $\kappa_y = 0.2/\lambda^2$ for $\lambda > 1.5$
	$\frac{b}{R} > 0.5\sqrt{\frac{R}{t}}$	$K = 0.267\frac{b^2}{R\,t}\left[3 - \frac{b}{R}\sqrt{\frac{t}{R}}\right]$ $\ge 0.4\frac{b^2}{R\,t}$	
3 	$\frac{b}{R} \le \sqrt{\frac{R}{t}}$	$K = \frac{0.6 \cdot b}{\sqrt{R\,t}} + \frac{\sqrt{R\,t}}{b} - 0.3\frac{R\,t}{b^2}$	as in load case 1a
	$\frac{b}{R} > \sqrt{\frac{R}{t}}$	$K = 0.3\frac{b^2}{R^2} + 0.291\left(\frac{R^2}{b\,t}\right)^2$	
4 	$\frac{b}{R} \le 8.7\sqrt{\frac{R}{t}}$	$K = K_\tau\sqrt{3}$ $K_\tau = \left[28.3 + \frac{0.67\,b^3}{R^{1.5}\,t^{1.5}}\right]^{0.5}$	$\kappa_\tau = 1$ for $\lambda \le 0.4$ $\kappa_\tau = 1.274 - 0.686 \cdot \lambda$ for $0.4 < \lambda \le 1.2$ $\kappa_\tau = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$
	$\frac{b}{R} > 8.7\sqrt{\frac{R}{t}}$	$K_\tau = 0.28\frac{b^2}{R\sqrt{R\,t}}$	

Explanations for boundary conditions
- - - - - plate edge free
——— plate edge simply supported
▬▬▬ plate edge clamped

[1] For curved plate fields with a very large radius the κ-value need not to be taken less than for the expanded plane field

[2] For curved single fields, e.g. bilge strake, which are located within plane partial or total fields, the reduction factor κ may taken as follow:
Load case 1b: $\kappa_x = \frac{0.8}{\lambda^2} \le 1{,}0$ Load case 2: $\kappa_y = \frac{0.65}{\lambda^2} \le 1.0$

3. Buckling criteria of elementary plate panels

3.1 Plates

3.1.1 General

The net thickness of the elementary plate panel is to comply with the following:

$t \geq b/100$

The verification of an elementary plate panel in a transverse section analysis is to be carried out according to [3.1.2]. It is to be performed for the two different following combinations of stresses:

- stress combination 1: 100% of the normal stress as defined in [2.1.2] and 70% of the shear stress as defined in [2.1.3]
- stress combination 2: 70% of the normal stress as defined in [2.1.2] and 100% of the shear stress as defined in [2.1.3].

The verification of elementary plate panel in a FEM analysis is to be carried out according to [3.2].

3.1.2 Verification of elementary plate panel in a transverse section analysis

Each elementary plate panel is to comply with the following criteria, taking into account the loads defined in [2.1]:

- longitudinally framed plating

$$\left(\frac{|\sigma_x| S}{\kappa_x R_{eH}}\right)^{e1} + \left(\frac{|\tau| S\sqrt{3}}{\kappa_\tau R_{eH}}\right)^{e3} \leq 1.0$$ for stress combination 1 with $\sigma_x = \sigma_n$ and $\tau = 0.7\tau_{SF}$

$$\left(\frac{|\sigma_x| S}{\kappa_x R_{eH}}\right)^{e1} + \left(\frac{|\tau| S\sqrt{3}}{\kappa_\tau R_{eH}}\right)^{e3} \leq 1.0$$ for stress combination 2 with $\sigma_x = 0.7\sigma_n$ and $\tau = \tau_{SF}$

- transversely framed plating

$$\left(\frac{|\sigma_y| S}{\kappa_y R_{eH}}\right)^{e2} + \left(\frac{|\tau| S\sqrt{3}}{\kappa_\tau R_{eH}}\right)^{e3} \leq 1.0$$ for stress combination 1 with $\sigma_y = \sigma_n$ and $\tau = 0.7\tau_{SF}$

$$\left(\frac{|\sigma_y| S}{\kappa_y R_{eH}}\right)^{e2} + \left(\frac{|\tau| S\sqrt{3}}{\kappa_\tau R_{eH}}\right)^{e3} \leq 1.0$$ for stress combination 2 with $\sigma_y = 0.7\sigma_n$ and $\tau = \tau_{SF}$

Each term of the above conditions must be less than 1.0.

The reduction factors κ_x and κ_y are given in Tab 2 and/or Tab 3.

The coefficients $e1$, $e2$ and $e3$ are defined in Tab 4.

For the determination of $e3$, κ_y is to be taken equal to 1 in case of longitudinally framed plating and κ_x is to be taken equal to 1 in case of transversely framed plating.

3.2 Verification of elementary plate panel within FEM analysis

3.2.1 General

The buckling check of the elementary plate panel is to be performed under the loads defined in [3.2.2], according to the requirements of [3].

The determination of the buckling and reduction factors is made for each relevant case of Tab 2 according to the stresses calculated in [3.2.2] loading the considered elementary plate panel.

3.2.2 Stresses

For the buckling check, the buckling stresses are to be determined according to Tab 2 and Tab 3 including their stress ratio Ψ for the loading conditions required in Ch 4, Sec 7 and according to the requirements of Ch 7.

3.2.3 Poisson effect

Stresses derived with superimposed or direct method have to be reduced for buckling assessment because of the Poisson effect, which is taken into consideration in both analysis methods. The correction has to be carried out after summation of stresses due to local and global loads.

Both stresses σ_x^* and σ_y^* are to be compressive stresses, in order to apply the stress reduction according to the following formulae:

$$\sigma_x = (\sigma_x^* - 0.3\sigma_y^*)/0.91$$

$$\sigma_y = (\sigma_y^* - 0.3\sigma_x^*)/0.91$$

where:

σ_x^*, σ_y^* : Stresses containing the Poisson effect

Where compressive stress fulfils the condition $\sigma_y^* < 0.3\sigma_x^*$, then $\sigma_y = 0$ and $\sigma_x = \sigma_x^*$

Where compressive stress fulfils the condition $\sigma_x^* < 0.3\sigma_y^*$, then $\sigma_x = 0$ and $\sigma_y = \sigma_y^*$

3.2.4 Checking Criteria

Each elementary plate panel is to comply with the following criteria, taking into account the loads defined in [2.1] :

$$\left(\frac{|\sigma_x|S}{\kappa_x R_{eH}}\right)^{e1} + \left(\frac{|\sigma_y|S}{\kappa_y R_{eH}}\right)^{e2} - B\left(\frac{\sigma_x \sigma_y S^2}{R_{eH}^2}\right) + \left(\frac{|\tau|S\sqrt{3}}{\kappa_\tau R_{eH}}\right)^{e3} \leq 1.0$$

In addition, each compressive stress σ_x and σ_y, and the shear stress τ are to comply with the following formulae:

$$\left(\frac{\sigma_x\, S}{\kappa_x\, R_{eH}}\right)^{e1} \leq 1.0$$

$$\left(\frac{\sigma_y\, S}{\kappa_y\, R_{eH}}\right)^{e2} \leq 1.0$$

$$\left(\frac{|\tau|\, S\sqrt{3}}{\kappa_\tau\, R_{eH}}\right)^{e3} \leq 1{,}0$$

The reduction factors κ_x , κ_y and κ_τ are given in Tab 2 and/or Tab 3.

- where $\sigma_x \le 0$ (tensile stress), $\kappa_x = 1.0$.
- where $\sigma_y \le 0$ (tensile stress), $\kappa_Y = 1.0$.

The coefficients $e1$, $e2$ and $e3$ as well as the factor B are defined in Tab 4.

Table 4: Coefficients *e*1, *e*2, *e*3 and factor *B*

Exponents *e*1 – *e*3 and factor *B*	Plate panel plane	Plate panel curved
$e1$	$1+\kappa_x^4$	1.25
$e2$	$1+\kappa_y^4$	1.25
$e3$	$1+\kappa_x\kappa_y\kappa_\tau^2$	2.0
B σ_x and σ_y positive (compressive stress)	$(\kappa_x\kappa_y)^5$	0
B σ_x or σ_y negative (tensile stress)	1	-

3.3 Webs and flanges

3.3.1

For non-stiffened webs and flanges of sections and girders proof of sufficient buckling strength as for elementary plate panels is to be provided according to [3.1].

4. Buckling criteria of partial and total panels

4.1 Longitudinal and transverse stiffeners

4.1.1

In a hull transverse section analysis, the longitudinal and transverse ordinary stiffeners of partial and total plate panels are to comply with the requirements of [4.2] and [4.3].

4.2 Ultimate strength in lateral buckling mode

4.2.1 Checking criteria

The longitudinal and transverse ordinary stiffeners are to comply with the following criteria:

$$\frac{\sigma_a + \sigma_b}{R_{eH}} S \le 1$$

σ_a : Uniformly distributed compressive stress, in N/mm^2 in the direction of the stiffener axis.

$\sigma_a = \sigma_n$ for longitudinal stiffeners

$\sigma_a = 0$ for transverse stiffeners

σ_b : Bending stress, in N/mm^2, in the stiffener.

σ_b calculated as in [4.2.2] with $\sigma_x = \sigma_n$ and $\tau = \tau_{SF}$

4.2.2 Evaluation of the bending stress σ_b

The bending stress σ_b, in N/mm^2, in the stiffeners is equal to:

$$\sigma_b = \frac{M_0 + M_1}{W_{st}\, 10^3}$$

with:

M_0 : Bending moment, in N.mm, due to the deformation w of stiffener, taken equal to:

$$M_0 = F_{Ki} \frac{p_z w}{c_f - p_z}$$

with $(c_f - p_z) > 0$

M_1 : Bending moment, in N.mm, due to the lateral load p, taken equal to:

$$M_1 = \frac{pba^2}{24 \cdot 10^3}$$ for longitudinal stiffeners

$$M_1 = \frac{pa(n \cdot b)^2}{8 c_S\, 10^3}$$ for transverse stiffeners, with n equal to 1 for ordinary transverse stiffeners.

W_{st} : Net section modulus of stiffener (longitudinal or transverse), in cm^3, including effective width of plating according to [5], taken equal to:

- if a lateral pressure is applied on the stiffener:

  W_{st} is the net section modulus calculated at flange if the lateral pressure is applied on the same side as the stiffener.

  W_{st} is the net section modulus calculated at attached plate if the lateral pressure is applied on the side opposite to the stiffener.

  Note: For stiffeners sniped at both ends, W_{st} is the net section modulus calculated at attached plate. However, if M_1 is larger than M_0 and the lateral pressure is applied on the same side as the stiffener, W_{st} is the net section modulus calculated at flange.

- if no lateral pressure is applied on the stiffener:

  W_{st} is the minimum net section modulus among those calculated at flange and attached plate

  Note: For stiffeners sniped at both ends, W_{st} is the net section modulus calculated at attached plate.

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c_S : Factor accounting for the boundary conditions of the transverse stiffener

$c_S = 1.0$ for simply supported stiffeners

$c_S = 2.0$ for partially constraint stiffeners

p : Lateral load in kN/m^2, as defined in Ch 4, Sec5 and Ch 4, Sec 6 calculated at the load point as defined in Ch 6, Sec 2, [1.4]

F_{Ki} : Ideal buckling force, in N, of the stiffener, taken equal to:

$$F_{Kix} = \frac{\pi^2}{a^2} EI_x\, 10^4$$ for longitudinal stiffeners

$$F_{Kiy} = \frac{\pi^2}{(nb)^2} EI_y\, 10^4$$ for transverse stiffeners

I_x, I_y : Net moments of inertia, in cm^4, of the longitudinal or transverse stiffener including effective width of attached plating according to [5]. I_x and I_y are to comply with the following criteria:

$$I_x \geq \frac{bt^3}{12 \cdot 10^4}$$

$$I_y \geq \frac{at^3}{12 \cdot 10^4}$$

p_z : Nominal lateral load, in N/mm^2, of the stiffener due to σ_x, σ_y and τ

$$p_{zx} = \frac{t_a}{b}\left(\sigma_{xl}\left(\frac{\pi b}{a}\right)^2 + 2c_y\sigma_y + \tau_1\sqrt{2}\right) \text{ for longitudinal stiffeners}$$

$$p_{zy} = \frac{t_a}{a}\left(2c_x\sigma_{xl} + \sigma_y\left(\frac{\pi a}{nb}\right)^2\left(1+\frac{A_y}{at_a}\right) + \tau_1\sqrt{2}\right) \text{ for transverse stiffeners}$$

$$\sigma_{xl} = \sigma_x\left(1+\frac{A_x}{b \cdot t_a}\right)$$

t_a : Net thickness offered of attached plate, in mm

c_x, c_y : Factor taking into account the stresses vertical to the stiffener's axis and distributed variable along the stiffener's length taken equal to:

$0.5\,(1+\psi)$ for $0 \leq \psi \leq 1$

$\dfrac{0.5}{1-\psi}$ for $\psi < 0$

A_x, A_y : Net sectional area, in mm^2, of the longitudinal or transverse stiffener respectively without attached plating

$$\tau_1 = \left[\tau - t\sqrt{R_{eH}E\left(\frac{m_1}{a^2}+\frac{m_2}{b^2}\right)}\right] \geq 0$$

m_1, m_2 : Coefficients taken equal to:

for longitudinal stiffeners:

$\dfrac{a}{b} \geq 2,0$: $m_1 = 1.47$ $m_2 = 0.49$

$\dfrac{a}{b} < 2,0$: $m_1 = 1.96$ $m_2 = 0.37$

for transverse stiffeners:

$\dfrac{a}{n \cdot b} \geq 0,5$: $m_1 = 0.37$ $m_2 = \dfrac{1.96}{n^2}$

$\dfrac{a}{n \cdot b} < 0,5$: $m_1 = 0.49$ $m_2 = \dfrac{1.47}{n^2}$

$w = w_0 + w_1$ generally

$w = |w_0 - w_1|$ for stiffeners sniped at both ends, on which the same side lateral pressure as the stiffener is applied.

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w_0 : Assumed imperfection, in mm, taken equal to:

$$w_0 = \min\left(\frac{a}{250}, \frac{b}{250}, 10\right) \text{ for longitudinal stiffeners}$$

$$w_0 = \min\left(\frac{a}{250}, \frac{n \cdot b}{250}, 10\right) \text{ for transverse stiffeners}$$

For stiffeners sniped at both ends w_0 must not be taken less than the distance from the midpoint of attached plating to the neutral axis of the stiffener calculated with the effective width of its attached plating.

w_1 : Deformation of stiffener, in mm, at midpoint of stiffener span due to lateral load p. In case of uniformly distributed load the following values for w_1 may be used:

$$w_1 = \frac{pba^4}{384 \cdot 10^7 EI_x} \quad \text{for longitudinal stiffeners}$$

$$w_1 = \frac{5ap(nb)^4}{384 \cdot 10^7 EI_y c_S^2} \quad \text{for transverse stiffeners}$$

c_f : Elastic support provided by the stiffener, in N/mm^2, taken equal to:

- for longitudinal stiffeners

$$c_f = F_{Kix} \frac{\pi^2}{a^2}(1 + c_{px})$$

$$c_{px} = \frac{1}{1 + \dfrac{0.91\left(\dfrac{12 \cdot 10^4 I_x}{t^3 b} - 1\right)}{c_{xa}}}$$

c_{xa} : Coefficient taken equal to :

$$c_{xa} = \left[\frac{a}{2b} + \frac{2b}{a}\right]^2 \quad \text{for} \quad a \geq 2b$$

$$c_{xa} = \left[1 + \left(\frac{a}{2b}\right)^2\right]^2 \quad \text{for} \quad a < 2b$$

- for transverse. stiffeners :

$$c_f = c_S F_{Kiy} \frac{\pi^2}{(n \cdot b)^2}\left(1 + c_{py}\right)$$

$$c_{py} = \frac{1}{1 + \dfrac{0.91\left(\dfrac{12 \cdot 10^4 I_y}{t^3 a} - 1\right)}{c_{ya}}}$$

c_{ya} : Coefficient taken equal to :

$$c_{ya} = \left[\frac{nb}{2a} + \frac{2a}{nb}\right]^2 \quad \text{for} \quad nb \geq 2a$$

$$c_{ya} = \left[1 + \left(\frac{nb}{2a}\right)^2\right]^2 \quad \text{for} \quad nb < 2a$$

4.2.3 Equivalent criteria for longitudinal and transverse ordinary stiffeners not subjected to lateral pressure

Longitudinal and transverse ordinary stiffeners not subjected to lateral pressure, except for sniped stiffeners, are considered as complying with the requirement of [4.2.1] if their net moments of inertia I_x and I_y, in cm^4, are not less than the value obtained by the following formula:

- For longitudinal stiffener : $I_x = \dfrac{p_{zx} a^2}{\pi^2 10^4}\left(\dfrac{w_0 h_w}{\dfrac{R_{eH}}{S} - \sigma_x} + \dfrac{a^2}{\pi^2 E}\right)$
- For transverse stiffener : $I_y = \dfrac{p_{zy} (nb)^2}{\pi^2 10^4}\left(\dfrac{w_0 h_w}{\dfrac{R_{eH}}{S} - \sigma_y} + \dfrac{(nb)^2}{\pi^2 E}\right)$

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4.3 Torsional buckling

4.3.1 Longitudinal stiffeners

The longitudinal ordinary stiffeners are to comply with the following criteria:

$$\frac{\sigma_x S}{\kappa_T R_{eH}} \le 1.0$$

κ_T : Coefficient taken equal to:

$$\kappa_T = 1.0 \text{ for } \lambda_T \le 0.2$$

$$\kappa_T = \frac{1}{\Phi + \sqrt{\Phi^2 - \lambda_T^2}} \text{ for } \lambda_T > 0.2$$

$$\Phi = 0.5\left(1 + 0.21(\lambda_T - 0.2) + \lambda_T^2\right)$$

λ_T : Reference degree of slenderness taken equal to:

$$\lambda_T = \sqrt{\frac{R_{eH}}{\sigma_{KiT}}}$$

$$\sigma_{KiT} = \frac{E}{I_P}\left(\frac{\pi^2 I_\omega 10^2}{a^2}\varepsilon + 0.385 I_T\right) \quad \text{, in N/mm}^2$$

I_P : Net polar moment of inertia of the stiffener, in cm^4, defined in Tab 5, and related to the point C as shown in Fig 2

I_T : Net St. Venant's moment of inertia of the stiffener, in cm^4, defined in Tab 5,

I_ω : Net sectorial moment of inertia of the stiffener, in cm^6, defined in Tab 5, related to the point C as shown in Fig 2

ε : Degree of fixation taken equal to:

$$\varepsilon = 1 + 10^{-3}\sqrt{\frac{a^4}{\frac{3}{4}\pi^4 I_w\left(b/t^3 + 4h_w/3t_w^3\right)}}$$

A_w : Net web area equal to: $A_w = h_w t_w$

A_f : Net flange area equal to: $A_f = b_f t_f$

$e_f = h_w + \dfrac{t_f}{2}$, in mm

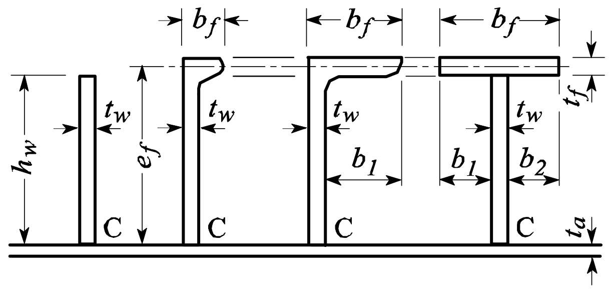

Figure 2: Dimensions of stiffeners

Table 5: Moments of inertia

Profile	I_P	I_T	I_w
Flat bar	$\dfrac{h_w^3 t_w}{3 \cdot 10^4}$	$\dfrac{h_w t_w^3}{3 \cdot 10^4}\left(1 - 0.63\dfrac{t_w}{h_w}\right)$	$\dfrac{h_w^3 t_w^3}{36 \cdot 10^6}$
Sections with bulb or flange	$\left(\dfrac{A_w h_w^2}{3} + A_f e_f^2\right)10^{-4}$	$\dfrac{h_w t_w^3}{3 \cdot 10^4}\left(1 - 0.63\dfrac{t_w}{h_w}\right)$ + $\dfrac{b_f t_f^3}{3 \cdot 10^4}\left(1 - 0.63\dfrac{t_f}{b_f}\right)$	for bulb and angle sections: $\dfrac{A_f e_f^2 b_f^2}{12 \cdot 10^6}\left(\dfrac{A_f + 2.6 A_w}{A_f + A_w}\right)$ for tee-sections $\dfrac{b_f^3 t_f e_f^2}{12 \cdot 10^6}$

4.3.2 Transverse stiffeners

Transverse stiffeners loaded by axial compressive stresses and which are not supported by longitudinal stiffeners are to comply with the requirements of [4.3.1] analogously.

5. Effective width of attached plating

5.1 Ordinary stiffeners

5.1.1

The effective width of attached plating of ordinary stiffeners is determined by the following formulae (see also Fig 1):

- for longitudinal stiffeners: $b_m = \min(\kappa_x b, \kappa_s s)$
- for transverse stiffeners: $a_m = \min(\kappa_y a, \kappa_s s)$

where:

$\kappa_s = 0.0035\left(\dfrac{\ell_{eff}}{s}\right)^3 - 0.0673\left(\dfrac{\ell_{eff}}{s}\right)^2 + 0.4422\left(\dfrac{\ell_{eff}}{s}\right) - 0.0056$, to be taken not greater than 1,0

s : Spacing of the stiffener, in mm

ℓ_{eff} : Value taken as follows:

- for longitudinal stiffeners:

  $\ell_{eff} = a$ if simply supported at both ends

  $\ell_{eff} = 0.6\ a$ if fixed at both ends

- for transverse stiffeners:

  $\ell_{eff} = b$ if simply supported at both ends

  $\ell_{eff} = 0.6\ b$ if fixed at both ends

5.2 Primary supporting members

The effective width $e_m^{'}$ of stiffened flange plates of primary supporting members may be determined as described in a) and b), with the notations:

e : Width of plating supported, in mm, measured from centre to centre of the adjacent unsupported fields

e_m : Effective width, in mm, of attached plating of primary supporting member according to Tab 6 considering the type of loading (special calculations may be required for determining the effective width of one-sided or non-symmetrical flanges).

e_{m1} is to be applied where primary supporting members are loaded by uniformly distributed loads or else by not less than 6 equally spaced single loads.

e_{m2} is to be applied where primary supporting members are loaded by 3 or less single loads.

a) Stiffening parallel to web of the primary supporting member (see Fig 3)

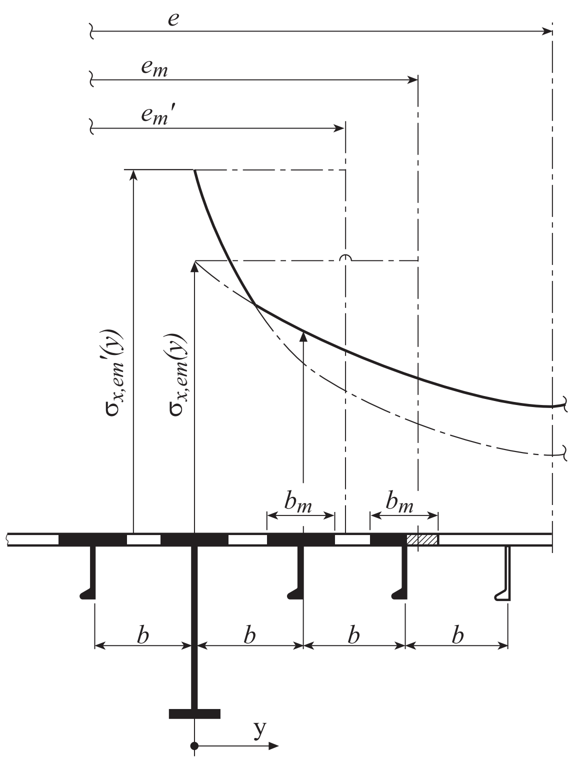

Figure 3: Stiffening parallel to web

$b < e_m$

$e_m^{'} = n \cdot b_m$

n : Integral number of the stiffener spacing b inside the effective width e_m., taken equal to:

$$n = \text{int}\left(\frac{e_m}{b}\right)$$

b) Stiffening perpendicular to web of the primary supporting member (see Fig 4)

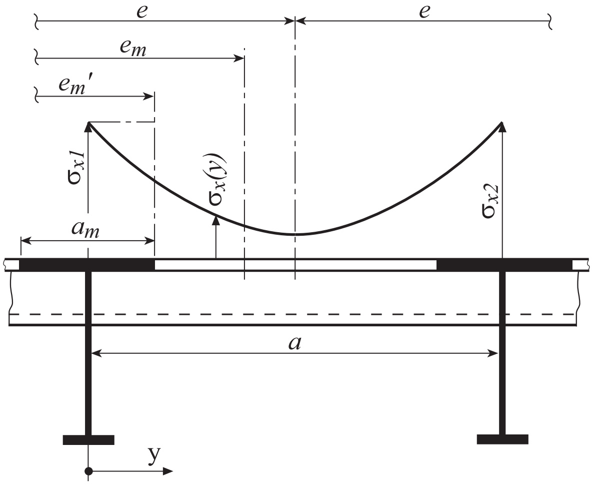

Figure 4: Stiffening perpendicular to web

$a \geq e_m$

$e_m^{'} = n a_m < e_m$

$n = 2.7\dfrac{e_m}{a}$, to be taken not greater than 1.0

For $b \geq e_m$ or $a < e_m$ respectively, b and a must be exchanged.

Table 6: Effective Width of attached plating

ℓ/e	0	1	2	3	4	5	6	7	≥ 8
e_{m1}/e	0	0.36	0.64	0.82	0.91	0.96	0.98	1.00	1.00
e_{m2}/e	0	0.20	0.37	0.52	0.65	0.75	0.84	0.89	0.90

Intermediate values may be obtained by direct interpolation.

ℓ : Length between zero-points of bending moment curve, i.e. unsupported span in case of simply supported girders and 0.6 times the unsupported span in case of constraint of both ends of girder

6. Transverse vertically corrugated watertight bulkhead in flooded conditions

6.1 General

6.1.1 Shear buckling check of the bulkhead corrugation webs

The shear stress τ, calculated according to Ch 6, Sec 2, [3.6.1], is to comply with the following formula:

$\tau \leq \tau_C$ *RCN 1 to July 2008 version (effective from 1 July 2009)*

where:

τ_C : Critical shear buckling stress to be obtained, in N/mm^2, from the following formulae:

$$\tau_c = \tau_E \qquad \text{for} \quad \tau_E \le \frac{R_{eH}}{2\sqrt{3}}$$

$$\tau_c = \frac{R_{eH}}{\sqrt{3}}\left(1 - \frac{R_{eH}}{4\sqrt{3}\,\tau_E}\right) \qquad \text{for} \quad \tau_E > \frac{R_{eH}}{2\sqrt{3}}$$

τ_E : Euler shear buckling stress to be obtained, in N/mm^2, from the following formula:

$$\tau_E = 0.9 k_t E \left(\frac{t_w}{10^3 c}\right)^2$$

k_t : Coefficient, to be taken equal to 6.34

t_W : Net thickness, in mm, of the corrugation webs

c : Width, in m of the corrugation webs (see Ch 3, Sec 6, Fig 28). *RCN 1 to July 2008 version (effective from 1 July 2009)*

Section 4 - PRIMARY SUPPORTING MEMBERS

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

L_2 : Rule length L, but to be taken not greater than 300 m

I_Y : Net moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis, to be calculated according to Ch 5, Sec 1, [1.5], on gross offered thickness reduced by $0.5t_C$ for all structural members

I_Z : Net moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis, to be calculated according to Ch 5, Sec 1, [1.5], on gross offered thickness reduced by $0.5t_C$ for all structural members

N : Z co-ordinate with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4], in m, of the centre of gravity of the hull net transverse section defined in Ch 5, Sec 1, [1.2], considering gross offered thickness reduced by $0.5t_C$ for all structural members

p_S, p_W : Still water and wave pressure, in kN/m^2, in intact conditions, defined in [2.1.2]

σ_X : Normal stress, in N/mm^2, defined in [2.1.5]

s : Spacing, in m, of primary supporting members

ℓ : Span, in m, of primary supporting members, measured between the supporting members, see Ch 3, Sec 6, [5.3]

h_w : Web height, in mm

t_w : Net web thickness, in mm

b_f : Face plate width, in mm

t_f : Net face plate thickness, in mm

b_p : Width, in m, of the plating attached to the member, for the yielding check, defined in Ch 3, Sec 6, [4.3]

w : Net section modulus, in cm^3, of the member, with an attached plating of width b_p, to be calculated as specified in Ch 3, Sec 6, [4.4]

A_{sh} : Net shear sectional area, in cm^2, of the member, to be calculated as specified in Ch 3, Sec 6, [5.5]

m : Coefficient taken equal to 10

τ_a : Allowable shear stress, in N/mm^2, taken equal to:

$\tau_a = 0.4\ R_Y$

k : Material factor, as defined in Ch 1, Sec 4, [2.2.1]

x, y, z : X, Y and Z co-ordinates, in m, of the evaluation point with respect to the reference co-ordinate system defined in Ch 1, Sec 4

1. General

1.1 Application

1.1.1

The requirements of this Section apply to the strength check of pillars and primary supporting members, subjected to lateral pressure and/or hull girder normal stresses for such members contributing to the hull girder longitudinal strength.

The yielding check is also to be carried out for such members subjected to specific loads.

1.2 Primary supporting members for ships less than 150 m in length *L*

1.2.1

For primary supporting members for ships having a length L less than 150 m, the strength check of such members is to be carried out according to the provisions specified in [2] and [4].

1.2.2

Notwithstanding the above, the strength check of such members may be carried out by a direct strength assessment deemed as appropriate by the Society.

1.3 Primary supporting members for ships of 150 m or more in length *L*

1.3.1

For primary supporting members for ships having a length L of 150 m or more, the direct strength analysis is to be carried out according to the provisions specified in Ch 7, and the requirements in [4] are also to be complied with. In addition, the primary supporting members for **BC-A** and **BC-B** ships are to comply with the requirements in [3].

1.4 Net scantlings

1.4.1

As specified in Ch 3, Sec 2, all scantlings referred to in this Section are net, i.e. they do not include any corrosion addition.

The gross scantlings are obtained as specified in Ch 3, Sec 2, [3].

1.5 Minimum net thicknesses of webs of primary supporting members

1.5.1

The net thickness of the web of primary supporting members, in mm, is to be not less than $0.6\sqrt{L_2}$.

1.6 Flooding check of primary supporting members

1.6.1 General

Flooding check of primary supporting members is to be carried out according to the requirements in [5].

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2. Scantling of primary supporting members for ships of less than 150 m in length *L*

2.1 Load model

2.1.1 General

The still water and wave lateral loads induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the primary supporting members under consideration and the type of the compartments adjacent to it.

The wave lateral loads and hull girder loads are to be calculated, for the probability level of 10^{-8}, in the mutually exclusive load cases H1, H2, F1, F2, R1, R2, P1 and P2, as defined in Ch 4, Sec 4.

2.1.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure (p_S) includes:

a) the hydrostatic pressure, defined in Ch 4, Sec 5, [1]
b) the still water internal pressure, defined in Ch 4, Sec 6 for the various types of cargoes and for ballast.

Wave pressure (p_W) includes for each load case H1, H2, F1, F2, R1, R2, P1 and P2:

c) the hydrodynamic pressure, defined in Ch 4, Sec 5, [1]
d) the inertial pressure, defined in Ch 4, Sec 6 for the various types of cargoes and for ballast.

2.1.3 Elements of the outer shell

The still water and wave lateral pressures are to be calculated considering separately:

- the still water and wave external sea pressures
- the still water and wave internal pressure, considering the compartment adjacent to the outer shell as being loaded

If the compartment adjacent to the outer shell is not intended to carry liquids, only the external sea pressures are to be considered.

2.1.4 Elements other than those of the outer shell

The still water and wave lateral pressures to be considered as acting on an element which separates two adjacent compartments are those obtained considering the two compartments individually loaded.

2.1.5 Normal stresses

The normal stress to be considered for the strength check of primary supporting members contributing to the hull girder longitudinal strength is the maximum value of σ_X between sagging and hogging conditions, when applicable, obtained , in N/mm^2, from the following formula:

$$\sigma_X = \left[C_{SW} \left| \frac{M_{SW}}{I_Y} \right| (z-N) + C_{WV} \left| \frac{M_{WV}}{I_Y} \right| (z-N) - C_{WH} \left| \frac{M_{WH}}{I_Z} \right| y \right] 10^{-3}$$

where:

M_{SW} : Permissible still water bending moments, in kN.m, in hogging or sagging as the case may be

M_{WV} : Vertical wave bending moment, in kN.m, in hogging or sagging as the case may be, as defined in Ch 4, Sec 3

M_{WH} : Horizontal wave bending moment, in kN.m, as defined in Ch 4, Sec 3

C_{SW} : Combination factor for each load case H1, H2, F1, F2, R1, R2, P1 and P2 and defined in the Tab 1

C_{WV}, C_{WH} : Combination factors defined in Ch 4, Sec 4, [2.2] for each load case H1, H2, F1, F2, R1, R2, P1 and P2 and given in the Tab 1

Table 1: Combination factors C_{SW}, C_{WV} and C_{WH}

LC	Hogging			Sagging		
	C_{SW}	C_{WV}	C_{WH}	C_{SW}	C_{WV}	C_{WH}
H1	Not Applicable			-1	-1	0
H2	1	1	0	Not Applicable		
F1	Not Applicable			-1	-1	0
F2	1	1	0	Not Applicable		
R1	1	0	$1.2-\frac{T_{LC}}{T_S}$	-1	0	$1.2-\frac{T_{LC}}{T_S}$
R2	1	0	$\frac{T_{LC}}{T_S}-1.2$	-1	0	$\frac{T_{LC}}{T_S}-1.2$
P1	1	$0.4-\frac{T_{LC}}{T_S}$	0	-1	$0.4-\frac{T_{LC}}{T_S}$	0
P2	1	$\frac{T_{LC}}{T_S}-0.4$	0	-1	$\frac{T_{LC}}{T_S}-0.4$	0

2.2 Center Girders and Side Girders

2.2.1 Net web thickness

The net thickness of girders in double bottom structure, in mm, is not to be less than the greatest of either of the value t_1 to t_3 specified in the followings according to each location:

$$t_1 = C_1 \frac{pS|x-x_c|}{(d_0-d_1)\tau_a}\left\{1-4\left(\frac{y}{B_{DB}}\right)^2\right\}$$ where $|x-x_c|$ is less than $0.25\ell_{DB}$, $|x-x_c|$ is to be taken as $0.25\ell_{DB}$

$$t_2 = 1.75\cdot\sqrt[3]{\frac{H^2a^2\tau_a}{C_1'}t_1}$$

$$t_3 = \frac{C_1''a}{\sqrt{k}}$$

where:

p : Differential pressure given by the following formula in kN/m^2:

$$p = \left|(p_{S,IB}+p_{W,IB})-(p_{S,BM}+p_{W,BM})\right|$$

$p_{S,IB}$: Cargo or ballast pressure of inner bottom plating in still water, in kN/m^2, as calculated at the center of the double bottom structure under consideration, according to Ch 4, Sec 6

$p_{W,IB}$: Cargo or ballast pressure of inner bottom plating due to inertia, in kN/m^2, as calculated at the center of the double bottom structure under consideration, according to Ch 4, Sec 6

$p_{S,BM}$: External sea and ballast pressure of bottom plating in still water, in kN/m^2, as calculated at the center of the double bottom structure under consideration, according to Ch 4, Sec 5 and Ch 4, Sec 6

$p_{W,BM}$: External sea and ballast pressure of bottom plating due to inertia, in kN/m^2, as calculated at the center of the double bottom structure under consideration, according to Ch 4, Sec 5 and Ch 4, Sec 6

S : Distance between the centers of the two spaces adjacent to the center or side girder under consideration, in m

d_0 : Depth of the center or side girder under consideration, in m

d_1 : Depth of the opening, if any, at the point under consideration, in m

ℓ_{DB} : Length of the double bottom, in m. Where stools are provided at transverse bulkheads, ℓ_{DB} may be taken as the distance between the toes.

x_c : X co-ordinate, in m, of the center of double bottom structure under consideration with respect to the reference co-ordinate system defined in Ch 1, Sec 4

B_{DB} : Distance between the toes of hopper tanks at the midship part, in m, see Fig 3

C_1 : Coefficient obtained from Tab 2 depending on B_{DB} / ℓ_{DB}. For intermediate values of B_{DB} / ℓ_{DB}, C_1 is to be obtained by linear interpolation

a : Depth of girders at the point under consideration, in m. However, where horizontal stiffeners are fitted on the girder, a is the distance from the horizontal stiffener under consideration to the bottom shell plating or inner bottom plating, or the distance between the horizontal stiffeners under consideration

S_1 : Spacing, in m, of vertical ordinary stiffeners or floors

C_1' : Coefficient obtained from Tab 3 depending on S_1 / a. For intermediate values of S_1 / a, C_1' is to be determined by linear interpolation

H : Value obtained from the following formulae:

- where the girder is provided with an unreinforced opening : $H = 1 + 0.5\dfrac{\phi}{\alpha}$
- In other cases: $H = 1.0$

ϕ : Major diameter of the openings, in m

α : The greater of a or S_1, in m.

C_1'' : Coefficient obtained from Tab 4 depending on S_1 / a. For intermediate values of S_1 / a, C_1'' is to be obtained by linear interpolation.

Table 2: Coefficient C_1

B_{DB} / ℓ_{DB}	0.4 and under	0.6	0.8	1.0	1.2	1.4	1.6 and over
C_1	0.5	0.71	0.83	0.88	0.95	0.98	1.00

Table 3: Coefficient C_1'

$\frac{S_1}{a}$	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_1'	64	38	25	19	15	12	10	9	8	7

Table 4: Coefficient C_1''

$\frac{S_1}{a}$		0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6 and over
C_1''	Centre girder	4.4	5.4	6.3	7.1	7.7	8.2	8.6	8.9	9.3	9.6	9.7
	Side girder	3.6	4.4	5.1	5.8	6.3	6.7	7.0	7.3	7.6	7.9	8.0

2.3 Floors

2.3.1 Net web thickness

The net thickness of floors in the double bottom structure, in mm, is not to be less than the greatest of values t_1 to t_3 specified in the following according to each location:

$t_1 = C_2 \dfrac{pSB_{DB}}{(d_0 - d_1)\tau_a}\left(\dfrac{2|y|}{B'_{DB}}\right)\left\{1-2\left(\dfrac{x-x_c}{l_{DB}}\right)^2\right\}$, where $|x-x_c|$ is less than $0.25\ell_{DB}$, $|x-x_c|$ is to be taken as $0.25\ell_{DB}$, and where $|y|$ is less than $B'_{DB}/4$, $|y|$ is to be taken as $B'_{DB}/4$,

$$t_2 = 1.75 \cdot \sqrt[3]{\frac{H^2 a^2 \tau_a}{C_2'} t_1}$$

$$t_3 = \frac{8.5 S_2}{\sqrt{k}}$$

where :

S : Spacing of solid floors, in m

d_0 : Depth of the solid floor at the point under consideration in m

d_1 : Depth of the opening, if any, at the point under consideration in m

B'_{DB} : Distance between toes of hopper tanks at the position of the solid floor under consideration, in m

C_2 : Coefficient obtained from Tab 5 depending on B_{DB}/ℓ_{DB}. For intermediate values of B_{DB}/ℓ_{DB}, C_2 is to be obtained by linear interpolation

p, B_{DB}, x_c, ℓ_{DB} : As defined in [2.2.1]

a : Depth of the solid floor at the point under consideration, in m. However, where horizontal stiffeners are fitted on the floor, a is the distance from the horizontal stiffener under consideration to the bottom shell plating or the inner bottom plating or the distance between the horizontal stiffeners under consideration

S_1 : Spacing, in m, of vertical ordinary stiffeners or girders

C_2' : Coefficient given in Tab 6 depending on S_1/d_0. For intermediate values of S_1/d_0, C_2' is to be determined by linear interpolation.

H : Value obtained from the following formulae:

a) where openings with reinforcement or no opening are provided on solid floors:

1) where slots without reinforcement are provided:

$$H = \sqrt{4.0\frac{d_2}{S_1} - 1.0}\text{, without being taken less than 1.0}$$

2) where slots with reinforcement are provided: $H = 1.0$

b) where openings without reinforcement are provided on solid floors:

1) where slots without reinforcement are provided:

$$H = \left(1 + 0.5\frac{\phi}{d_0}\right)\sqrt{4.0\frac{d_2}{S_1} - 1.0}\text{, without being taken less than } 1 + 0.5\frac{\phi}{d_0}$$

2) where slots with reinforcement are provided:

$$H = 1 + 0.5\frac{\phi}{d_0}$$

d_2 : Depth of slots without reinforcement provided at the upper and lower parts of solid floors, in m, whichever is greater

ϕ : Major diameter of the openings, in m

S_2 : The smaller of S_1 or a , in m.

Table 5: Coefficient C_2

$\frac{B_{DB}}{\ell_{DB}}$	0.4 and under	0.6	0.8	1.0	1.2	1.4	1.6 and over
C_2	0.48	0.47	0.45	0.43	0.40	0.37	0.34

Table 6: Coefficient C_2'

S_1 / d_0	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_2'	64	38	25	19	15	12	10	9	8	7

2.4 Stringer of double side structure

2.4.1 Net web thickness

The net thickness of stringers in double side structure, in mm, is not to be less than the greatest of either of the value t_1 to t_3 specified in the followings according to each location:

$$t_1 = C_3\frac{pS|x - x_c|}{(d_0 - d_1)\tau_a}$$, where $|x - x_c|$ is under $0.25\ell_{DS}$, $|x - x_c|$ is to be taken as $0.25\ell_{DS}$

$$t_2 = 1.75\sqrt[3]{\frac{H^2 a^2 \tau_a}{C_3'} t_1}$$

$$t_3 = \frac{8.5S_2}{\sqrt{k}}$$

where :

p : Differential pressure given by the following formula in kN/m^2:

$$p = \left| \left(p_{S,SS} + p_{W,SS} \right) - \left(p_{S,LB} + p_{W,LB} \right) \right|$$

$p_{S,SS}$: External sea and ballast pressure of side shell plating in still water, in kN/m^2, as measured vertically at the upper end of hopper tank, longitudinally at the centre of ℓ_{DS}, according to Ch 4, Sec 5 and Ch 4, Sec 6

$p_{W,SS}$: External sea and ballast pressure of side shell plating due to inertia, in kN/m^2, as measured vertically at the upper end of hopper tank, longitudinally at the centre of ℓ_{DS}, according to Ch 4, Sec 5 and Ch 4, Sec 6

$p_{S,LB}$: Ballast pressure of longitudinal bulkhead in still water, in kN/m^2, as measured vertically at the upper end of hopper tank, longitudinally at the centre of ℓ_{DS}, according to Ch 4, Sec 6

$p_{W,LB}$: Ballast pressure of longitudinal bulkhead due to inertia, in kN/m^2, as measured vertically at the upper end of hopper tank, longitudinally at the centre of ℓ_{DS}, according to Ch 4, Sec 6

S : Breadth of part supported by stringer, in m

d_0 : Depth of stringers, in m

d_1 : Depth of opening, if any, at the point under consideration, in m.

x_c : X co-ordinate, in m, of the center of double side structure under consideration with respect to the reference co-ordinate system defined in Ch 1, Sec 4

ℓ_{DS} : Length of the double side structure between the transverse bulkheads under consideration, in m

h_{DS} : Height of the double side structure between the upper end of hopper tank and the lower end of topside tank, in m

C_3 : Coefficient obtained from Tab 7 depending on h_{DS} / ℓ_{DS}. For intermediate values of h_{DS} / ℓ_{DS}, C_3 is to be obtained by linear interpolation.

a : Depth of stringers at the point under consideration, in m. However, where horizontal stiffeners are fitted on the stringer, a is the distance from the horizontal stiffener under consideration to the side shell plating or the longitudinal bulkhead of double side structure or the distance between the horizontal stiffeners under consideration

S_1 : Spacing, in m, of transverse ordinary stiffeners or web frames

C_3' : Coefficient obtained from Tab 8 depending on S_1 / a. For intermediate values of S_1 / a, C_3' is to be obtained by linear interpolation.

H : Value obtained from the following formulae:

- where the stringer is provided with an unreinforced opening: $H = 1 + 0.5\dfrac{\phi}{\alpha}$
- in other cases: $H = 1.0$

ϕ : Major diameter of the openings, in m

α : The greater of a or S_1, in m

S_2 : The smaller of a or S_1, in m

Table 7: Coefficient C_3

$\frac{h_{DS}}{\ell_{DS}}$	0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_3	0.16	0.23	0.30	0.36	0.41	0.44	0.47	0.50	0.54

Table 8: Coefficient C_3'

$\frac{S_1}{a}$	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_3'	64	38	25	19	15	12	10	9	8	7

2.5 Transverse web in double side structure

2.5.1 Net web thickness

The net thickness of transverse webs in double side structure, in mm, is not to be less than the greatest of either of the value t_1 to t_3 specified in the followings according to each location:

$t_1 = C_4 \dfrac{pSh_{DS}}{(d_0 - d_1)\tau_a}\left(1 - 1.75\dfrac{z - z_{BH}}{h_{DS}}\right)$, where $z - z_{BH}$ is greater than $0.4h_{DS}$, $z - z_{BH}$ is to be taken as $0.4h_{DS}$

$$t_2 = 1.75\sqrt[3]{\frac{H^2 a^2 \tau_a}{C_4'} t_1}$$

$$t_3 = \frac{8.5S_2}{\sqrt{k}}$$

where :

S : Breadth of part supported by transverses, in m

d_0 : Depth of transverses, in m

d_1 : Depth of opening at the point under consideration, in m

C_4 : Coefficient obtained from Tab 9 depending on h_{DS}/ℓ_{DS}. For intermediate values of h_{DS}/ℓ_{DS}, C_4 is to be obtained by linear interpolation

z_{BH} : Z co-ordinates, in m, of the upper end of hopper tank with respect to the reference co-ordinate system defined in Ch 1, Sec 4

p, h_{DS} and ℓ_{DS} : as defined in the requirements of [2.4.1]

a : Depth of transverses at the point under consideration, in m. However, where vertical stiffeners are fitted on the transverse, a is the distance from the vertical stiffener under consideration to the side shell or the longitudinal bulkhead of double side hull or the distance between the vertical stiffeners under consideration.

S_1 : Spacing, in m, of horizontal ordinary stiffeners or stringers

C_4' : Coefficient obtained from Tab 10 depending on S_1/a. For intermediate values of S_1/a, C_4' is to be obtained by linear interpolation.

H : Value obtained from the following formulae :

- where the transverse is provided with an unreinforced opening: $H = 1 + 0.5\dfrac{\phi}{\alpha}$
- in other cases: $H = 1.0$

ϕ : Major diameter of the openings, in m

α : The greater of a or S_1. in m

S_2 : The smaller of a or S_1, in m

Table 9: Coefficient C_4

$\dfrac{h_{DS}}{\ell_{DS}}$	0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_4	0.62	0.61	0.59	0.55	0.52	0.49	0.46	0.43	0.41

Table 10: Coefficient C_4'

$\dfrac{S_1}{a}$	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_4'	64	38	25	19	15	12	10	9	8	7

2.6 Primary supporting member in bilge hopper tanks and topside tanks and other structures

2.6.1 Load calculation point

For horizontal members, the lateral pressure and hull girder stress, if any, are to be calculated at mid-span of the primary supporting members considered, unless otherwise specified.

For vertical members, the lateral pressure p is to be calculated as the maximum between the values obtained at mid-span and the pressure obtained from the following formula:

- $p = \dfrac{p_U + p_L}{2}$, when the upper end of the vertical member is below the lowest zero pressure level
- $p = \dfrac{\ell_1}{\ell}\dfrac{p_L}{2}$, when the upper end of the vertical member is at or above the lowest zero pressure level (see Fig 1)

where:

ℓ_1 : Distance, in m, between the lower end of vertical member and the lowest zero pressure level

p_U, p_L : Lateral pressures at the upper and lower end of the vertical member span ℓ, respectively

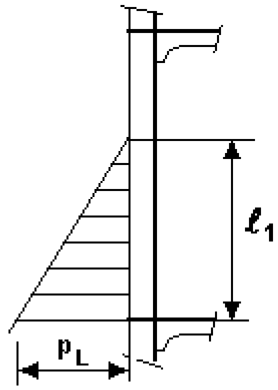


Figure 1: Definition of pressure for vertical members

2.6.2 Boundary conditions

The requirements of this sub-article apply to primary supporting members considered as clamped at both ends. For boundary conditions deviated from the above, the yielding check is to be considered on a case by case basis.

2.6.3 Net section modulus, net shear sectional area and web thickness under intact conditions

The net section modulus w, in cm^3, the net shear sectional area A_{sh}, in cm^2, and the net web thickness t_w, in mm, subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \frac{(p_S + p_W)s\ell^2}{m\lambda_S R_Y}10^3$$

$$A_{sh} = \frac{5(p_S + p_W)s\ell}{\tau_a \sin\phi}$$

$$t_w = 1.75 \cdot \sqrt[3]{\frac{h_w \tau_a}{10^4 C_5} A_{sh}}$$

where:

λ_S : Coefficient defined in Tab 11

ϕ : Angle, in deg, between the primary supporting member web and the shell plate, measured at the middle of the member span; the correction is to be applied when ϕ is less than 75 deg.

C_5 : Coefficient defined in Tab 12 according to s_1 and d_0. For intermediate values of s_1 / d_0, coefficient C_5 is to be obtained by linear interpolation.

s_1 : Spacing of stiffeners or tripping brackets on web plate, in m

d_0 : Spacing of stiffeners parallel to shell plate on web plate, in m

Table 11: Coefficient λ_S

Primary supporting members	Coefficient λ_S
Longitudinal members contributing to the hull girder longitudinal strength	$1.1\left(1.0-0.85\left\|\dfrac{\sigma_X}{R_Y}\right\|\right)$, without being taken greater than 0.8
Other members	0.8

Table 12: Coefficient C_5

s_1/d_0	0.3 and less	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0 and over
C_5	60.0	40.0	26.8	20.0	16.4	14.4	13.0	12.3	11.1	10.2

3. Additional requirements for primary supporting members of BC-A and BC-B ships

3.1 Evaluation of double bottom capacity and allowable hold loading in flooded conditions

3.1.1 Shear capacity of the double bottom

The shear capacity of the double bottom is to be calculated as the sum of the shear strength at each end of:

- all floors adjacent to both hopper tanks, less one half of the shear strength of the two floors adjacent to each stool, or transverse bulkhead if no stool is fitted (see Fig 2); the floor shear strength is to be calculated according to [3.1.2]
- all double bottom girders adjacent to both stools, or transverse bulkheads if no stool is fitted; the girder shear strength is to be calculated according to [3.1.3].

Where in the end holds, girders or floors run out and are not directly attached to the boundary stool or hopper tank girder, their strength is to be evaluated for the one end only.

The floors and girders to be considered in calculating the shear capacity of the double bottom are those inside the hold boundaries formed by the hopper tanks and stools (or transverse bulkheads if no stool is fitted). The hopper tank side girders and the floors directly below the connection of the stools (or transverse bulkheads if no stool is fitted) to the inner bottom may not be included.

When the geometry and/or the structural arrangement of the double bottom is/are such as to make the above assumptions inadequate, the shear capacity of the double bottom is to be calculated by means of direct calculations to be carried out according to the requirements specified in Ch 7, as far as applicable.

3.1.2 Floor shear strength

The floor shear strength, in kN, is to be obtained from the following formulae:

- in way of the floor panel adjacent to the hopper tank:

$$S_{f1} = A_f \frac{\tau_A}{\eta_1} 10^{-3}$$

- in way of the openings in the outermost bay (i.e. that bay which is closer to the hopper tank):

$$S_{f2} = A_{f,h} \frac{\tau_A}{\eta_2} 10^{-3}$$

where:

A_f : Net sectional area, in mm^2, of the floor panel adjacent to the hopper tank

$A_{f,h}$: Net sectional area, in mm^2, of the floor panels in way of the openings in the outermost bay (i.e. that bay which is closer to the hopper tank)

τ_A : Allowable shear stress, in N/mm^2, equal to the lesser of:

$$\tau_A = 0.645 \frac{R_{eH}^{0.6}}{\left(s / t_N\right)^{0.8}} \text{ and } \tau_A = \frac{R_{eH}}{\sqrt{3}}$$

t_N : Floor web net thickness, in mm

s : Spacing, in m, of stiffening members of the panel considered

η_1 : Coefficient to be taken equal to 1.1

η_2 : Coefficient to be taken equal to 1.2. It may be reduced to 1.1 where appropriate reinforcements are fitted in way of the openings in the outermost bay, to be examined by the Society on a case-by-case basis.

3.1.3 Girder shear strength

The girder shear strength, in kN, is to be obtained from the following formulae:

- in way of the girder panel adjacent to the stool (or transverse bulkhead, if no stool is fitted):

$$S_{g1} = A_g \frac{\tau_A}{\eta_1} 10^{-3}$$

- in way of the largest opening in the outermost bay (i.e. that bay which is closer to the stool, or transverse bulk-head, if no stool is fitted):

$$S_{g2} = A_{g,h} \frac{\tau_A}{\eta_2} 10^{-3}$$

A_g : Net sectional area, in mm^2, of the girder panel adjacent to the stool (or transverse bulkhead, if no stool is fitted)

$A_{g,h}$: Net sectional area, in mm^2, of the girder panel in way of the largest opening in the outermost bay (i.e. that bay which is closer to the stool, or transverse bulkhead, if no stool is fitted)

τ_A : Allowable shear stress, in N/mm^2, defined in [3.1.2], where t_N is the girder web net thickness

η_1 : Coefficient to be taken equal to 1.1

η_2 : Coefficient to be taken equal to 1.15. It may be reduced to 1.1 where appropriate reinforcements are fitted in way of the largest opening in the outermost bay, to be examined by the Society on a case-by-case basis.

3.1.4 Allowable hold loading

The allowable hold loading is to be obtained, in t, from the following formula:

$$W = \rho_C V \frac{1}{F}$$

where:

F : Coefficient to be taken equal to:

$F = 1.1$ in general

$F = 1.05$ for steel mill products

V : Volume, in m^3, occupied by cargo at a level h_B

h_B : Level of cargo, in m^2, to be obtained from the following formula:

$$h_B = \frac{X}{\rho_C g}$$

X : Pressure, in kN/m^2, to be obtained from the following formulae:

- for dry bulk cargoes, the lesser of:

$$X = \frac{Z + \rho g(z_F - 0.1D_1 - h_F)}{1 + \frac{\rho}{\rho_C}(perm - 1)}$$

$$X = Z + \rho g(z_F - 0.1D_1 - h_F\, perm)$$

- for steel mill products:

$$X = \frac{Z + \rho g(z_F - 0.1D_1 - h_F)}{1 - \frac{\rho}{\rho_C}}$$

D_1 : Distance, in m, from the base line to the freeboard deck at side amidships

h_F : Inner bottom flooding head is the distance, in m, measured vertically with the ship in the upright position, from the inner bottom to a level located at a distance z_F, in m, from the baseline.

z_F : Flooding level, in m, defined in Ch 4, Sec 6, [3.4.3]

perm : Permeability of cargo, which need not be taken greater than 0.3

Z : Pressure, in kN/m^2, to be taken as the lesser of:

$$Z = \frac{C_H}{A_{DB,H}}$$

$$Z = \frac{C_E}{A_{DB,E}}$$

C_H : Shear capacity of the double bottom, in kN, to be calculated according to [3.1.1], considering, for each floor, the lesser of the shear strengths S_{f1} and S_{f2} (see [3.1.2]) and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} (see [3.1.3])

C_E : Shear capacity of the double bottom, in kN, to be calculated according to [3.1.1], considering, for each floor, the shear strength S_{f1} (see [3.1.2]) and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} (see [3.1.3])

- $$A_{DB,H} = \sum_{i=1}^{n} S_i B_{DB,i}$$

- $A_{DB,E} = \sum_{i=1}^{n} S_i \left(B_{DB} - s\right)$

n : Number of floors between stools (or transverse bulkheads, if no stool is fitted)

S_i : Space of i-th floor, in m

$B_{DB,i}$: Length, in m, to be taken equal to :

$B_{DB,i} = B_{DB} - s$ for floors for which $S_{f1} < S_{f2}$ (see [3.1.2])

$B_{DB,i} = B_{DB,h}$ for floors for which $S_{f1} \geq S_{f2}$ (see [3.1.2])

B_{DB} : Breadth, in m, of double bottom between the hopper tanks (see Fig 3)

$B_{DB,h}$: Distance, in m, between the two openings considered (see Fig 3)

s : Spacing, in m, of inner bottom longitudinal ordinary stiffeners adjacent to the hopper tanks.

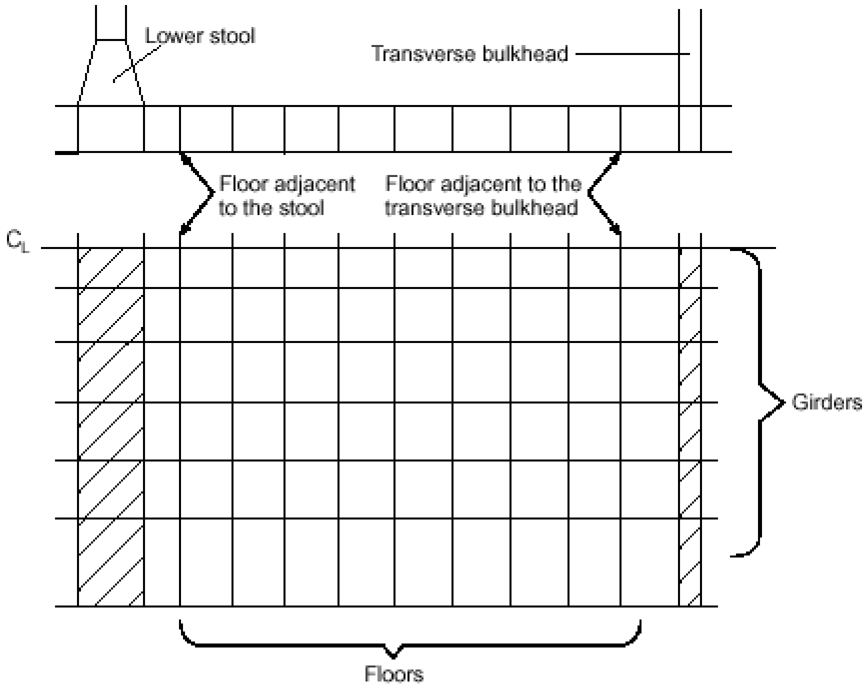


Figure 2: Double bottom structure

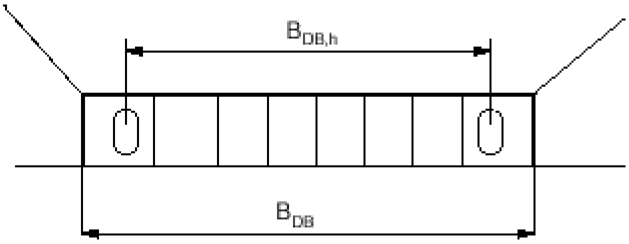


Figure 3: Dimensions B_{DB} and $B_{DB,h}$

4. Pillars

4.1 Buckling of pillars subjected to compressive axial load

4.1.1 General

It is to be checked that the compressive stress of pillars does not exceed the critical column buckling stress calculated according to [4.1.2].

4.1.2 Critical column buckling stress of pillars

The critical column buckling stress of pillars is to be obtained, in N/mm^2, from the following formulae:

$$\sigma_{cB} = \sigma_{E1} \qquad \text{for } \sigma_{E1} \le \frac{R_{eH}}{2}$$

$$\sigma_{cB} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E1}}\right) \qquad \text{for } \sigma_{E1} > \frac{R_{eH}}{2}$$

where:

σ_{E1} : Euler column buckling stress, to be obtained, in N/mm^2, from the following formula:

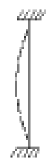
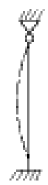
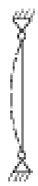
$$\sigma_{E1} = \pi^2 E \frac{I}{A(fl)^2} 10^{-4}$$

I : Minimum net moment of inertia, in cm^4, of the pillar

A : Net cross-sectional area, in cm^2, of the pillar

f : Coefficient to be obtained from Tab 13.

Table 13: Coefficient *f*

Boundary conditions of the pillar	f
Both ends fixed 	0.5
One end fixed, one end pinned 	$\frac{\sqrt{2}}{2}$
Both ends pinned 	1.0

5. Flooding check of primary supporting members

5.1 Net section modulus and net shear sectional area under flooded conditions

5.1.1

The net section modulus w, in cm^3, the net shear sectional area A_{sh}, in cm^2 subjected to flooding are to be not less than the values obtained from the following formulae:

$$w = \frac{p_F s \ell^2}{16 \alpha \lambda_S R_Y} 10^3$$

$$A_{sh} = \frac{5 p_F s \ell}{\alpha \tau_a \sin \phi}$$

Where :

α: Coefficient taken equal to:

- $\alpha = 0.95$ for the primary supporting member of collision bulkhead,
- $\alpha = 1.15$ for the primary supporting member of other watertight boundaries of compartments.

λ_S : Coefficient defined in Ch 6, Sec 4 Table 11, determined by considering σ_X in flooded condition.

p_F : Pressure, in kN/m^2, in flooded conditions, defined in Ch 4, Sec 6, [3.2.1].

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Appendix 1 – BUCKLING & ULTIMATE STRENGTH

1. Application of Ch 6, Sec 3

1.1 General application

1.1.1 Mutable shear stress

If shear stresses are not uniform on the width b of the elementary plate panel, the greater of the two following values is to be used:

- mean value of τ
- $0.5\tau_{max}$

1.1.2 Change of thickness within an elementary plate panel

If the plate thickness of an elementary plate panel varies over the width b, the buckling check may be performed for an equivalent elementary plate panel $a \times b'$ having a thickness equal to the smaller plate thickness t_1.

The width of this equivalent elementary plate panel is defined by the following formula:

$$b' = b_1 + b_2\left(\frac{t_1}{t_2}\right)^{1.5}$$

where:

b_1 : Width of the part of the elementary plate panel with the smaller plate thickness t_1

b_2 : Width of the part of the elementary plate panel with the greater plate thickness t_2

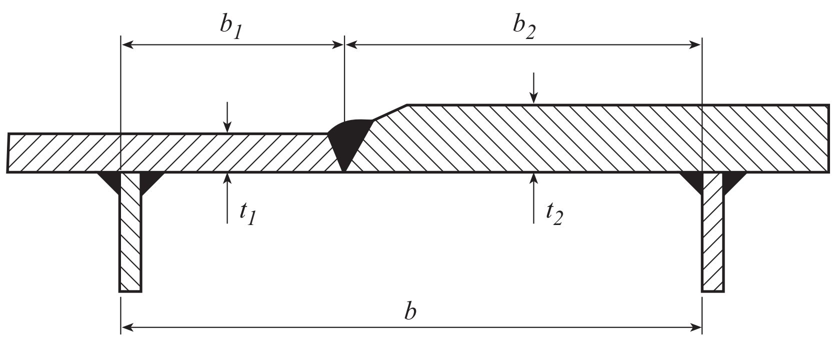


Figure 1: Plate thickness change within the field breath

1.1.3 Evaluation of floors or other high girders with holes

The following procedure may be used to assess high girders with holes:

a) Divide the plate field in sub elementary plate panels according the Fig 2

b) Assess the elementary plate panel and all sub elementary plate panels separately with the following boundary conditions:

- for sub panels 1 to 4: all edges are simply supported (load cases 1 and 2 in Ch 6, Sec 3, Tab 2)
- for sub panels 5 and 6: simply supported, one side free (load case 3 in Ch 6, Sec 3, Tab 2).

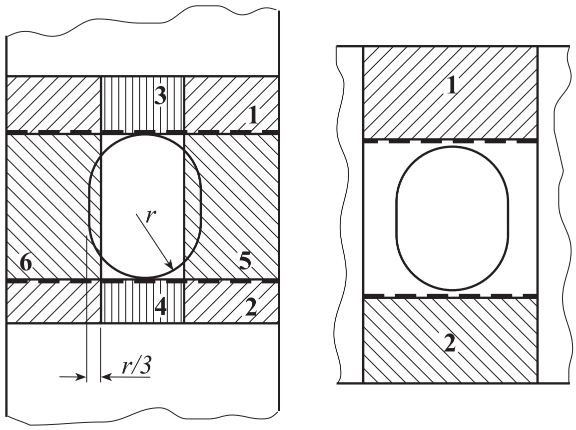


Figure 2: Elementary plate panels of high girder with hole

1.2 Application to hull transverse section analysis

1.2.1 Idealization of elementary plate panels

The buckling check of the elementary plate panel is to be performed under the loads defined in Ch 6, Sec 3, [2.1], according to the requirements of Ch 6, Sec 3, [3].

The determination of the buckling and reduction factors is made according to the Ch 6, Sec 3, Tab 2 for the plane plate panel and Ch 6, Sec 3, Tab 3 for the curved plate panel.

For the determination of the buckling and reduction factors in Ch 6, Sec 3, Tab 2, the following cases are to be used according to the type of stresses and framing system of the plating:

- For the normal compressive stress:
  - Buckling load case 1 for longitudinally framed plating, the membrane stress in *x*-direction σ_x being the normal stress σ_n defined in Ch 6, Sec 3, [2.1.2]
  - Buckling load case 2 for transversely framed plating, the membrane stress in y-direction σ_y being the normal stress σ_n defined in Ch 6, Sec3, [2.1.2], and the values *a* and *b* being exchanged to obtain α value greater than 1 as it is considered in load case 2.
- For the shear stress: Buckling case 5, τ being the shear stress τ_{SF} defined in Ch 6, Sec 3, [2.1.3].

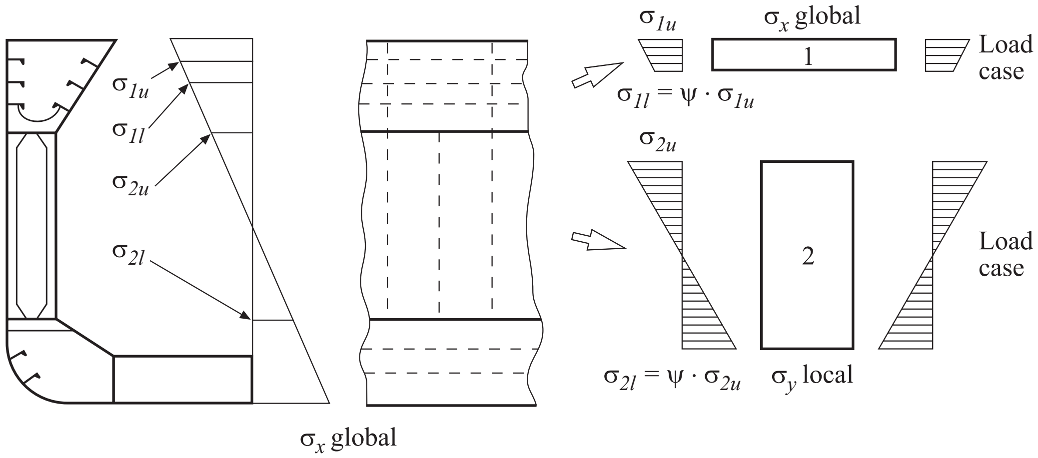


Figure 3: Idealization of elementary plate panels

1.2.2 Ordinary stiffeners

The buckling check of the longitudinal and transverse ordinary stiffeners of partial and total plate panels is to be performed under the loads defined in Ch 6, Sec 3, [2.1], according to Ch 6, Sec 3, [4] with:

- σ_x = normal stress σ_n defined in Ch 6 Sec 3 [2.1.2]
- $\sigma_y = 0$

The effective width of the attached plating of the stiffeners is to be determined in accordance with Ch 6, Sec 3 [5]. A constant stress is to be assumed corresponding to the greater of the following values:

- stress at half length of the stiffener
- 0.5 of the maximum compressive stress of adjacent elementary plate panels

1.2.3 Primary supporting members with stiffeners in parallel

The effective width of the attached plating of the primary supporting members is to be determined in accordance with Ch 6, Sec 3, [5.2].

In addition, when ordinary stiffeners are fitted on the attached plate and parallel to a primary supporting member, the buckling check is to consider a moment of inertia I_x taking account the moments of inertia of the parallel ordinary stiffeners connected to its attached plate (see Ch 6, Sec 3, Fig 3).

1.2.4 Primary supporting members with stiffener perpendicular to girder

The effective width of the attached plating of the primary supporting members is to be determined in accordance with Ch 6, Sec 3, [5.2].

In addition, when ordinary stiffeners are fitted on the attached plate and perpendicular to a primary supporting member, the buckling check is to consider a moment of inertia I_x taking account the effective width according to (see Ch 6, Sec 3, Fig. 4).

1.3 Additional application to FEM analysis

1.3.1 Non uniform compressive stresses along the length of the buckling panel

If compressive stresses are not uniform over the length of the unloaded plate edge (e.g. in case of girders subjected to bending), the compressive stress value is to be taken at a distance of $b/2$ from the transverse plate edge having the largest compressive stress (see Fig 4). This value is not to be less than the average value of the compressive stress along the longitudinal edge.

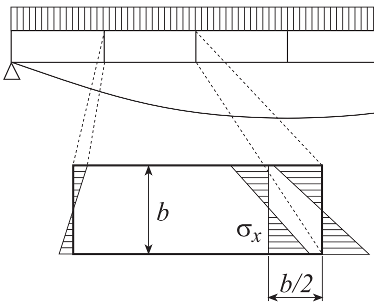
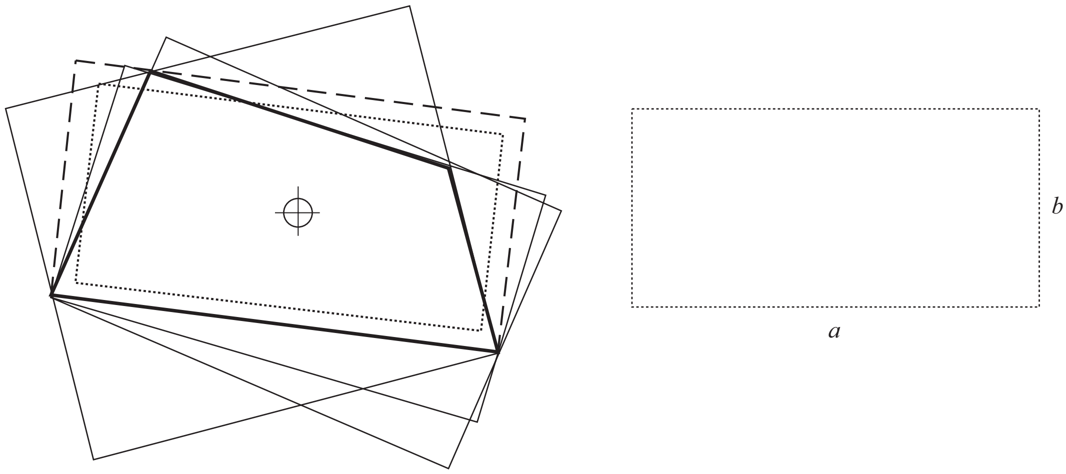


Figure 4: Non uniform compressive stress along longitudinal edge *a*

1.3.2 Buckling stress calculation of non rectangular elementary plate panels

a) Quadrilateral panels

According to Fig 5, rectangles that completely surround the irregular buckling panel are searched. Among several possibilities the rectangle with the smallest area is taken. This rectangle is shrunk to the area of the original panel, where the aspect ratio and the centre are maintained. This leads to the final rectangular panel with the dimensions a, b.



Original irregular panel ( )

Intermediate rectangles ( )

Rectangle with smallest area ( )

Final rectangle ( )

Figure 5: Approximation of non rectangular elementary plate panels

b) Trapezoidal elementary plate panel

A rectangle is derived with *a* being the mean value of the bases and *b* being the height of the original panel.

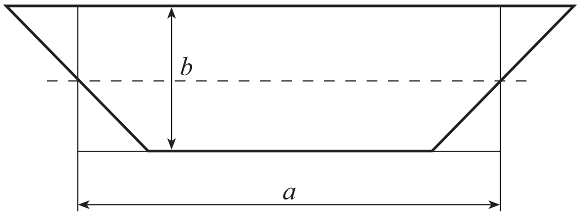


Figure 6: Approximation of trapezoidal elementary plate panel

c) Right triangle

The legs of the right triangle are reduced by $\sqrt{0.5}$ to obtain a rectangle of same area and aspect ratio.

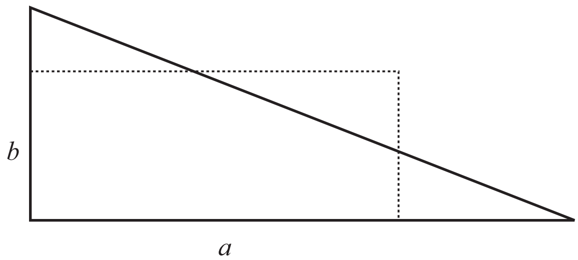


Figure 7: Approximation of right triangle

d) General triangle

General triangle is treated according to a) above.

1.3.3 Buckling assessment of side shell plates

In order to assess the buckling criteria for vertically stiffened side shell plating, the following cases have to be considered:

In case vertical and shear stresses are approximately constant over the height of the elementary plate panel:

- Buckling load cases 1, 2 and 5, according to Ch 6, Sec 3, Tab 2 are to be considered
- $\psi = f(\sigma_1, \sigma_2)$ for horizontal stresses
- $\psi = 1.0$ for vertical stresses
- $t = t_{min}$ (Elementary plate panel)

In case of distributed horizontal, vertical and shear stresses over the height of the elementary plate panel, the following stress situations are to be considered separately:

a) Pure vertical stress

- The size of buckling field to be considered is *b* times *b* ($\alpha = 1$)
- $\psi = 1.0$
- The maximum vertical stress in the elementary plate panel is to be considered in applying the criteria

b) Shear stress associated to vertical stress

- The size of buckling field to be considered is $2b$ times b ($\alpha = 2$)
- $\psi = 1.0$
- The following two stress combinations are to be considered:
  - The maximum vertical stress in the elementary plate panel plus the shear stress and longitudinal stress at the location where maximum vertical stress occurs
  - The maximum shear stress in the elementary plate panel plus the vertical stress and longitudinal stress at the location where maximum shear stress occurs
- The plate thickness t to be considered is the one at the location where the maximum vertical/shear stress occurs

c) Distributed longitudinal stress associated with vertical and shear stress

- The actual size of the elementary plate panel is to be used ($\alpha = f(a,b)$).
- The actual edge factor ψ for longitudinal stress is to be used
- The average values for vertical stress and shear stress are to be used.
- $t = t_{min}$ (Elementary plate panel)

1.3.4 Buckling assessment of corrugated bulkheads

The transverse elementary plate panel (face plate) is to be assesed using the normal stress parallel to the corrugation. The slanted elementary plate panel (web plate) is to be assessed using the combination of normal and shear stresses.

The plate panel breadth b is to be measured according to Fig 8.

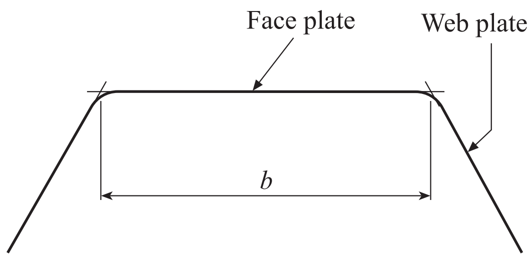


Figure 8: Measuring *b* of corrugated bulkheads

a) Face plate assessment

- The buckling load case 1, according to Ch 6, Sec 3, Tab 2, is to be used
- The size of the buckling field to be considered is b times b ($\alpha = 1$)
- $\psi = 1.0$
- The maximum vertical stress in the elementary plate panel is to be considered in applying the criteria
- The plate thickness t to be considered is the one at the location where the maximum vertical stress occurs

b) Web plate assessment

- The buckling load cases 1 and 5, according to Ch 6, Sec 3, Tab 2, are to be used.
- The size of the buckling field to be considered is 2*b* times *b* ($\alpha = 2$)
- $\psi = 1.0$
- The following two stress combinations are to be considered:
  - The maximum vertical stress in the elementary plate panel plus the shear stress and longitudinal stress at the location where maximum vertical stress occurs
  - The maximum shear stress in the elementary plate panel plus the vertical stress and longitudinal stress at the location where maximum shear stress occurs
- The plate thickness *t* to be considered is the one at the location where the maximum vertical/shear stress occurs.

Common Structural Rules for Bulk Carriers

Chapters 7 to 13

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Lloyd's Register

Chapter 7

Direct Strength Analysis

Section 1 – DIRECT STRENGTH ASSESSMENT OF THE PRIMARY SUPPORTING MEMBERS

1. General

1.1 Application

1.1.1

Direct strength assessment of primary supporting members based on a three-dimensional (3D) finite element (FE) analysis is to be applied to ships having length L of 150 m or above.

1.1.2

Three kinds of FE analysis procedures are specified in this Chapter:

a) global strength FE analysis (first FE analysis step) to assess global strength of primary supporting members of the cargo hold structure, according to Sec 2.
b) detailed stress assessment (second FE analysis step) to assess highly stressed areas with refined meshes, according to Sec 3
c) hot spot stress analysis (third FE analysis step) to calculate hot spot stresses at stress concentration points with very fine meshes for fatigue strength assessment, according to Sec 4.

A flowchart of FE analysis procedure for direct strength assessment is shown in Fig 1.

1.2 Computer program

1.2.1

Computer programs for FE analysis are to be suitable for the intended analysis. Reliability of unrecognized programs is to be demonstrated to the satisfaction of the Society prior to the commencement of the analysis.

1.3 Submission of analysis report

1.3.1

A detailed report of direct strength FE analysis is to be submitted, including background information of the analysis. This report is to include the following items:

a) list of drawings/plans used in the analysis, including their versions and dates
b) detailed description of structural modeling principles and any deviations in the model from the actual structures
c) plots of structural model
d) material properties, plate thickness and beam properties used in the model
e) details of boundary conditions
f) all loading conditions analyzed
g) data for loads application
h) summaries and plots of calculated deflections
i) summaries and plots of calculated stresses

j) details of buckling strength assessment

k) tabulated results showing compliance with the design criteria

l) reference of the finite element computer program, including its version and date.

1.4 Net scantling

1.4.1

Direct strength analysis is to be based on the net scantling approach according to Ch 3, Sec 2.

1.5 Applied loads

1.5.1 Design loads

Direct strength analysis is to be carried out by applying design loads given in Ch 4 at a probability level of 10^{-8}, except for fatigue strength assessment where probability level is 10^{-4}. Combination of static and dynamic loads which are likely to impose the most severe load regime are to be applied to the 3D FE model.

1.5.2 Structural weight

Effect of the hull structure weight is to be included in static loads, but is not to be included in dynamic loads. Standard density of steel is to be taken as 7.85 t/m^3.

1.5.3 Loading conditions

The loading conditions specified in Ch 4, Sec 7 are to be considered in 3D FE analysis.

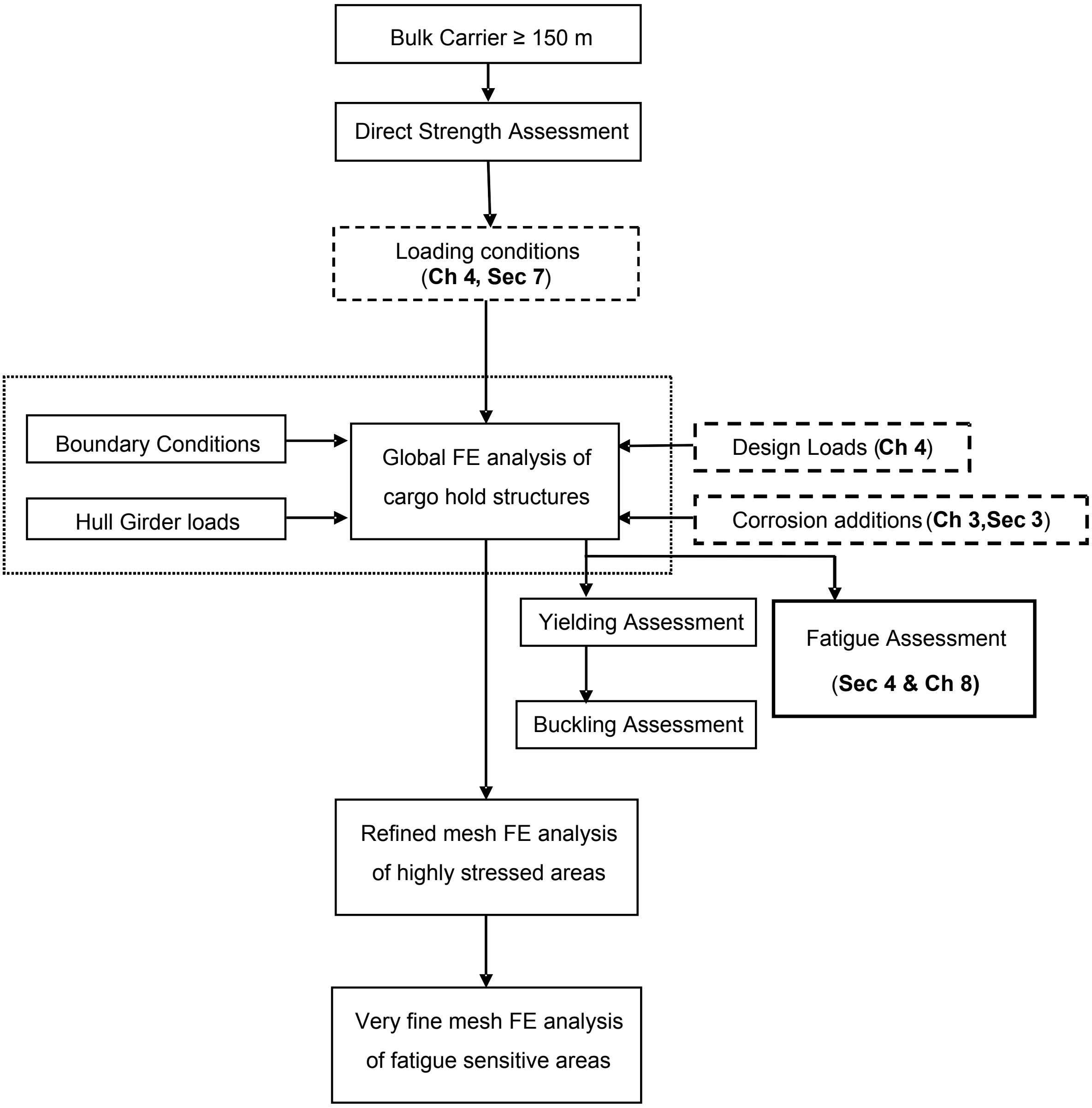

Figure 1: Flowchart of FE analysis procedure

Section 2 – GLOBAL STRENGTH FE ANALYSIS OF CARGO HOLD STRUCTURES

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

M_{SW} : Design vertical bending moment as defined in Ch 4, Sec 7, Tab 2.

M_{WV} : Vertical wave bending moment, in hogging or sagging condition, as defined in Ch 4, Sec 3, [3.1.1]

M_{WH} : Horizontal wave bending moment, as defined in Ch 4, Sec 3, [3.3.1]

Q_{SW} : Allowable still water shear force at the considered bulkhead position as provided in Ch 4, Sec 7, Tab 3

Q_{WV} : Vertical wave shear force as defined in Ch 4, Sec 3, [3.2.1]

C_{WV} , C_{WH} : Load combination factors, as defined in Ch 4, Sec 4, Tab 3.

1. General

1.1 Application

1.1.1

The procedure given in this Section focuses on direct strength analysis of cargo hold structures in midship area.

1.1.2

The global strength FE analysis of cargo hold structures is intended to verify that the following are within the acceptance criteria under the applied static and dynamic loads:

a) stress level in the hull girder and primary supporting members
b) buckling capability of primary supporting members
c) deflection of primary supporting members.

2. Analysis model

2.1 Extent of model

2.1.1

The longitudinal extent of FE model is to cover three cargo holds and four transverse bulkheads. The transverse bulkheads at the ends of the model extent are to be included, together with their associated stools. Both ends of the model are to form vertical planes and to include any transverse web frames on the planes if any. The details of the extent of the model are given in App 1.

2.1.2

FE model is to include both sides of ship structures considering unsymmetrical wave-induced loads in the transverse direction.

2.1.3

All main structural members are to be represented in FE model. These include inner and outer shell, floor and girder system in double bottom, transverse and vertical web frames, stringers, transverse and longitudinal bulkhead structures. All plates and stiffeners on these structural members are to be modelled.

2.2 Finite element modeling

2.2.1

All main structural members (plates and stiffeners) detailed in [2.1.3] are to be represented in FE model.

2.2.2

Mesh boundaries of finite elements are to simulate the stiffening systems on the actual structures as far as practical and are to represent the correct geometry of the panels between stiffeners.

2.2.3

Stiffness of each structural member is to be represented correctly by using proper element type for the structural member. The principle for selection of element type is given below.

(1) Stiffeners are to be modeled by beam or bar element having axial, torsional, bi-directional shear and bending stiffness. However, web stiffeners and face plates of primary supporting members may be modeled by rod element having only axial stiffness and a constant cross-sectional area along its length.

(2) Plates are to be modeled by shell element having out-of-plane bending stiffness in addition to bi-axial and in-plane stiffness. However, membrane element having only bi-axial and in-plane stiffness can be used for plates that are not subject to lateral pressures.

For membrane and shell elements, only linear quad or triangle elements, as shown in Fig 1, are to be adopted.

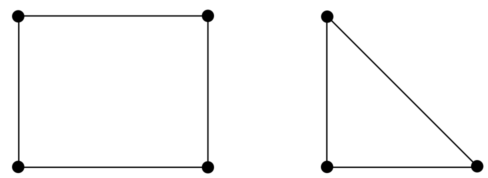

Figure 1: Linear membrane and shell quad and triangle elements

Triangle elements are to be avoided as far as possible, especially in highly stressed areas and in such areas around openings, at bracket connections and at hopper connections where significant stress gradient should be predicted.

(3) Stiffened panels may be modeled by two-dimensional (2D) orthotropic elements that can represent the stiffness of the panels properly.

2.2.4

When orthotropic elements are not used in FE model:

- mesh size is to be equal to or less than the representative spacing of longitudinal stiffeners or transverse side frames
- stiffeners are to be modeled by using rod and/or beam/bar elements

- webs of primary supporting members are to be divided by at least three elements height-wise. However, for transverse primary supporting members inside hopper tank and top side tank, which are less in height than the space between ordinary longitudinal stiffeners, two elements on the height of supporting primary members are accepted.

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- side shell frames and their end brackets are to be modeled by using shell elements for web and shell/beam/rod elements for face plate. Webs of side shell frames need not be divided along the direction of depth

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- aspect ratio of elements is not to exceed 1:4.

An example of typical mesh is given in App 1.

2.2.5

When orthotropic elements are used in FE model for stiffened panels:

- for the members such as the double bottom girder or floor, the element height is to be the double bottom height.
- where a stiffener is located along the edge between two orthotropic elements, either it is to be modelled by using beam/rod element, or it is virtually modelled by reporting the stiffness of the stiffener onto the two orthotropic elements
- where a stiffener is located along the edge between an orthotropic element and a membrane/shell element, it is to be modelled by using beam/rod element
- where a stiffener is located along the edge between two membrane/shell elements, it is to be modelled by using beam/rod element
- where a double hull is fitted, the web of the primary supporting members is to be modelled with one element on its height
- where no double hull construction is fitted, at least one over three frame and its associated end brackets are to be modelled by using shell elements for the webs and shell/beam elements for the flanges
- the aspect ratio of the elements is not to exceed 1:2.

2.3 Boundary conditions

2.3.1

Both ends of the model are to be simply supported according to Tab 1 and Tab 2. The nodes on the longitudinal members at both end sections are to be rigidly linked to independent points at the neutral axis on the centreline as shown in Tab 1. The independent points of both ends are to be fixed as shown in Tab 2.

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Table 1: Rigid-link of both ends

Nodes on longitudinal members at both ends of the model	Translational			Rotational		
	Dx	Dy	Dz	Rx	Ry	Rz
All longitudinal members	RL	RL	RL	-	-	-
RL means rigidly linked to the relevant degrees of freedom of the independent point						

Table 2: Support condition of the independent point

Location of the independent point	Translational			Rotational		
	Dx	Dy	Dz	Rx	Ry	Rz
Independent point on aft end of model	-	Fix	Fix	Fix	-	-
Independent point on fore end of model	Fix	Fix	Fix	Fix	-	-

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2.4 Loading conditions

2.4.1 General

The loading conditions, combined with loading patterns and load cases, as illustrated in Ch 4, App 2, are to be considered as mandatory conditions for the conventional designs.

2.5 Consideration of hull girder loads

2.5.1 General

Each loading condition is to be associated with its corresponding hull girder loads. The load combination is to be considered using Load Combination Factors (LCFs) of the wave-induced vertical and horizontal bending moments and of the wave-induced vertical shear forces specified in Ch 4, Sec 4 for each Load Case.

2.5.2 Vertical bending moment analysis

Vertical bending moment analysis is to be performed for cases listed in Ch 4, Sec 7, Tab 2, the minimum required cases being listed in Ch 4, App 2.

In vertical bending moment analysis the target hull girder loads are the maximum vertical bending moments which may occur at the centre of the mid-hold in the FE model. The target values of hull girder loads are to be obtained in accordance with Tab 3 with considering still water vertical bending moments specified in Ch 4, Sec 7, Tab 2, and in Ch 4, App 2.

Table 3: Target loads for vertical bending moment analysis

Hull girder effect	Still water	Wave	Considered Location
Vertical bending moment	M_{SW}	$C_{WV}\,M_{WV}$	Centre of mid-hold
Vertical shear force	0	0	Centre of mid-hold
Horizontal bending moment	---	$C_{WH}\,M_{WH}$	Centre of mid-hold
Horizontal shear force	---	0	Centre of mid-hold

2.5.3 Vertical shear force analysis

Vertical shear force analysis is to be performed for cases listed in Ch 4, Sec 7, Tab 3, the minimum required cases being listed in Ch 4, App 2.

In vertical shear force analysis the target hull girder loads are the maximum vertical shear force which may occur at one of the transverse bulkheads of the mid-hold in the FE model. Reduced vertical bending moments are considered simultaneously. The target values of hull girder loads are to be obtained in accordance with Tab 4 with considering still water vertical bending moments and shear forces specified in Ch 4, Sec 7, Tab 2 and Ch 4, Sec 7, Tab 3, and in Ch 4, App 2.

Table 4: Target loads for vertical shear force analysis

Hull girder effect	Still water	Wave	Location
Vertical bending moment	$0.8M_{SW}$	$0.65\ C_{WV}\ M_{WV}$	Transverse bulkhead
Vertical shear force	Q_{SW}	Q_{WV}	Transverse bulkhead
Horizontal bending moment	---	0	Transverse bulkhead
Horizontal shear force	---	0	Transverse bulkhead

2.5.4 Influence of local loads

The distribution of hull girder shear force and bending moment induced by local loads applied on the model are calculated using a simple beam theory for the hull girder.

Reaction forces at both ends of the model and distributions of shearing forces and bending moments induced by local loads can be determined by following formulae:

$$R_{V\_fore} = -\frac{\sum_i (x_i - x_{aft})\vec{f}_i \cdot \vec{z}}{x_{fore} - x_{aft}} \qquad R_{V\_aft} = \sum_i \vec{f}_i \cdot \vec{z} + R_{V\_fore}$$

$$R_{H\_fore} = \frac{\sum_i (x_i - x_{aft})\vec{f}_i \cdot \vec{y}}{x_{fore} - x_{aft}} \qquad R_{H\_aft} = -\sum_i \vec{f}_i \cdot \vec{y} + R_{H\_fore}$$

$$Q_{V\_FEM}(x) = R_{V\_aft} - \sum_i \vec{f}_i \cdot \vec{z} \qquad \text{when } x_i < x$$

$$Q_{H\_FEM}(x) = R_{H\_aft} + \sum_i \vec{f}_i \cdot \vec{y} \qquad \text{when } x_i < x$$

$$M_{V\_FEM}(x) = (x - x_{aft})R_{V\_aft} - \sum_i (x - x_i)\vec{f}_i \cdot \vec{z} \qquad \text{when } x_i < x$$

$$M_{H\_FEM}(x) = (x - x_{aft})R_{H\_aft} + \sum_i (x - x_i)\vec{f}_i \cdot \vec{y} \qquad \text{when } x_i < x$$

where:

x_{aft} : Location of the aft end support,

x_{fore} : Location of the fore end support,

x : Considered location,

R_{V_aft}, R_{V_fore}, R_{H_aft} and R_{H_fore} : Vertical and horizontal reaction forces at the fore and aft ends

Q_{V_FEM}, Q_{H_FEM}, M_{V_FEM} and M_{H_FEM} : Vertical and horizontal shear forces and bending moments created by the local loads applied on the FE model. Sign of Q_{V_FEM}, M_{V_FEM} and M_{H_FEM} is in accordance with the sign convention defined in Ch 4, Sec 3. The sign convention for reaction forces is that a positive creates a positive shear force.

$\vec{f}_i$: Applied force on node i due to all local loads,

x_i : Longitudinal coordinate of node *i*.

2.5.5 Methods to account for hull girder loads

For bending moment analysis, two alternative methods can be used to consider the hull girder loads/stresses in the assessment of the primary supporting members:

a) to add the hull girder loads directly to FE model (direct method), or

b) to superimpose the hull girder stresses separately onto the stresses obtained from the structural analysis using the lateral loads (superimposition method).

For shear force analysis, the "direct method" is to be used.

2.5.6 Direct method

In direct method the effect of hull girder loads are directly considered in 3D FE model. The equilibrium loads are to be applied at both model ends in order to consider the hull girder loads as specified in [2.5.2] and [2.5.3] and influence of local loads as specified in [2.5.4].

In order to control the shear force at the target locations, two sets of enforced moments are applied at both ends of the model. These moments are calculated by following formulae:

$$M_{Y\_aft\_SF} = M_{Y\_fore\_SF} = \frac{(x_{fore} - x_{aft})}{2}\left[Q_{V\_T}(x_{eq}) - Q_{V\_FEM}(x_{eq})\right]$$

$$M_{Z\_aft\_SF} = M_{Z\_fore\_SF} = \frac{(x_{fore} - x_{aft})}{2}\left[Q_{H\_T}(x_{eq}) - Q_{H\_FEM}(x_{eq})\right]$$

In order to control the bending moments at the target locations, another two sets of enforced moments are applied at both ends of the model. These moments are calculated by following formulae:

$$M_{Y\_aft\_BM} = -M_{Y\_fore\_BM} = -\left[M_{V\_T}(x_{eq}) - M_{V\_FEM}(x_{eq}) - M_{Y\_aft\_SF}\left(2\frac{x_{eq} - x_{aft}}{x_{fore} - x_{aft}} - 1\right)\right]$$

$$M_{Z\_aft\_BM} = -M_{Z\_fore\_BM} = -\left[M_{H\_T}(x_{eq}) - M_{H\_FEM}(x_{eq}) - M_{Z\_aft\_SF}\left(2\frac{x_{eq} - x_{aft}}{x_{fore} - x_{aft}} - 1\right)\right]$$

where:

x_{eq} : Considered location for the hull girder loads evaluation,

Q_{V_FEM}, Q_{H_FEM}, M_{V_FEM}, M_{H_FEM} : As defined in [2.5.4]

Q_{V_T}, Q_{H_T}, M_{V_T}, M_{H_T} : Target vertical and horizontal shear forces and bending moments, defined in Tab 3 or Tab 4, at the location x_{eq}. Sign of Q_{V_T}, M_{V_T} and M_{H_T} is in accordance with sign convention defined in Ch 4, Sec 3.

$M_{Y\_aft\_SF}$, $M_{Y\_fore\_SF}$, $M_{Y\_aft\_BM}$, $M_{Y\_fore\_BM}$: Enforced moments to apply at the aft and fore ends for vertical shear force and bending moment control, positive for clockwise around *y*-axis. The sign convention for $M_{Y\_aft\_SF}$, $M_{Y\_fore\_SF}$, $M_{Y\_aft\_BM}$ and $M_{Y\_fore\_BM}$ is that of the FE model axis. The sign convention for other bending moment, shear forces and reaction forces is in accordance with the sign convention defined in Ch 4, Sec 3.

$M_{Z\_aft\_SF}$, $M_{Z\_fore\_SF}$, $M_{Z\_aft\_BM}$, $M_{Z\_fore\_BM}$: Enforced moments to apply at the aft and fore ends for horizontal shear force and bending moment control, positive for clockwise around *z*-axis. The sign convention for $M_{Z\_aft\_SF}$, $M_{Z\_fore\_SF}$, $M_{Z\_aft\_BM}$ and $M_{Z\_fore\_BM}$ is that of the FE model axis. The sign

convention for other bending moment, shear forces and reaction forces is in accordance with the sign convention defined in Ch 4, Sec 3.

The enforced moments at the model ends can be generated by one of the following methods:

- to apply distributed forces at the end section of the model, with a resulting force equal to zero and a resulting moment equal to the enforced moment. The distributed forces are applied to the nodes on the longitudinal members where boundary conditions are given according to Tab 1. The distributed forces are to be determined by using the thin wall beam theory
- to apply concentrated moments at the independent points defined in [2.3.1].

2.5.7 Superimposition method

For vertical bending moment analysis in the superimposition method, the stress obtained from the following formula is to be superimposed to the longitudinal stress of each element in longitudinal members obtained from 3D FE analysis. Vertical shear force analyses are to be in accordance with [2.5.6].

$$\sigma_{SIM} = \frac{M_{V\_T}}{I_Y/(z-N)} - \frac{M_{H\_T}}{I_Z/y}$$

where

M_{V_T}, M_{H_T} : Target vertical and horizontal bending moments at considering section, respectively, with corrections due to local loads, taken equal to:

$$M_{V\_T} = M_{SW} + C_{WV} \cdot M_{WV} - M_{V\_FEM}$$

$$M_{H\_T} = C_{WH} \cdot M_{WH} - M_{H\_FEM}$$

I_Y : Vertical inertia of the section around horizontal neutral axis, calculated according to Ch 3, Sec 2, [3.2.1]

I_Z : Horizontal inertia of the section, calculated according to Ch 3, Sec 2, [3.2.1]

N : Z co-ordinate of the centre of gravity of the hull transverse section, as defined in Ch 5, Sec 1

y : Y co-ordinate of the element

z : Z co-ordinate of the element.

3. Analysis criteria

3.1 General

3.1.1 Assessment holds

All the primary supporting members in the mid-hold of the three-hold (1+1+1) FE model, including bulkheads, are to be evaluated in 3D FE analysis.

3.1.2

The results of the structural analysis are to satisfy the criteria for yielding strength, buckling strength and deflection of primary members.

3.2 Yielding strength assessment

3.2.1 Reference stresses

Reference stress is Von Mises equivalent stress at the centre of a plane element (shell or membrane) or axial stress of a line element (bar, beam or rod) obtained by FE analysis through considering hull girder loads according to [2.5.4] or [2.5.5].

Where the effects of openings are not considered in the FE model, the reference stresses in way of the openings are to be properly modified with adjusting shear stresses in proportion to the ratio of web height and opening height.

Where elements under assessment are smaller than the standard mesh size specified in [2.2.4] or [2.2.5], the reference stress may be obtained from the averaged stress over the elements within the standard mesh size.

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3.2.2 Equivalent stress

Von Mises equivalent stress is given by the following formula:

$$\sigma_{eq} = \sqrt{\sigma_x{}^2 - \sigma_x \sigma_y + \sigma_y{}^2 + 3\tau_{xy}{}^2}$$

σ_x, σ_y : Element normal stresses, in N/mm^2

τ_{xy} : Element shear stress, in N/mm^2

In superimposition method, the stress σ_{SIM} , defined in [2.5.7], is to be superimposed onto to longitudinal stress component.

3.2.3 Allowable stress

The reference stresses in FE model that does not include orthotropic elements, as specified in [2.2.4], are not to exceed 235/*k* N/mm^2, where *k* is the material factor defined in Ch 3, Sec 1.

The reference stresses in FE model that includes orthotropic elements, as specified in [2.2.5], are not to exceed 205/*k* N/mm^2, where *k* is the material factor defined in Ch 3, Sec 1.

3.3 Buckling and ultimate strength assessment

3.3.1 General

Buckling and ultimate strength assessment is to be performed for the panels on primary supporting members according to Ch 6, Sec 3.

3.3.2 Stresses of panel

The stresses in each panel are to be obtained according to the following procedures:

1) when the mesh model differs from the elementary plate panel geometry, the stresses σ_x.,σ_y and τ acting on an elementary plate panel are to be evaluated by extrapolation and/or interpolation of surrounding meshes using the elements stresses or using the displacement based method described in App 2.
2) stresses obtained from with superimposed or direct method have to be reduced for buckling assessment because of the Poisson effect, which is taken into consideration in both analysis methods. The correction has to be carried out after summation of stresses due to local and global loads.

When the stresses σ_x^* and σ_y^* are both compressive stresses, a stress reduction is to be made according to the following formulae:

$\sigma_x = (\sigma_x^* - 0.3\sigma_y^*) / 0.91$

$\sigma_y = (\sigma_y^* - 0.3\sigma_x^*) / 0.91$

Where compressive stress fulfils the condition $\sigma_y^* < 0.3\sigma_x^*$, then $\sigma_y = 0$ and $\sigma_x = \sigma_x^*$

Where compressive stress fulfils the condition $\sigma_x^* < 0.3\sigma_y^*$, then $\sigma_x = 0$ and $\sigma_y = \sigma_y^*$

σ_x^*, σ_y^* : Stresses containing the Poisson effect

3) determine stress distributions along edges of the considered buckling panel by introducing proper linear approximation as shown in Fig 2.
4) calculate edge factor ψ according to Ch 6, Sec 3.

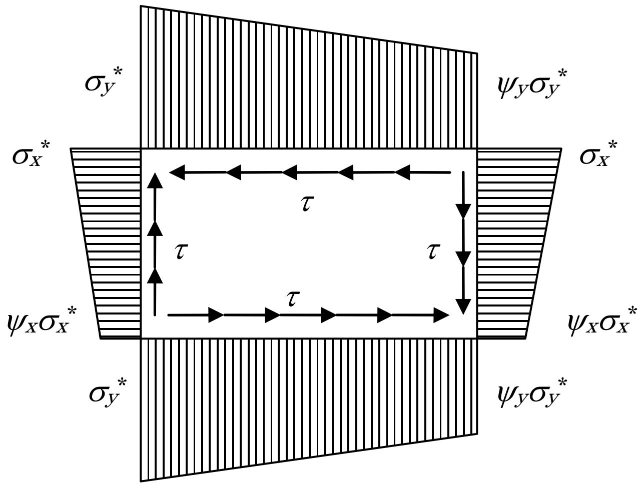

Figure 2: Stresses of panel for buckling assessment

3.3.3 Boundary conditions

Buckling load cases 1, 2, 5 or 6 of Ch 6, Sec 3, Tab 2 are to be applied to the buckling panel under evaluation, depending on the stress distribution and geometry of openings.

If the actual boundary conditions are significantly different from simple support condition, another case in Ch 6, Sec 3, Tab 2 can be applied.

3.3.4 Safety factor

The safety factor for the buckling and ultimate strength assessment of the plate is to be taken equal to 1.0.

3.4 Deflection of primary supporting members

The relative deflection, δ_{max}, in mm, in the outer bottom plate obtained by FEA is not to exceed the following criteria: *RCN 1 to July 2008 version (effective from 1 July 2009)*

$$\delta_{max} \le \frac{\ell_i}{150}$$

where:

δ_{max} : Maximum relative deflection, in mm, obtained by the following formula, and not including secondary deflection

$$\delta_{\max} = \max(|\delta_{B1}|, |\delta_{B2}|)$$

where, δ_{B1} and δ_{B2} are shown in Fig 3.

ℓ_i : Length or breadth of the flat part of the double bottom, in mm, whichever is the shorter.

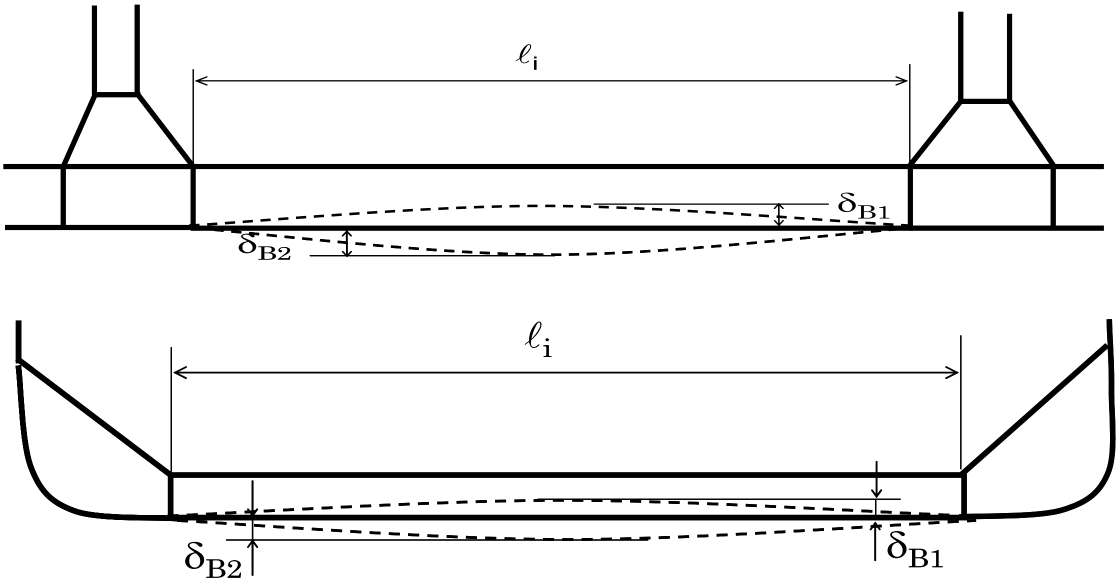

Figure 3: Definition of relative deflection

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Section 3 – DETAILED STRESS ASSESSMENT

1. General

1.1 Application

1.1.1

This Section describes the procedure for the detailed stress assessment with refined meshes to evaluate highly stressed areas of primary supporting members.

Where the global cargo hold analysis of Sec 2 is carried out using a model complying with the modeling criteria of Sec 2, [2.2.4], the areas listed in Tab 1 are to be refined at the locations whose calculated stresses exceed 95% for non-orthotropic elements or 85% for orthotropic element but do not exceed 100% of the allowable stress as specified in Sec 2, [3.2.3].

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2. Analysis model

2.1 Areas to be refined

2.1.1

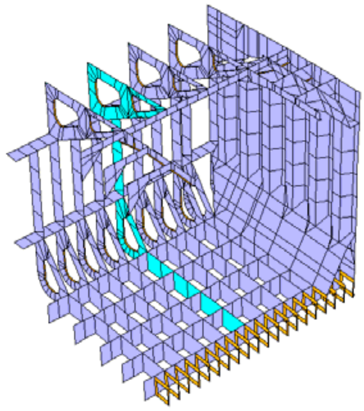
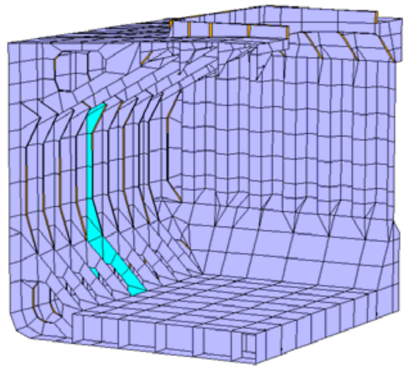
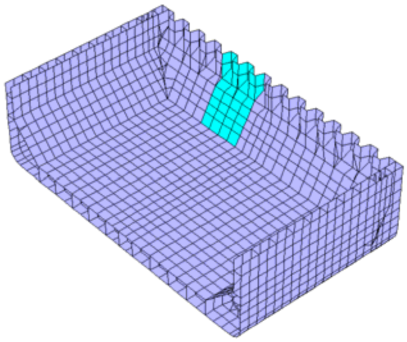
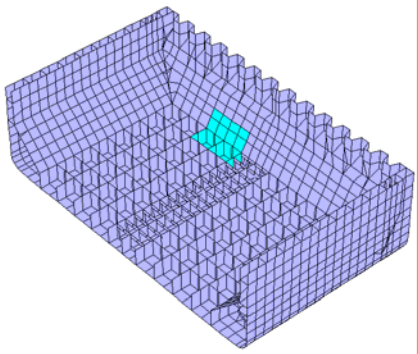
Where the global cargo hold analysis of Sec 2 is carried out using a model complying with the modeling criteria of Sec 2, [2.2.4], the areas listed in Tab 1 are to be refined at the locations whose calculated stresses exceed 95% of the allowable stress as specified in Sec 2, [3.2.3].

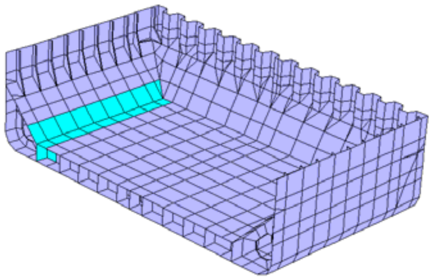
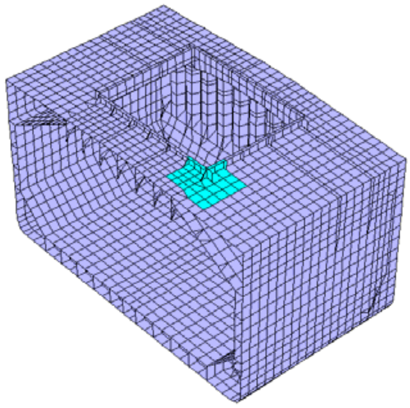
2.1.2

Where the global cargo hold analysis of Sec 2 is carried out using a model complying with the modeling criteria of Sec 2, [2.2.5], all the high stressed areas listed below are to be refined:

- areas whose calculated stresses exceed 85% of the allowable stress as specified in Sec 2, [3.2.3].
- typical details of the primary supporting members as shown in Tab 1.
- typical details of the transverse bulkheads of the considered hold as shown in Tab 1.

Table 1: Typical details to be refined

Structural member	Area of interest	Additional specifications	Description
Primary supporting member	Most stressed transverse primary supporting member for double side skin constructions	Refining of the most stressed transverse primary supporting members located in: • double bottom • hopper tank • double skin side • topside tank	
	Most stressed transverse primary supporting member for single side skin constructions	Refining of the most stressed transverse primary supporting members located in: • double bottom • hopper tank • topside tank side shell frame with end brackets and connections to hopper tank and topside tank	
Transverse bulkhead and its associated lower stool	Most stressed connection of the corrugations with the lower stool	High stressed elements, including the diaphragm(s) of the lower stool, are to be modeled	
	Most stressed connection of the lower stool with the inner bottom	High stressed elements are to be modeled	

Structural member	Area of interest	Additional specifications	Description
Inner bottom and hopper sloping plates with their associated supporting members	Most stressed connection of the inner bottom with the hopper sloping plate	Refining of the most stressed following members: • inner bottom • hopper sloping plate • floor • girder	
Deck plating	Deck plating in way of the most stressed hatch corners	High stressed elements are to be modeled	

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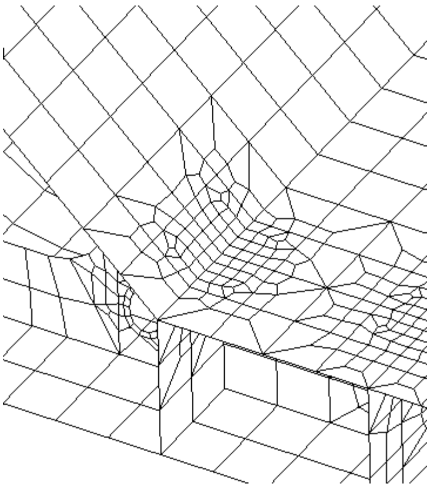
2.2 Refining method

2.2.1

Two methods can be used for refining the high stressed areas:

- refined areas can be directly included in FE model used for the global cargo hold analysis of Ch 7, Sec 2 (See Fig 1).
- detailed stresses in refined areas can be analysed by separate sub-models.



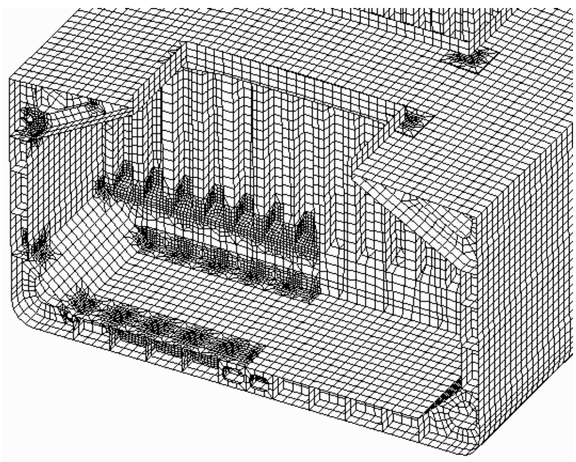


Figure 1: "Direct" modelling with refined meshes

2.3 Modeling

2.3.1 Element type

Each structural members is to be modeled by using proper element type for the structure in accordance with the principle in Sec 2, [2.2.3]. Orthotropic elements are not to be used in refined areas.

2.3.2 Mesh

The element size in refined areas is to be approximately one fourth of the representative spacing of ordinary stiffeners in the corresponding area, i.e. 200 × 200mm mesh size for structures whose ordinary stiffener spacing is 800 mm.

In addition, the web height of primary supporting members and web frames of single side bulk carriers is to be divided at least into 3 elements.

The aspect ratio of element is not to exceed 3. Quad elements are to have 90° angles as much as practicable, or to have angles between 45° and 135°.

2.3.3 Extent of sub-model

The minimum extent of sub-model is to be such that the boundaries of the sub-model correspond to the locations of adjacent supporting members (see Fig 2).

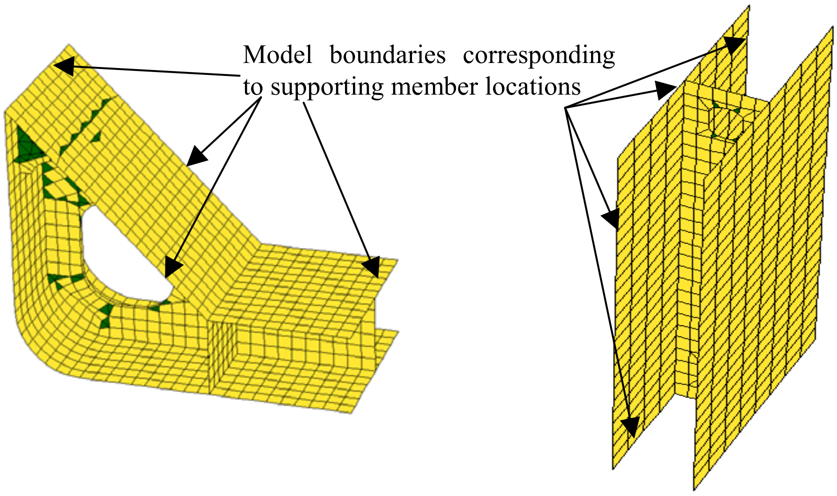


Figure 2: Boundaries of sub-models

2.4 Loading conditions

2.4.1

Loading conditions, which are applied to 3D FE model for the global cargo hold analysis according to Sec 2 and which induce stresses at considered locations exceeding the criteria specified in [2.1], are to be considered in the detailed stress assessment.

2.5 Boundary conditions

2.5.1

Boundary conditions as specified in Sec 2, [2.3.1] are to be applied to the global cargo hold FE model with refined meshes.

2.5.2
Nodal forces or nodal displacements obtained from the global cargo hold analysis of Sec 2 are to be applied to the sub-models. Where nodal forces are given, the supporting members located at the boundaries of a sub-model are to be included in the sub-model. Where nodal displacements are given and additional nodes are provided in sub-models, nodal displacements at the additional nodes are to be determined by proper interpolations.

3. Analysis criteria

3.1 Allowable stress

3.1.1
Von Mises equivalent stresses in plate elements and axial stresses in line elements within refined areas are not to exceed $280/k$ N/mm^2, where k is the material factor defined in Ch3, Sec 1.
In case elements significantly smaller than the size defined in [2.3.2] are used, this criteria applies to the average stress of all elements included in an area corresponding to a single element having the size specified in [2.3.2].

Section 4 – HOT SPOT STRESS ANALYSIS FOR FATIGUE STRENGTH ASSESSMENT

1. General

1.1 Application

1.1.1

This Section describes the procedure to compute hot spot stresses for fatigue strength assessment of each location specified in Ch 8, Sec 1, Tab 1 by using finite element method.

1.1.2

The loading conditions and the load cases specified in [2.2] are to be considered for hot spot stress analysis.

2. Analysis model

2.1 Modeling

2.1.1

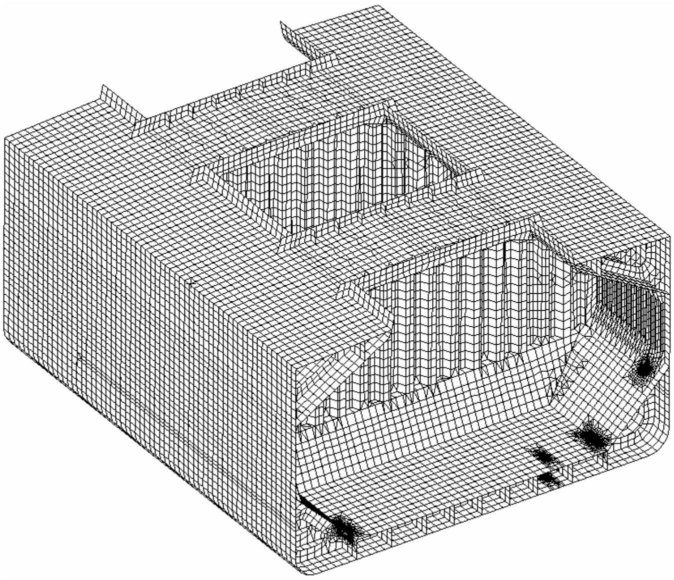
Hot spot stresses for fatigue assessment are to be obtained by the global cargo hold models where the areas for fatigue assessment are modeled by very fine meshes, as shown in Fig 1.
Alternatively, hot spot stresses can be obtained from sub-models, by using the similar procedures specified in Sec 3, [2].

2.1.2

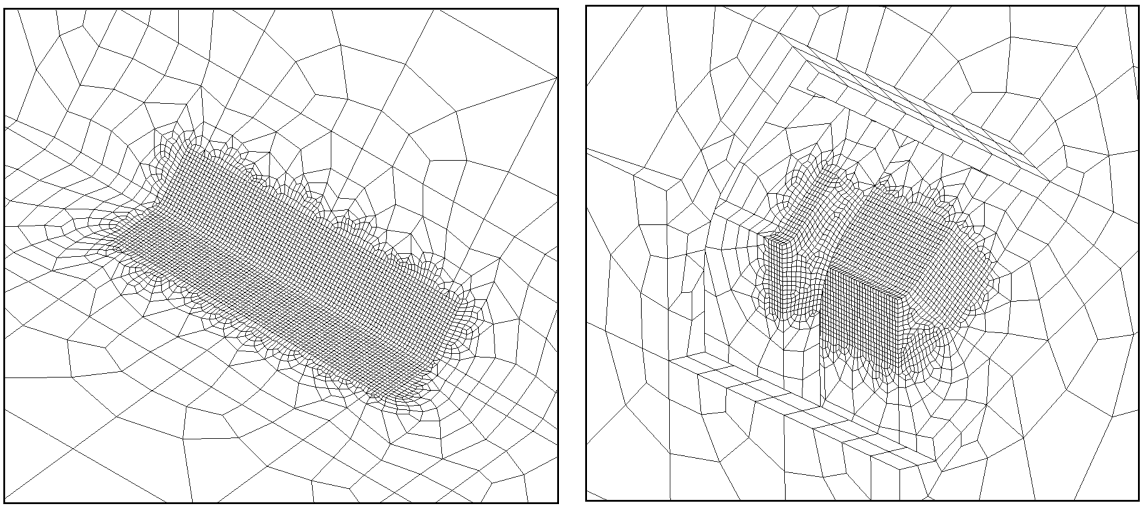
Areas within at least a quarter of frame spacing in all directions from the hot spot position are to be modeled by very fine meshes. The element size in very fine mesh areas is to be approximately equal to the representative net thickness in the assessed areas, and the aspect ratio of elements is to be close to 1.

2.1.3

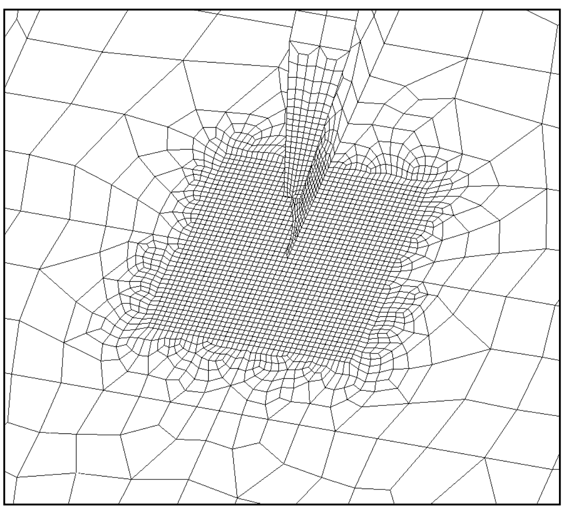
The mesh size is to be gradually changed from very fine mesh to fine mesh through the transition areas as shown in Fig 2. All structural members, including brackets, stiffeners, longitudinals and faces of transverse rings, etc., within transition areas are to be modeled by shell elements with bending and membrane properties. Geometries of welds are not to be modeled.



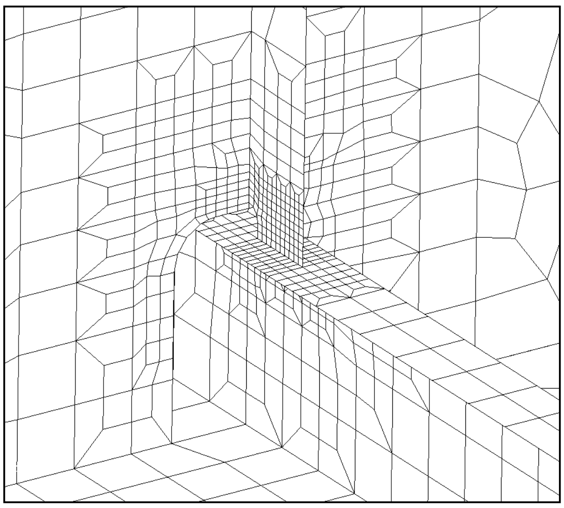
(a) Part of global cargo hold model with very fine mesh



(b) Bilge hopper knuckle part



(c) End of hold frame



(d) Longitudinal

Figure 1: Example of very fine mesh model

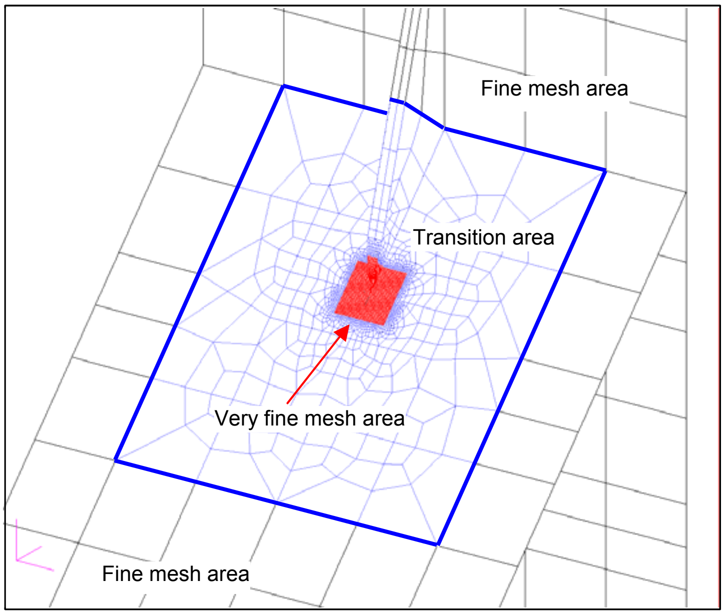


Figure 2: Very fine mesh area, transition area and fine mesh area

2.2 Loading conditions

2.2.1

The loading conditions, specified in Ch 8, Sec 1, Tab 2 and illustrated in Ch 4, App 3, are to be considered.

2.2.2

Probability level of 10^{-4} is to be used for calculation of design loads.

2.3 Boundary conditions

2.3.1

The boundary conditions specified in Sec2, [2.3.1] are to be applied to the cargo hold model with localized very fine meshes or the mother model for sub-models. When using sub-models, nodal displacements or forces obtained from the mother model are to be applied to sub-models.

3. Hot spot stress

3.1 Definition

3.1.1

The hot spot stress is defined as the structural geometric stress on the surface at a hot spot.

3.1.2

The hot spot stresses obtained by using superimposition method are to be modified according to Ch 8, Sec 3, [2.2] and [3.2].

3.2 Evaluation of hot spot stress

3.2.1

The hot spot stress in a very fine mesh is to be obtained using a linear extrapolation. The surface stresses located at 0.5 times and 1.5 times the net plate thickness are to be linearly extrapolated at the hot spot location, as described in Fig 3 and Fig.4.

The principal stress at the hot spot location having an angle with the assumed fatigue crack greater than 45° is to be considered as the hot spot stress.

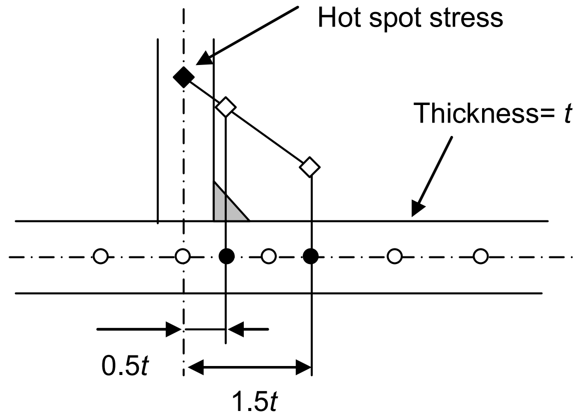


Figure 3: Definition of hot spot stress at an intersection of two plates

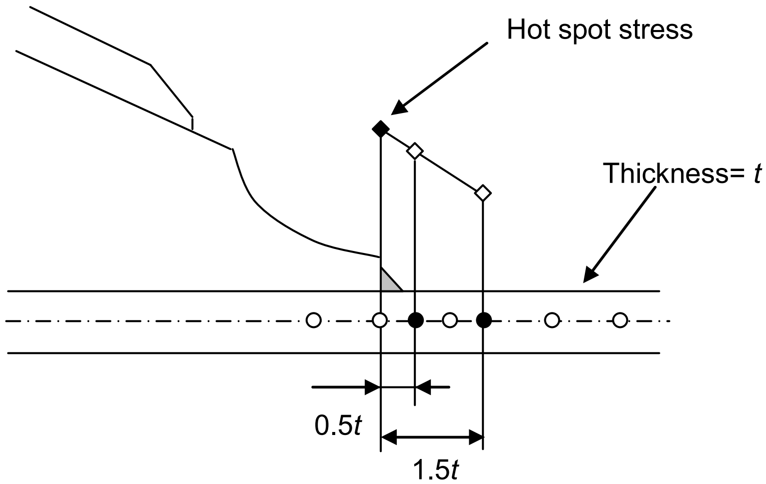


Figure 4: Definition of hot spot stress at an intersection of plating and bracket

3.2.2

The hot spot stress at the intersection of two plates, as obtained from [3.2.1], is to be multiplied by the correction factor λ defined below, considering the difference between the actual hot spot location and assumed location and the difference of stress gradient depending on the angle θ, in deg, between the two plates, to be measured between 0° and 90°.

- welded intersection between plane plates:

$$\lambda = \begin{cases} 0.8 & : \ \theta \le 75 \\ 0.8 - \dfrac{0.2}{15}(\theta - 75) & : \ 75 < \theta \end{cases}$$

- welded intersection between bent plate and plane plate: $\lambda = 0.7$ (i.e. bend type bilge knuckle part)

3.2.3

The hot spot stress in a non-welded area or along free edge is to be determined by extrapolating the principal stresses of the two adjacent elements, as shown in Fig 5.

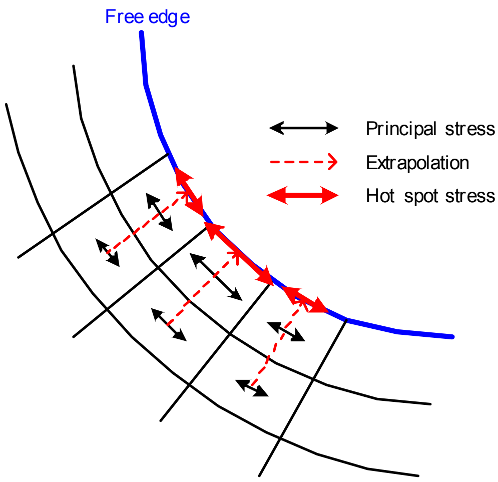


Figure 5: Definition of the hot spot stress along free edge

3.3 Simplified method for the bilge hopper knuckle part

3.3.1

At the bilge knuckle part, the hot spot stress $\sigma_{hotspot}$ may be computed by multiplying the nominal stress $\sigma_{nominal}$ with the stress concentration factor K_{gl} defined in [3.3.3].

$$\sigma_{hotspot} = K_{gl}\,\sigma_{nominal}$$

3.3.2

The nominal stress at the hot spot location is to be determined by extrapolating the membrane stresses located at 1.5 times and 2.5 times the frame spacing from the hot spot location, as shown in Fig 6.

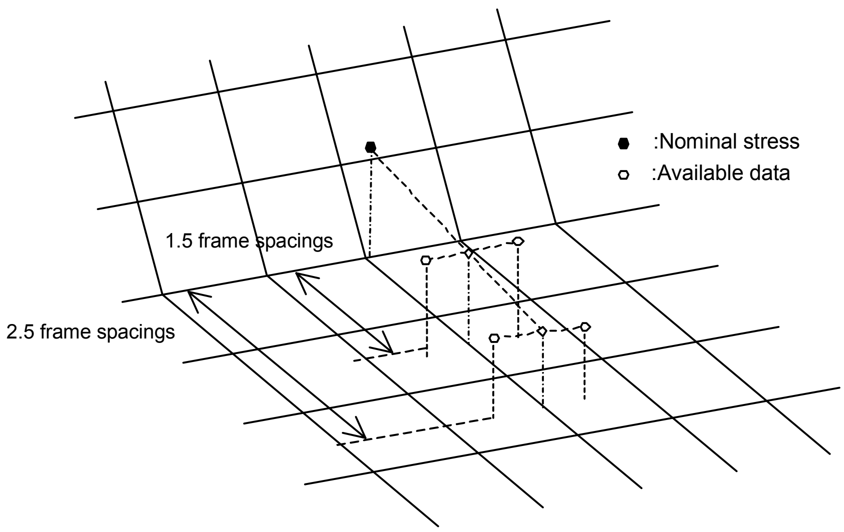


Figure 6: Definition of nominal stress at the bilge hopper knuckle part

3.3.3

The geometrical stress concentration factor K_{gl} for the bilge hopper knuckle part is given by the following equation:

$K_{gl} = K_0 \, K_1 \, K_2 \, K_3 \, K_4$

where:

K_0 : Stress concentration factor depending on the dimensions of the considered structure, defined in Tab 1

K_1 : Correction coefficient depending on the type of knuckle connection, defined in Tab 2

K_2 : Correction coefficient depending on the thickness increment of the transverse web, defined in Tab 2 or taken equal to 1.0 if there is no thickness increment

K_3 : Correction coefficient depending on the insertion of horizontal gusset or longitudinal rib (see Fig 7), defined in Tab 2 or taken equal to 1.0 if there is no horizontal gusset or longitudinal rib

K_4 : Correction coefficient depending on the insertion of transverse rib, defined in Tab 2 (see Fig 8) or taken equal to 1.0 if there is no transverse rib

Table 1: Stress concentration factor K_0

Plate net thickness in FE model t (mm)	Angle of hopper slope plate to the horizontal θ (deg.)			
	40	**45**	**50**	**90**
16	3.0	3.2	3.4	4.2
18	2.9	3.1	3.3	4.0
20	2.8	3.0	3.2	3.8
22	2.7	2.9	3.1	3.6
24	2.6	2.8	3.0	3.5
26	2.6	2.7	2.9	3.4
28	2.5	2.7	2.8	3.3
30	2.4	2.6	2.7	3.2

Note: Alternatively, K_0 can be determined by the following formula.

$$K_0 = \frac{0.14\theta \cdot (1.15 - 0.0033\theta)}{(0.5t)^{(0.2+0.0028\theta)}}$$

Table 2: **Correction coefficients**

Type of knuckle	K_1	K_2	K_3	K_4
Weld Type	1.7	0.9	0.9	0.9
Bend Type	1.75 ; $R/t < 4$ 2.80 ; $R/t > 8$		0.85 ; $R/t < 4$ 0.55 ; $R/t > 8$	

Notes :

(1) The linear interpolation is applied between $4 \le R/t \le 8$

"R" denotes the radius of bend part and "*t*" denotes the plate thickness

(2) In using the correction coefficient K_2, the members should be arranged such that the bending deformation of the radius part is effectively suppressed.

(3) The increase in web thickness is taken based on the plate thickness of the inner bottom plating.

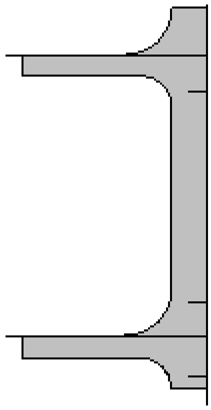


Figure 7: **Example of insertion of horizontal gusset or longitudinal rib**

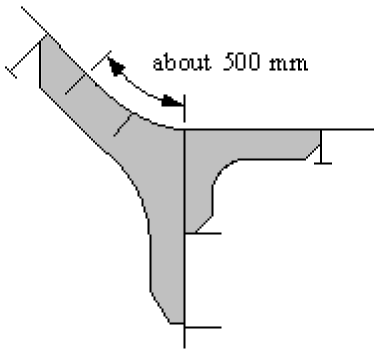


Figure 8: **Example of insertion of transverse rib**

Appendix 1 – LONGITUDINAL EXTENT OF THE FINITE ELEMENT MODELS

1. Longitudinal extent

A three-hold length finite element model is recommended for the analysis, with the mid-hold as the target of assessment.

The three-hold length finite element model reduces the adverse effects of the boundary conditions to a minimum in the assessed mid-hold.

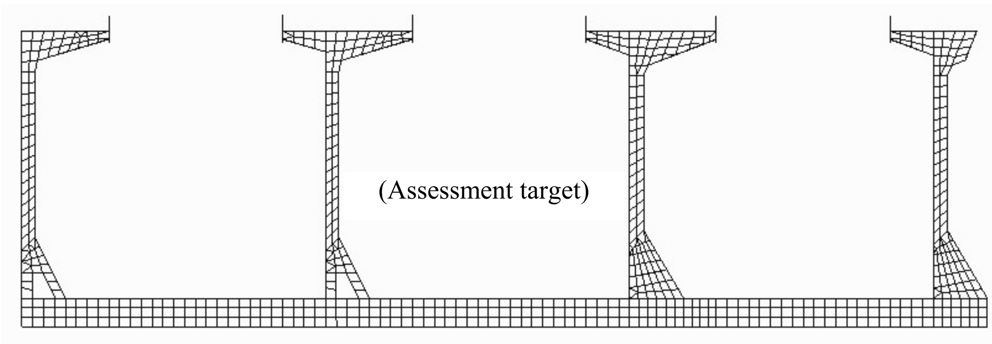


Figure 1: Longitudinal extent of the finite element model

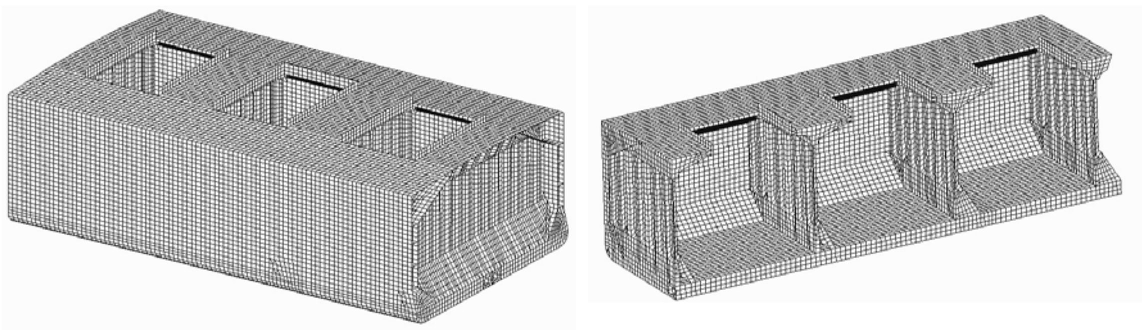


Figure 2: Example of a finite element model

2. Typical Mesh

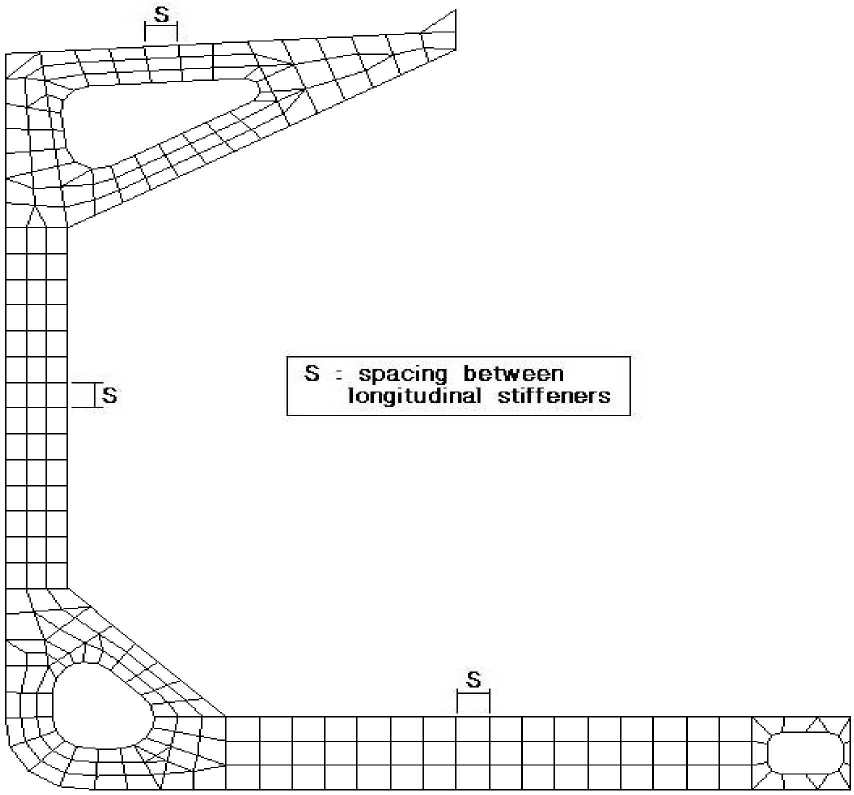


Figure 3: Typical mesh of a web frame

Appendix 2 – DISPLACEMENT BASED BUCKLING ASSESSMENT IN FINITE ELEMENT ANALYSIS

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

a : Length of the longer plate panel side

b : Length of the shorter plate panel side

x : Direction parallel to a, taken as the longitudinal direction

y : Direction parallel to b, taken as the transverse direction

C : Coefficient taken equal to:

for 4-node buckling panel: $C = \dfrac{E}{2(1-\nu^2)}$

for 8-node buckling panel: $C = \dfrac{E}{4(1-\nu^2)}$

ν : Poisson ratio

m : Coefficient taken equal to:

$m = 1 - \nu$

1. Introduction

1.1

1.1.1

This Appendix provides a method to obtain the buckling stresses and edge stress ratios for elementary plate panels (EPP) from a finite element calculation. This method is called “Displacement Method”.

2. Displacement method

2.1 General

2.1.1

As the mesh of the finite elements does not correspond, in general, to the buckling panels the nodal points of the EPP can be mapped onto the FE-mesh and the displacements of these nodes can be derived from the FE-calculation.

Whenever operations on displacements are performed, full numerical accuracy of the displacements should be used.

2.1.2 4-node and 8-node panels

When the aspect ratio of the EPP is less than 3 and the variation of the longitudinal stresses in longitudinal direction of the EPP is small, a 4-node panel may be used. Otherwise an 8-node panel is to be taken.

2.1.3 Calculation of nodal displacements

Three different node locations are possible:

- If a node of the buckling panel is located at an FE-node, then the displacements can be transferred directly.
- If a node of the buckling panel is located on the edge of a plane stress element, then the displacements can be linearly interpolated between the FE-nodes at the edge.
- If a node of the buckling panel is located inside of an element, then the displacements can be obtained using bi-linear interpolation of all nodes of the element.

2.1.4 Transformation in local system

The transformation of the nodal displacements from the global FE-system into the local system of the buckling panel is performed by

$$(u) = [\lambda] \cdot (u_g)$$

where:

(u) : Local displacement vector

(u_g) : Global displacement vector

$[\lambda]$: Transformation matrix (2×3), of direction cosines of angles formed between the two sets of axes.

2.2 Calculation of buckling stresses and edge stress ratios

2.2.1

The displacements, derived at the corners of the elementary plate panel, are to be considered as input from which the stresses at certain stress-points are derived. In the 4-node buckling panel these points are identical but in the 8-node buckling panel they differ. The locations and the numbering convention may be taken from Fig 1 and Fig 2.

The derived stresses at EPP corner nodes can be directly used as input for the buckling assessment according Ch 6, Sec 3. The buckling load cases, which have to be considered in the FEM buckling assessment and defined in Ch 7 are buckling load cases 1, 2 and 5 of Ch 6, Sec 3, Tab 2 and 1a, 1b, 2 and 4 of Ch 6, Sec 3, Tab 3. In special cases, other buckling load cases may be used for the buckling assessment by a hand calculation.

2.2.2 4-node buckling panel

Stress displacement relationship for a 4-node buckling panel (compressive Stresses are positive)

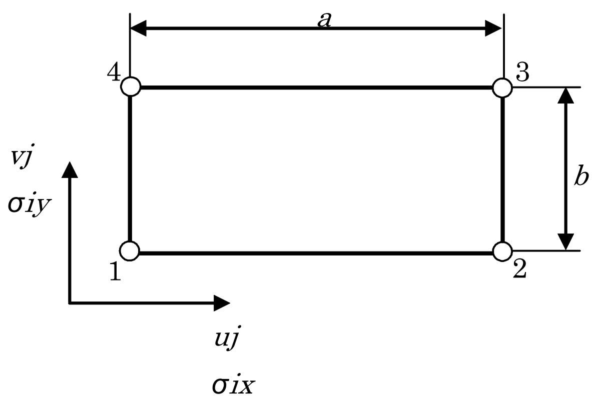


Figure 1: 4-node buckling panel

From the displacements of the EPP corner nodes the stresses of these nodes can be obtained using

$$
\begin{pmatrix} \sigma_{1x}^* \\ \sigma_{1y}^* \\ \tau_1 \\ \sigma_{2x}^* \\ \sigma_{2x}^* \\ \tau_2 \\ \sigma_{3x}^* \\ \sigma_{3y}^* \\ \tau_3^* \\ \sigma_{4x}^* \\ \sigma_{4y}^* \\ \tau_4 \end{pmatrix} = -C \cdot \begin{pmatrix}
-2/a & -2\nu/b & 2/a & 0 & 0 & 0 & 0 & 2\nu/b \\
-2\nu/a & -2/b & 2\nu/a & 0 & 0 & 0 & 0 & 2/b \\
-m/b & -m/a & 0 & m/a & 0 & 0 & m/b & 0 \\
-2/a & 0 & 2/a & -2\nu/b & 0 & 2\nu/b & 0 & 0 \\
-2\nu/a & 0 & 2\nu/a & -2/b & 0 & 2/b & 0 & 0 \\
0 & -m/a & -m/b & m/a & m/b & 0 & 0 & 0 \\
0 & 0 & 0 & -2\nu/b & 2/a & 2\nu/b & -2/a & 0 \\
0 & 0 & 0 & -2/b & 2\nu/a & 2/b & -2\nu/a & 0 \\
0 & 0 & -m/b & 0 & m/b & m/a & 0 & -m/a \\
0 & -2\nu/b & 0 & 0 & 2/a & 0 & -2/a & 2\nu/b \\
0 & -2/b & 0 & 0 & 2\nu/a & 0 & -2\nu/a & 2/b \\
-m/b & 0 & 0 & 0 & 0 & m/a & m/b & -m/a
\end{pmatrix} \cdot \begin{pmatrix} u_1 \\ v_1 \\ u_2 \\ v_2 \\ u_3 \\ v_3 \\ u_4 \\ v_4 \end{pmatrix}
$$

where:

$(\sigma_{1x}^*, \sigma_{1y}^*, \tau_1, \cdots, \sigma_{4x}^*, \sigma_{4y}^*, \tau_4)^T = (\sigma^*)$: Element stress vector

$(u_1, v_1, \cdots, u_4, v_4)^T = (u)$: Local node displacement vector

If both σ_x^* and σ_y^* are compressive stresses then the stresses σ_x and σ_y must be obtained as follows:

$$\sigma_x = (\sigma_x^* - 0.3\sigma_y^*)/0.91$$

$$\sigma_y = (\sigma_y^* - 0.3\sigma_x^*)/0.91$$

Where compressive stress fulfils the condition $\sigma_y^* < 0.3\sigma_x^*$, then $\sigma_y = 0$ and $\sigma_x = \sigma_x^*$

Where compressive stress fulfils the condition $\sigma_x^* < 0.3\sigma_y^*$, then $\sigma_x = 0$ and $\sigma_y = \sigma_y^*$

This leads to the following stress vector:

$(\sigma) = (\sigma_{1x}, \sigma_{1y}, \tau_1, \cdots, \sigma_{4x}, \sigma_{4y}, \tau_4)^T$

Finally the relevant buckling stresses and edge stress ratios are obtained by:

- LC 1: longitudinal compression

$$\sigma_l = \max\left(\frac{\sigma_{1x} + \sigma_{4x}}{2}, \frac{\sigma_{2x} + \sigma_{3x}}{2}\right)$$

$$\Delta\sigma_l = \frac{1}{2}\left(-\sigma_{1x} + \sigma_{4x} - \sigma_{2x} + \sigma_{3x}\right)$$

$$\sigma_x = \sigma_l + 0.5\left|\Delta\sigma_l\right|$$

$$\psi_x = 1 - \left|\Delta\sigma_l\right| / \sigma_x$$

- LC 2: transverse compression

$$\sigma_t = 0.25\sum_{i=1}^{4}\sigma_{iy}$$

$$\Delta\sigma_t = \frac{1}{2}\left(-\sigma_{1y} - \sigma_{4y} + \sigma_{2y} + \sigma_{3y}\right)$$

$$\sigma_y = \sigma_t + 0.5\left|\Delta\sigma_t\right|$$

$$\psi_y = 1 - \left|\Delta\sigma_t\right| / \sigma_y$$

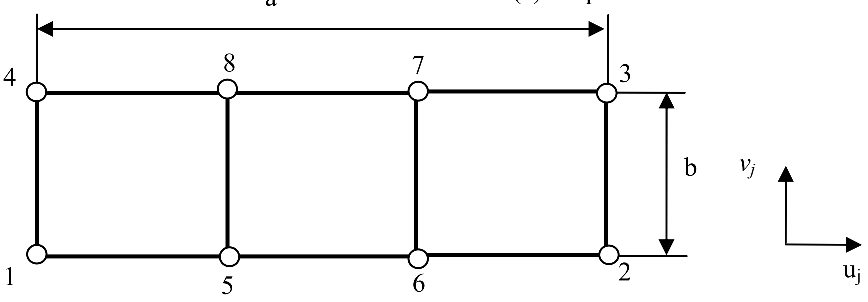
- LC 5: shear

$$\tau = \left| \frac{\tau_1 + \tau_2 + \tau_3 + \tau_4}{4} \right|$$

2.2.3 8-node buckling panel

Stress displacement relationship for a 8-node buckling panel (compressive stresses are positive)

(a) Displacement Nodes



(b) Stress Nodes

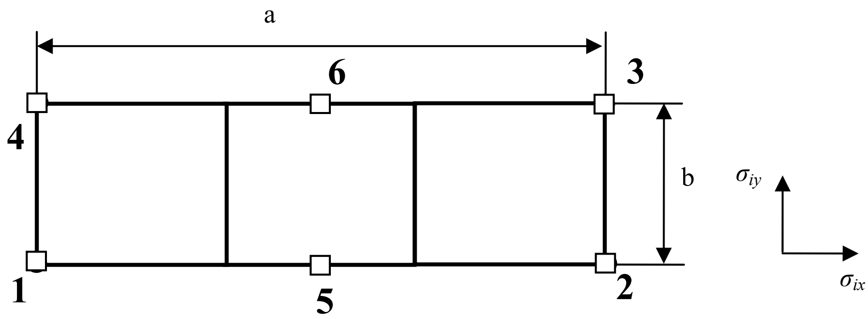


Figure 2: 8-node buckling panel

From the displacements of the EPP corner nodes the stresses of these nodes and on mid positions can be obtained using:

$$\begin{pmatrix} \sigma^*_{1x} \\ \sigma^*_{1y} \\ \tau_1 \\ \sigma^*_{2x} \\ \sigma^*_{2y} \\ \tau_2 \\ \sigma^*_{3x} \\ \sigma^*_{3y} \\ \tau_3 \\ \sigma^*_{4x} \\ \sigma^*_{4y} \\ \tau_4 \\ \sigma^*_{5x} \\ \sigma^*_{5y} \\ \tau_5 \\ \sigma^*_{6x} \\ \sigma^*_{6y} \\ \tau_6 \end{pmatrix} = -C \cdot \begin{pmatrix}
-12/a & -4\nu/b & 0 & 0 & 0 & 0 & 0 & 4\nu/b & 12/a & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-12\nu/a & -4/b & 0 & 0 & 0 & 0 & 0 & 4/b & 12\nu/a & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-2m/b & -6m/a & 0 & 0 & 0 & 0 & 2m/b & 0 & 0 & 6m/a & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 12/a & -4\nu/b & 0 & 4\nu/b & 0 & 0 & 0 & 0 & -12/a & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 12\nu/a & -4/b & 0 & 4/b & 0 & 0 & 0 & 0 & -12\nu/a & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & -2m/b & 6m/a & 2m/b & 0 & 0 & 0 & 0 & 0 & 0 & -6m/a & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -4\nu/b & 12/a & 4\nu/b & 0 & 0 & 0 & 0 & 0 & 0 & -12/a & 0 & 0 & 0 \\
0 & 0 & 0 & -4/b & 12\nu/a & 4/b & 0 & 0 & 0 & 0 & 0 & 0 & -12\nu/a & 0 & 0 & 0 \\
0 & 0 & -2m/b & 0 & 2m/b & 6m/a & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -6m/a & 0 & 0 \\
0 & -4\nu/b & 0 & 0 & 0 & 0 & -12/a & 4\nu/b & 0 & 0 & 0 & 0 & 0 & 0 & 12/a & 0 \\
0 & -4/b & 0 & 0 & 0 & 0 & -12\nu/a & 4/b & 0 & 0 & 0 & 0 & 0 & 0 & 12\nu/a & 0 \\
-2m/b & 0 & 0 & 0 & 0 & 0 & 2m/b & -6m/a & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 6m/a \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -12/a & -2\nu/b & 12/a & -2\nu/b & 0 & 2\nu/b & 0 & 2\nu/b \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -12\nu/a & -2/b & 12\nu/a & -2/b & 0 & 2/b & 0 & 2/b \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -m/b & -6m/a & -m/b & 6m/a & m/b & 0 & m/b & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -2\nu/b & 0 & -2\nu/b & 12/a & 2\nu/b & -12/a & 2\nu/b \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -2/b & 0 & -2/b & 12\nu/a & 2/b & -12\nu/a & 2/b \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -m/b & 0 & -m/b & 0 & m/b & 6m/a & m/b & -6m/a
\end{pmatrix} \cdot \begin{pmatrix} u_1 \\ v_1 \\ u_2 \\ v_2 \\ u_3 \\ v_3 \\ u_4 \\ v_4 \\ u_5 \\ v_5 \\ u_6 \\ v_6 \\ u_7 \\ v_7 \\ u_8 \\ v_8 \end{pmatrix}$$

where:

$$(\sigma^*) = (\sigma^*_{1x}, \sigma^*_{1y}, \tau_1, \cdots, \sigma^*_{6x}, \sigma^*_{6y}, \tau_6)^T$$

$$(u) = (u_{1x}, v_{1y}, \cdots, u_{8x}, v_{8y})^T$$

If both σ^*_x and σ^*_y are compressive stresses then the stresses σ_x and σ_y must be obtained as follows:

$$\sigma_x = (\sigma^*_x - 0.3 \cdot \sigma^*_y) / 0.91$$
$$\sigma_y = (\sigma^*_y - 0.3 \cdot \sigma^*_x) / 0.91$$

Where compressive stress fulfils the condition $\sigma^*_y < 0.3\sigma^*_x$, then $\sigma_y = 0$ and $\sigma_x = \sigma^*_x$

Where compressive stress fulfils the condition $\sigma^*_x < 0.3\sigma^*_y$, then $\sigma_x = 0$ and $\sigma_y = \sigma^*_y$

This leads to the following stress vector:

$$(\sigma) = (\sigma_{1x}, \sigma_{1y}, \tau_1, \cdots, \sigma_{6x}, \sigma_{6y}, \tau_6)^T$$

The relevant buckling stresses can be obtained by:

- LC 1: longitudinal compression

$$\sigma_l = \max\left(\frac{\sigma_{1x} + \sigma_{4x}}{2}, \frac{\sigma_{6x} + \sigma_{5x}}{2}, \frac{\sigma_{2x} + \sigma_{3x}}{2}\right)$$
$$\Delta\sigma_l = \frac{1}{3}\left(\sigma_{4x} - \sigma_{1x} - \sigma_{5x} + \sigma_{6x} + \sigma_{3x} - \sigma_{2x}\right)$$
$$\sigma_x = \sigma_l + 0.5\left|\Delta\sigma_l\right|$$
$$\psi_x = 1 - \left|\Delta\sigma_l\right| / \sigma_x$$

- LC 2: transverse compression

$$\sigma_t = \frac{1}{6}\sum_{i=1}^{6}\sigma_{iy}$$
$$\Delta\sigma_t = \frac{1}{2}\left(-\sigma_{1y} - \sigma_{4y} + \sigma_{2y} + \sigma_{3y}\right)$$
$$\sigma_y = \sigma_t + 0.5\left|\Delta\sigma_t\right|$$
$$\psi_y = 1 - \left|\Delta\sigma_t\right| / \sigma_y$$

- LC 5: shear

$$\tau = Max\left\{\left|\frac{\tau_1 + \tau_4 + \tau_5 + \tau_6}{4}\right|, \left|\frac{\tau_2 + \tau_3 + \tau_5 + \tau_6}{4}\right|\right\}$$

Chapter 8

Fatigue Check of Structural Details

Section 1 – GENERAL CONSIDERATION

1. General

1.1 Application

1.1.1

The requirements of this Chapter are to be applied to ships having length *L* of 150 m or above, with respect to 25 years operation life in North Atlantic.

1.1.2

The requirements of this Chapter apply to fatigue cycles induced by wave loads. Fatigue induced by vibrations, low cycle loads or impact loads such as slamming, is out of the scope of this Chapter.

1.1.3

The requirements of this Chapter are applicable where steel materials have a minimum yield stress less than 400 N/mm^2.

1.2 Net scantlings

1.2.1

All scantlings and stresses referred to in this Chapter are net scantlings obtained in accordance with Ch 3, Sec 2.

1.3 Subject members

1.3.1

Fatigue strength is to be assessed, in cargo hold area, for all the connected members at the considered locations described in Tab 1.

RCN 1 to July 2010 version (effective from 1July 2012)

Table 1: Members and locations subjected to fatigue strength assessment

Members	Details
Inner bottom plating	Connection with sloping and /or vertical plate of lower stool
	Connection with sloping plate of hopper tank
Inner side plating	Connection with sloping plate of hopper tank
Transverse bulkhead	Connection with sloping plate of lower stool
	Connection with sloping plate of upper stool
Hold frames of single side bulk carriers	Connection to the upper and lower wing tank
Ordinary stiffeners in double side space	Connection of longitudinal stiffeners with web frames and transverse bulkhead
	Connection of transverse stiffeners with stringer or similar
Ordinary stiffeners in upper and lower wing tank	Connection of longitudinal stiffeners with web frames and transverse bulkhead
Ordinary stiffeners in double bottom	Connection of longitudinal stiffeners with floors and floors in way of lower stool or transverse bulkhead
Hatch corners	Free edges of hatch corners

RCN 1 to July 2008 version (effective from 1 July 2009)

2. Definitions

2.1 Hot spot

2.1.1
Hot spot is the location where fatigue crack may initiate.

2.2 Nominal stress

2.2.1
Nominal stress is the stress in a structural component taking into account macro-geometric effects but disregarding the stress concentration due to structural discontinuities and to the presence of welds.

Nominal stresses are to be obtained either with the coarse mesh FE analysis specified in Ch 7, Sec 4, or with the simplified procedure specified in Sec4.

2.3 Hot spot stress

2.3.1
Hot spot stress is defined as the local stress at the hot spot. The hot spot stress takes into account the influence of structural discontinuities due to the geometry of the connection but excludes the effects of welds.

Hot spot stresses are to be obtained either by fine mesh FE analysis specified in Ch 7, Sec 4, or by multiplying nominal stresses by stress concentration factors defined in Sec 4.

2.4 Notch stress

2.4.1
Notch stress is defined as the peak stress at the weld toe taking into account stress concentrations due to the effects of structural geometry as well as the presence of welds.

Notch stress is to be obtained by multiplying hot spot stress by fatigue notch factor defined in Sec 2, [2.3.1], Tab 1.

3. Loading

3.1 Loading condition

3.1.1
The loading conditions to be considered are defined in Tab 2 depending on the ship type. The standard loading conditions illustrated in Ch 4, App 3 are to be considered. *RCN 1 to July 2008 version (effective 1 July 2009)*

Table 2: Loading conditions

Ship type	Full load condition		Ballast condition	
	Homogeneous	Alternate	Normal ballast	Heavy ballast
BC-A	✓	✓	✓	✓
BC-B	✓	---	✓	✓
BC-C	✓	---	✓	✓

3.2 Load case

3.2.1 Load cases

For each loading condition, the load cases to be considered, defined in Ch 4, Sec 4, [2], are:

(a) "H1" and "H2" corresponding to the EDW "H" (head sea)

(b) "F1" and "F2" corresponding to the EDW "F" (following sea)

(c) "R1" and "R2" corresponding to the EDW "R" (beam sea)

(d) "P1" and "P2" corresponding to the EDW "P" (beam sea)

3.2.2

In the case of fatigue assessment of hatch corners, only oblique sea is to be considered, taking into account the wave torsional moments defined in Ch 4, Sec 3, [3.4].

3.2.3 Predominant load case

From the above mentioned load cases and for each loading condition, the load case where the combined stress range is maximum, corresponds to the predominant load case.

Section 2 – FATIGUE STRENGTH ASSESSMENT

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

i : Suffix which denotes load case "H", "F", "R" or "P" specified in Ch 4, Sec 4
"i1" denotes load case "H1", "F1", "R1" or "P1" and "i2" denotes load case "H2", "F2", "R2" or "P2"

(k) : Suffix which denotes loading condition "homogeneous condition", "alternate condition", "normal ballast condition" or "heavy ballast condition" as defined in Sec 1, Tab 2

$\Delta\sigma_{W,\,i(k)}$: Hot spot stress range, in N/mm^2, in load case "i" of loading condition "(k)"

$\sigma_{mean,\,i(k)}$: Structural hot spot mean stress, in N/mm^2, in load case "i" of loading condition "(k)"

1. General

1.1 Application

1.1.1

This Section gives the linear cumulative damage procedure for the fatigue strength assessment of this Chapter.

1.1.2

Fatigue strength is assessed based on an equivalent notch stress range obtained by multiplying an equivalent hot spot stress range by a fatigue notch factor.

1.1.3

Hot spot stress ranges and hot spot mean stresses of primary members, longitudinal stiffeners connections and hatch corners are to be assessed respectively by Sec 3, Sec 4 and Sec 5.

1.1.4 Primary members and longitudinal stiffeners connections

Predominant load cases and 'condition 1' are to be obtained respectively in [2.1] and [2.2]. The hot spot stress ranges calculated in Sec 3 or Sec 4, corresponding to the predominant load case for each loading condition, are to be used in [2.3.2] to calculate the equivalent hot spot stress range.

1.1.5 Hatch corners

The hot spot stress range calculated in Sec 5 is to be used in [2.3.2] to calculate the equivalent hot spot stress range.

2. Equivalent notch stress range

2.1 Predominant load case

2.1.1

The predominant load case "I" in fatigue assessment for each loading condition is the load case for which the combined stress range for the considered member is the maximum among the load cases "H", "F", "R" and "P" specified in Sec 1, [3.2.1].

$$\Delta\sigma_{W,I(k)} = \max_i\left(\Delta\sigma_{W,i(k)}\right)$$

where:

$\Delta\sigma_{W,i(k)}$: Combined hot spot stress range, in N/mm^2, defined either in Sec 3, [2.1.1], [2.2.1] or Sec 4, [2.3.1].

I : Suffix which denotes the selected predominant load case of loading condition "(k)".

2.2 Loading 'condition 1'

2.2.1

The 'condition 1' is the condition in which the maximum stress calculated by the equation below for the considered member is the largest on the tension side among the loading conditions "homogeneous", "alternate", "normal ballast" and "heavy ballast" specified in Sec 1, Tab 2.

$$\sigma_{\max,1} = \max_k\left(\sigma_{mean,I(k)} + \frac{\Delta\sigma_{W,I(k)}}{2}\right)$$

where:

$\sigma_{mean,I(k)}$: Structural hot spot mean stress, in N/mm^2, in predominant load case of loading condition "(k)" defined in [2.1.1]

$\Delta\sigma_{W,I(k)}$: Hot spot stress range, in N/mm^2, in predominant load case of loading condition "(k)" defined in [2.1.1]

2.2.2

Further to the determination of 'condition 1'according to [2.2.1], the corresponding loading condition is to be indexed with the suffix "j" equal 1.

2.3 Equivalent notch stress range

2.3.1 Equivalent notch stress range

The equivalent notch stress range, in N/mm^2, for each loading condition is to be calculated with the following formula:

$$\Delta\sigma_{eq,j} = K_f \Delta\sigma_{equiv,j}$$

where:

$\Delta\sigma_{equiv,j}$: Equivalent hot spot stress range, in N/mm^2, in loading condition "j" obtained by [2.3.2].

K_f : Fatigue notch factor defined in Tab 1.

Table 1: Fatigue notch factors K_f *(RCN 3, effective from 12 Sept 2008)*

Subject	Without weld grinding	With weld grinding (not applicable for ordinary stiffeners and boxing fillet welding[1])
Butt welded joint	1.25	1.10
Fillet welded joint	1.30	1.15[2]
Non welded part	1.00	-

Note:

1) Boxing fillet welding is defined as a fillet weld around a corner of a member as an extension of the principal weld.
2) This is applicable for deep penetration welding, or full penetration welding only

In case where grinding is performed, full details regarding grinding standards including the extent, smoothness particulars, final welding profiles and grinding workmanship as well as quality acceptance criteria are to be submitted to the Society for approval.

It is preferred that any grinding is carried out by rotary burrs, is to extend below plate surfaces in order to remove any toe defects and ground areas are to have sufficient corrosion protection. Such treatments are to procedure smooth concave profiles at weld toes with the depth of these depressions penetrating into plate surfaces to at least 0.5mm below the bottom of any visible undercuts.

The depth of any grooves produced is to be kept to a minimum and, in general, kept to a maximum of 1mm. Under no circumstances is grinding depth to exceed 2mm or 7% of plate growth thickness, whichever is smaller. Grinding has to extend to 0.5 longitudinal spacing or 0.5 frame spacing at the each side of hot spot locations.

(RCN 3, effective from 12 Sept 2008)

2.3.2 Equivalent hot spot stress range

The equivalent hot spot stress range, in N/mm^2, is to be calculated for each loading condition with the following formula:

$$\Delta\sigma_{equiv,\,j} = f_{mean,\,j}\,\Delta\sigma_{W,\,j}$$

where:

$f_{mean,j}$: Correction factor for mean stress:

- for hatch corners $f_{mean,j} = 0.77$
- for primary members and longitudinal stiffeners connections, $f_{mean,j}$ corresponding to the condition "*j*" taken equal to:

$$f_{mean,\,j} = \max\left\{0.4,\left[\max\left(0,\ \frac{1}{2} + \frac{-\ln\left(10^{-4}\right)}{4}\frac{\sigma_{m,\,j}}{\Delta\sigma_{W,\,j}}\right)\right]^{0.25}\right\}$$

$\sigma_{m,1}$: Local hot spot mean stress, in N/mm^2, in the condition "1", obtained from the following formulae:

- if $0.6\Delta\sigma_{W,1} \geq 2.5R_{eH}$:

$$\sigma_{m,1} = -0.18\Delta\sigma_{W,1}$$

- if $0.6\Delta\sigma_{W,1} < 2.5R_{eH}$:

$$\sigma_{m,1} = R_{eH} - 0.6\Delta\sigma_{W,1} \quad \text{for} \quad 0.6\Delta\sigma_{W,1} > R_{eH} - \sigma_{res} - \sigma_{mean,1}$$

$$\sigma_{m,1} = \sigma_{mean,1} + \sigma_{res} \quad \text{for} \quad 0.6\Delta\sigma_{W,1} \leq R_{eH} - \sigma_{res} - \sigma_{mean,1}$$

$\sigma_{m,j}$: Local hot spot mean stress, in N/mm^2, in the condition "*j*", obtained from the following formulae:

- if $0.24\Delta\sigma_{W,j} \geq R_{eH}$:

$$\sigma_{m,j(j\neq1)} = -0.18\Delta\sigma_{W,j}$$

- if $0.24\Delta\sigma_{W,j} < R_{eH}$:

$$\sigma_{m,j(j\neq1)} = -R_{eH} + 0.24\Delta\sigma_{W,j} \quad \text{for} \quad 0.24\Delta\sigma_{W,j} > R_{eH} + \sigma_{m,1} - \sigma_{mean,1} + \sigma_{mean,j}$$

$$\sigma_{m,j(j\neq 1)} = \sigma_{m,1} - \sigma_{mean,1} + \sigma_{mean,j} \quad \text{for} \quad 0.24\Delta\sigma_{W,j} \leq R_{eH} + \sigma_{m,1} - \sigma_{mean,1} + \sigma_{mean,j}$$

$\sigma_{mean,j}$: Structural hot spot mean stress, in N/mm^2, corresponding to the condition "*j*"

σ_{res} : Residual stress, in N/mm^2, taken equal to:

$\sigma_{res} = 0.25 R_{eH}$ for stiffener end connection

$\sigma_{res} = 0$ for non welded part and primary members (cruciform joint or butt weld)

(RCN 3, effective from 12 Sept 2008)

3. Calculation of fatigue damage

3.1 Correction of the equivalent notch stress range

3.1.1

The equivalent notch stress range is to be corrected with the following formula:

$$\Delta\sigma_{E,j} = f_{coat}\, f_{material}\, f_{thick}\, \Delta\sigma_{eq,j}$$

where:

f_{coat} : Correction factor for corrosive environment, taken equal to:

$f_{coat} = 1.05$ for water ballast tanks and fuel oil tank

$f_{coat} = 1.03$ for dry bulk cargo holds and void space

$f_{material}$: Correction factor for material, taken equal to:

$$f_{material} = \frac{1200}{965 + R_{eH}}$$

f_{thick} : Correction factor for plate thickness, taken equal to 1.0 for hatch corners, flat bar or bulb stiffeners, otherwise to be taken equal to:

$$f_{thick} = \left(\frac{t}{22}\right)^{0.25} \quad \text{for } t \geq 22 \text{ mm}$$

$$f_{thick} = 1.0 \quad \text{for } t < 22 \text{ mm}$$

t : Net thickness, in mm, of the considered member, taken as the flange in case of stiffeners

$\Delta\sigma_{eq,j}$: Equivalent notch stress range, in N/mm^2, defined in [2.3.1].

3.2 Long-term distribution of stress range

3.2.1

The cumulative probability density function of the long-term distribution of combined notch stress ranges is to be taken as a two-parameter Weibull distribution:

$$F(x) = 1 - \exp\left[-\left(\frac{x}{\Delta\sigma_{E,j}}\right)^{\xi} (\ln N_R)\right]$$

where:

ξ : Weibull shape parameter, taken equal to 1.0

N_R : Number of cycles, taken equal to 10^4.

3.3 Elementary fatigue damage

3.3.1

The elementary fatigue damage for each loading condition is to be calculated with the following formula:

$$D_j = \frac{\alpha_j N_L}{K} \frac{{\Delta\sigma_{E,j}}^4}{(\ln N_R)^{4/\xi}} \left[\Gamma\left(\frac{4}{\xi}+1, \nu\right) + \nu^{-3/\xi} \gamma\left(\frac{7}{\xi}+1, \nu\right) \right]$$

where:

K : S-N curve parameter, taken equal to $1.014 \cdot 10^{15}$

α_j : Coefficient taken equal to 1.0 for the assessment of hatch corners and depending on the loading condition specified in Tab 2 for primary members and longitudinal stiffeners connections.

N_L : Total number of cycles for the design ship's life, taken equal to:

$$N_L = \frac{0.85 T_L}{4 \log L}$$

T_L : Design life, in seconds, corresponding to 25 years of ship's life, taken equal to $7.884 \cdot 10^8$

$$\nu = \left(\frac{100.3}{\Delta\sigma_{E,j}}\right)^{\xi} \ln N_R$$

Γ : Type 2 incomplete gamma function

γ : Type 1 incomplete gamma function

Table 2: Coefficient α_j depending on the loading condition

	Loading Conditions	BC-A	BC-B, BC-C
$L < 200$ m	Homogeneous	0.6	0.7
	Alternate	0.1	---
	Normal ballast	0.15	0.15
	Heavy ballast	0.15	0.15
$L \geq 200$ m	Homogeneous	0.25	0.5
	Alternate	0.25	---
	Normal ballast	0.2	0.2
	Heavy ballast	0.3	0.3

4. Fatigue strength criteria

4.1 Cumulative fatigue damage

4.1.1

The cumulative fatigue damage D calculated for the combined equivalent stress is to comply with the following criteria:

$$D = \sum_j D_j \leq 1.0$$

where

D_j : Elementary fatigue damage for each loading condition "j".

Section 3 – STRESS ASSESSMENT OF PRIMARY MEMBERS

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

i : Suffix which denotes load case "H", "F", "R" or "P" specified in Ch 4, Sec 4
"$i1$" denotes load case "H1", "F1", "R1" or "P1" and "$i2$" denotes load case "H2", "F2", "R2" or "P2"

(k) : Suffix which denotes loading condition, "homogeneous condition", "alternate condition", "normal ballast condition" or "heavy ballast condition" as defined in Sec 1, Tab 2

$\Delta\sigma_{W,\,i(k)}$: Hot spot stress range, in N/mm^2, in load case "i" of loading condition "(k)"

$\sigma_{mean,\,i(k)}$: Structural hot spot mean stress, in N/mm^2, in load case "i" of loading condition "(k)".

1. General

1.1 Application

1.1.1

Hot spot stress ranges and structural hot spot mean stresses of primary members are to be assessed according to the requirements of this Section, with the requirements given in Ch 7, Sec 4.

2. Hot spot stress range

2.1 Stress range according to the direct method

2.1.1

The hot spot stress range, in N/mm^2, in load case "i" of loading condition "(k)" is to be obtained from the following formula:

$$\Delta\sigma_{W,i(k)} = \left|\sigma_{W,i1(k)} - \sigma_{W,i2(k)}\right|$$

where:

$\sigma_{W,\,i1(k)}$, $\sigma_{W,\,i2(k)}$: Hot spot stress, in N/mm^2, in load case "$i1$" and "$i2$" of loading condition "(k)", obtained by direct FEM analysis using fine mesh model specified in Ch 7, Sec 4.

2.2 Stress range according to the superimposition method

2.2.1 Hot spot stress range

The hot spot stress range, in N/mm^2, in load case "i" of loading condition "(k)" is to be obtained from the following formula:

$$\Delta\sigma_{W,i(k)} = \left|\left(\sigma_{GW,i1(k)} + \sigma_{LW,i1(k)}\right) - \left(\sigma_{GW,i2(k)} + \sigma_{LW,i2(k)}\right)\right|$$

where:

$\sigma_{LW,i1(k)}$, $\sigma_{LW,i2(k)}$: Hot spot stress, in N/mm^2, due to local loads in load cases "i1" and "i2" for loading condition "(k)" obtained by the direct analysis using fine mesh FE model specified in Ch 7, Sec 4

$\sigma_{GW,i1(k)}$, $\sigma_{GW,i2(k)}$: Hot spot stress, in N/mm^2, due to hull girder moments in load cases "i1" and "i2" for loading condition "(k)" obtained according to [2.2.2].

2.2.2 Stress due to hull girder moments

The hull girder hot spot stress, in N/mm^2, in load cases "i1" and "i2" for loading condition "(k)" is to be obtained from the following formula:

$$\sigma_{GW,ij(k)} = C_{WV,ij}\,\sigma_{WV,ij} - C_{WH,ij}\,\sigma_{WH,(k)} \qquad (j = 1, 2)$$

where:

$C_{WV,i1}$, $C_{WV,i2}$, $C_{WH,i1}$, $C_{WH,i2}$: Load combination factors for each load case defined in Ch 4, Sec 4, [2.2]

$\sigma_{WV,i1}$: Nominal hull girder stress, in N/mm^2, in sagging condition induced by vertical wave bending moment

$$\sigma_{WV,i1} = \frac{M_{WV,S}\,(z-N)}{I_Y}\,10^{-3}$$

$\sigma_{WV,i2}$: Nominal hull girder stress, in N/mm^2, in hogging condition induced by vertical wave bending moment

$$\sigma_{WV,i2} = \frac{M_{WV,H}\,(z-N)}{I_Y}\,10^{-3}$$

$M_{WV,H}$, $M_{WV,S}$: Vertical wave bending moments, in kN.m, in hogging and sagging conditions defined in Ch 4, Sec 3, [3.1.1], with $f_p = 0.5$

N : Z co-ordinate, in m, of the neutral axis , as defined in Ch 5, Sec 1

z : Z co-ordinate, in m, of the point considered

$\sigma_{WH,(k)}$: Nominal hull girder stress, in N/mm^2, induced by horizontal wave bending moment

$$\sigma_{WH,(k)} = \frac{M_{WH,(k)}\,y}{I_Z}\,10^{-3}$$

$M_{WH,(k)}$: Horizontal wave bending moment, in kN.m, in loading condition "(k)"defined in Ch 4, Sec 3, [3.3.1], with $f_p = 0.5$

y : Y co-ordinate, in m, of the point considered, to be taken positive at port side and negative at starboard side

I_Y , I_Z : Net moments of inertia of hull cross-section, in m^4, about transverse and vertical axis respectively, as defined in Ch 5, Sec 1.

3. Hot spot mean stress

3.1 Mean stress according to the direct method

3.1.1

The structural hot spot mean stress, in N/mm^2, in load case "i" for loading condition "(k)" is to be obtained from the following formula:

$$\sigma_{mean,i(k)} = \frac{\sigma_{W,i1(k)} + \sigma_{W,i2(k)}}{2}$$

3.2 Mean stress according to the superimposition method

3.2.1 Hot spot mean stresses

The structural hot spot mean stress, in N/mm^2, in load case "*i*" for loading condition "(*k*)" is to be obtained from the following formula:

$$\sigma_{mean,\,i(k)} = \sigma_{GS,\,(k)} + \frac{\sigma_{LW,\,i1(k)} + \sigma_{LW,\,i2(k)}}{2}$$

where:

$\sigma_{GS,\,(k)}$: Hot spot mean stress, in N/mm^2, due to still water hull girder moment in loading condition "(*k*)" obtained according to [3.2.2].

$\sigma_{LW,i1(k)}$, $\sigma_{LW,i2(k)}$: As defined in 2.2.1

3.2.2 Stress due to still water hull girder moment

The hot spot stress, in N/mm^2, due to still water bending moment in loading condition "(*k*)" is to be obtained from the following formula:

$$\sigma_{GS,\,(k)} = \frac{M_{S,\,(k)}\left(z - N\right)}{I_Y} 10^{-3}$$

where:

$M_{S,\,(k)}$: Still water vertical bending moment, in kN.m, depending on the loading condition defined in Ch 4, Sec 3, [2.2]. If the design still water bending moments are not defined at a preliminary design stage, still water bending moment in each loading condition may be obtained from the following formulae:

homogeneous condition ; $M_{S,(1)} = -0.5 F_{MS} M_{SW,S}$

alternate condition ; $M_{S,(2)} = F_{MS} M_{SW,H}$

normal ballast condition ; $M_{S,(3)} = F_{MS} M_{SW,H}$

heavy ballast condition ;
$$M_{S,(4)} = \begin{cases} 2.66 \dfrac{x}{L} M_{SW,H} & ; \quad 0 < x \le 0.15L \\ 2.66\left(0.3 - \dfrac{x}{L}\right) M_{SW,H} & ; \quad 0.15L < x \le 0.3L \\ -3.5\left(\dfrac{x}{L} - 0.3\right) M_{SW,S} & ; \quad 0.3L < x \le 0.5L \\ -3.5\left(0.7 - \dfrac{x}{L}\right) M_{SW,S} & ; \quad 0.5L < x \le 0.7L \\ 2.66\left(\dfrac{x}{L} - 0.7\right) M_{SW,H} & ; \quad 0.7L < x \le 0.85L \\ 2.66\left(1 - \dfrac{x}{L}\right) M_{SW,H} & ; \quad 0.85L < x \le L \end{cases}$$

$M_{SW,H}$, $M_{SW,S}$: Permissible still water bending moment, in kN.m, in hogging and sagging conditions

F_{MS} : Distribution factor defined in Ch 4, Sec 3, Fig 2

Section 4 – STRESS ASSESSMENT OF STIFFENERS

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

i : Suffix which denotes load case "H", "F", "R" or "P" specified in Ch 4, Sec 4
"i1" denotes load case "H1", "F1", "R1" or "P1" and "i2" denotes load case "H2", "F2", "R2" or "P2"

(k) : Suffix which denotes loading condition, "homogeneous condition", "alternate condition", "normal ballast condition" or "heavy ballast condition" as defined in Sec 1, Tab 2

$\Delta\sigma_{W\,,\,i(k)}$: Hot spot stress range, in N/mm^2, in load case "i" of loading condition "(k)"

$\sigma_{mean\,,\,i(k)}$: Structural hot spot mean stress, in N/mm^2, in load case "i" of loading condition "(k)"

1. General

1.1 Application

1.1.1

Hot spot stress ranges and structural hot spot mean stresses of longitudinal stiffeners are to be assessed in line with the requirements of this Section.

1.1.2

The hot spot stress ranges and structural hot spot mean stresses of longitudinal stiffeners are to be evaluated at the face plate of the longitudinal considering the type of longitudinal end connection and the following locations.

(1) Transverse webs or floors other than those at transverse bulkhead of cargo hold or in way of stools, such that additional hot spot stress due to the relative displacement may not be considered. These longitudinal end connections are defined in Tab.1. When transverse webs or floors are watertight, the coefficients K_{gl} and K_{gh} as defined in Tab 2 are to be considered instead of those defined in Tab 1.

(2) Transverse webs or floors at transverse bulkhead of cargo hold in way of stools, such that additional hot spot stress due to the relative displacement should be considered. These longitudinal end connections are defined in Tab 2. When transverse webs or floors at transverse bulkhead of cargo hold or in way of stools are not watertight, the coefficients K_{gl} and K_{gh} as defined in Tab 1 are to be considered instead of those defined in Tab 2.

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2. Hot spot stress range

2.1 Stress range obtained by the direct method

2.1.1

Hot spot stress ranges, in N/mm^2, calculated with direct calculation for each load case "H", "F", "R" and "P" of each loading condition, are to be obtained according to Sec 3, [2.1].

2.2 Stress range according to the superimposition method

2.2.1

The hot spot stress ranges, in N/mm², for each load case "H", "F", "R" and "P" of each loading condition according to the superimposition method are to be obtained according to Sec 3, [2.2].

2.3 Stress range according to the simplified procedure

2.3.1 Hot spot stress ranges

The hot spot stress range, in N/mm², due to dynamic loads in load case "*i*" of loading condition "(*k*)" is to be obtained from the following formula:

$$\Delta\sigma_{W,i(k)} = \left|\left(\sigma_{GW,i1(k)} + \sigma_{W1,i1(k)} - \sigma_{W2,i1(k)} + \sigma_{d,i1(k)}\right) - \left(\sigma_{GW,i2(k)} + \sigma_{W1,i2(k)} - \sigma_{W2,i2(k)} + \sigma_{d,i2(k)}\right)\right|$$

where

$\sigma_{GW,i1(k)}$, $\sigma_{GW,i2(k)}$: Stress due to hull girder moment, defined in [2.3.2]

$\sigma_{W1,i1(k)}$, $\sigma_{W1,i2(k)}$: Stress $\sigma_{LW,ij(k)}$, $\sigma_{CW,ij(k)}$ and $\sigma_{LCW,ij(k)}$ due to hydrodynamic or inertial pressure when the pressure is applied on the same side as the ordinary stiffener depending on the considered case

$\sigma_{W2,i1(k)}$, $\sigma_{W2,i2(k)}$: Stress $\sigma_{LW,ij(k)}$, $\sigma_{CW,ij(k)}$ and $\sigma_{LCW,ij(k)}$ due to hydrodynamic or inertial pressure when the pressure is applied on the side opposite to the stiffener depending on the considered case

$\sigma_{LW,i1(k)}$, $\sigma_{LW,i2(k)}$: Stresses due to wave pressure, defined in [2.3.3]

$\sigma_{CW,i1(k)}$, $\sigma_{CW,i2(k)}$: Stresses due to liquid pressure, defined in [2.3.4]

$\sigma_{LCW,i1(k)}$, $\sigma_{LCW,i2(k)}$: Stresses due to dry bulk cargo pressure, defined in [2.3.5]

$\sigma_{d,i1(k)}$, $\sigma_{d,i2(k)}$: Stress due to relative displacement of transverse bulkhead, or floor in way of stools, defined in [2.3.6].

RCN 1 to July 2008 version (effective from 1July 2009)

2.3.2 Stress due to hull girder moments

The hull girder hot spot stress, in N/mm², in load case "*i*1" and "*i*2" for loading condition "(*k*)" is to be obtained from the following formula:

$$\sigma_{GW,ij(k)} = K_{gh} \cdot \left(C_{WV,ij}\,\sigma_{WV,ij} - C_{WH,ij}\,\sigma_{WH,(k)}\right) \qquad (j = 1, 2)$$

where:

K_{gh} : Geometrical stress concentration factor for nominal hull girder stress. K_{gh} is given in Tab 1 and Tab 2 for the longitudinal end connection specified in [1.1.2] (1) and [1.1.2] (2), respectively.
The stress concentration factor can be evaluated directly by the FE analysis.

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$C_{WV,i1}$, $C_{WV,i2}$, $C_{WH,i1}$, $C_{WH,i2}$: Load combination factors for each load case defined in Ch 4, Sec 4, [2.2]

$\sigma_{WV,i1}$, $\sigma_{WV,i2}$, $\sigma_{WH,(k)}$: Nominal hull girder stresses, in N/mm², defined in Sec 3, [2.2.2]

2.3.3 Stress due to wave pressure

The hot spot stress, in N/mm^2, due to the wave pressure in load case "*i*1" and "*i*2" for loading condition "(*k*)" is to be obtained from the following formula:

$$\sigma_{LW,\,i\,j(k)} = \frac{K_{gl} K_s p_{CW,i\,j(k)}\, s\ell^2 \left(1 - \frac{6x_f}{\ell} + \frac{6x_f^{\,2}}{\ell^2}\right)}{12w} 10^3 \qquad (j = 1,\ 2)$$

$$p_{CW,i1(k)} = \begin{cases} 2C_{NE,i1(k)} p_{W,i1(k)} & ; C_{NE,i1(k)} < 0.5 \\ p_{w,i1(k)} & ; C_{NE,i1(k)} \geq 0.5 \end{cases}$$

$$p_{CW,i2(k)} = \begin{cases} 0 & ; C_{NE,i2(k)} < 0.5 \\ (2C_{NE,i2(k)} - 1) p_{W,i2(k)} & ; C_{NE,i2(k)} \geq 0.5 \end{cases}$$

RCN 1 to July 2008 version (effective from 1 July 2009)

where:

$p_{W,\,i\,j(k)}$: Hydrodynamic pressure, in kN/m^2, specified in Ch 4, Sec 5, [1.3], [1.4] and [1.5] , with f_p = 0.5, in load case "*i*1" and "*i*2" for loading condition "(*k*)". When the location of the considered member is above the waterline, the hydrodynamic pressure is to be taken as the pressure at waterline.

K_{gl} : Geometrical stress concentration factor for stress due to lateral pressure. K_{gl} is given in Tab 1 and Tab 2 for the longitudinal end connection specified in [1.1.2] (1) and [1.1.2] (2), respectively. The stress concentration factor can be evaluated directly by the FE analysis.

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K_s : Geometrical stress concentration factor due to stiffener geometry

$$K_s = 1 + \left[\frac{t_f (a^2 - b^2)}{2w_b}\right]\left[1 - \frac{b}{b_f}\left(1 + \frac{w_b}{w_a}\right)\right] 10^{-3}$$

a , b : Eccentricity, in mm, of the face plate as defined in Fig 1. For angle profile, "*b*" is to be taken as half the net actual thickness of the web.

t_f, b_f : Thickness and breadth of face plate, in mm, respectively, as defined in Fig 1

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w_a , w_b : Net section modulus in A and B respectively (see Fig.1), in cm^3, of the stiffener about the neutral axis parallel to Z axis without attached plating.

$C_{NE,\,i\,j(k)}$: Correction factor for the non linearity of the wave pressure range in load case "*i*1" and "*i*2" of loading condition "(*k*)"

$$C_{NE,\,i\,j(k)} = \begin{cases} \exp\left[-\left(\dfrac{z - T_{LC(k)} + \dfrac{|p_{W,\,i\,j(k),WL}|}{\rho g}}{\dfrac{|p_{W,\,i\,j(k),WL}|}{\rho g}(-\ln 0.5)^{-1/2.5}}\right)^{2.5}\right] & \text{for} \quad z > T_{LC(k)} - \dfrac{|p_{W,\,i\,j(k),WL}|}{\rho g} \\ 1.0 & \text{for} \quad z \leq T_{LC(k)} - \dfrac{|p_{W,\,i\,j(k),WL}|}{\rho g} \end{cases}$$

$T_{LC(k)}$: Draught, in m, of the considered loading condition "(*k*)"

$p_{W,\,i\,j(k),\,WL}$: Hydrodynamic pressure, in kN/m^2, at water line in load case "*i*1" and "*i*2" of loading condition "(*k*)"

z : Z co-ordinate, in m, of the point considered

s : Stiffener spacing, in m

ℓ : Span, in m, to be measured as shown in Fig 2. The ends of the span are to be taken at points where the depth of the end bracket, measured from the face plate of the stiffener is equal to half the depth of the stiffener

x_f : Distance, in m, to the hot spot from the closest end of the span ℓ (see Fig 2)

w : Net section modulus, in cm^3, of the considered stiffener. The section modulus w is to be calculated considering an effective breadth s_e, in m, of attached plating obtained from the following formulae:

$$s_e = \begin{cases} 0.67s \cdot \sin\left[\dfrac{\pi}{6}\left(\dfrac{\ell\left(1-1/\sqrt{3}\right)}{2s}\right)\right] & \text{for} \quad \dfrac{\ell}{s} \le \dfrac{6}{1-1/\sqrt{3}} \\ 0.67s & \text{for} \quad \dfrac{\ell}{s} > \dfrac{6}{1-1/\sqrt{3}} \end{cases}$$

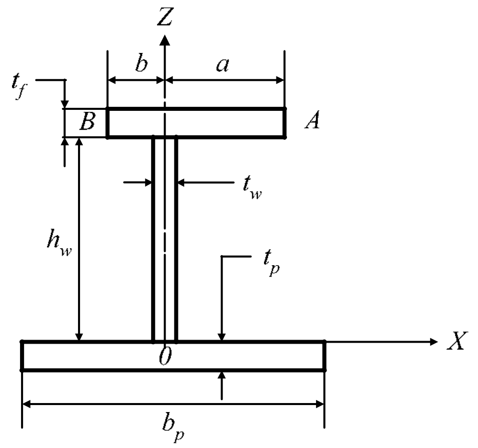

Figure 1: Sectional parameters of a stiffener

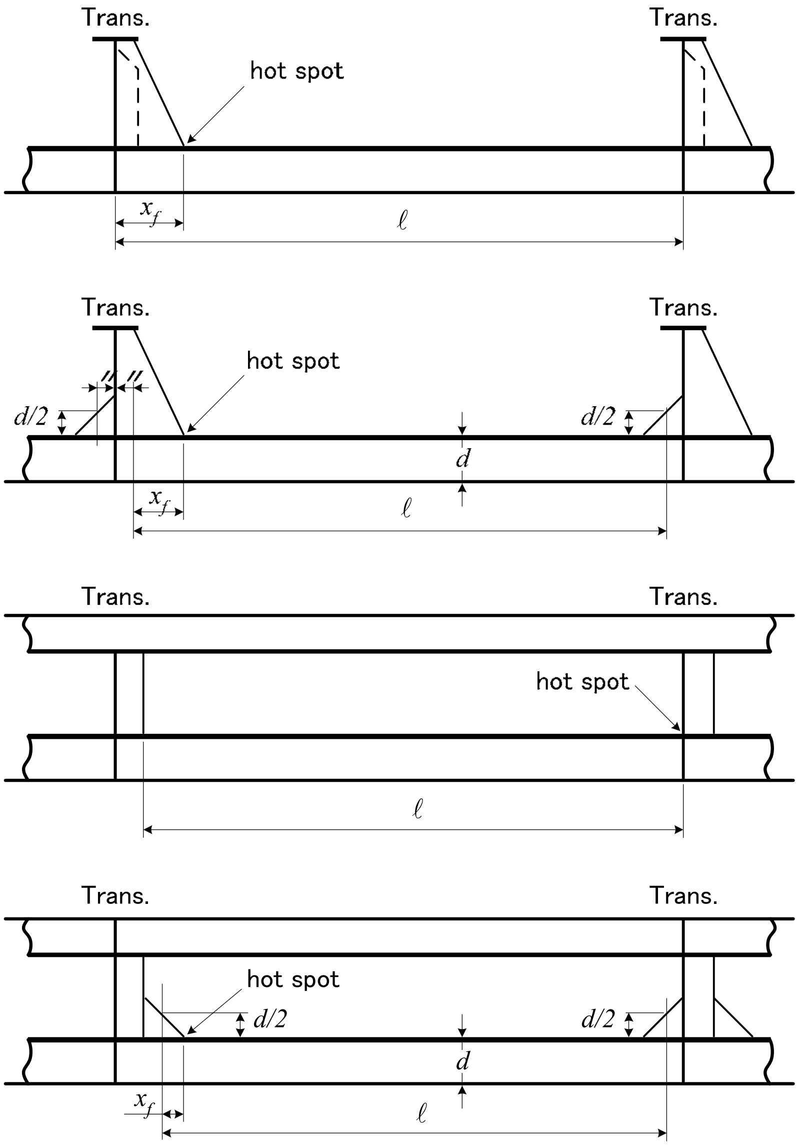

Figure 2: Span and hot spot of longitudinal stiffeners

2.3.4 Stress due to liquid pressure

The hot spot stress, in N/mm^2, due to the liquid pressure in load case "$i1$" and "$i2$" for loading condition "(k)" is to be obtained from the following formula:

$$\sigma_{CW,ij(k)} = \frac{K_{gl} K_s C_{NI,ij(k)} p_{BW,ij(k)} s \ell^2 \left(1 - \frac{6x_f}{\ell} + \frac{6x_f^{\ 2}}{\ell^2}\right)}{12w} \cdot 10^3 \qquad (j = 1, 2)$$

where:

$p_{BW,ij(k)}$: Inertial pressure, in kN/m^2, due to liquid specified in Ch 4, Sec 6, [2.2], with $f_p = 0.5$, in load case "$i1$" and "$i2$" for loading condition "(k)". Where the considered location is located in fuel oil, other oil or fresh water tanks, no inertial pressure is considered for the tank top longitudinals and when the location of the considered member is above the liquid surface in static and upright condition, the inertial pressure is to be taken at the liquid surface line. *RCN 1 to July 2008 version (effective from 1 July 2009)*

$C_{NI,\,i\,j(k)}$: Correction factor for the non linearity of the inertial pressure range due to liquid in load case "*i*1" and "*i*2" for loading condition "(*k*)"

$$C_{NI,\,i\,j(k)}=\begin{cases}\exp\left[-\left(\dfrac{z-z_{SF}+\dfrac{\left|p_{BW,\,i\,j(k),\,SF}\right|}{\rho g}}{\dfrac{\left|p_{BW,\,i\,j(k),\,SF}\right|}{\rho g}\left(-\ln 0.5\right)^{-1/2.5}}\right)^{2.5}\right] & \text{for}\quad z>z_{SF}-\dfrac{\left|p_{BW,\,i\,j(k),\,SF}\right|}{\rho g}\\ 1.0 & \text{for}\quad z\le z_{SF}-\dfrac{\left|p_{BW,\,i\,j(k),\,SF}\right|}{\rho g}\end{cases}$$

z_{SF} : Z co-ordinate, in m, of the liquid surface. In general, it is taken equal to "Z_{TOP}" defined in Ch 4, Sec 6. If the considered location is located in fuel oil, other oil or fresh water tanks, it may be taken as the distance to the half height of the tank. *RCN 1 to July 2008 version (effective from 1 July 2009)*

z : Z co-ordinate, in m, of the point considered

$p_{BW,\,i\,j(k),\,SF}$: Inertial pressure due to liquid, in kN/m^2, taken at the liquid surface in load case "*i*1" and "*i*2" for loading condition "(*k*)". In calculating the inertial pressure according to Ch 4, Sec 6, [2.2.1], x and y coordinates of the reference point are to be taken as liquid surface instead of tank top.

RCN 1 to July 2008 version (effective from 1 July 2009)

$K_{gh}\,K_s$: The stress concentration factor defined in [2.3.3] *RCN 1 to July 2008 version (effective from 1 July 2009)*

2.3.5 Stress due to dry bulk cargo pressure

The hot spot stress, in N/mm^2, due to the dry bulk cargo pressure in load case "*i*1" and "*i*2" for loading condition "(*k*)" is to be obtained from the following formula:

$$\sigma_{LCW,\,i\,j\,(k)}=\frac{K_{gl}K_s\,p_{CW,\,i\,j(k)}s\ell^2\left(1-\dfrac{6x_f}{\ell}+\dfrac{6x_f^{\,2}}{\ell^2}\right)}{12w}10^3\qquad(j=1,2)$$

where:

$p_{CW,\,i\,j(k)}$: Inertial pressure, in kN/m^2, due to dry bulk cargo specified in Ch 4, Sec 6, [1.3] for a cargo density ρ_C specified in Ch.4 Annex 3 and with $f_p = 0.5$, in load case "*i*1" and "*i*2" for loading condition "(*k*)"

RCN 1 to July 2010 version (effective from 1July 2012)

2.3.6 Stress due to relative displacement of transverse bulkhead or floor in way of transverse bulkhead or stool

For longitudinal end connection specified in [1.1.2] (2), the additional hot spot stress, in N/mm^2, due to the relative displacement in the direction perpendicular to the attached plate between the transverse bulkhead or floor in way of stools and the adjacent transverse web or floor in load case "*i*1" and "*i*2" for loading condition "(*k*)" is to be obtained from the following formula:

$$\sigma_{d,\,i\,j(k)}=\begin{cases}K_{dF-a}\sigma_{dF-a,\,i\,j(k)}+K_{dA-a}\sigma_{dA-a,\,i\,j(k)} & \text{for point "}a\text{"}\\ K_{dF-f}\sigma_{dF-f,\,i\,j(k)}+K_{dA-f}\sigma_{dA-f,\,i\,j(k)} & \text{for point "}f\text{"}\end{cases}\qquad(j=1,2)$$

RCN1 to July 2008 version (effective from 1July 2009)

where:

a , f : Suffix which denotes the location considered as indicated in Tab 2.

A , F : Suffix which denotes the direction, forward (F) and afterward (A), of the transverse web or floor where the relative displacement is occurred as indicated in Tab 2. (see Fig 3)

$\sigma_{dF\text{-}a\,,\,i\,j(k)}$, $\sigma_{dA\text{-}a\,,\,i\,j(k)}$, $\sigma_{dF\text{-}f\,,\,i\,j(k)}$, $\sigma_{dA\text{-}f\,,\,i\,j(k)}$: Additional stress at point "a" and "f", in N/mm^2, due to the relative displacement between the transverse bulkhead or floors in way of stools and the forward (F) and afterward (A) transverse web or floor respectively in load case "i1" and "i2" for loading condition "(k)" *RCN 1 to July 2008 version (effective from 1 July 2009)*

$$\sigma_{dF-a,i\,j(k)} = \frac{3.9\delta_{F,i\,j(k)} E I_A I_F}{w_A \ell_F (\ell_A I_F + \ell_F I_A)} \left(1 - 1.15 \frac{|x_{fA}|}{\ell_A}\right) 10^{-5}$$

$$\sigma_{dA-a,i\,j(k)} = \left[\frac{3.9\delta_{A,i\,j(k)} E I_A I_F}{w_A \ell_A (\ell_A I_F + \ell_F I_A)} \left(1 - 1.15 \frac{|x_{fA}|}{\ell_A}\right) - \frac{0.9\delta_{A,i\,j(k)} E I_A |x_{fA}|}{w_A \ell_A^{\,3}}\right] 10^{-5}$$

$$\sigma_{dF-f,i\,j(k)} = \left[\frac{3.9\delta_{F,i\,j(k)} E I_A I_F}{w_F \ell_F (\ell_A I_F + \ell_F I_A)} \left(1 - 1.15 \frac{|x_{fF}|}{\ell_F}\right) - \frac{0.9\delta_{F,i\,j(k)} E I_F |x_{fF}|}{w_F \ell_F^{\,3}}\right] 10^{-5}$$

$$\sigma_{dA-f,i\,j(k)} = \frac{3.9\delta_{A,i\,j(k)} E I_A I_F}{w_F \ell_A (\ell_A I_F + \ell_F I_A)} \left(1 - 1.15 \frac{|x_{fF}|}{\ell_F}\right) 10^{-5}$$

$\delta_{F\,,\,i\,j(k)}$, $\delta_{A\,,\,i\,j(k)}$: Relative displacement, in mm, in the direction perpendicular to the attached plate between the transverse bulkhead or floor in way of stools and the forward (F) and afterward (A) transverse web or floor in load case "i1" and "i2" for loading condition "(k)" (see Fig 3)

(a) For longitudinals penetrating floors in way of stools

Relative displacement is defined as the displacement of the longitudinal in relation to the line passing through the stiffener end connection at the base of the stool measured at the first floor forward (F) or afterward (A) of the stool.

(b) For longitudinals other than (a)

Relative displacement is defined as the displacement of the longitudinal in relation to its original position measured at the first forward (F) or afterward (A) of the transverse bulkhead.

Where the stress of the face of longitudinal at the assessment point due to relative displacement is tension, the sign of the relative displacement is positive. *RCN 1 to July 2008 version (effective from 1 July 2009)*

I_F , I_A : Net moment of inertia, in cm^4, of forward (F) and afterward (A) longitudinal

$K_{dF\text{-}a}$, $K_{dA\text{-}a}$, $K_{dF\text{-}f}$, $K_{dA\text{-}f}$: Stress concentration factor for stiffener end connection at point "a" and "f" subject to relative displacement between the transverse bulkhead and the forward (F) and afterward (A) transverse web or floors in way of stool respectively as defined in Tab 2. The stress concentration can be evaluated directly by the FE analysis when the detail of end connection is not defined in Tab 2.

ℓ_F , ℓ_A : Span, in m, of forward (F) and afterward (A) longitudinal to be measured as shown in Fig 2

x_{fF} , x_{fA} : Distance, in m, to the hot spot from the closest end of ℓ_F and ℓ_A respectively (see Fig 2).

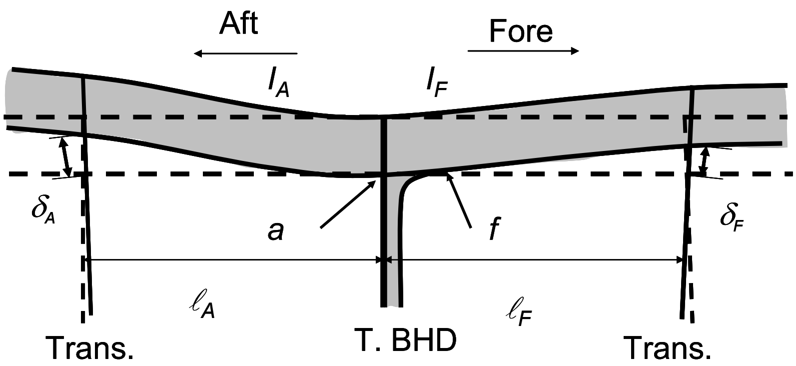

Figure 3: Definition of the relative displacement (Example of the side longitudinal)

RCN 1 to July 2008 version (effective from 1 July 2009)

3. Hot spot mean stress

3.1 Mean stress according to the direct method

3.1.1

The structural hot spot mean stress, in N/mm^2, in each loading condition calculated with the direct method is to be obtained according to Sec 3, [3.1].

3.2 Mean stress according to the superimposition method

3.2.1

The structural hot spot mean stress, in N/mm^2, in each loading condition calculated with the superimposition method is to be obtained according to Sec 3, [3.2].

3.3 Mean stress according to the simplified procedure

3.3.1 Hot spot mean stresses

The structural hot spot mean stress, in N/mm^2, in loading condition "(k)" regardless of load case "i" is to be obtained from the following formula:

$$\sigma_{mean,(k)} = \sigma_{GS,(k)} + \sigma_{S1,(k)} - \sigma_{S2,(k)} + \sigma_{dS,(k)}$$

where

$\sigma_{GS,(k)}$: Stress due to still water hull girder moment, defined in [3.3.2]

$\sigma_{S1,(k)}$: Stress due to static pressure when the pressure is applied on the same side as the ordinary stiffener depending on the considered case, with consideration of the stresses defined in [3.3.3] to [3.3.5]

$\sigma_{S2,(k)}$: Stress due to static pressure when the pressure is applied on the side opposite to the stiffener depending on the considered case

$\sigma_{dS,(k)}$: Stress due to relative displacement of transverse bulkhead in still water, defined in [3.3.6]. *RCN 1 to July 2008 version (effective from 1 July 2009)*

3.3.2 Stress due to still water hull girder moment

The hot spot stress due to still water bending moment, in N/mm^2, in loading condition "(k)" is to be obtained with the following formula:

$$\sigma_{GS,(k)} = K_{gh} \frac{M_{S,(k)}(z-N)}{I_Y} 10^{-3}$$

where:

$M_{S,(k)}$: Still water vertical bending moment, in kN.m, defined in Sec 3, [3.2.2].

3.3.3 Stress due to hydrostatic and hydrodynamic pressure

The hot spot stress due to hydrostatic and hydrodynamic pressure, in N/mm^2, in loading condition "(k)" is to be obtained with the following formula:

$$\sigma_{LS,(k)} = \frac{K_{gl}K_s\left\{p_{s,(k)} + \frac{p_{CW,i1(k)}+p_{CW,i2(k)}}{2}\right\}s\ell^2\left(1-\frac{6x_f}{\ell}+\frac{6x_f{}^2}{\ell^2}\right)}{12w} 10^3$$

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where:

$p_{S,(k)}$: Hydrostatic pressure, in kN/m^2, in loading condition "(k)" specified in Ch 4, Sec 5, [1.2].

$p_{CW,ij(k)}$: Corrected hydrodynamic pressure, in kN/m², according to [2.3.3], with $f_p = 0.5$, in load case "i1" and "i2" for loading condition "(k)"

i : Suffix which denotes the load case specified in Sec 2 [2.1.1], when calculating the mean stress, "I" is to be used.

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3.3.4 Stress due to liquid pressure in still water

The structural hot spot mean stress due to liquid pressure in still water, in N/mm^2, in loading condition "(k)" is to be obtained with the following formula:

$$\sigma_{CS,(k)} = \frac{K_{gl}K_s p_{CS,(k)} s\ell^2\left(1-\frac{6x_f}{\ell}+\frac{6x_f{}^2}{\ell^2}\right)}{12w} 10^3$$

where:

$p_{CS,(k)}$: Liquid pressure in still water, in kN/m^2, in loading condition "(k)" specified in Ch 4, Sec 6 [2.1]. Where the considered location is located in fuel oil, other oil or fresh water tanks, d_{AP} and P_{PV} defined in Ch 4, Sec 6 are to be taken equal to 0 and z_{TOP} specified in Ch 4, Sec 6, [2.1] is to be taken equal to z_{SF} specified in [2.3.4] *RCN 1 to July 2008 version (effective from 1 July 2009)*

3.3.5 Stress due to dry bulk cargo pressure in still water

The structural hot spot mean stress due to dry bulk cargo pressure in still water, in N/mm^2, in loading condition "(k)" is to be obtained with the following formula:

$$\sigma_{LCS,(k)} = \frac{K_{gl}K_s p_{CS,(k)} s\ell^2\left(1-\frac{6x_f}{\ell}+\frac{6x_f{}^2}{\ell^2}\right)}{12w} 10^3$$

where:

$p_{CS,(k)}$: Dry bulk cargo pressure in still water, in kN/m^2, in loading condition "(k)" specified in Ch 4, Sec 6, [1.2]

3.3.6 Stress due to relative displacement of transverse bulkhead in still water

The additional hot spot mean stress, in N/mm^2, due to the relative displacement in the transverse direction between the transverse bulkhead and the adjacent transverse web or floor in loading condition "(k)", is to be obtained with the following formula:

$$\sigma_{dS,(k)} = \begin{cases} K_{dF-a}\sigma_{dSF-a,(k)} + K_{dA-a}\sigma_{dSA-a,(k)} & \text{for point "}a\text{"} \\ K_{dF-f}\sigma_{dSF-f,(k)} + K_{dA-f}\sigma_{dSA-f,(k)} & \text{for point "}f\text{"} \end{cases}$$

where:

$\sigma_{dSF-a,(k)}$, $\sigma_{dSA-a,(k)}$, $\sigma_{dSF-f,(k)}$, $\sigma_{dSA-f,(k)}$: Additional stress at point "a" and "f", in N/mm^2, due to the relative displacement between the transverse bulkhead and the forward (F) and afterward (A) transverse web or floor respectively in loading condition (k)

$$\sigma_{dSF-a,(k)} = \frac{3.9\delta_{SF,(k)} E I_A I_F}{w_A \ell_F (\ell_A I_F + \ell_F I_A)} \left(1 - 1.15\frac{|x_{fA}|}{\ell_A}\right) 10^{-5}$$

$$\sigma_{dSA-a,(k)} = \left[\frac{3.9\delta_{SA,(k)} E I_A I_F}{w_A \ell_A (\ell_A I_F + \ell_F I_A)} \left(1 - 1.15\frac{|x_{fA}|}{\ell_A}\right) - \frac{0.9\delta_{SA,(k)} E I_A |x_{fA}|}{w_A {\ell_A}^3}\right] 10^{-5}$$

$$\sigma_{dSF-f,(k)} = \left[\frac{3.9\delta_{SF,(k)} E I_A I_F}{w_F \ell_F (\ell_A I_F + \ell_F I_A)} \left(1 - 1.15\frac{|x_{fF}|}{\ell_F}\right) - \frac{0.9\delta_{SF,(k)} E I_F |x_{fF}|}{w_F {\ell_F}^3}\right] 10^{-5}$$

$$\sigma_{dSA-f,(k)} = \frac{3.9\delta_{SA,(k)} E I_A I_F}{w_F \ell_A (\ell_A I_F + \ell_F I_A)} \left(1 - 1.15\frac{|x_{fF}|}{\ell_F}\right) 10^{-5}$$

$\delta_{SF,(k)}$, $\delta_{SA,(k)}$: Relative displacement, in mm, in still water in the transverse direction between the transverse bulkhead and the forward (F) and afterward (A) transverse web or floor respectively in loading condition (k)

Table 1: Stress concentration factors for non-watertight longitudinal end connection at transverse webs or floors other than transverse bulkheads or floors in way of stools

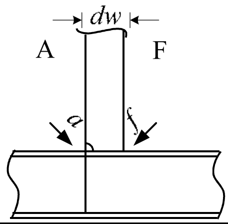
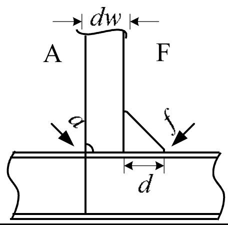
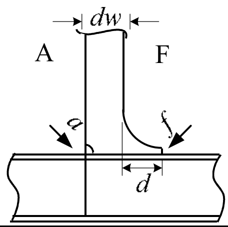
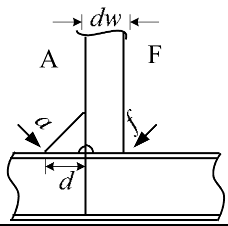
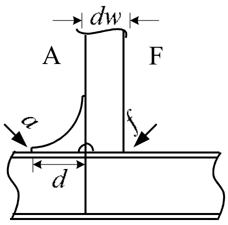
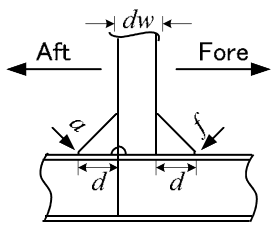
Bracket type	Assessed point	Bracket size	Stress concentration factors K_{gl}	Stress concentration factors K_{gh}
1 	*a*	-----	1.65	1.1
2 	*a*	$dw \le d < 1.5dw$	1.55	1.1
		$1.5dw \le d$	1.5	1.05
3 	*a*	$dw \le d < 1.5dw$	1.5	1.1
		$1.5dw \le d$	1.45	1.05
4 	*f*	$dw \le d < 1.5dw$	1.4	1.1
		$1.5dw \le d$	1.4	1.05
5 	*f*	$dw \le d < 1.5dw$	1.35	1.1
		$1.5dw \le d$	1.35	1.05
6 	*a*	$dw \le d < 1.5dw$	1.15	1.05
		$1.5dw \le d$	1.1	1.05

Table 1: Stress concentration factors for non-watertight longitudinal end connection at transverse webs or floors other than transverse bulkheads or floors in way of stools (continued)

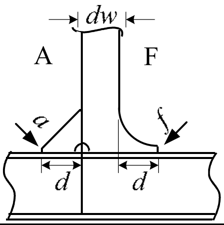
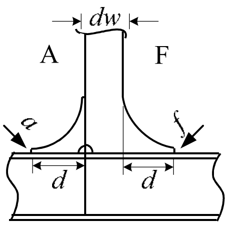
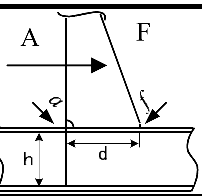
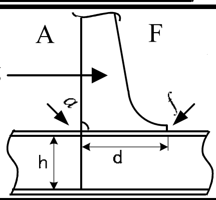
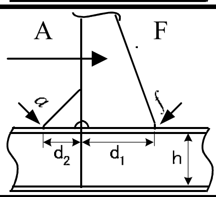
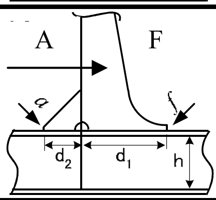
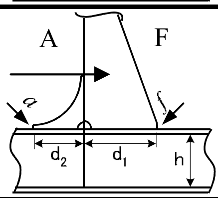
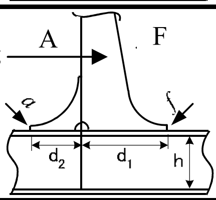
Bracket type	Assessed point	Bracket size	Stress concentration factors K_{gl}	Stress concentration factors K_{gh}
7 	a	$dw \le d < 1.5dw$	1.15	1.05
		$1.5dw \le d$	1.1	1.05
8 	a	$dw \le d < 1.5dw$	1.1	1.1
		$1.5dw \le d$	1.05	1.05
9 Tripping bracket 	a	$d \le 2h$	1.45	1.1
10 Tripping bracket 	a	$d \le 2.5h$	1.35	1.1
11 Tripping bracket 	a	$d_1 \le 2h$ and $h \le d_2$	1.15	1.1
	f		1.85	1.1
12 Tripping bracket 	a	$d_1 \le 2.5h$ and $h \le d_2$	1.15	1.1
	f		1.35	1.1
13 Tripping bracket 	a	$d_1 \le 2h$ and $h \le d_2$	1.1	1.1
	f		2.05	1.1
14 Tripping bracket 	a	$d_1 \le 2.5h$ and $h \le d_2$	1.1	1.1
	f		1.8	1.1

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Table 2: Stress concentration factors for watertight longitudinal end connection at transverse bulkheads and floors in way of stools

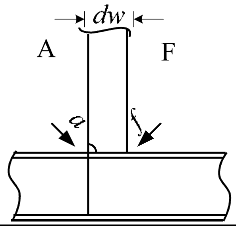
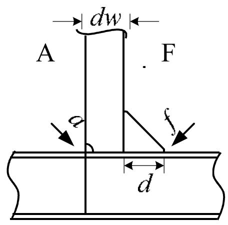
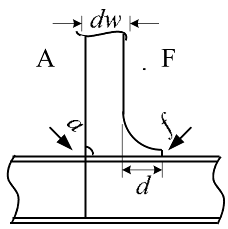
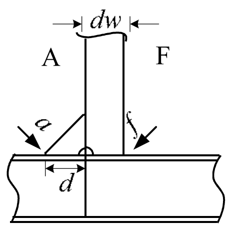
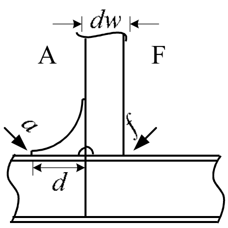
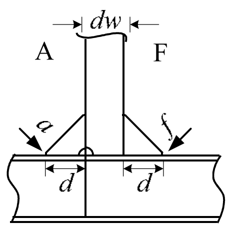
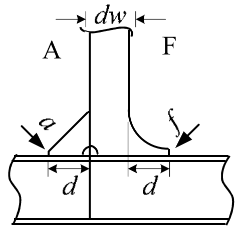
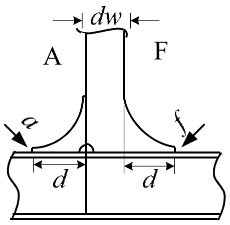
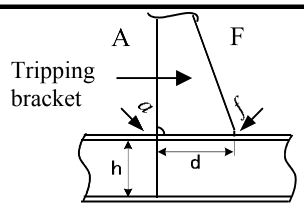
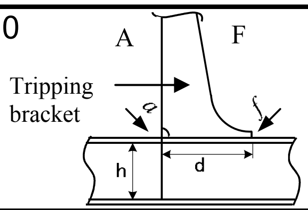
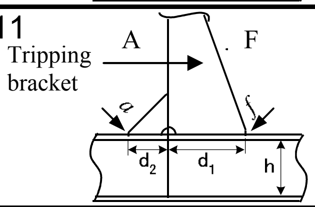
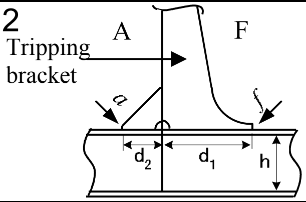
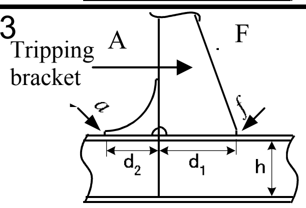
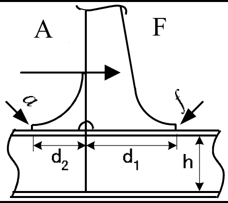
Bracket type	Assessed point	Bracket size	Stress concentration factors			
			K_{gl}	K_{gh}	K_{dF}	K_{dA}
1 	*a*	-----	1.5	1.1	1.15	1.5
	f	-----	1.1	1.05	1.55	1.05
2 	*a*	$dw \le d < 1.5dw$	1.45	1.1	1.15	1.4
		$1.5dw \le d$	1.4	1.05	1.15	1.35
	f	$dw \le d < 1.5dw$	1.1	1.05	1.15	1.1
		$1.5dw \le d$	1.05	1.05	1.1	1.05
3 	*a*	$dw \le d < 1.5dw$	1.4	1.1	1.1	1.35
		$1.5dw \le d$	1.35	1.05	1.05	1.3
	f	$dw \le d < 1.5dw$	1.05	1.05	1.1	1.05
		$1.5dw \le d$	1.05	1.05	1.05	1.05
4 	*a*	$dw \le d < 1.5dw$	1.1	1.05	1.05	1.25
		$1.5dw \le d$	1.05	1.05	1.05	1.2
	f	$dw \le d < 1.5dw$	1.3	1.1	1.35	1.05
		$1.5dw \le d$	1.3	1.05	1.3	1.05
5 	*a*	$dw \le d < 1.5dw$	1.1	1.05	1.05	1.2
		$1.5dw \le d$	1.05	1.05	1.05	1.15
	f	$dw \le d < 1.5dw$	1.3	1.1	1.55	1.1
		$1.5dw \le d$	1.3	1.05	1.5	1.05
6 	*a*	$dw \le d < 1.5dw$	1.1	1.05	1.05	1.1
		$1.5dw \le d$	1.05	1.05	1.05	1.05
	f	$dw \le d < 1.5dw$	1.05	1.05	1.1	1.05
		$1.5dw \le d$	1.05	1.05	1.05	1.05

Table 2: Stress concentration factors for watertight longitudinal end connection at transverse bulkheads and floors in way of stools (continued)

Bracket type	Assessed point	Bracket size	Stress concentration factors			
			K_{gl}	K_{gh}	K_{dF}	K_{dA}
7 	*a*	$dw \le d < 1.5dw$	1.1	1.05	1.05	1.2
		$1.5dw \le d$	1.05	1.05	1.05	1.15
	f	$dw \le d < 1.5dw$	1.05	1.05	1.05	1.05
		$1.5dw \le d$	1.05	1.05	1.05	1.05
8 	*a*	$dw \le d < 1.5dw$	1.1	1.1	1.05	1.15
		$1.5dw \le d$	1.05	1.05	1.05	1.1
	f	$dw \le d < 1.5dw$	1.05	1.05	1.1	1.05
		$1.5dw \le d$	1.05	1.05	1.05	1.05
9 	*a*	$d \le 2h$	1.4	1.05	1.05	1.75
	f		1.6	1.05	1.7	1.05
10 	*a*	$d \le 2.5h$	1.3	1.05	1.05	1.75
	f		1.55	1.05	1.3	1.05
11 	*a*	$d_1 \le 2h$ *and* $h \le d_2$	1.1	1.05	1.05	1.2
	f		1.75	1.05	1.4	1.05
12 	*a*	$d_1 \le 2.5h$ *and* $h \le d_2$	1.1	1.05	1.05	1.2
	f		1.3	1.05	1.05	1.05
13 	*a*	$d_1 \le 2h$ *and* $h \le d_2$	1.05	1.05	1.05	1.15
	f		1.95	1.05	1.55	1.05

14 Tripping bracket 	*a*	$d_1 \leq 2.5h$ *and* $h \leq d_2$	1.05	1.05	1.05	1.15
	f		1.7	1.05	1.15	1.05

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Section 5 – STRESS ASSESSMENT OF HATCH CORNERS

1. General

1.1 Application

1.1.1

Hot spot stress ranges and structural hot spot mean stresses of hatch corners based on the simplified procedure are to be assessed according to the requirements of this Section.

2. Nominal stress range

2.1 Nominal stress range due to wave torsional moment

2.1.1

The nominal stress range, in N/mm^2, due to cross deck bending induced by wave torsion moments is to be obtained from the following formula:

$$\Delta\sigma_{WT} = \frac{2}{1000} F_S F_L \frac{Q \cdot B_H}{W_Q}$$

where:

$$Q = 1000u \Big/ \left(\frac{(B_H + b_s)^3}{12 E I_Q} + \frac{2.6 B_H}{E A_Q} \right)$$

u : Displacement of hatch corner in longitudinal direction, in m, taken equal to:

$$u = \frac{31.2}{1000} \frac{M_{WT}\ \omega}{I_T E\ DOC}$$

DOC : Deck opening coefficient, taken equal to:

$$DOC = \frac{L_C B}{\sum_{i=1}^{n} L_{H,i} B_{H,i}}$$

M_{WT} : Maximum wave torsional moment, in kN.m, defined in Ch 4, Sec 3, [3.4.1], with $f_p = 0.5$

F_S : Stress correction factor, taken equal to:

$$F_S = 5$$

F_L : Correction factor for longitudinal position of hatch corner, taken equal to:

$$F_L = 1.75 \frac{x}{L} \quad \text{for } 0.57 \le x/L \le 0.85$$

$$F_L = 1.0 \quad \text{for } x/L < 0.57 \text{ and } x/L > 0.85$$

B_H : Breadth of hatch opening, in m

W_Q : Section modulus of the cross deck about z-axis, in m^3, including upper stool, near hatch corner (see Fig 2)

I_Q : Moment of inertia of the cross deck about z-axis, in m^4, including upper stool, near the hatch corner (see Fig 2)

A_Q : Effective shear area of the whole section of the cross deck, in m^2, including upper stool, near the hatch corner (see Fig 2). For the determination of the effective shear area the consideration of only the plate elements is sufficient, and the stiffeners can be neglected.

b_S : Breadth of remaining deck strip on one side, in m, beside the hatch opening

I_T : Torsion moment of inertia of ships cross section, in m^4, calculated within cross deck area by neglecting upper and lower stool of the bulkhead (see Fig 1). It may be calculated according to App 1

ω : Sector coordinate, in m^2, calculated at the same cross section as I_T and at the Y and Z location of the hatch corner (see Fig 1) It may be calculated according to App 1

L_C : Length of cargo area, in m , being the distance between engine room bulkhead and collision bulkhead

$B_{H,i}$: Breadth of hatch opening of hatch i, in m

$L_{H,i}$: Length of hatch opening of hatch i, in m

n : Number of hatches.

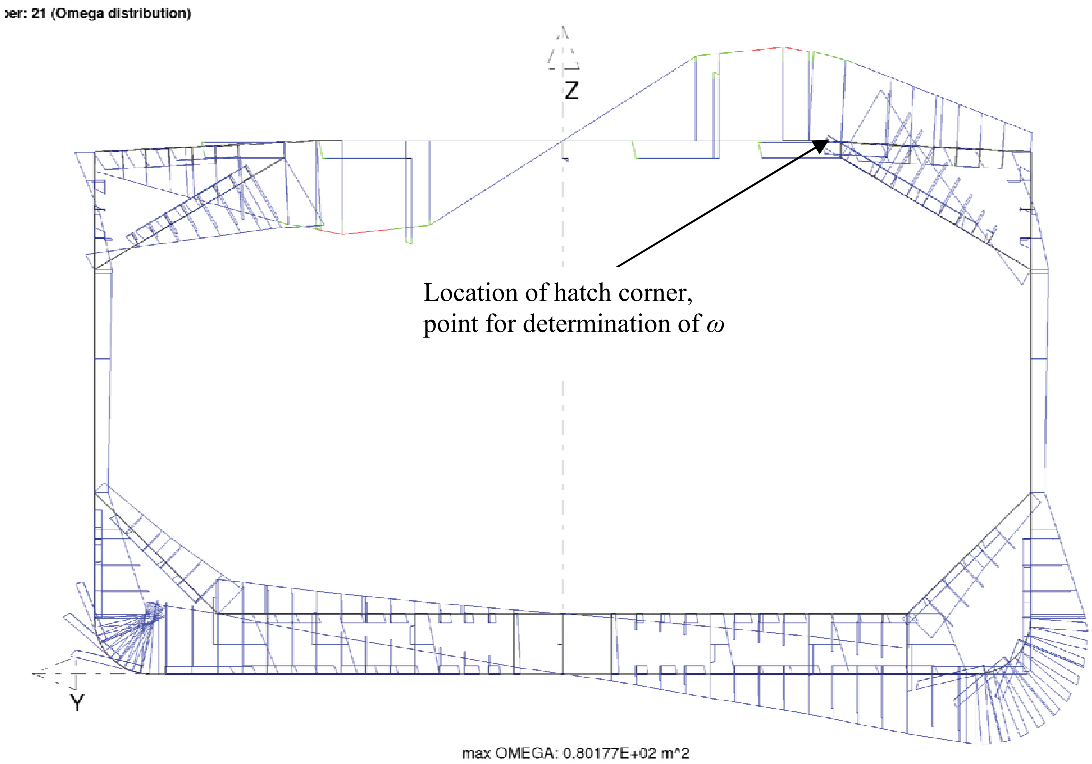

Figure 1: Cross section for determination of I_T and ω

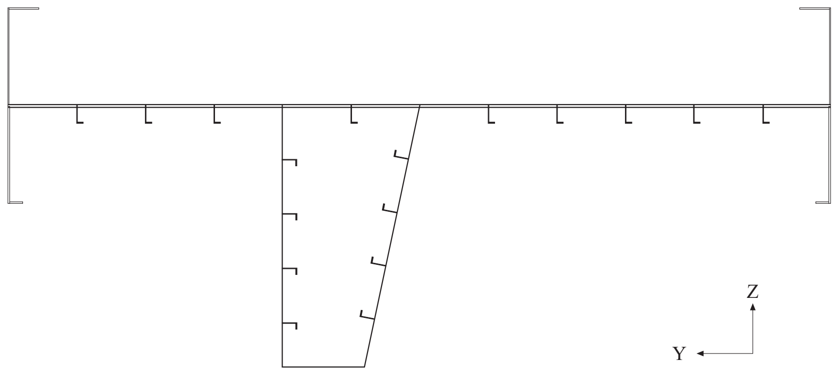

Figure 2: Elements to be considered for the determination of A_Q, W_Q and I_Q

2.2 Nominal mean stress

2.2.1

The mean stress due to still water bending moment within the cross deck is set to 0.

3. Hot spot stress

3.1 Hot spot stress range

3.1.1

The hot spot stress range, in N/mm^2, is to be obtained from the following formula:

$$\Delta\sigma_W = K_{gh} \cdot \Delta\sigma_{WT}$$

where:

K_{gh} : Stress concentration factor for the hatch corner, taken equal to:

$$K_{gh} = \frac{r_a + 2r_b}{3r_a}\left\{1 + \left(\frac{2b}{1.23\ell_{CD} + 1.6b}\frac{0.22\ell_{CD}}{r_a}\right)^{0.65}\right\}$$, to be taken not less than 1.0

r_a : Radius, in m, in major axis

r_b : Radius, in m, in minor axis (if the shape of corner is a circular arc, r_b is to be equal to r_a)

ℓ_{CD} : Length of cross deck, in m, in longitudinal direction

b : Distance, in m, from the edge of hatch opening to the ship's side.

Appendix 1 – CROSS SECTIONAL PROPERTIES FOR TORSION

1. Calculation Formulae

1.1 Torsion Function Φ

1.1.1

For any partial area of closed cells the following geometric figures and ratios have to be computed:

$$A_y = \frac{1}{2}(z_i + z_k)(y_k - y_i)$$

$$l = \sqrt{(y_k - y_i)^2 + (z_k - z_i)^2}$$

$$\frac{s}{t} = \frac{\ell}{t}$$

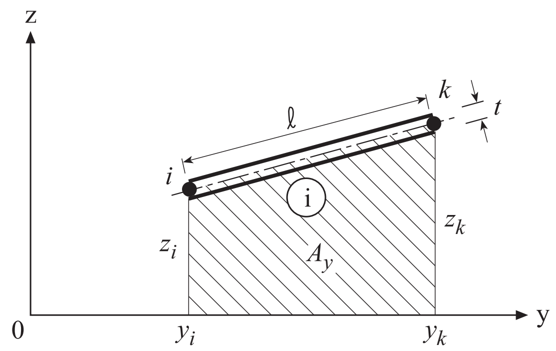

Figure 1:

The following three versions of algorithms may be applied depending on the type of cross section:

Version A: Asymmetric open cross sections as shown in Fig 2

Version B: Symmetric cross sections with particular closed cells (closed cells without shared walls) as shown in Fig 3. In this case the torsion function can be calculated for each cell separately.

$$\Phi_0 = \frac{2\sum_{Cell\,0} A_y}{\sum_{Cell\,0} \frac{s}{t}} \quad ; \quad \Phi_2 = \frac{2\sum_{Cell\,2} A_y}{\sum_{Cell\,2} \frac{s}{t}}$$

Version C: Symmetric cross sections with multiple closed cells (closed cells with shared walls) as shown in Fig 4. In this case the torsion function for each cell i can be calculated by solving a linear system of equations considering the shared walls.

$$\Phi_0 \sum_{Cell\,0} \frac{s}{t} + \Phi_1 \left(\frac{s}{t}\right)_{Common\ Wall} = 2A_{Cell0}$$

$$\Phi_1 \sum_{Cell\,1} \frac{s}{t} + \Phi_0 \left(\frac{s}{t}\right)_{Common\ Wall} = 2A_{Cell1}$$

From this system of equations the torsion functions Φ_0 and Φ_1 can be derived.

1.2 Co-ordinate system, running coordinate *s*

1.2.1

A 2-D cartesian co-ordinate system is to be used. The choice of the reference point O (origin of co-ordinate system) is free, but for symmetric cross sections it is advantageous to define the origin at the line of symmetry of the cross section. The running co-ordinate *s* starts within symmetric cross sections at the intersection of the line of symmetry with the cross section geometry, e.g. in hull cross sections at the intersection of centreline and bottom shell or double-bottom as indicated by '0' in Fig 2 to Fig 4. The orientation of *s* as well as the direction of integration within closed cells is to be considered with respect to the algebraic signs and the assembly of the system of equations for the torsion function.

1.3 Computation of several properties for each part of the cross section

1.3.1

ω_i = ω_k of the preceding partial area or of the preceding point of bifurcation. (to be set equal to zero at the beginning of the computation)

ω_k = $\omega_i + y_i z_k - y_k z_i - \Phi \dfrac{\ell_i}{t_i}$, with $\Phi \dfrac{\ell_i}{t_i}$ within closed cells

l = $\sqrt{(y_k - y_i)^2 + (z_k - z_i)^2}$

		Summation
A	$= \ell t$	$\sum A$
S_y	$= A/2\,(z_i + z_k)$	$\sum S_y$
S_z	$= A/2\,(y_i + y_k)$	$\sum S_z$
S_ω	$= A/2\,(\omega_i + \omega_k)$	$\sum S_\omega$
I_y	$= A/3\,(z_i^2 + z_i z_k + z_k^2)$	$\sum I_y$
I_z	$= A/3\,(y_i^2 + y_i y_k + y_k^2)$	$\sum I_y$
I_{yz}	$= A/6\,[(2y_k + y_i)z_k + (2y_i + y_k)z_i]$	$\sum I_{yz}$
I_ω	$= A/3\,(\omega_i^2 + \omega_i\omega_k + \omega_k^2)$	$\sum I_\omega$
$I_{\omega y}$	$= A/6\,[(2y_k + y_i)\omega_k + (2y_i + y_k)\omega_i]$	$\sum I_{\omega y}$
$I_{\omega z}$	$= A/6\,[(2z_k + z_i)\omega_k + (2z_i + z_k)\omega_i]$	$\sum I_{\omega z}$
$s\,t^3$	$= \ell t^3$	$\sum s \cdot t^3$

1.4 Computation of cross sectional properties for the entire cross section

Asymmetric cross section:			Symmetric cross section (only half of the section is modeled)		
A	=	$\sum A$	A	=	$2\sum A$
y_s	=	$\dfrac{\sum S_z}{\sum A}$	y_s	=	$\dfrac{\sum S_z}{\sum A}$
z_s	=	$\dfrac{\sum S_y}{\sum A}$	z_s	=	$\dfrac{\sum S_y}{\sum A}$
I_y	=	$\sum I_y - \sum A z_s^2$	I_y	=	$2\left(\sum I_y - \sum A z_s^2\right)$
I_z	=	$\sum I_z - \sum A y_s^2$	I_z	=	$2\left(\sum I_z - \sum A y_s^2\right)$
I_{yz}	=	$\sum I_{yz} - \sum A y_s z_s$			
I_T	=	$\sum \dfrac{s t^3}{3} + \sum_{Cell\ i} \left(2 A_{yi} \Phi_i\right)$	I_T	=	$2\left[\sum \dfrac{s t^3}{3} + \sum_{Cell\ i} \left(2 A_{yi} \Phi_i\right)\right]$
ω_0	=	$\dfrac{\sum S_\omega}{\sum A}$			
$I_{\omega y}$	=	$\sum I_{\omega y} - \sum A y_s \omega_0$	$I_{\omega y}$	=	$2\sum I_{\omega y}$
$I_{\omega z}$	=	$\sum I_{\omega z} - \sum A z_s \omega_0$			
y_M	=	$\dfrac{I_{\omega z} I_z - I_{\omega y} I_{yz}}{I_y I_z - I_{yz}^2}$			
z_M	=	$\dfrac{I_{\omega z} I_{yz} - I_{\omega y} I_y}{I_y I_z - I_{yz}^2}$	z_M	=	$-\dfrac{I_{\omega y}}{I_z}$
I_ω	=	$\sum I_\omega - \sum A \omega_0^2 + z_M I_{\omega y} - y_M I_{\omega z}$	I_ω	=	$2\sum I_\omega + z_M I_{\omega y}$

I_y, I_z, I_{yz} are to be computed with relation to the centre of gravity.

S_x, S_y, S_ω, I_ω, $I_{\omega y}$ and $I_{\omega z}$ are to be computed with relation to shear centre M

The sector-coordinate ω has to be transformed with respect to the location of the shear centre M. For cross sections of type **A**, ω_0 is to be added to each ω_i and ω_k as defined in [1.3]

For cross sections of type **B** and **C**, $\Delta\omega$ can be calculated as follows:

$\Delta\omega_i \quad = z_M y_i$

where:

ω_O : Calculated sector co-ordinate with respect to the centre of the coordinate system (O) selected for the calculation according to the formulae for ω_k given in [1.3]

ω : Transformed sector co-ordinate with respect to shear centre M

y_M, z_M : Distance between shear centre M and centre of the coordinate system B.

The transformed values of ω can be obtained by adding $\Delta\omega$ to the values of ω_O obtained according to the formulae in [1.3].

The transformed value for ω is to be equal to zero at intersections of the cross section with the line of symmetry (centreline for ship-sections).

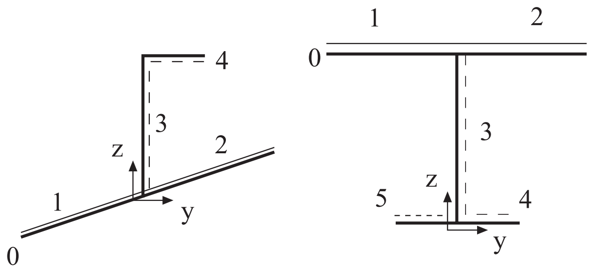

Figure 2: Cross sections of type A

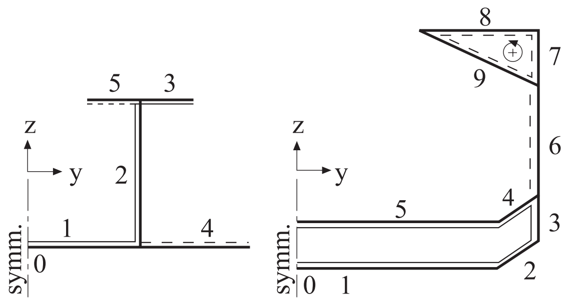

Figure 3: Cross sections of type B

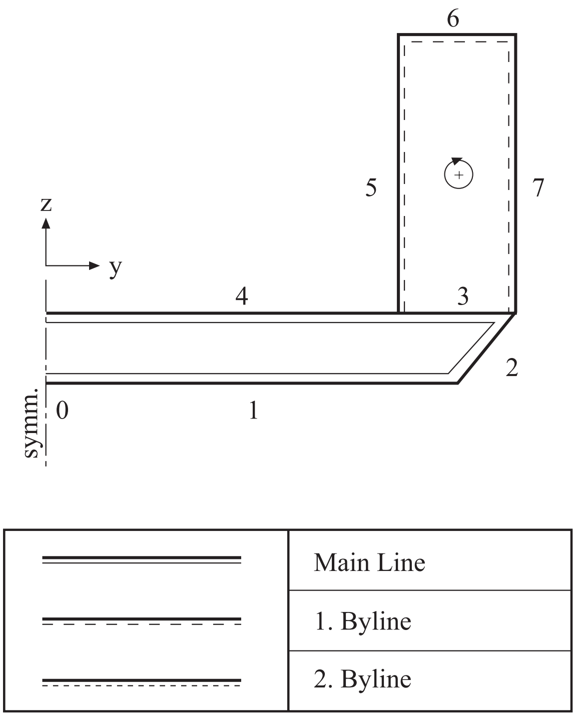

Figure 4: Cross section of type C

Designation of line types (numbers at particular parts of cross sections) gives the order of the particular parts for the calculation and therefore the direction of the running coordinate *s*.

2. Example calculation for a single side hull cross section

2.1 Cross section data

2.1.1

The cross section is shown in Fig 5. The co-ordinates of the node-points marked by filled black circles in Fig 5 are given in the Tab 1, where the plate thicknesses and the line segments (marked by circles in Fig 5) of the cross section are given in Tab 2.

Table 1: Node-coordinates of cross-section

Node number	*Y* Coordinate	*Z* Coordinate
0	0.00	0.00
1	14.42	0.00
2	16.13	1.72
3	16.13	6.11
4	11.70	1.68
5	0.00	1.68
6	16.13	14.15
7	16.13	19.6
8	7.50	20.25
9	7.50	19.63
10	0.00	20.25

2.2 Determination of the torsion function Φ

2.2.1

The first step is to build a linear system of equation for the determination of the torsion function Φ of each closed cell. The cross section and the cells are shown in Fig 5.

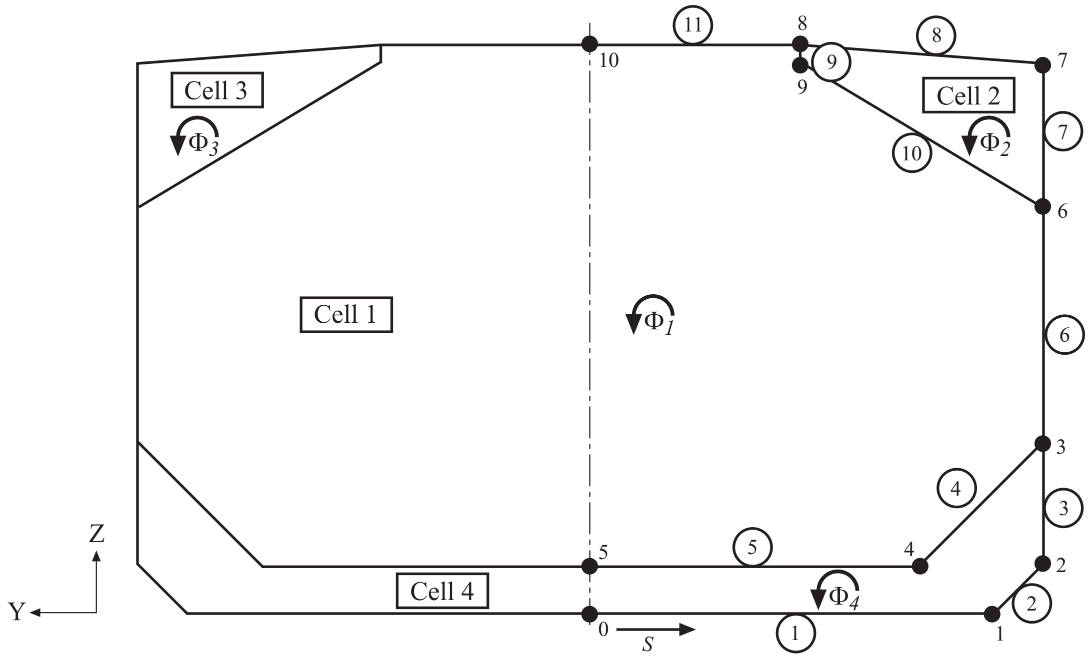

Figure 5: Single side hull cross section

Table 2: Dimensions and nodes of line segments of the cross section

Line-No.	Node i	Node k	y_i	z_i	y_k	z_k	Length	Thickness
1	0	1	0.00	0.00	14.42	0.00	14.42	0.017
2	1	2	14.42	0.00	16.13	1.72	2.43	0.017
3	2	3	16.13	1.72	16.13	6.11	4.39	0.018
4	3	4	16.13	6.11	11.70	1.68	6.26	0.019
5	4	5	11.70	1.68	0.00	1.68	11.70	0.021
6	3	6	16.13	6.11	16.13	14.15	8.04	0.018
7	6	7	16.13	14.15	16.13	19.6	5.45	0.021
8	7	8	16.13	19.60	7.50	20.25	8.65	0.024
9	8	9	7.50	20.25	7.50	19.63	0.62	0.024
10	9	6	7.50	19.63	16.13	14.15	10.22	0.015
11	8	10	7.50	20.25	0.00	20.25	7.50	0.012

Under consideration of the 4 cells (marked by rectangles in Fig 5) of the cross section, the following system of equation for the determination of the torsion function Φ can be developed. It should be noted that the direction of the rotation is to be considered (the rotation directions for the torsion functions Φ_i should point in the same direction for all Φ_i to build up the system of equations).

$$\begin{aligned}
\sum_{1}\frac{s}{t}\Phi_1 \quad -\sum_{1-2}\frac{s}{t}\Phi_2 \quad -\sum_{1-3}\frac{s}{t}\Phi_3 \quad -\sum_{1-4}\frac{s}{t}\Phi_4 &= 2\sum_{1} A \\
-\sum_{1-2}\frac{s}{t}\Phi_1 \quad +\sum_{2}\frac{s}{t}\Phi_2 &= 2\sum_{2} A \\
-\sum_{1-3}\frac{s}{t}\Phi_1 \quad +\sum_{3}\frac{s}{t}\Phi_3 &= 2\sum_{3} A \\
-\sum_{1-4}\frac{s}{t}\Phi_1 \quad +\sum_{4}\frac{s}{t}\Phi_4 &= 2\sum_{4} A
\end{aligned}$$

The coefficients of the matrix can be calculated as follows:

$$\sum_{1}\frac{s}{t}=\frac{2\cdot 11700}{21}+\frac{2\cdot 6265}{19}+\frac{2\cdot 8040}{18}+\frac{2\cdot 10223}{15}+\frac{2\cdot 620}{24}+\frac{2\cdot 7500}{12}=5331.81$$

$$\sum_{2}\frac{s}{t}=\frac{10223}{15}+\frac{5450}{21}+\frac{620}{24}+\frac{8654}{24}=1327.48$$

$$\sum_{3}\frac{s}{t}=1327.48$$

$$\sum_{4}\frac{s}{t}=\frac{2\cdot 14420}{17}+\frac{2\cdot 11700}{21}+\frac{2\cdot 6265}{19}+\frac{2\cdot 2425}{17}+\frac{2\cdot 4390}{18}=4243.34$$

$$\sum_{1-2}\frac{s}{t}=\frac{10223}{15}+\frac{620}{24}=707.36$$

$$\sum_{1-3}\frac{s}{t}=707.36$$

$$\sum_{1-4}\frac{s}{t}=\frac{2\cdot 11700}{21}+\frac{2\cdot 6265}{19}=1773.76$$

The areas of the cells can be calculated as follows:

$$2\sum_{1}A=2\cdot 2\cdot 260.72=1042.90 \quad m^2$$

$$2\sum_{2}A=2\cdot 26.19=52.38 \quad m^2$$

$$2\sum_{3}A=52.38 \quad m^2$$

$$2\sum_{4}A=2\cdot 2\cdot 35.44=141.76 \quad m^2$$

With these results the coefficient matrix will become:

$$\begin{array}{lllllll}
5331.81\Phi_1 & -707.360\Phi_2 & -707.36\Phi_3 & -1773.76\Phi_4 & = & 1042.90 \\
-707.36\Phi_1 & +1327.48\Phi_2 & & & = & 52.38 \\
-707.36\Phi_1 & & +1327.48\Phi_3 & & = & 52.38 \\
-1773.76\Phi_1 & & & +4243.34\Phi_4 & = & 141.76
\end{array}$$

The solution of this system gives:

$$\Phi_1=0.3018$$
$$\Phi_2=0.2003$$
$$\Phi_3=0.2003$$
$$\Phi_4=0.1596$$

2.3 Determination of the line-segment properties

2.3.1

The next step is the determination of ω_k according to the formulae given in [1.3]. '*s*' starts at point 0 (Fig 5) with ω_i=0 and follows the path from point 0 to point 1, 2, 3, 4 up to point 5. It is to be noted, that the term $\Phi\left(\ell_i/t_i\right)$ is for the line segments 1 to 3 (between points 0 and 3) calculated as $\Phi_4\left(\ell_{1\ldots 3}/t_{1\ldots 3}\right)$ where for the line segments 4 and 5 this term becomes $(\Phi_4-\Phi_1)\left(\ell_{4\ldots 5}/t_{4\ldots 5}\right)$ because line segments 4 and 5 are shared walls of cell 4 and

cell 1. The rotation direction for the torsion functions together with the direction of integration (direction of path, which one follows for the calculation) determines the algebraic sign within this term.

For the line segment 6 ω_i has to be set to the value at point 3 and $\Phi\left(\ell_i / t_i\right) = \Phi_1\left(\ell_6 / t_6\right)$. '$s$' follows now the path from point 6 to point 7, 8, 9 back to point 6. The shared wall between cell 2 and cell 1 has to be considered for the terms which include the torsion function Φ. For the line segment 11 between point 8 and 10, ω_i has to be set to the value at point 8.

The other properties of the line segments can be calculated by the formulas given in [1.3].

2.4 Determination of cross-section properties

2.4.1

After the summation of the line-segment properties, the cross section properties can be calculated as described in [1.4].

The sector coordinate has to be transformed with respect to the shear centre as described in [1.4]

The result of the calculations gives the sector co-ordinates, as indicated in Tab 3.

Table 3: Sector co-ordinates for the cross section of Fig 5

Point i	$\omega_{O,i}$	$\Delta\omega_i$	ω_i
0	0.00	0.00	0.00
1	-135.97	84.99	-50.98
2	-134.04	95.07	-38.97
3	-102.32	95.07	-7.25
4	-99.49	68.96	-30.53
5	-0.06	0.00	-0.06
6	-108.20	95.07	-13.13
7	-72.30	95.07	22.77
8	35.07	44.21	79.27
9	33.08	44.21	77.28
10	-2.75	0.00	-2.75

2.5 Notes

2.5.1

For holds of single side skin construction, the hull cross section normally can be simplified in a section with four boxes (cell 1 cargo hold, cell 2 and 3 wing tanks and cell 4 hopper tanks and double bottom as shown in the calculation example) whereas the cross section of holds of double side skin construction can be simplified to a cross section with two closed cells only (cell 1 cargo hold, cell 2 double hull). For the plate thickness of the line elements with variable thicknesses an equivalent plate thickness can be used calculated by the following formulae:

$$t_{eq} = \frac{t_1\ell_1 + t_2\ell_2 + \ldots + t_i\ell_i + \ldots + t_k\ell_k}{\sum_{i=1}^{k}\ell_i}$$

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Due to the simplifications, the value of the sector co-ordinate ω can differ from 0 at the intersections between the cross section and centreline. The difference between the value of the sector co-ordinate ω and the value of the torsional moment of inertia I_T for the simplified cross section is in normal cases less than 3% compared to the values of the original cross section.

Chapter 9

Other Structures

Section 1 – FORE PART

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

L_2 : Rule length L, but to be taken not greater than 300 m

T_B : Minimum ballast draught, in m, for normal ballast conditions

k : Material factor, defined in Ch 3, Sec 1, [2.2]

m : Coefficient taken equal to:

m = 10 for vertical stiffeners, vertical primary supporting members

m = 12 for other stiffeners, other primary supporting members

τ_α : Allowable shear stress, in N/mm^2, taken equal to:

$$\tau_a = \frac{R_Y}{\sqrt{3}}$$

s : Spacing, in m, of ordinary stiffeners or primary supporting members, measured at mid-span along the chord

ℓ : Span, in m, of ordinary stiffeners or primary supporting members, measured along the chord between the supporting members, see Ch 3, Sec 6, [4.2] or [5.3] respectively.

c_a : Aspect ratio of the plate panel, equal to:

$$c_a = 1.21\sqrt{1 + 0.33\left(\frac{s}{\ell}\right)^2} - 0.69\frac{s}{\ell}$$, to be taken not greater than 1.0

c_r : Coefficient of curvature of the panel, equal to:

$$c_r = 1 - 0.5\frac{s}{r}$$, to be taken not less than 0.4

r : Radius of curvature, in m.

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1. General

1.1 Application

1.1.1

The requirement of this Section apply to:

- the structures located forward of the collision bulkhead, i.e.:
  - the fore peak structures
  - the stem
- the reinforcements of the bow flare area, according to [4.1]
- the reinforcements of the flat bottom forward area, according to [5.1].

1.1.2
Fore part structures which form the boundary of spaces not intended to carry liquids, and which do not belong to the outer shell, are to be subjected to lateral pressure in flooding conditions. Their scantlings are to be determined according to the relevant criteria in Ch.6.

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1.2 Net thicknesses

1.2.1
As specified in Ch 3, Sec 2, all thicknesses referred to in this Section are net, i.e. they do not include any corrosion addition. The gross thicknesses are to be obtained as specified in Ch 3, Sec 2, [3].

2. Arrangement

2.1 Structural arrangement principles

2.1.1 General
Scantlings of the shell envelope, upper deck and inner bottom, if any, are to be tapered towards the forward end. Special consideration is to be paid to the structural continuity of major longitudinal members in order to avoid abrupt changes in section.

Structures within the fore peak, such as platforms, decks, horizontal ring frames or side stringers are to be scarphed into the structure aft into the cargo hold.

Where inner hull structures terminate at the collision bulkhead, the structural continuity is to be ensured forward of the collision bulkhead by adequate structure with tapering brackets.

Longitudinal stiffeners of deck, bottom and side shell are to be extended as far forward as practicable.

All shell frames and tank boundary stiffeners are to be continuous, or are to be bracketed tat their ends.

Where the brackets are provided to ensure the structural continuity from the forward end to 0.15L behind fore perpendicular, flanged brackets have to be used.

2.1.2 Structures in tanks
Where peaks are used as tanks, stringer plates are to be flanged or face bars are to be fitted at their inner edges. Stringers are to be effectively fitted to the collision bulkhead so that the forces can be properly transmitted.

2.2 Tripping brackets

2.2.1
For peaks or other tanks forward of the collision bulkhead transversely framed, tripping brackets vertically spaced not more than 2.6 m are to be fitted, according to Fig 1, between primary supporting members, decks and/or platforms.

The as-built thickness of the tripping brackets is to be not less than the as-built thickness of the side frame webs to which they are connected.

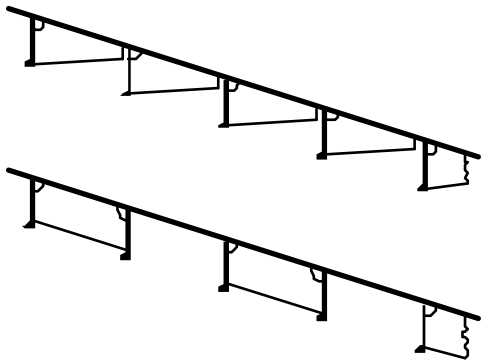

Figure 1: Tripping brackets

2.3 Floors and bottom girders

2.3.1

Where no centreline bulkhead is provided, a centre bottom girder is to be fitted.

In general, the minimum depth of the floor at the centerline and center girders is to be not less than the required depth of the double bottom of the foremost cargo hold.

2.3.2 Solid floors

In case of transverse framing, solid floors are to be fitted at every frame.

In case of the longitudinal framing, the spacing of solid floors is not to be greater than 3.5m or four transverse frame spaces, whichever is the smaller. Larger spacing of solid floors may be accepted, provided that the structure is verified by means of FEA deemed appropriate by the Society.

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2.3.3 Bottom girders

In case of transverse framing, the spacing of bottom girders is not to exceed 2.5m.

In case of longitudinal framing, the spacing of bottom girders is not to exceed 3.5m.

Larger spacing of bottom girders may be accepted, provided that the structure is verified by means of FEA deemed appropriate by the Society.

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3. Load model

3.1 Load point

3.1.1

Unless otherwise specified, lateral pressure is to be calculated at load points according to:

- Ch 6, Sec 1, [1.5], for plating
- Ch 6, Sec 2, [1.4], for stiffeners.

3.2 Pressure in bow area

3.2.1 Lateral pressure in intact conditions

The pressure in bow area, in kN/m^2, is to be taken equal to ($p_S + p_W$).

where:

p_S, p_W : Hydrostatic and hydrodynamic pressures according to Ch 4, Sec 5, or internal still water and inertial pressures according to Ch 4, Sec 6, [2], to be considered among load cases H, F, R and P.

3.2.2 Lateral pressure in testing conditions

The lateral pressure p_T in testing conditions is taken equal to:

$p_T = p_{ST} - p_S$ for bottom shell plating and side shell plating

$p_T = p_{ST}$ otherwise

where:

p_{ST} : Testing pressure defined in Ch 4, Sec 6, [4]

p_S : Pressure taken equal to:

- if the testing is carried out afloat: hydrostatic pressure defined in Ch 4, Sec 5, [1] for the draught T_1, defined by the Designer, at which the testing is carried out. If T_1 is not defined, the testing is considered as being not carried out afloat.
- if the testing is not carried out afloat: $p_S = 0$

3.2.3 Elements of the outer shell

The still water and wave lateral pressures are to be calculated considering separately:

- the still water and wave external sea pressures
- the still water and wave internal pressure considering the compartment adjacent to the outer shell as being loaded. If the compartment adjacent to the outer shell is intended to carry liquids, this still water and wave internal pressures are to be reduced from the corresponding still water and wave external sea pressures.

3.2.4 Elements other than those of the outer shell

The still water and wave lateral pressures to be considered as acting on an element which separates two adjacent compartments are those obtained considering the two compartments individually loaded.

3.3 Bow flare area pressure

3.3.1

The bow pressure p_{FB}, in kN/m^2, is to be obtained according to Ch 4, Sec 5, [4.1].

3.4 Bottom slamming pressure

3.4.1

The bottom slamming pressure p_{SL}, in kN/m^2, in the flat bottom forward is to be obtained according to Ch 4, Sec 5, [4.2].

4. Scantlings

4.1 Bow flare reinforcement

4.1.1

The bow flare area to be reinforced is that extending forward of $0.9L$ from the aft end and above the normal ballast waterline according to the applicable requirements in [4.2] to [4.4].

4.2 Plating

4.2.1

The net thickness of plating are to be not less than those obtained from the formulae in Tab 1 and Tab 2.

Table 1: Net minimum thickness of plating

Minimum net thickness, in mm	
Bottom,	$5.5 + 0.03L$
Side	$0.85L^{1/2}$
Inner bottom	$5.5 + 0.03L$
Strength deck	$4.5 + 0.02L$
Platform and wash bulkhead	6.5
Transverse and longitudinal watertight bulkheads	$0.6L^{1/2}$

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Table 2: Net thickness of plating

Net thickness, in mm	
Intact conditions	$t = 15.8 c_a c_r s \sqrt{\dfrac{p_S + p_W}{0.9 R_Y}}$
Bow flare area	$t = 15.8 c_a c_r s \sqrt{\dfrac{p_{FB}}{0.9 R_Y}}$
Testing conditions	$t = 15.8 c_a c_r s \sqrt{\dfrac{p_T}{1.05 R_Y}}$

4.3 Ordinary stiffeners

4.3.1 General

The requirements of this sub-article apply to ordinary stiffeners considered as clamped at both ends. For other boundary conditions, the yielding check is to be considered on a case by case basis.

4.3.2

The net dimensions of ordinary stiffeners are to comply with the requirements in Ch 6, Sec 2, [2.3]

4.3.3

The net thickness of the web of ordinary stiffeners, in mm, is to be not less than the greater of:

- $t = 3.0 + 0.015L_2$
- 40% of the net required thickness of the attached plating, to be determined according to [4.2] and [5.2].

The net dimensions of ordinary stiffeners are to comply with the requirement in Ch 6 Sec 2, [2.2.2] and [2.3].

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4.3.4

The net scantlings of single-span ordinary stiffeners are to be not less than those obtained from the formulae in Tab 3.

Table 3: Net scantlings of single span ordinary stiffeners

Stiffener type	Net section modulus w, in cm^3	Net sectional shear area A_{sh}, in cm^2
Single span ordinary stiffeners subjected to lateral pressure	$w = \dfrac{(p_S + p_W)s\ell^2}{0.9 m R_Y} 10^3$	$A_{sh} = \dfrac{5(p_S + p_W)s\ell}{\tau_a \sin\phi}$
Single span ordinary stiffeners located in bow flare area	$w = \dfrac{p_{FB} s\ell^2}{0.9 m R_Y} 10^3$	$A_{sh} = \dfrac{5 p_{FB} s\ell}{\tau_a \sin\phi}$
Single span ordinary stiffeners subjected to testing pressure	$w = \dfrac{p_T s\ell^2}{1.05 m R_Y} 10^3$	$A_{sh} = \dfrac{5 p_T s\ell}{1.05\tau_a \sin\phi}$

where:

ϕ : Angle, in deg, between the stiffener web and the shell plate, measured at the middle of the stiffener span; the correction is to be applied when ϕ is less than 75.

4.3.5

The maximum normal stress σ and shear stress τ in a multi-span ordinary stiffener are to comply with the formulae in Tab 4.

The maximum normal stress σ and shear stress τ in a multi-span ordinary stiffener are to be determined by a direct calculation taking into account:

- the distribution of still water and wave pressure and forces, if any
- the number and position of intermediate supports (decks, girders, etc.)
- the condition of fixity at the ends of the stiffener and at intermediate supports
- the geometrical characteristics of the stiffener on the intermediate spans.

Table 4: Checking criteria for multi-span ordinary stiffeners

Condition	Intact	Testing
Normal stress	$\sigma \le 0.9 R_Y$	$\sigma \le 1.05 R_Y$
Shear stress	$\tau \le \tau_a$	$\tau \le 1.05\tau_a$

4.4 Primary supporting members

4.4.1 Minimum thickness

The net thickness of the web of primary supporting members, in mm, is to be not less than that obtained from the following formula:

$$t = 0.7\sqrt{L_2}$$

4.4.2 Side transverses

The net section modulus w, in cm^3 , and the net shear sectional area A_{sh}, in cm^2 , of side transverses are to be not less than the values obtained from the following formulae:

$$w = \frac{(p_S + p_W)s\ell^2}{0.9mR_Y}10^3$$

$$A_{sh} = \frac{5(p_S + p_W)s\ell}{\tau_a \sin\phi}$$

In addition, the net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2 , of side transverses located within the bow flare area are to be not less than the values obtained from the following formulae:

$$w = \frac{p_{FB}s\ell^2}{0.9mR_Y}10^3$$

$$A_{sh} = \frac{5p_{FB}s\ell}{\tau_a \sin\phi}$$

4.4.3 Side girders

The net section modulus w, in cm^3 , and the net shear sectional area A_{sh}, in cm^2 , of side girders are to be not less than the values obtained from the following formulae:

$$w = \frac{(p_S + p_W)s\ell^2}{0.9mR_Y}10^3$$

$$A_{sh} = \frac{5(p_S + p_W)s\ell}{\tau_a \sin\phi}$$

In addition, the net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of side girders located within the bow flare area are to be not less than the values obtained from the following formulae:

$$w = \frac{p_{FB}s\ell^2}{0.9mR_Y}10^3$$

$$A_{sh} = \frac{5p_{FB}s\ell}{\tau_a \sin\phi}$$

4.4.4 Deck primary supporting members

The net scantlings of deck primary supporting members are to be not less than those obtained from the formulae in Table 5. The design pressures in the formulae are taken from intact conditions and testing conditions respectively as stated in [3.2]. For a complex deck structure, a calculation deemed appropriate by the Society may be carried out in lieu of the formulae.

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Table 5 Net scantlings of deck primary supporting members

Condition	Net section modulus w, in cm^3	Net sectional shear area A_{sh}, in cm^2
Primary supporting members subjected to lateral pressure in intact conditions	$w = \dfrac{(p_S + p_W)s\ell^2}{0.9mR_Y}10^3$	$A_{sh} = \dfrac{5(p_S + p_W)s\ell}{\tau_a \sin\phi}$
Primary supporting members subjected to lateral pressure in testing conditions	$w = \dfrac{p_T s\ell^2}{1.05mR_Y}10^3$	$A_{sh} = \dfrac{5p_T s\ell}{1.05\tau_a \sin\phi}$
where:		
ϕ : Angle, in deg, between the primary supporting member's web and the shell plate, measured at the middle of the primary supporting member's span; the correction is to be applied when ϕ is less than 75.		

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5. Strengthening of bottom forward area

RCN 1 to July 2010 version (effective from 1July 2012)

5.1 Application

5.1.1

The bottom forward area to be reinforced is the part of the ship's bottom extending forward of $0.2V\sqrt{L}$ from the fore perpendicular end, up to a height of $0.05T_B$ or 0.3 m above base line, whichever is the smaller.

RCN 1 to July 2010 version (effective from 1July 2012)

5.2 Bottom plating

5.2.1

The net thickness, in mm, of the bottom forward area, is not to be less than:

$$t = 15.8C_a C_r s\sqrt{\frac{C_s p_{SL}}{R_{eH}}}$$

where:

C_s : Coefficient relating to load patch of impact pressure, taken equal to:

$C_s = 1.0$, where no intermediate longitudinals is provided between ordinary stiffeners

$C_s = 1.3$ where intermediate longitudinals are provided between ordinary stiffeners.

RCN 1 to July 2010 version (effective from 1July 2012)

5.2.2

For ships with a rise of floor the strengthened plating must at least extend to the bilge curvature.

5.3 Ordinary stiffeners

5.3.1

The net section modulus, in cm^3, of transverse or longitudinal ordinary stiffeners of the bottom forward area is not to be less than:

$$w = \frac{C_s p_{SL} s\ell^2}{16R_{eH}}10^3$$

where:

C_s : Coefficient defined in [5.2.1].

RCN 1 to July 2010 version (effective from 1July 2012)

5.3.2

The net shear area, in cm², of transverse or longitudinal ordinary stiffeners of the bottom forward area is not to be less than:

$$A = \frac{5\sqrt{3}p_{SL}s(\ell - 0.5s)}{R_{eH}\sin\phi}$$

The area of the welded connection has to be at least twice this value.

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5.4 Primary supporting members

5.4.1 Girders

The net thickness of girders in double bottom forward area, in mm, is not to be less than the greatest of either of the value t_1 to t_3 specified in the followings according to each location:

$$t_1 = \frac{c_A p_{SL} S\ell}{2(d_0 - d_1)\tau_a}$$

$$t_2 = 1.75\sqrt[3]{\frac{H^2 a^2 \tau_a}{C_1'}t_1}$$

$$t_3 = \frac{C_1'' a}{\sqrt{k}}$$

where:

c_A : Coefficient taken equal to:

$c_A = 3/A$, with $0.3 \le c_A \le 1.0$

A : Loaded area, in m², between the supports of the structure considered, obtained from the following formula:

$A = S\ell$

p_{SL} : As defined in [3.4]

S : Spacing of centre or side girders under consideration, in m

ℓ : Span of centre or side girders between floors under consideration, in m

d_0 : Depth of the centre or side girder under consideration, in m

d_1 : Depth of the opening, if any, at the point under consideration, in m

H : Value obtained from the following formulae:

(a) Where the girder is provided with an unreinforced opening : $H = 1 + 0.5\dfrac{\phi}{\alpha}$

(b) In other cases: $H = 1.0$

ϕ : Major diameter of the openings, in m

α : The greater of a or S_1, in m.

a : Depth of girders at the point under consideration, in m, Where, however, if horizontal stiffeners are fitted on the girder, a is the distance from the horizontal stiffener under consideration to the bottom shell plating or inner bottom plating, or the distance between the horizontal stiffeners under consideration

S_1 : Spacing, in m, of vertical ordinary stiffeners or floors

C_1' : Coefficient obtained from Tab 6 depending on S_1/a. For intermediate values of S_1/a, C_1' is to be determined by linear interpolation.

C_1'' : Coefficient obtained from Tab 7 depending on S_1/a. For intermediate values of S_1/a, C_1'' is to be obtained by linear interpolation.

Table 6 Coefficient C_1'

$\frac{S_1}{a}$	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_1'	64	38	25	19	15	12	10	9	8	7

Table 7 Coefficient C_1''

$\frac{S_1}{a}$		0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6 and over
C_1''	Centre girder	4.4	5.4	6.3	7.1	7.7	8.2	8.6	8.9	9.3	9.6	9.7
	Side girder	3.6	4.4	5.1	5.8	6.3	6.7	7.0	7.3	7.6	7.9	8.0

5.4.2 Floors

The net thickness of floors in double bottom forward area, in mm, is not to be less than the greatest of either of the value t_1 to t_3 specified in the followings according to each location:

$$t_1 = \frac{c_A p_{SL} S\ell}{2(d_0 - d_1)\tau_a}$$

$$t_2 = 1.75 \cdot \sqrt[3]{\frac{H^2 a^2 \tau_a}{C_2'} t_1}$$

$$t_3 = \frac{8.5 S_2}{\sqrt{k}}$$

where :

c_A : Coefficient taken equal to:

$c_A = 3/A$, with $0.3 \le c_A \le 1.0$

A : Loaded area, in m^2, between the supports of the structure considered, obtained from the following formula:

$A = S\ell$

p_{SL} : As defined in [3.4]

S : Spacing of floors under consideration, in m

ℓ : Span of floors between centre girder and side girder or side girders under consideration, in m

d_0 : Depth of the solid floor at the point under consideration in m

d_1 : Depth of the opening, if any, at the point under consideration in m

H : Value obtained from the following formulae:

a) Where openings with reinforcement or no opening are provided on solid floors:

1) Where slots without reinforcement are provided:

$$H = \sqrt{4.0\frac{d_2}{S_1} - 1.0}$$, without being taken less than 1.0

2) Where slots with reinforcement are provided: $H = 1.0$

b) Where openings without reinforcement are provided on solid floors:

1) Where slots without reinforcement are provided:

$$H = \left(1 + 0.5\frac{\phi}{d_0}\right)\sqrt{4.0\frac{d_2}{S_1} - 1.0}$$, without being taken less than $1 + 0.5\frac{\phi}{d_0}$

2) Where slots with reinforcement are provided:

$$H = 1 + 0.5\frac{\phi}{d_0}$$

d_2 : Depth of slots without reinforcement provided at the upper and lower parts of solid floors, in m, whichever is greater

S_1 : Spacing, in m, of vertical ordinary stiffeners or girders

ϕ : Major diameter of the openings, in m.

a : Depth of the solid floor at the point under consideration, in m, Where, however, if horizontal stiffeners are fitted on the floor, a is the distance from the horizontal stiffener under consideration to the bottom shell plating or the inner bottom plating or the distance between the horizontal stiffeners under consideration

S_2 : The smaller of S_1 or a , in m

C_2' : Coefficient given in Tab 8 depending on S_1 / d_0 . For intermediate values of S_1 / d_0 , C_2' is to be determined by linear interpolation.

Table 8 Coefficient C_2'

S_1 / d_0	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_2'	64	38	25	19	15	12	10	9	8	7

6. Stem

6.1 Bar stem

6.1.1

The gross cross sectional area, in cm^2, of a bar stem below the load waterline is not to be less than:

$$A_b = 1.25L$$

6.1.2

Starting from the load waterline, the cross sectional area of the bar stem may be reduced towards the upper end to $0.75A_b$.

6.2 Plate stem and bulbous bows

6.2.1

The gross thickness, in mm, is not to be less than the values obtained from the following formula:

$t = (0.6 + 0.4s_B)(0.08L + 6)\sqrt{k}$, without being taken greater than $22\sqrt{k}$

where:

s_B : Spacing, in m, between horizontal stringers (partial or not), breasthooks, or equivalent horizontal stiffening members.

The gross plate thickness is to be not less than the net thickness, obtained according to [4.2], plus the corrosion addition t_C as defined in Ch 3, Sec 3.

Scantlings of the ordinary stiffeners are to be determined according to [4.3].

6.2.2

Starting from 0.6 m above the load waterline up to $T + C$, the gross thickness may gradually be reduced to $0.8t$, where t is the gross thickness defined in [6.2.1].

6.2.3

Plate stems and bulbous bows must be stiffened by breasthooks and/or frames.

7. Forecastle

7.1 General

7.1.1

An enclosed forecastle is to be fitted on the freeboard deck.

The aft bulkhead of the enclosed forecastle is to be fitted in way or aft of the forward bulkhead of the foremost hold, as shown in Fig 2.

However, if this requirement hinders hatch cover operation, the aft bulkhead of forecastle may be fitted forward of the forward bulkhead of the foremost cargo hold provided the forecastle length is not less than 7% of ship length for freeboard as specified in Ch 1, Sec 4, [3.2] abaft the fore side of stem.

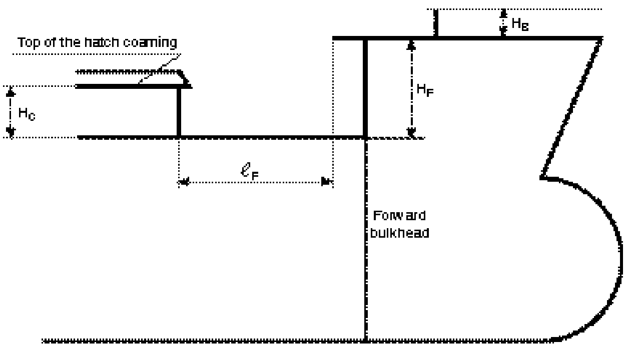

Figure 2: Forecastle

7.1.2

The forecastle height H_F above the main deck is to be not less than the greater of the following values:

the standard height of a superstructure as specified in Ch 1, Sec 4, [3.18]

H_C + 0.5 m, where H_C is the height of the forward transverse hatch coaming of the foremost cargo hold, i.e. cargo hold No.1.

7.1.3

All points of the aft edge of the forecastle deck are to be located at a distance less than or equal to ℓ_F:

$$\ell_F = 5\sqrt{H_F - H_C}$$

from the hatch coaming plate in order to apply the reduced loading to the No.1 forward transverse hatch coaming and No.1 hatch cover in applying Ch 9, Sec 5, [6.2.2] and Ch 9, Sec 5, [7.3.8].

7.1.4

A breakwater is not to be fitted on the forecastle deck with the purpose of protecting the hatch coaming or hatch covers. If fitted for other purposes, it is to be located such that its upper edge at centreline is not less than H_B/tan20° forward of the aft edge of the forecastle deck, where H_B is the height of the breakwater above the forecastle (see Fig 2).

Section 2 - AFT PART

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

L_1 : Rule length L, but to be taken not greater than 200 m

L_2 : Rule length L, but to be taken not greater than 300 m

k : Material factor, defined in Ch 3, Sec 1, [2.2]

z_{TOP} : Z co-ordinate, in m, of the top of the tank

m : Coefficient taken equal to:

m = 10 for vertical stiffeners, vertical primary supporting members

m = 12 for other stiffeners, other primary supporting members

τ_α : Allowable shear stress, in N/mm^2, taken equal to:

$$\tau_a = \frac{R_Y}{\sqrt{3}}$$

s : Spacing, in m, of ordinary stiffeners or primary supporting members, measured at mid-span along the chord

ℓ : Span, in m, of ordinary stiffeners or primary supporting members, measured along the chord between the supporting members, see Ch 3, Sec 6, [4.2] or [5.3] respectively.

c_a : Aspect ratio of the plate panel, equal to:

$$c_a = 1.21\sqrt{1+0.33\left(\frac{s}{\ell}\right)^2} - 0.69\frac{s}{\ell}$$, to be taken not greater than 1.0

c_r : Coefficient of curvature of the panel, equal to:

$$c_r = 1 - 0.5\frac{s}{r}$$, to be taken not less than 0.4

r : Radius of curvature, in m.

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1. General

1.1 Introduction

1.1.1

The requirements of this Section apply for the scantlings of structures located aft of the aft peak bulkhead and for the reinforcements of the flat bottom aft area.

1.1.2

Aft peak structures which form the boundary of spaces not intended to carry liquids, and which do not belong to the outer shell, are to be subjected to lateral pressure in flooding conditions. Their scantlings are to be determined according to the relevant criteria in Ch 6.

1.2 Connections of the aft part with structures located fore of the aft peak bulkhead

1.2.1 Tapering

Adequate tapering is to be ensured between the scantlings in the aft part and those fore of the aft peak bulkhead. The tapering is to be such that the scantling requirements for both areas are fulfilled.

1.3 Net scantlings

1.3.1

As specified in Ch 3, Sec 2, all thicknesses referred to in this Section are net, i.e. they do not include any corrosion addition. The gross thicknesses are to be obtained as specified in Ch 3, Sec 2, [3].

2. Load model

2.1 Load point

2.1.1

Unless otherwise specified, lateral pressure is to be calculated at load points according to:

- Ch 6, Sec 1, [1.5], for plating
- Ch 6, Sec 2, [1.4], for stiffeners.

2.2 Lateral pressures

2.2.1 Lateral pressure in intact conditions

The aft part lateral pressure in intact conditions, in kN/m^2, is to be taken equal to ($p_S + p_W$).

where:

p_S, p_W : Hydrostatic and hydrodynamic pressures according to Ch 4, Sec 5, or internal still water and inertial pressures according to Ch 4, Sec 6, [2], to be considered among load cases H, F, R and P.

2.2.2 Lateral pressure in testing conditions

The lateral pressure p_T in testing conditions is taken equal to:

- $p_T = p_{ST} - p_S$ for bottom shell plating and side shell plating
- $p_T = p_{ST}$ otherwise

where:

p_{ST} : Testing pressure defined in Ch 4, Sec 6, [4]

p_S : Pressure taken equal to:

- if the testing is carried out afloat: hydrostatic pressure defined in Ch 4, Sec 5, [1] for the draught T_1, defined by the Designer, at which the testing is carried out. If T_1 is not defined, the testing is considered as being not carried out afloat.
- if the testing is not carried out afloat: $p_S = 0$

2.2.3 Elements of the outer shell

The still water and wave lateral pressures are to be calculated considering separately:

- the still water and wave external sea pressures
- the still water and wave internal pressure considering the compartment adjacent to the outer shell as being loaded. If the compartment adjacent to the outer shell is intended to carry liquids, this still water and wave internal pressures are to be reduced from the corresponding still water and wave external sea pressures.

2.2.4 Elements other than those of the outer shell

The still water and wave lateral pressures to be considered as acting on an element which separates two adjacent compartments are those obtained considering the two compartments individually loaded.

3. Aft peak

3.1 Arrangement

3.1.1 General

The aft peak is, in general, to be transversely framed.

3.1.2 Floors

Solid floors are to be fitted at every frame spacing.

The floor height is to be adequate in relation to the shape of the hull. Where a sterntube is fitted, the floor height is to extend at least above the sterntube. Where the hull lines do not allow such extension, plates of suitable height with upper and lower edges stiffened and securely fastened to the frames are to be fitted above the sterntube.

In way of and near the rudder post, propeller post and rudder horn, floors are to be extended up to the peak tank top and are to be increased in thickness; the increase will be considered by the Society on a case by case basis, depending on the arrangement proposed.

Floors are to be provided with stiffeners located at intervals not exceeding 800 mm.

3.1.3 Side frames

Side frames are to be extended up to a deck located above the full load waterline.

Side frames are to be supported by one of the following types of structure:

- non-tight platforms, to be fitted with openings having a total area not less than 10% of the area of the platforms
- side girders supported by side primary supporting members connected to deck transverses.

3.1.4 Platforms and side girders

Platforms and side girders within the peak are to be arranged in line with those located in the area immediately forward.

Where this arrangement is not possible due to the shape of the hull and access needs, structural continuity between the peak and the structures of the area immediately forward is to be ensured by adopting wide tapering brackets.

Where the aft peak is adjacent to a machinery space whose side is longitudinally framed, the side girders in the aft peak are to be fitted with tapering brackets.

3.1.5 Longitudinal bulkheads

A longitudinal non-tight bulkhead is to be fitted on the centreline of the ship, in general in the upper part of the peak, and stiffened at each frame spacing.

Where either the stern overhang is very large or the maximum breadth of the space divided by watertight and wash bulkheads is greater than 20 m, additional longitudinal wash bulkheads may be required.

4. Scantlings

4.1 Plating

4.1.1

The net thickness of plating are to be not less than those obtained from the formulae in Tab 1 and Tab 2.

Table 1: Net minimum thickness of plating

Minimum net thickness, in mm	
Bottom	$5.5 + 0.03L$
Side and transom	$0.85L^{1/2}$
Inner bottom	$5.5 + 0.03L$
Strength deck	$4.5 + 0.02L$
Platform and wash bulkhead	6.5
Transverse and longitudinal watertight bulkheads	$0.6L^{1/2}$

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Table 2: Net thickness of plating

Net thickness, in mm	
Intact conditions	$t = 15.8 c_a c_r s \sqrt{\dfrac{p_S + p_W}{0.9 R_Y}}$
Testing conditions	$t = 15.8 c_a c_r s \sqrt{\dfrac{p_T}{1.05 R_Y}}$

4.2 Ordinary stiffeners

4.2.1 General

The requirements of this sub-article apply to ordinary stiffeners considered as clamped at both ends. For other boundary conditions, the yielding check is to be considered on a case by case basis.

4.2.2

The net dimensions of ordinary stiffeners are to comply with the requirements in Ch 6, Sec 2, [2.3].

4.2.3

The net thickness of the web of ordinary stiffeners, in mm, is to be not less than the greater of:

- $t = 3.0 + 0.015L_2$

- 40% of the net required thickness of the attached plating, to be determined according to [4.1].

The net dimensions of ordinary stiffeners are to comply with the requirement in Ch 6 Sec 2, [2.2.2] and [2.3].

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4.2.4

The net scantlings of single-span ordinary stiffeners are to be not less than those obtained from the formulae in Tab 3.

Table 3: Net scantlings of single span ordinary stiffeners

Stiffener type	Net section modulus w, in cm^3	Net sectional shear area A_{sh}, in cm^2
Single span ordinary stiffeners subjected to lateral pressure	$w = \frac{(p_S + p_W)s\ell^2}{0.9 m R_Y} 10^3$	$A_{sh} = \frac{5(p_S + p_W)s\ell}{\tau_a \sin\phi}$
Single span ordinary stiffeners subjected to testing pressure	$w = \frac{p_T s\ell^2}{1.05 m R_Y} 10^3$	$A_{sh} = \frac{5 p_T s\ell}{1.05\tau_a \sin\phi}$
where: ϕ : Angle, in deg, between the stiffener web and the shell plate, measured at the middle of the stiffener span; the correction is to be applied when ϕ is less than 75.		

4.2.5

The maximum normal stress σ and shear stress τ in a multi-span ordinary stiffener are to comply with the formulae in Tab 4.

The maximum normal stress σ and shear stress τ in a multi-span ordinary stiffener are to be determined by a direct calculation taking into account:

- the distribution of still water and wave pressure and forces, if any
- the number and position of intermediate supports (decks, girders, etc.)
- the condition of fixity at the ends of the stiffener and at intermediate supports
- the geometrical characteristics of the stiffener on the intermediate spans.

Table 4: Checking criteria for multi-span ordinary stiffeners

Condition	Intact	Testing
Normal stress	$\sigma \le 0.9 R_Y$	$\sigma \le 1.05 R_Y$
Shear stress	$\tau \le \tau_a$	$\tau \le 1.05\tau_a$

4.3 Primary supporting members

4.3.1 Floors

The net thickness of floors is to be not less than that obtained, in mm, from the following formula:

$$t = 0.7\sqrt{L_2}$$

4.3.2 Side transverses

The net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of side transverses are to be not less than the values obtained from the following formulae:

$$w = \frac{(p_S + p_W)s\ell^2}{0.9mR_Y}10^3$$

$$A_{sh} = \frac{5(p_S + p_W)s\ell}{\tau_a \sin\phi}$$

4.3.3 Side girders

The net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of side girders are to be not less than the values obtained from the following formulae:

$$w = \frac{(p_S + p_W)s\ell^2}{0.9mR_Y}10^3$$

$$A_{sh} = \frac{5(p_S + p_W)s\ell}{\tau_a \sin\phi}$$

4.3.4 Deck primary supporting members

The net scantlings of deck primary supporting members are to be not less than those obtained from the formulae in Table 5. The design pressures in the formulae are taken from intact conditions and testing conditions respectively as stated in [2.2]. For a complex deck structure, a direct strength calculation may be carried out in lieu of the formulae.

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Table 5: Net scantlings of deck primary supporting members

Condition	Net section modulus w, in cm^3	Net sectional shear area A_{sh}, in cm^2
Primary supporting members subjected to lateral pressure in intact conditions	$w = \frac{(p_S + p_W)s\ell^2}{0.9mR_Y}10^3$	$A_{sh} = \frac{5(p_S + p_W)s\ell}{\tau_a \sin\phi}$
Primary supporting members subjected to lateral pressure in testing conditions	$w = \frac{p_T s\ell^2}{1.05mR_Y}10^3$	$A_{sh} = \frac{5 p_T s\ell}{1.05\tau_a \sin\phi}$

where:

ϕ : Angle, in deg, between the primary supporting member's web and the shell plate, measured at the middle of the primary supporting member's span; the correction is to be applied when ϕ is less than 75.

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5. Connection of hull structures with the rudder horn

5.1 Connection of aft peak structures with the rudder horn

5.1.1 General

The requirement of this sub-article apply to the connection between peak structure and rudder horn where the stern-frame is of an open type and is fitted with the rudder horn.

5.1.2 Rudder horn

Horn design is to be such as to enable sufficient access for welding and inspection.

The scantlings of the rudder horn, which are to comply with Ch 10, Sec 1, [9.2], may be gradually tapered inside the hull.

Connections by slot welds are not acceptable.

5.1.3 Hull structures

The vertical extension of hull structure to support the rudder horn between the horn intersection with the shell and the peak tank top is in accordance with the requirements of Ch 10, Sec 1, [9.2.6] and [9.2.7].

The thickness of the structures adjacent to the rudder horn, such as shell plating, floors, platforms and side girders, the centreline bulkhead and any other structures, is to be adequately increased in relation to the horn scantlings.

(RCN 2, effective from 1 July 2008)

5.2 Structural arrangement above the aft peak

5.2.1 Side transverses

Where a rudder horn is fitted, side transverses, connected to deck beams, are to be arranged between the platform forming the peak tank top and the weather deck.

The side transverse spacing is to be not greater than:

- 2 frame spacings in way of the horn
- 4 frame spacings for and aft of the rudder horn
- 6 frame spacings in the area close to the aft peak bulkhead.

The side transverses are to be fitted with end brackets and located within the poop. Where there is no poop, the scantlings of side transverses below the weather deck are to be adequately increased with respect to those obtained from the formulae in [4.3.2].

5.2.2 Side girders

Where the depth from the peak tank top to the weather deck is greater than 2.6 m and the side is transversely framed, one or more side girders are to be fitted, preferably in line with similar structures existing forward.

6. Sternframes

6.1 General

6.1.1

Sternframes may be made of cast or forged steel, with a hollow section, or fabricated from plate.

6.1.2

Cast steel and fabricated sternframes are to be strengthened by adequately spaced horizontal plates.

Abrupt changes of section are to be avoided in castings; all sections are to have adequate tapering radius.

6.2 Connections

6.2.1 Connection with hull structure

Sternframes are to be effectively attached to the aft structure and the lower part of the sternframe is to be extended forward of the propeller post to a length not less than $1500 + 6L$ mm, in order to provide an effective connection with the keel. However, the sternframe need not extend beyond the aft peak bulkhead.

The net thickness of shell plating connected with the sternframe is to be not less than that obtained, in mm, from the following formula:

$t = 8.5 + 0.045L$

6.2.2 Connection with the keel

The thickness of the lower part of the sternframes is to be gradually tapered to that of the solid bar keel or keel plate.

Where a keel plate is fitted, the lower part of the sternframe is to be so designed as to ensure an effective connection with the keel.

6.2.3 Connection with transom floors

Rudder posts and propeller posts are to be connected with transom floors having height not less than that of the double bottom and net thickness not less than that obtained, in mm, from the following formula:

$t = 9 + 0.023L_1$

6.2.4 Connection with centre keelson

Where the sternframe is made of cast steel, the lower part of the sternframe is to be fitted, as far as practicable, with a longitudinal web for connection with the centre keelson.

6.3 Propeller posts

6.3.1 Gross scantlings

With reference to Ch 3, Sec 2, all scantlings and dimensions referred to in [6.3.2] to [6.3.4] are gross, i.e. they include the margins for corrosion.

6.3.2 Gross scantlings of propeller posts

The gross scantlings of propeller posts are to be not less than those obtained from the formulae in Tab 6 for single screw ships and Tab 7 for twin screw ships.

Scantlings and proportions of the propeller post which differ from those above may be considered acceptable provided that the section modulus of the propeller post section about its longitudinal axis is not less than that calculated with the propeller post scantlings in Tab 6 or Tab 7, as applicable.

6.3.3 Section modulus below the propeller shaft bossing

In the case of a propeller post without a sole piece, the section modulus of the propeller post may be gradually reduced below the propeller shaft bossing down to 85% of the value calculated with the scantlings in Tab 6 or Tab 7, as applicable.

In any case, the thicknesses of the propeller posts are to be not less than those obtained from the formulae in the tables.

6.3.4 Welding of fabricated propeller post with the propeller shaft bossing

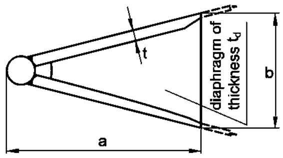
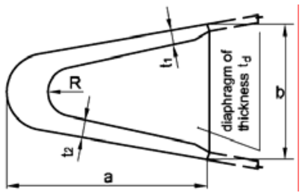
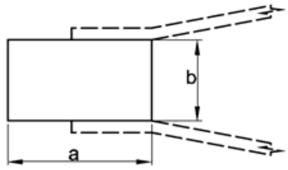
Welding of a fabricated propeller post with the propeller shaft bossing is to be in accordance with Ch 11, Sec 2.

6.4 Propeller shaft bossing

6.4.1

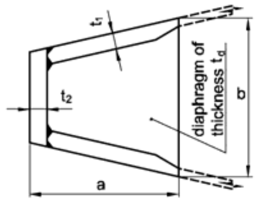
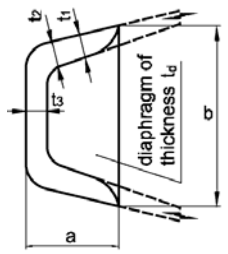
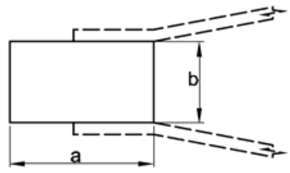
In single screw ships, the thickness of the propeller shaft bossing, included in the propeller post, is to be not less than 60% of the dimension *b* required in [6.3.2] for bar propeller posts with a rectangular section.

Table 6: Single screw ships - Gross scantlings of propeller posts

Gross scantlings of propeller posts, in mm	Fabricated propeller post 	Cast propeller post 	Bar propeller post, cast or forged, having rectangular section 
a	$50\ L^{1/2}$	$33\ L^{1/2}$	$10\sqrt{7.2L-256}$
b	$35\ L^{1/2}$	$23\ L^{1/2}$	$10\sqrt{4.6L-164}$
t_1 (1)	$2.5\ L^{1/2}$	$3.2\ L^{1/2}$ to be taken not less than 19 mm	-
t_2 (1)	-	$4.4\ L^{1/2}$ to be taken not less than 19 mm	-
t_D	$1.3\ L^{1/2}$	$2.0\ L^{1/2}$	-
R	-	$50\ L^{1/2}$	-

(1) Propeller post thicknesses t_1, and t_2 are, in any case, to be not less than $(0.05\ L + 9.5)$ mm.

Table 7: Twin screw ships - Gross scantlings of propeller posts

Gross scantlings of propeller posts, in mm	Fabricated propeller post 	Cast propeller post 	Bar propeller post, cast or forged, having rectangular section 
a	$25\ L^{1/2}$	$12.5\ L^{1/2}$	$2.4L + 6$
b	$25\ L^{1/2}$	$25\ L^{1/2}$	$0.8L + 2$
t_1 **(1)**	$2.5\ L^{1/2}$	$2.5\ L^{1/2}$	-
t_2 **(1)**	$3.2\ L^{1/2}$	$3.2\ L^{1/2}$	-
t_3	-	$4.4\ L^{1/2}$	-
t_D	$1.3\ L^{1/2}$	$2.0\ L^{1/2}$	-
(1) Propeller post thicknesses t_1, t_2 and t_3 are, in any case, to be not less than $(0.05L + 9.5)$ mm.			

6.5 Sterntubes

6.5.1 Sterntubes

The sterntube thickness is considered by the Society on a case by case basis. In no case, however, may it be less than the thickness of the side plating adjacent to the stern-frame.

Where the materials adopted for the sterntube and the plating adjacent to the sternframe are different, the sterntube thickness is to be at least equivalent to that of the plating.

Section 3 – MACHINERY SPACE

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

k : Material factor, defined in Ch 3, Sec 1, [2.2]

P : Maximum continuous rating, in kW, of the engine

n_r : Number of revolutions per minute of the engine shaft at power equal to P

L_E : Effective length, in m, of the engine foundation plate required for bolting the engine to the seating, as specified by the engine manufacturer.

1. General

1.1 Application

1.1.1

The requirements of this Section apply for the arrangement and scantling of machinery space structures as regards general strength. It is no substitute to machinery manufacturer's requirements that have to be dealt with at Shipyard diligence.

1.2 Scantlings

1.2.1 Net scantlings

As specified in Ch 3, Sec 2 all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 3, Sec 2, [3.1].

1.2.2 General

Unless otherwise specified in this Section, the scantlings of plating, ordinary stiffeners and primary supporting members in the machinery space are to be determined according to the relevant criteria in Ch 6.

In addition, the minimum thickness requirements specified in this Section apply.

1.2.3 Primary supporting members

The Designer may propose arrangements and scantlings alternative to the requirements of this Section, on the basis of direct calculations which are to be submitted to the Society for examination on a case by case basis.

The Society may also require such direct calculations to be carried out whenever deemed necessary.

1.3 Connections of the machinery space with structures located aft and forward

1.3.1 Tapering

Adequate tapering is to be ensured between the scantlings in the machinery space and those aft and forward. The tapering is to be such that the scantling requirements for all areas are fulfilled.

1.3.2 Transition zone between engine room and cargo area

In the transition zone between the engine room and the aftermost cargo hold due consideration is to be given to the proper tapering of major longitudinal members within the engine room such as flats, decks, horizontal rings or side stringers into the cargo hold, and for longitudinal bulkheads (inner skin, upper and lower wing tank) into the engine room.

Where such structure is in line with longitudinal members aft or forward of the cargo hold bulkhead, adequate tapering is to be achieved by fitting large tapering brackets inside the wing tanks or engine room.

1.3.3 Deck discontinuities

Decks which are interrupted in the machinery space are to be tapered on the side by means of horizontal brackets.

2. Double bottom

2.1 Arrangement

2.1.1 General

Where the machinery space is immediately forward of the after peak, the double bottom is to be transversely framed. In all other cases it may be transversely or longitudinally framed.

2.1.2 Double bottom height

The double bottom height at the centreline, irrespective of the location of the machinery space, is to be not less than the value defined in Ch 3, Sec 6, [6.1]. This depth may need to be considerably increased in relation to the type and depth of main machinery seatings.

The above height is to be increased by the Shipyard where the machinery space is very large and where there is a considerable variation in draught between light ballast and full load conditions.

Where the double bottom height in the machinery space differs from that in adjacent spaces, structural continuity of longitudinal members is to be ensured by sloping the inner bottom over an adequate longitudinal extent. The knuckles in the sloped inner bottom are to be located in way of floors.

2.1.3 Centre bottom girder

In general, the centre bottom girder may not be provided with holes. In any case, in way of any openings for manholes on the centre girder, permitted only where absolutely necessary for double bottom access and maintenance, local strengthening is to be arranged.

2.1.4 Side bottom girders

In the machinery space the number of side bottom girders is to be adequately increased, with respect to the adjacent areas, to ensure adequate rigidity of the structure. The side bottom girders are to be a continuation of any bottom longitudinals in the areas adjacent to the machinery space and are generally to have a spacing not greater than 3 times that of longitudinals and in no case greater than 3 m.

2.1.5 Side bottom girders in way of machinery seatings

Additional side bottom girders are to be fitted in way of machinery seatings.

Side bottom girders arranged in way of main machinery seatings are to extend for the full length of the machinery space.

Bottom girders are to extend as far aft as practicable in relation to the shape of the bottom and are to be supported by floors and side primary supporting members at the ends.

Forward of the machinery space forward bulkhead, the bottom girders are to be generally tapered for at least three frame spaces and are to be effectively connected to the hull structure.

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2.1.6 Floors in longitudinally framed double bottom

Where the double bottom is longitudinally framed, the floor spacing is to be not greater than:

- 1 frame spacing in way of the main engine and thrust bearing
- 2 frame spacings in other areas of the machinery space.

Additional floors are to be fitted in way of other important machinery.

2.1.7 Floors in transversely framed double bottom

Where the double bottom in the machinery space is transversely framed, floors are to be arranged at every frame. Furthermore, additional floors are to be fitted in way of boiler foundations or other important machinery.

2.1.8 Floors stiffeners

In addition to the requirements in Ch 3, Sec 6, floors are to have web stiffeners sniped at the ends and spaced not more than approximately 1 m apart.

The section modulus of web stiffeners is to be not less than 1.2 times that required in Ch 6, Sec 2, [4.1.2].

2.1.9 Manholes and wells

The number and size of manholes in floors located in way of seatings and adjacent areas are to be kept to the minimum necessary for double bottom access and maintenance.

The depth of manholes is generally to be not greater than 40% of the floor local depth, and in no case greater than 750 mm, and their width is to be equal to approximately 400 mm.

In general, manhole edges are to be stiffened with flanges; failing this, the floor plate is to be adequately stiffened with flat bars at manhole sides.

Manholes with perforated portable plates are to be fitted in the inner bottom in the vicinity of wells arranged close to the aft bulkhead of the engine room.

Drainage of the tunnel is to be arranged through a well located at the aft end of the tunnel.

2.2 Minimum thicknesses

2.2.1

The net thicknesses of inner bottom, floor and girder webs are to be not less than the values given in Tab 1.

Table 1: Double bottom - Minimum net thicknesses of inner bottom, floor and girder webs

Element	Minimum net thickness, in mm
Inner bottom	$6.6 + 0.024L$ The Society may require the thickness of the inner bottom in way of the machinery seatings and on the main thrust blocks to be increased, on a case by case basis.
Margin plate	$0.9L^{1/2} + 1$
Centre girder	$1.55L^{1/3} + 3.5$
Floors and side girders	$1.7L^{1/3} +1$
Girder bounding a duct keel	$0.8L^{1/2} + 2.5$, to be taken not less than that required for the centre girder.

3. Side

3.1 Arrangement

3.1.1 General

The type of side framing in machinery spaces is generally to be the same as that adopted in the adjacent areas.

3.1.2 Extension of the hull longitudinal structure within the machinery space

In ships where the machinery space is located aft and where the side is longitudinally framed, the longitudinal structure is preferably to extend for the full length of the machinery space.

In any event, the longitudinal structure is to be maintained for at least 0.3 times the length of the machinery space, calculated from the forward bulkhead of the latter, and abrupt structural discontinuities between longitudinally and transversely framed structures are to be avoided.

3.1.3 Side transverses

Side transverses are to be aligned with floors. One is preferably to be located in way of the forward end and another in way of the after end of the machinery casing.

For a longitudinally framed side, the side transverse spacing is to be not greater than 4 frame spacings.

For a transversely framed side, the side transverse spacing is to be not greater than 5 frame spaces. The web height is to be not less than twice that of adjacent frames and the section modulus is to be not less than four times that of adjacent frames.

Side transverse spacing greater than that above may be accepted provided that the scantlings of ordinary frames are increased, according to the Society's requirements to be defined on a case by case basis.

4. Platforms

4.1 Arrangement

4.1.1 General

The location and extension of platforms in machinery spaces are to be arranged so as to be a continuation of the structure of side longitudinals, as well as of platforms and side girders located in the adjacent hull areas.

4.1.2 Platform transverses

In general, platform transverses are to be arranged in way of side or longitudinal bulkhead transverses.

For longitudinally framed platforms, the spacing of platform transverses is to be not greater than 4 frame spacings.

4.2 Minimum thicknesses

4.2.1

The net thickness of platforms is to be not less than 6.5 mm.

5. Pillaring

5.1 Arrangement

5.1.1 General

The pillaring arrangement in machinery spaces is to account both for the concentrated loads transmitted by machinery and superstructures and for the position of main machinery and auxiliary engines.

5.1.2 Pillars

Pillars are to be arranged in the following positions:

- in way of machinery casing corners and corners of large openings on platforms; alternatively, two pillars may be fitted on the centreline (one at each end of the opening)
- in way of the intersection of platform transverses and girders
- in way of transverse and longitudinal bulkheads of the superstructure.

In general, pillars are to be fitted with brackets at their ends.

5.1.3 Pillar bulkheads

In general, pillar bulkheads, fitted in ‘tween decks below the upper deck, are to be located in way of load-bearing bulkheads in the superstructures.

Longitudinal pillar bulkheads are to be a continuation of main longitudinal hull structures in the adjacent spaces forward and aft of the machinery space.

Pillar bulkhead scantlings are to be not less than those required in [6.3] for machinery casing bulkheads.

6. Machinery casing

6.1 Arrangement

6.1.1 Ordinary stiffener spacing

Ordinary stiffeners are to be located:

- at each frame, in longitudinal bulkheads
- at a distance of about 750 mm, in transverse bulkheads.

The ordinary stiffener spacing in portions of casings that are particularly exposed to wave action is considered by the Society on a case by case basis.

6.2 Openings

6.2.1 General

All machinery space openings, which are to comply with the requirements in Sec 6, [6], are to be enclosed in a steel casing leading to the highest open deck. Casings are to be reinforced at the ends by deck beams and girders associated to pillars.

In the case of large openings, the arrangement of cross-ties as a continuation of deck beams may be required.

Skylights, where fitted with openings for light and air, are to have coamings of a height not less than:

- 900 mm, if in position 1
- 760 mm, if in position 2.

6.2.2 Access doors

Access doors to casings are to comply with Sec 6, [6.2].

6.3 Scantlings

6.3.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than those obtained according to the applicable requirements in Ch 9, Sec 4.

6.3.2 Minimum thicknesses

The net thickness of bulkheads is to be not less than:

- 5.5 mm for bulkheads in way of cargo holds
- 4 mm for bulkheads in way of accommodation spaces.

7. Main machinery seating

7.1 Arrangement

7.1.1 General

The scantlings of main machinery seatings and thrust bearings are to be adequate in relation to the weight and power of engines and the static and dynamic forces transmitted by the propulsive installation.

7.1.2 Seating supporting structure

Transverse and longitudinal members supporting the seatings are to be located in line with floors and double or single bottom girders, respectively.

They are to be so arranged as to avoid discontinuity and ensure sufficient accessibility for welding of joints and for surveys and maintenance.

7.1.3 Seatings included in the double bottom structure

Where high-power internal combustion engines or turbines are fitted, seatings are to be integral with the double bottom structure. Girders supporting the bedplates in way of seatings are to be aligned with double bottom girders and are to be extended aft in order to form girders for thrust blocks.

The girders in way of seatings are to be continuous from the bedplates to the bottom shell.

7.1.4 Seatings above the double bottom plating

Where the seatings are situated above the double bottom plating, the girders in way of seatings are to be fitted with flanged brackets, generally located at each frame and extending towards both the centre of the ship and the sides.

The extension of the seatings above the double bottom plating is to be limited as far as practicable while ensuring adequate spaces for the fitting of bedplate bolts. Bolt holes are to be located such that they do not interfere with seating structures.

7.1.5 Seatings in a single bottom structure

For ships having a single bottom structure within the machinery space, seatings are to be located above the floors and to be adequately connected to the latter and to the girders located below.

7.1.6 Number of girders in way of machinery seatings

At least two girders are to be fitted in way of main machinery seatings.

One girder may be fitted only where the following three formulae are complied with:

$L < 150$ m

$P < 7100$ kW

$P < 2.3\, n_r\, L_E$

7.2 Minimum scantlings

7.2.1

The net scantlings of the structural elements in way of the internal combustion engine seatings are to be obtained from the formulae in Tab 2. However, the net cross-sectional area of each bedplate of the seatings may be determined by the engine manufacturers, provided the information regarding permissible foundation stiffness considering the engine characteristics and engine room arrangement, etc.

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Table 2: Minimum scantlings of the structural elements in way of machinery seatings

Scantling minimum value	Scantling minimum value
Net cross-sectional area, in cm^2, of each bedplate of the seatings	$40 + 70\dfrac{P}{n_r L_E}$
Bedplate net thickness, in mm	Bedplates supported by two or more girders: $\sqrt{240 + 175\dfrac{P}{n_r L_E}}$ Bedplates supported by one girder: $5 + \sqrt{240 + 175\dfrac{P}{n_r L_E}}$
Total web net thickness, in mm, of girders fitted in way of machinery seatings	Bedplates supported by two or more girders: $\sqrt{320 + 215\dfrac{P}{n_r L_E}}$ Bedplates supported by one girder:

	$\sqrt{95+65\dfrac{P}{n_r L_E}}$
Web net thickness, in mm, of floors fitted in way of machinery seatings	$\sqrt{55+40\dfrac{P}{n_r L_E}}$

Section 4 – SUPERSTRUCTURES AND DECKHOUSES

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

L_2 : Rule length L, but to be taken not greater than 300 m

p_D : Lateral pressure for decks, in kN/m^2, as defined in [3.2.1]

p_{SI} : Lateral pressure for sides of superstructures, in kN/m^2, as defined in [3.2.3]

k : Material factor, defined in Ch 3, Sec 1, [2.2]

s : Spacing, in m, of ordinary stiffeners, measured at mid-span along the chord

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members, see Ch 3, Sec 6, [4.2]

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c : Coefficient taken equal to:

$c = 0.75$ for beams, girders and transverses which are simply supported on one or both ends

$c = 0.55$ in other cases

m_a : Coefficient taken equal to:

$$m_a = 0.204\frac{s}{\ell}\left[4-\left(\frac{s}{\ell}\right)^2\right], \text{ with } \frac{s}{\ell}\le 1$$

1. General

1.1 Definitions

1.1.1 Superstructure

See Ch 1, Sec 4, [3.12.1]

1.1.2 Deckhouse

See Ch 1, Sec 4, [3.15.1]

1.1.3 Long deckhouse

A long deckhouse is a deckhouse the length of which within $0.4L$ amidships exceeds $0.2L$. The strength of a long deckhouse is to be specially considered.

1.1.4 Short deckhouse

A short deckhouse is a deckhouse not covered by the definition given in [1.1.3].

1.1.5 Non-effective superstructure

For the purpose of this section, all superstructures being located beyond $0.4L$ amidships or having a length of less than $0.15L$ are considered as non-effective superstructures.

1.1.6 Insulated funnel

Scantlings of insulated funnels are to be determined as for deckhouses.

1.1.7 Effective superstructure

Effective superstructure is a superstructure not covered by the definition given in [1.1.5]

1.2 Gross scantlings

1.2.1

With reference to Ch 3, Sec 2, all scantlings and dimensions referred to in [4] and [5] are gross, i.e. they include the margins for corrosion.

2. Arrangement

2.1 Strengthening at the ends of superstructures

2.1.1

In way of end bulkheads of superstructures located within 0.4L amidships, the thickness of the strength deck in a breadth of 0.1B from the shell, the thickness of the sheerstrake, and the thickness of the superstructure side plating are to be increased by the percentage of strengthening specified in Tab 1. The strengthening is to be extended over a region from 4 frame spacings abaft the end bulkhead to 4 frame spacings forward of the end bulkhead.

Table 1: Percentage of strengthening

Type of superstructure	Strength deck and sheerstrake	Side plating of superstructure
Effective	30%	20%
Non-effective	20%	10%

2.1.2

Under strength decks in way of 0.6L amidships, girders are to be fitted in alignment with longitudinal walls, which are to extend at least over three frame spacings beyond the end points of the longitudinal walls. The girders are to overlap with the longitudinal walls by at least two frame spacings.

2.2 Attachment of stiffening members

2.2.1 Attachment of deck beams

Transverse deck beams are to be connected to the frames by brackets according to Ch 3, Sec 6.

Deck beams crossing longitudinal walls and girders may be attached to the stiffeners of longitudinal walls and the webs of girders respectively by welding without brackets.

2.2.2 Attachment of deck girders and transverses

End attachments of girders at bulkheads are to be so dimensioned that the bending moments and shear forces can be transferred. Bulkhead stiffeners under girders are to be sufficiently dimensioned to support the girders.

Face plates are to be stiffened by tripping brackets according to Ch 3, Sec 6. At girders of symmetrical section, they are to be arranged alternately on both sides of the web.

2.2.3 End attachment of superstructure frames

Superstructure frames are to be connected to the main frames below, or to the deck. The end attachment may be carried out in accordance with Fig 1.

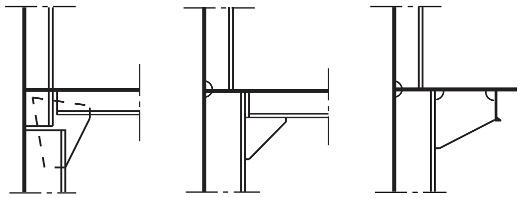

Figure 1: End attachment of superstructure frames

2.3 Transverse structure of superstructures and deckhouses

2.3.1

The transverse structure of superstructures and deckhouses is to be sufficiently dimensioned by a suitable arrangement of end bulkheads, web frames, steel walls of cabins and casings, or by other measures.

2.4 Openings in enclosed superstructures

2.4.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 12(1))

All access openings in bulkheads at ends of enclosed superstructures are to be fitted with weathertight doors permanently attached to the bulkhead, and framed, stiffened and fitted so that the whole structure is of equivalent strength to the un-pierced bulkhead. The doors are to be so arranged that they can be operated from both sides of the bulkhead.

2.4.2

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 12(3))

The height of the sills of access openings in bulkheads at ends of enclosed superstructures shall be at least 380 mm above the deck.

2.4.3

Any opening in a superstructure deck or in a deckhouse deck directly above the freeboard deck (deckhouse surrounding companionways), is to be protected by efficient weathertight closures.

3. Load model

3.1 Load calculation point

3.1.1

Unless otherwise specified, lateral pressure is to be calculated at load calculation points defined in:

- Ch 6, Sec 1, [1.5], for plating
- Ch 6, Sec2, [1.4] for ordinary stiffeners and primary supporting members.

3.2 Loads

3.2.1 Lateral pressure for decks

The lateral pressure for decks of superstructures and deckhouses, in kN/m^2, is to be taken equal to:

- the external pressure p_D defined in Ch 4, Sec 5, [2.1] for exposed decks,
- 5 kN/m^2 for unexposed decks.

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3.2.2 Lateral pressure for exposed wheel house top

The lateral pressure p for exposed wheel house tops, in kN/m^2, is to be obtained according to Ch 4, Sec 5, [3.2].

3.2.3 Lateral pressure for sides of superstructures

The lateral pressure p_{SI} for sides of superstructures, in kN/m^2, is to be obtained according to Ch 4, Sec 5, [3.3].

4. Scantlings

4.1 Side plating of non-effective superstructures

4.1.1

The gross thickness, in mm, of the side plating of non-effective superstructures is not to be less than the greater of the following values:

$t = 1.21s\sqrt{kp_{SI}} + 1.5$ *RCN 1 to July 2008 version (effective from 1July 2009)*

$t = 0.8\sqrt{kL}$

4.2 Deck plating of non-effective superstructures

4.2.1

The gross thickness, in mm, of deck plating of non-effective superstructures is not to be less than the greater of the following values:

$t = 1.21s\sqrt{kp_D} + 1.5$ *RCN 1 to July 2008 version (effective from 1 July 2009)*

$t = (5.5 + 0,02L)\sqrt{k}$

where L is not to be taken greater than 200 m.

4.2.2

Where additional superstructures are arranged on non-effective superstructures located on the freeboard deck, the gross thickness required by [4.2.1] may be reduced by 10%. *RCN 1 to July 2008 version (effective from 1 July 2009)*

4.2.3

Where plated decks are protected by sheathing, the gross thickness of the deck plating according to [4.2.1] and [4.2.2] may be reduced by 1.5mm. *RCN 1 to July 2008 version (effective from 1 July 2009)* However, such deck plating is not to be less than 5 mm.

Where a sheathing other than wood is used, attention is to be paid that the sheathing does not affect the steel. The sheathing is to be effectively fitted to the deck.

4.3 Deck beams and supporting deck structure

4.3.1 Transverse deck beams and deck longitudinal ordinary stiffeners

The section modulus w, in cm^3, and the shear area A_{sh}, in cm^2, of transverse deck beams and of deck longitudinal ordinary stiffeners are not to be less than the values obtained from the following formulae:

$$w = ckp_D s\ell^2$$

$$A_{sh} = 0.05(1-0.817m_a)kp_D s\ell$$

4.3.2 Deck girders and transverses

The section modulus w, in cm^3, and the shear area A_{sh}, in cm^2, of deck girders and transverses are not to be less than the values obtained from the following formulae:

$$w = ckp_D e\ell^2$$

$$A_{sh} = 0.05kp_D e\ell$$

where:

e : Width of loaded area, in m, of the unsupported adjacent plate fields, measured from each mid of plate field to mid of opposite plate filed.

The girder depth is not to be less than $\ell/25$. The web depth of girders scalloped for continuous deck beams is to be at least 1.5 times the depth of the deck beams.

Where a girder does not have the same section modulus throughout all girder fields, the greater scantlings are to be maintained above the supports and are to be reduced gradually to the smaller scantlings.

4.4 Superstructure frames

4.4.1 Section modulus and shear area

The section modulus w, in cm^3, and the shear area A_{sh}, in cm^2, of the superstructure frames are not to be less than the values obtained from the following formulae:

$$w = 0.55kp_{SI} s\ell^2$$

$$A_{sh} = 0.05(1-0.817m_a)kp_{SI} s\ell$$

4.4.2

Where frames are supported by a longitudinally framed deck, the frames fitted between web frames are to be connected to the adjacent longitudinal ordinary stiffeners by brackets. The scantlings of the brackets are to be determined in accordance with Ch 3, Sec 6 on the basis of the section modulus of the frames.

4.4.3

Where further superstructures or deckhouses are arranged on the superstructures, strengthening of the frames of the space below may be required.

4.5 Decks of short deckhouses

4.5.1 Plating

The thickness, in mm, of weather deck of short deckhouses and is not to be less than:

$t = 8s\sqrt{k} + 1.5$ *RCN 1 to July 2008 version (effective from 1 July 2009)*

For weather decks of short deckhouses protected by sheathing and for decks within deckhouses, the gross thickness may be reduced by 1.5mm. However, such deck plating is not to be less than 5 mm.

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4.5.2 Deck beams

The scantlings of deck beams and supporting deck structure are to be determined according to [4.3].

5. End bulkheads of superstructure and deckhouse

(RCN 2, effective from 1 July 2008)

5.1 Application

5.1.1

The requirements in [5.2] and [5.3] apply to end bulkhead of superstructure and deckhouse forming the only protection for openings, as required by ILLC as amended, and for accommodations.

(RCN 2, effective from 1 July 2008)

5.2 Loads

5.2.1

The design load p_A, in kN/m², for determining the scantlings is to be obtained according to Ch 4, Sec 5, [3.4].

5.3 Scantlings

5.3.1 Stiffeners

The section modulus w, in cm^3, of the stiffeners is not to be less than the value obtained from the following formula:

$$w = 0.35kp_A s\ell^2$$

This requirement assume the webs of lowest tier stiffeners to be efficiently welded to the decks. Scantlings for other types of end connections may be specially considered.

The section modulus of deckhouse side stiffeners needs not to be greater than that of side frames on the deck situated directly below; taking account of spacing s and span ℓ.

(RCN 2, effective from 1 July 2008)

5.3.2 Plate thickness

The gross thickness of the plating, in mm, is not to be less than the greater of the values obtained from the following formulae:

$t = 0.9s\sqrt{kp_A} + 1.5$ *RCN 1 to July 2008 version (effective from 1 July 2009)*

$t_{min} = \left(5.0 + \dfrac{L_2}{100}\right)\sqrt{k}$, for the lowest tier

$t_{min} = \left(4.0 + \dfrac{L_2}{100}\right)\sqrt{k}$, for the upper tiers, without being less than 5.0 mm.

Section 5 – HATCH COVERS

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

p_S : Still water pressure, in kN/m^2, defined in [4.1]

p_W : Wave pressure, in kN/m^2, defined in [4.1]

p_C : Pressure acting on the hatch coaming, in kN/m^2, defined in [6.2]

F_S, F_W : Coefficients taken equal to:

$F_S = 0$ and $F_W = 0.9$ for ballast water loads on hatch covers of the ballast hold

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$F_S = 1.0$ and $F_W = 1.0$ in other cases

s : Length, in m, of the shorter side of the elementary plate panel

ℓ : Length, in m, of the longer side of the elementary plate panel

b_p : Effective width, in m, of the plating attached to the ordinary stiffener or primary supporting member, defined in [3]

w : Net section modulus, in cm^3, of the ordinary stiffener or primary supporting member, with an attached plating of width b_p

A_{sh} : Net shear sectional area, in cm^2, of the ordinary stiffener or primary supporting member

m : Boundary coefficient for ordinary stiffeners and primary supporting members, taken equal to:

$m = 8$, in the case of ordinary stiffeners and primary supporting members simply supported at both ends or supported at one end and clamped at the other end

$m = 12$, in the case of ordinary stiffeners and primary supporting members clamped at both ends

t_C : Total corrosion addition, in mm, defined in [1.4]

σ_a , τ_a : Allowable stresses, in N/mm^2, defined in [1.5]

1. General

1.1 Application

1.1.1

The requirements in [1] to [8] apply to steel hatch covers in positions 1 and 2 on weather decks, defined in Ch 1, Sec 4, [3.20].

The requirements in [9] apply to steel hatch covers of small hatches fitted on the exposed fore deck over the forward 0.25L.

1.2 Materials

1.2.1 Steel

The formulae for scantlings given in [5] are applicable to steel hatch covers.

Materials used for the construction of steel hatch covers are to comply with the applicable requirements of the Society.

1.2.2 Other materials

The use of materials other than steel is considered by the Society on a case by case basis, by checking that criteria adopted for scantlings are such as to ensure strength and stiffness equivalent to those of steel hatch covers.

1.3 Net scantlings

1.3.1

All scantlings referred to in this Section, except otherwise specified, are net, i.e. they do not include any margin for corrosion.

When calculating the stresses σ and τ in [5.3] and [5.4], the net scantlings are to be used.

The gross scantlings are obtained as specified in Ch 3, Sec 2.

The corrosion additions are given in [1.4].

1.4 Corrosion additions

1.4.1

The total corrosion addition for both sides to be considered for the plating and internal members of hatch covers is equal to the value specified in Tab 1.

The corrosion addition for hatch coamings and coaming stays is defined according to Ch 3, Sec 3.

Table 1: Corrosion addition t_C for hatch covers

Corrosion addition t_C, in mm, for both sides	
Plating and stiffeners of single skin hatch cover	2.0
Top and bottom plating of double skin hatch cover	2.0
Internal structures of double skin hatch cover	1.5

1.5 Allowable stresses

1.5.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 15(6) and 16(5))

The allowable stresses σ_a and τ_a, in N/mm^2, are to be obtained from Tab 2.

Table 2: Allowable stresses, in N/mm^2

Members of	Subjected to	σ_a, in N/mm^2	τ_a, in N/mm^2
Weathertight hatch cover	External pressure, as defined in Ch 4, Sec 5, [5.2.1]	0.80 R_{eH}	0.46 R_{eH}
Pontoon hatch cover		0.68 R_{eH}	0.39 R_{eH}
Weathertight hatch cover and pontoon hatch cover	Other loads, as defined in Ch 4, Sec 5, [5.1.1] and Ch 4, Sec 6, [2]	0.90 R_{eH}	0.51 R_{eH}

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2. Arrangements

2.1 Height of hatch coamings

2.1.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 14 (1, 1))

The height above the deck of hatch coamings is to be not less than:

- *600 mm in position 1*
- *450 mm in position 2.*

2.1.2

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 14 (1, 2))

The height of hatch coamings in positions 1 and 2 closed by steel covers provided with gaskets and securing devices may be reduced with respect to the above values or the coamings may be omitted entirely, on condition that the Administration is satisfied that the safety of the ship is not thereby impaired in any sea conditions.

In such cases the scantlings of the covers, their gasketing, their securing arrangements and the drainage of recesses in the deck are considered by the Society on a case by case basis.

2.1.3

Regardless of the type of closing arrangement adopted, the coamings may have reduced height or be omitted in way of openings in closed superstructures.

2.2 Hatch covers

2.2.1

Hatch covers on exposed decks are to be weathertight.

Hatch covers in closed superstructures need not be weathertight.

However, hatch covers fitted in way of ballast tanks, fuel oil tanks or other tanks are to be watertight.

2.2.2

The ordinary stiffeners and primary supporting members of the hatch covers are to be continuous over the breadth and length of the hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to ensure sufficient load carrying capacity.

2.2.3

The spacing of primary supporting members parallel to the direction of ordinary stiffeners is to be not greater than 1/3 of the span of primary supporting members.

2.2.4

The breadth of the primary supporting member face plate is to be not less than 40% of their depth for laterally unsupported spans greater than 3 m. Tripping brackets attached to the face plate may be considered as a lateral support for primary supporting members.

The face plate outstand is not to exceed 15 times the gross face plate thickness.

2.2.5
Efficient retaining arrangements are to be provided to prevent translation of the hatch cover under the action of the longitudinal and transverse forces exerted by cargoes on the cover, if any. These retaining arrangements are to be located in way of the hatch coaming side brackets.

2.2.6
The width of each bearing surface for hatch covers is to be at least 65 mm.

2.3 Hatch coamings

2.3.1
Coamings, stiffeners and brackets are to be capable of withstanding the local forces in way of the clamping devices and handling facilities necessary for securing and moving the hatch covers as well as those due to cargo stowed on the latter.

2.3.2
Special attention is to be paid to the strength of the fore transverse coaming of the forward hatch and to the scantlings of the closing devices of the hatch cover on this coaming.

2.3.3
Longitudinal coamings are to be extended at least to the lower edge of deck beams.

- where they are not part of continuous deck girders, the lower edge of longitudinal coamings are to extend for at least two frame spaces beyond the end of the openings.
- where longitudinal coamings are part of deck girders, their scantlings are to be as required in Ch 6, Sec 4.

2.3.4
A web frame or a similar structure is to be provided below the deck in line with the transverse coaming. Transverse coamings are to extend below the deck and to be connected with the web frames.

2.4 Small hatchways

2.4.1
The height of small hatchway coamings is to be not less than 600 mm if located in position 1 and 450 mm if located in position 2.
Where the closing appliances are in the form of hinged steel covers secured weathertight by gaskets and swing bolts, the height of the coamings may be reduced or the coamings may be omitted altogether.

2.4.2
Small hatch covers are to have strength equivalent to that required for main hatchways and are to be of steel, weathertight and generally hinged.
Securing arrangements and stiffening of hatch cover edges are to be such that weathertightness can be maintained in any sea condition.

At least one securing device is to be fitted at each side. Circular hole hinges are considered equivalent to securing devices.

2.4.3
Hold accesses located on the weather deck are to be provided with weathertight metallic hatch covers, unless they are protected by a closed superstructure. The same applies to accesses located on the forecastle deck and leading directly to a dry cargo hold through a trunk.

2.4.4
Accesses to cofferdams and ballast tanks are to be manholes fitted with watertight covers fixed with bolts which are sufficiently closely spaced.

2.4.5
Hatchways of special design are considered by the Society on a case by case basis.

3. Width of attached plating

3.1 Ordinary stiffeners

3.1.1
The width of the attached plating to be considered for the check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- where the attached plating extends on both sides of the stiffener:

  $b_p = s$

- where the attached plating extends on one side of the stiffener:

  $b_p = 0.5s$

3.2 Primary supporting members

3.2.1
The effective width of the attached plating to be considered for the yielding and buckling checks of primary supporting members analysed through isolated beam or grillage model is to be obtained, in m, from the following formulae:

- where the plating extends on both sides of the primary supporting member:

  $b_p = b_{p,1} + b_{p,2}$

- where the plating extends on one side of the primary supporting member:

  $b_p = b_{p,1}$

where:

$b_{p,1} = \min\left(0.165\ell_p\ ,\ S_{p,1}\right)$

$b_{p,2} = \min\left(0.165\ell_p\ ,\ S_{p,2}\right)$

ℓ_p : Span, in m, of the considered primary supporting member

$S_{p,1}$, $S_{p,2}$: Half distance, in m, between the considered primary supporting member and the adjacent ones, $S_{p,1}$ for one side, $S_{p,2}$ for the other side.

When a isolated beam or a grillage analysis is used, the areas of ordinary stiffeners are not to be included in the attached plating of the primary members.

4. Load model

4.1 Lateral pressures and forces

4.1.1 General

The lateral pressures and forces to be considered as acting on hatch covers are indicated in [4.1.2] to [4.1.6]. When two or more panels are connected by hinges, each individual panel is to be considered separately.

In any case, the sea pressures defined in [4.1.2] are to be considered for hatch covers located on exposed decks.

Additionally, when the hatch cover is intended to carry uniform cargoes, special cargoes or containers, the pressures and forces defined in [4.1.3] to [4.1.6] are to be considered independently from the sea pressures.

4.1.2 Sea pressures

The still water and wave lateral pressures are to be considered and are to be taken equal to:

- still water pressure: $p_S = 0$
- wave pressure p_W, as defined in Ch 4, Sec 5 [5.2].

4.1.3 Internal pressures due ballast water

If applicable, the static and dynamic lateral pressures are to be considered and are defined in Ch 4, Sec 6, [2].

4.1.4 Pressures due to uniform cargoes

If applicable, the static and dynamic pressures are to be considered and are defined in Ch 4, Sec 5, [2.4.1]

4.1.5 Pressures or forces due to special cargoes

In the case of carriage on the hatch covers of special cargoes (e.g. pipes, etc.) which may temporarily retain water during navigation, the lateral pressures or forces to be applied are considered by the Society on a case by case basis.

4.1.6 Forces due to containers

In the case of carriage of containers on the hatch covers, the concentrated forces under the containers corners are to be determined in accordance with the applicable requirements of the Society.

4.2 Load point

4.2.1 Sea pressures

The wave lateral pressure to be considered as acting on each hatch cover is to be calculated at a point located longitudinally, at the hatch cover mid-length.

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4.2.2 Other pressures

The lateral pressure is to be calculated:

- in way of the geometrical centre of gravity of the plate panel, for plating
- at mid-span, for ordinary stiffeners and primary supporting members.

Internal dynamic lateral pressure to be considered as acting on the bottom of a hatch cover is to be calculated at a point located:

- longitudinally, at the hatch cover mid-length
- transversely, at hatchway side
- Vertically, at the top of the hatch coaming for internal ballast water pressures

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5. Strength check

5.1 General

5.1.1 Application

The strength check is applicable to rectangular hatch covers subjected to a uniform pressure, designed with primary supporting members arranged in one direction or as a grillage of longitudinal and transverse primary supporting members.

In the latter case, the stresses in the primary supporting members are to be determined by a grillage or a finite element analysis.

It is to be checked that stresses induced by concentrated loads are in accordance with the criteria in [5.4.4].

5.1.2 Hatch covers supporting containers

The scantlings of hatch covers supporting containers are to comply with the applicable provisions of the Society.

5.1.3 Hatch covers subjected to special cargoes

For hatch covers supporting special cargoes, ordinary stiffeners and primary supporting members are generally to be checked by direct calculations, taking into account the stiffener arrangements and their relative inertia. It is to be checked that stresses induced by special cargoes are in accordance with the criteria in [5.4.4].

5.1.4 Covers of small hatchways

The gross thickness of covers is to be not less than 8 mm. This thickness is to be increased or an efficient stiffening fitted to the Society's satisfaction where the greatest horizontal dimension of the cover exceeds 0.6 m.

5.2 Plating

5.2.1 Net thickness

The net thickness of steel hatch cover top plating, in mm, is to be not less than the value obtained from the following formula:

$$t = 15.8 F_p s \sqrt{\frac{F_S p_S + F_W p_W}{0.95 R_{eH}}}$$

where:

F_p : Factor for combined membrane and bending response, equal to:

$F_p = 1.5$ in general

$F_p = 1.9\,\sigma/\sigma_a$, for $\sigma \geq 0.8\sigma_a$ for the attached plating of primary supporting members

σ : Normal stress, in N/mm^2, in the attached plating of primary supporting members, calculated according to [5.4.3] or determined through a grillage analysis or a finite element analysis, as the case may be.

5.2.2 Minimum net thickness

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 16 (5, c))

In addition to [5.2.1], *the net thickness, in mm, of the plating forming the top of the hatch cover is to be not less than the greater of the following values:*

$t = 10s$

$t = 6$

5.2.3 Critical buckling stress check

The compressive stress σ in the hatch cover plating, induced by the bending of primary supporting members, parallel to the direction of ordinary stiffeners is to comply with the following formula:

$$\sigma \leq \frac{0.88}{S}\sigma_{C1}$$

where:

S : Safety factor defined in Ch 6, Sec 3

σ_{C1} : Critical buckling stress, in N/mm^2, taken equal to:

$\sigma_{C1} = \sigma_{E1}$ for $\sigma_{E1} \leq \frac{R_{eH}}{2}$

$\sigma_{C1} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E1}}\right)$ for $\sigma_{E1} > \frac{R_{eH}}{2}$

$$\sigma_{E1} = 3.6\,E\left(\frac{t}{1000s}\right)^2$$

t : Net thickness, in mm, of plate panel

The compressive stress σ in the hatch cover plating, induced by the bending of primary supporting members, perpendicular to the direction of ordinary stiffeners is to comply with the following formula:

$$\sigma \leq \frac{0.88}{S}\sigma_{C2}$$

where:

S : Safety factor defined in Ch 6, Sec 3

σ_{C2} : Critical buckling stress, in N/mm², taken equal to:

$$\sigma_{C2} = \sigma_{E2} \quad \text{for} \quad \sigma_{E2} \le \frac{R_{eH}}{2}$$

$$\sigma_{C2} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E2}}\right) \quad \text{for} \quad \sigma_{E2} > \frac{R_{eH}}{2}$$

$$\sigma_{E2} = 0.9\, m\, E\left(\frac{t}{1000 s_s}\right)^2$$

m : Coefficient taken equal to:

$$m = c\left[1 + \left(\frac{s_s}{\ell_s}\right)^2\right]^2 \frac{2.1}{\psi + 1.1}$$

t : Net thickness, in mm, of plate panel

s_s : Length, in m, of the shorter side of the plate panel

ℓ_s : Length, in m, of the longer side of the plate panel

ψ : Ratio between smallest and largest compressive stress

c : Coefficient taken equal to:

c = 1.3 when plating is stiffened by primary supporting members

c = 1.21 when plating is stiffened by ordinary stiffeners of angle or T type

c = 1.1 when plating is stiffened by ordinary stiffeners of bulb type

c = 1.05 when plating is stiffened by flat bar.

c= 1.30 when plating is stiffened by ordinary stiffeners of U type. The higher c value but not greater than 2.0 may be taken if it is verified by buckling strength check of panel using non-linear FEA and deemed appropriate by the Society.

An averaged value of c is to be used for plate panels having different edge stiffeners.

The bi-axial compression stress in the hatch cover plating, when calculated by means of finite element analysis, is to comply with the requirements in Ch 6, Sec 3.

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5.3 Ordinary stiffeners

5.3.1

For flat bar ordinary stiffeners, the ratio h_w/t_w is to comply with the following formula:

$$\frac{h_w}{t_w} \le 15\sqrt{\frac{235}{R_{eH}}}$$

5.3.2 Minimum net thickness of web

The web net thickness of the ordinary stiffener, in mm, is to be not less than 4mm.

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5.3.3 Net section modulus and net shear sectional area

The net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of an ordinary stiffener subject to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \frac{(F_S p_S + F_W p_W) s \ell_s^2}{m \sigma_a} 10^3$$

$$A_{sh} = \frac{5(F_S p_S + F_W p_W) s \ell_s}{\tau_a}$$

where:

ℓ_s : Ordinary stiffener span, in m, to be taken as the spacing, in m, of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all ordinary stiffener spans, the ordinary stiffener span may be reduced by an amount equal to 2/3 of the minimum brackets arm length, but not greater than 10% of the gross span, for each bracket.

5.3.4 Critical buckling stress check

The compressive stress σ in the face plate of ordinary stiffeners, induced by the bending of primary supporting members, parallel to the direction of ordinary stiffeners is to comply with the following formula:

$$\sigma \le \frac{0.88 \sigma_{CS}}{S}$$

where:

S : Safety factor defined in Ch 6, Sec 3

σ_{CS} : Critical buckling stress, in N/mm^2, taken equal to:

$$\sigma_{CS} = \sigma_{ES} \quad \text{for} \quad \sigma_{ES} \le \frac{R_{eH}}{2}$$

$$\sigma_{CS} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{ES}}\right) \quad \text{for} \quad \sigma_{ES} > \frac{R_{eH}}{2}$$

$$\sigma_{ES} = \min(\sigma_{E3}, \sigma_{E4})$$

$$\sigma_{E3} = 0.001 \frac{E I_a}{A \ell^2}$$

I_a : Moment of inertia, in cm^4, of the ordinary stiffener, including a face plate equal to spacing of ordinary stiffeners

A : Cross-sectional area, in cm^2, of the ordinary stiffener, including a face plate equal to spacing of ordinary stiffeners

ℓ : Span, in m, of the ordinary stiffener

$$\sigma_{E4} = \frac{\pi^2 E I_w}{10^4 I_p \ell^2}\left(m^2 + \frac{K}{m^2}\right) + 0.385 E \frac{I_t}{I_p}$$

$$K = \frac{C \ell^4}{\pi^4 E I_w} 10^6$$

m : Number of half waves, given in Tab 3.

Table 3: Number of half waves

	$0 < K < 4$	$4 < K < 36$	$36 < K < 144$	$(m-1)^2\, m^2 < K \le m^2\, (m+1)^2$
m	1	2	3	m

I_w : Sectorial moment of inertia, in cm^6, of the ordinary stiffener about its connection with the plating, taken equal to:

$$I_w = \frac{h_w^3\, t_w^3}{36} 10^{-6}$$ for flat bar ordinary stiffeners

$$I_w = \frac{t_f\, b_f^3\, h_w^2}{12} 10^{-6}$$ for "Tee" ordinary stiffeners

$$I_w = \frac{b_f^3\, h_w^2}{12\left(b_f + h_w\right)^2}\left[t_f\left(b_f^2 + 2\, b_f\, h_w + 4\, h_w^2\right) + 3\, t_w\, b_f\, h_w\right] 10^{-6}$$ for angles and bulb ordinary stiffeners

I_p : Polar moment of inertia, in cm^4, of the ordinary stiffener about its connection with the plating, taken equal to:

$$I_t = \frac{h_w^3\, t_w}{3} 10^{-4}$$ for flat bar ordinary stiffeners

$$I_p = \left(\frac{h_w^3\, t_w}{3} + h_w^2\, b_f\, t_f\right) 10^{-4}$$ for flanged ordinary stiffeners

I_t : St Venant's moment of inertia, in cm^4, of the ordinary stiffener without face plate, taken equal to:

$$I_t = \frac{h_w\, t_w^3}{3} 10^{-4}$$ for flat bar ordinary stiffeners

$$I_t = \frac{1}{3}\left[h_w\, t_w^3 + b_f\, t_f^3\left(1 - 0.63\frac{t_f}{b_f}\right)\right] 10^{-4}$$ for flanged ordinary stiffeners

C : Spring stiffness exerted by the hatch cover top plating, taken equal to:

$$C = \frac{k_p\, E\, t_p^3}{3\, s\left(1 + \frac{1.33\, k_p\, h_w\, t_p^3}{1000\, s\, t_w^3}\right)} 10^{-3}$$

$k_p = 1 - \eta_p$, to be taken not less than zero; for flanged ordinary stiffeners, k_p need not be taken less than 0.1

$$\eta_p = \frac{\sigma}{\sigma_{E1}}$$

σ_{E1} : As defined in [5.2.3]

t_p : Net thickness, in mm, of the hatch cover plate panel.

5.4 Primary supporting members

5.4.1 Application

The requirements in [5.4.3] to [5.4.5] apply to primary supporting members which may be analysed through isolated beam models.

Primary supporting members whose arrangement is of a grillage type and which cannot be analysed through isolated beam models are to be checked by direct calculations, using the checking criteria in [5.4.4].

5.4.2 Minimum net thickness of web

The web net thickness of primary supporting members, in mm, is to be not less than 6mm.

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5.4.3 Normal and shear stress for isolated beam

In case that grillage analysis or finite element analysis are not carried out, according to the requirements in [5.1.1], the maximum normal stress σ and shear stress τ in the primary supporting members are to be obtained, in N/mm^2, from the following formulae:

$$\sigma = \frac{s(F_S p_S + F_W p_W)\ell_m^2}{mW} 10^3$$

$$\tau = \frac{5s(F_S p_S + F_W p_W)\ell_m}{A_{sh}}$$

where:

ℓ_m : Span of the primary supporting member.

5.4.4 Checking criteria

The normal stress σ and the shear stress τ, calculated according to [5.4.3] or determined through a grillage analysis or finite element analysis, as the case may be, are to comply with the following formulae:

$$\sigma \le \sigma_a$$

$$\tau \le \tau_a$$

5.4.5 Deflection limit

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 15 (6) and 16 (5, b))

The net moment of inertia of a primary supporting member, when loaded by sea pressure, is to be such that the deflection does not exceed $\mu\ell_{\max}$*, where:*

μ : *Coefficient taken equal to:*

$\mu = 0.0056$ *for weathertight hatch covers*

$\mu = 0.0044$ *for pontoon hatch covers*

$\ell_{\max}$: *Greatest span, in m, of primary supporting members.*

5.4.6 Critical buckling stress check of the web panels of the primary supporting members.

The shear stress τ in the web panels of the primary supporting members, calculated according to [5.4.3] or determined through a grillage analysis or a finite element analysis, as the case may be, is to comply with the following formula:

$$\tau \le \frac{0.88\tau_C}{S}$$

where:

S : Safety factor defined in Ch 6, Sec 3

τ_C : Critical shear buckling stress, in N/mm^2, taken equal to:

$$\tau_C = \tau_E \qquad \text{for} \qquad \tau_E \le \frac{R_{eH}}{2\sqrt{3}}$$

$$\tau_C = \frac{R_{eH}}{\sqrt{3}}\left(1 - \frac{R_{eH}}{4\sqrt{3}\tau_E}\right) \quad \text{for} \qquad \tau_E > \frac{R_{eH}}{2\sqrt{3}}$$

$$\tau_E = 0.9k_t E\left(\frac{t_{pr,n}}{1000d}\right)^2$$

$$k_t = 5.35 + 4.0\left(\frac{a}{d}\right)^2$$

$t_{pr,n}$: Net thickness, in mm, of web of primary supporting member

a : Greater dimension, in m, of web panel of primary supporting member

d : Smaller dimension, in m, of web panel of primary supporting member.

For primary supporting members parallel to the direction of ordinary stiffeners, τ_C is to be calculated by considering the actual dimensions of the panels.

For primary supporting members perpendicular to the direction of ordinary stiffeners or for hatch covers built without ordinary stiffeners, a presumed square panel of dimension d is to be taken for the determination of the stress τ_C, where d is the smaller dimension, in m, of web panel of the primary supporting member. the In such a case, the average shear stress τ between the values calculated at the ends of this panel is to be considered.

5.4.7

For buckling stiffeners on webs of primary supporting members, the ratio h_w/t_w is to comply with the following formula:

$$\frac{h_w}{t_w} \le 15\sqrt{\frac{235}{R_{eH}}}$$

5.5 Ordinary stiffeners and primary supporting members of variable cross-section

5.5.1

The net section modulus of ordinary stiffeners and primary supporting members with a variable cross-section is to be not less than the greater of the value obtained, in cm^3, from the following formulae:

$$w = w_{CS}$$

$$w = \left(1 + \frac{3.2\alpha - \psi - 0.8}{7\psi + 0.4}\right) w_{CS}$$

where:

w_{CS} : Net section modulus, in cm^3, for a constant cross-section, complying with the checking criteria in [5.4.4]

α : Coefficient taken equal to:

$$\alpha = \frac{\ell_1}{\ell_0}$$

ψ : Coefficient taken equal to:

$$\psi = \frac{w_1}{w_0}$$

ℓ_1 : Length of the variable section part, in m (see Fig 1)

ℓ_0 : Span measured, in m, between end supports (see Fig 1)

w_1 : Net section modulus at end, in cm^3 (see Fig 1)

w_0 : Net section modulus at mid-span, in cm^3 (see Fig 1).

Moreover, the net moment of inertia of ordinary stiffeners and primary supporting members with a variable cross-section is to be not less than the greater of the values obtained, in cm^4, from the following formulae:

$$I = I_{CS}$$

$$I = \left[1 + 8\alpha^3\left(\frac{1-\varphi}{0.2 + 3\sqrt{\varphi}}\right)\right] I_{CS}$$

where:

I_{CS} : Net moment of inertia with a constant cross-section, in cm^4, complying with [5.4.5]

φ : Coefficient taken equal to:

$$\varphi = \frac{I_1}{I_0}$$

I_1 : Net moment of inertia at end, in cm^4 (see Fig 1)

I_0 : Net moment of inertia at mid-span, in cm^4 (see Fig 1).

The use of these formulae is limited to the determination of the strength of ordinary stiffeners and primary supporting members in which abrupt changes in the cross-section do not occur along their length.

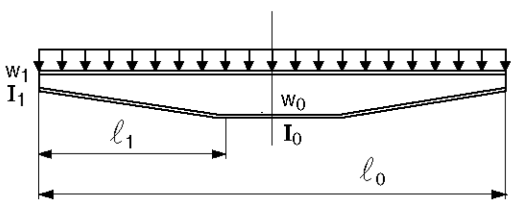

Figure 1: Variable cross-section stiffener

6. Hatch coamings

6.1 Stiffening

6.1.1

The ordinary stiffeners of the hatch coamings are to be continuous over the breadth and length of the hatch coamings.

6.1.2

Coamings are to be stiffened on their upper edges with a stiffener suitably shaped to fit the hatch cover closing appliances.

Moreover, when covers are fitted with tarpaulins, an angle or a bulb section is to be fitted all around coamings of more than 3 m in length or 600 mm in height; this stiffener is to be fitted at approximately 250 mm below the upper edge. The width of the horizontal flange of the angle is not to be less than 180 mm.

6.1.3

Where hatch covers are fitted with tarpaulins, coamings are to be strengthened by brackets or stays with a spacing not greater than 3 m.

Where the height of the coaming exceeds 900 mm, additional strengthening may be required.

However, reductions may be granted for transverse coamings in protected areas.

6.1.4

When two hatches are close to each other, underdeck stiffeners are to be fitted to connect the longitudinal coamings with a view to maintaining the continuity of their strength.

Similar stiffening is to be provided over 2 frame spacings at ends of hatches exceeding 9 frame spacings in length.

In some cases, the Society may require the continuity of coamings to be maintained above the deck.

6.1.5

Where watertight metallic hatch covers are fitted, other arrangements of equivalent strength may be adopted.

6.2 Load model

6.2.1

The lateral pressure p_C to be considered as acting on the hatch coamings is defined in [6.2.2] and [6.2.3].

6.2.2

The wave lateral pressure p_C, in kN/m^2, on the No 1 forward transverse hatch coaming is to be taken equal to:

- $p_C = 220$, when a forecastle is fitted in accordance with Sec 1, [7.1]
- $p_C = 290$, in the other cases.

6.2.3

The wave lateral pressure p_C, in kN/m^2, on the hatch coamings other than the No 1 forward transverse hatch coaming is to be taken equal to:

- $p_C = 220$

6.2.4

For cargo holds intended for the carriage of liquid cargoes, the liquid internal pressures applied on hatch coaming is also to be determined according to Ch 4, Sec 6.

6.3 Scantlings

6.3.1 Plating

The net thickness of the hatch coaming plate is to be not less than the greater value obtained, in mm, from the following formulae:

$$t = 15.98 s \sqrt{\frac{p_C}{0.95 R_{eH}}}$$

$t = 9.5$

6.3.2 Ordinary stiffeners

The net section modulus of the longitudinal or transverse ordinary stiffeners of hatch coamings is to be not less than the value obtained, in cm^3, from the following formula:

$$w = 1.21 \frac{p_C s \ell^2 10^3}{m c_p R_{eH}}$$

where:

m : Coefficient taken equal to:

$m = 16$ in general

$m = 12$ for the end span of stiffeners sniped at the coaming corners

c_p : Ratio of the plastic section modulus to the elastic section modulus of the ordinary stiffeners with an attached plate breadth, in mm, equal to $40t$, where t is the plate net thickness.

$c_p = 1.16$ in the absence of more precise evaluation.

6.3.3 Coaming stays

The net section modulus w, in cm^3, and the net thickness t_w, in mm, of the coaming stays designed as beams with flange connected to the deck or sniped and fitted with a bracket (examples shown in Fig 2 and Fig 3) are to be not less than the values obtained from the following formulae at the connection with deck:

$$w = \frac{s_C p_C H_C^2 10^3}{1.9 R_{eH}}$$

$$t_w = \frac{s_C p_C H_C 10^3}{0.5 h R_{eH}}$$

where:

H_C : Stay height, in m

s_C : Stay spacing, in m

h : Stay depth, in mm, at the connection with deck.

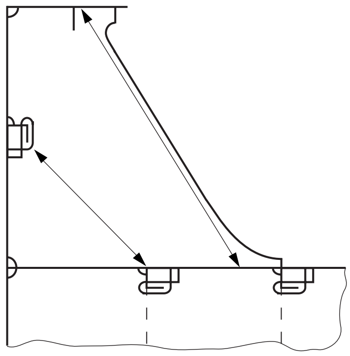

Figure 2: Coaming stay: example1

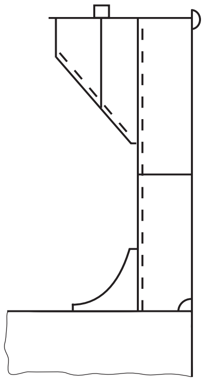

Figure 3: Coaming stay: example 2

For calculating the section modulus of coaming stays, their face plate area may be taken into account only when it is welded with full penetration welds to the deck plating and adequate underdeck structure is fitted to support the stresses transmitted by it.

For other designs of coaming stays, such as, for example, those shown in Fig 4 and Fig 5, the stress levels determined through a grillage analysis or finite element analysis, as the case may be, apply and are to be checked at the highest stressed locations. The stress levels are to comply with the following formulae:

$\sigma \leq 0.95 R_{eH}$

$\tau \leq 0.5 R_{eH}$

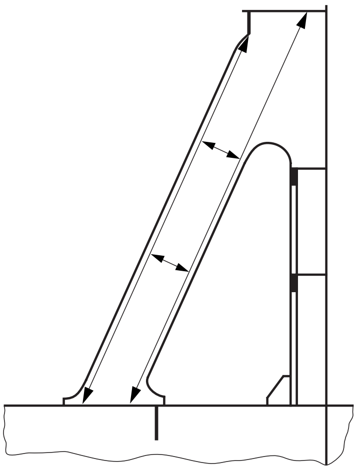

Figure 4: Coaming stay: example 3

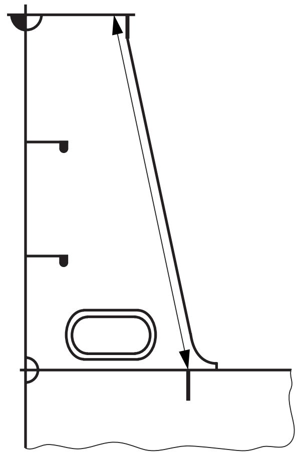

Figure 5: Coaming stay: example 4

6.3.4 Local details

The design of local details is to comply with the requirements in this section for the purpose of transferring the pressures on the hatch covers to the hatch coamings and, through them, to the deck structures below.

Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.

The normal stress σ and the shear stress τ, in N/mm^2, induced in the underdeck structures by the loads transmitted by stays are to comply with the following formulae:

$\sigma \leq 0.95R_{eH}$

$\tau \leq 0.5R_{eH}$

Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the Society's requirements.

Double continuous fillet welding is to be adopted for the connections of stay webs with deck plating and the weld throat thickness is to be not less than $0.44t_w$, where t_w is the gross thickness of the stay web.

Toes of stay webs are to be connected to the deck plating with deep penetration double bevel welds extending over a distance not less than 15% of the stay width.

6.3.5 Coamings of small hatchways

The gross thickness of coaming plate is to be not less than the lesser of the following values:

- the gross thickness for the deck inside line of openings calculated for that position, assuming as spacing of stiffeners the lesser of the values of the height of the coaming and the distance between its stiffeners, if any, or
- 10 mm.

Coamings are to be suitably strengthened where their height exceeds 0.8 m or their greatest horizontal dimension exceeds 1.2 m, unless their shape ensures an adequate rigidity.

7. Weathertightness, closing arrangement, securing devices and stoppers

7.1 Weathertightness

7.1.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 16 (1))

Where the hatchway is exposed, the weathertightness is to be ensured by gaskets and clamping devices sufficient in number and quality.

Weathertightness may also be ensured means of tarpaulins.

7.1.2

In general, a minimum of two securing devices or equivalent is to be provided on each side of the hatch cover.

7.2 Gaskets

7.2.1

The weight of hatch covers and any cargo stowed thereon, together with inertia forces generated by ship motions, are to be transmitted to the ship's structure through steel to steel contact.

This may be achieved by continuous steel to steel contact of the hatch cover skirt plate with the ship's structure or by means of defined bearing pads.

7.2.2

The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness. Similar sealing is to be arranged between cross-joint elements.

Where fitted, compression flat bars or angles are to be well rounded where in contact with the gasket and to be made of a corrosion-resistant material.

7.2.3

The gasket and the securing arrangements are to maintain their efficiency when subjected to large relative movements between the hatch cover and the ship's structure or between hatch cover elements.

If necessary, suitable devices are to be fitted to limit such movements.

7.2.4

The gasket material is to be of a quality suitable for all environmental conditions likely to be encountered by the ship, and is to be compatible with the cargoes transported.

The material and form of gasket selected are to be considered in conjunction with the type of hatch cover, the securing arrangement and the expected relative movement between the hatch cover and the ship's structure.

The gasket is to be effectively secured to the hatch cover.

7.2.5

Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

7.2.6

Metallic contact is required for an earthing connection between the hatch cover and the hull structures. If necessary, this is to be achieved by means of a special connection for the purpose.

7.3 Closing arrangement, securing devices and stoppers

7.3.1 General

Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced alongside the coamings and between cover elements.

The securing and stop arrangements are to be fitted using appropriate means which cannot be easily removed.

In addition to the requirements above, all hatch covers, and in particular those carrying deck cargo, are to be effectively secured against horizontal shifting due to the horizontal forces resulting from ship motions.

Towards the ends of the ship, vertical acceleration forces may exceed the gravity force. The resulting lifting forces are to be considered when dimensioning the securing devices according to [7.3.5] to [7.3.7]. Lifting forces from cargo secured on the hatch cover during rolling are also to be taken into account.

Hatch coamings and supporting structure are to be adequately stiffened to accommodate the loading from hatch covers.

Hatch covers provided with special sealing devices, insulated hatch covers, flush hatch covers and those having coamings of a reduced height (see [2.1]) are considered by the Society on a case by case basis.
In the case of hatch covers carrying containers, the scantlings of the closing devices are to take into account the possible upward vertical forces transmitted by the containers.

7.3.2 Arrangements

The securing and stopping devices are to be arranged so as to ensure sufficient compression on gaskets between hatch covers and coamings and between adjacent hatch covers.
Arrangement and spacing are to be determined with due attention to the effectiveness for weathertightness, depending on the type and the size of the hatch cover, as well as on the stiffness of the hatch cover edges between the securing devices.
At cross-joints of multipanel covers, (male/female) vertical guides are to be fitted to prevent excessive relative vertical deflections between loaded/unloaded panels.
The location of stoppers is to be compatible with the relative movements between hatch covers and the ship's structure in order to prevent damage to them. The number of stoppers is to be as small as possible.

7.3.3 Spacing

The spacing of the securing arrangements is to be generally not greater than 6 m.

7.3.4 Construction

Securing arrangements with reduced scantlings may be accepted provided it can be demonstrated that the possibility of water reaching the deck is negligible.
Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or hatch covers.
Individual securing devices on each hatch cover are to have approximately the same stiffness characteristics.

7.3.5 Area of securing devices

The net cross area of each securing device is to be not less than the value obtained, in cm², from the following formula:

$$A = 1.4 S_S \left(\frac{235}{R_{eH}} \right)^{\alpha}$$

where:

S_S : Spacing, in m, of securing devices

α : Coefficient taken equal to:

$\alpha = 0.75$ for $R_{eH} > 235$ N/mm^2

$\alpha = 1.0$ for $R_{eH} \le 235$ N/mm^2

In the above calculations, R_{eH} may not be taken greater than $0.7 R_m$.

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Between hatch cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weathertightness is to be maintained by securing devices. For packing line pressures exceeding 5 N/mm, the net cross area *A* is to be increased in direct proportion. The packing line pressure is to be specified.
In the case of securing arrangements which are particularly stressed due to the unusual width of the hatchway, the net cross area *A* of the above securing arrangements is to be determined through direct calculations.

7.3.6 Inertia of edges elements

The hatch cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices. The moment of inertia of edge elements is to be not less than the value obtained, in cm^4, from the following formula:

$$I = 6 p_L S_S^4$$

where:

p_L : Packing line pressure, in N/mm, to be taken not less than 5

S_S : Spacing, in m, of securing devices.

7.3.7 Diameter of rods or bolts

Rods or bolts are to have a gross diameter not less than 19 mm for hatchways exceeding 5 m^2 in area.

7.3.8 Stoppers

Hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m^2.
With the exclusion of No 1 hatch cover, hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m^2.
No 1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 230 kN/m^2. This pressure may be reduced to 175 kN/m^2 if a forecastle is fitted in accordance with Sec 1, [7.1].
The equivalent stress in stoppers, their supporting structures and calculated in the throat of the stopper welds is to be equal to or less than the allowable value, equal to $0.8R_{eH}$.

7.4 Tarpaulins

7.4.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 15 (11))
Where weathertightness of hatch covers is ensured by means of tarpaulins, at least two layers of tarpaulins are to be fitted.
Tarpaulins are to be free from jute and waterproof and are to have adequate characteristics of strength and resistance to atmospheric agents and high and low temperatures.
The mass per unit surface of tarpaulins made of vegetable fibres, before the waterproofing treatment, is to be not less than:

- 0.65 kg/m^2 for waterproofing by tarring
- 0.60 kg/m^2 for waterproofing by chemical dressing

- 0.55 kg/m^2 for waterproofing by dressing with black oil.

In addition to tarpaulins made of vegetable fibres, those of synthetic fabrics or plastic laminates may be accepted by the Society provided their qualities, as regards strength, waterproofing and resistance to high and low temperatures, are equivalent to those of tarpaulins made of vegetable fibres.

7.5 Cleats

7.5.1

Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

7.5.2

Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

7.6 Wedges

7.6.1 Wedges

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 15 (10))

Wedges are to be of tough wood, generally not more than 200 mm in length and 50 mm in width.

They are generally to be tapered not more than 1 in 6 and their thickness is to be not less than 13 mm.

8. Drainage

8.1 Arrangement

8.1.1

Drainage is to be arranged inside the line of gaskets by means of a gutter bar or vertical extension of the hatch side and end coaming.

8.1.2

Drain openings are to be arranged at the ends of drain channels and are to be provided with efficient means for preventing ingress of water from outside, such as non-return valves or equivalent.

8.1.3

Cross-joints of multi-panel hatch covers are to be arranged with drainage of water from the space above the gasket and a drainage channel below the gasket.

8.1.4

If a continuous outer steel contact is arranged between the cover and the ship's structure, drainage from the space between the steel contact and the gasket is also to be provided.

9. Small hatches fitted on the exposed fore deck

9.1 Application

9.1.1

The requirements of this article apply to steel covers of small hatches fitted on the exposed fore deck over the forward 0.25L, where the height of the exposed deck in way of the hatch is less than 0.1L or 22 m above the summer load waterline, whichever is the lesser.

Small hatches are hatches designed for access to spaces below the deck and are capable to be closed weather-tight or watertight, as applicable. Their opening is generally equal to or less than 2.5 m^2.

9.1.2

Small hatches designed for use of emergency escape are to comply with the requirements of this article with exception of [9.4.1] a) and b), [9.4.3] and [9.5.1].

9.2 Strength

9.2.1

For small rectangular steel hatch covers, the gross plate thickness, stiffener arrangement and scantlings are to be not less than those obtained, in mm, from Tab 4 and Fig 6.

Ordinary stiffeners, where fitted, are to be aligned with the metal-to-metal contact points, required in [9.3.1] (see also Fig 6).

Primary stiffeners are to be continuous.

All stiffeners are to be welded to the inner edge stiffener (see Fig 7).

Table 4: Gross scantlings for small steel hatch covers on the fore deck

Nominal size (mm × mm)	Cover plate thickness (mm)	Primary stiffeners	Ordinary stiffeners
		Flat bar (mm × mm); number	
630 × 630	8	–	–
630 × 830	8	100 × 8 ; 1	–
830 × 630	8	100 × 8 ; 1	–
830 × 830	8	100 × 10 ; 1	–
1030 × 1030	8	120 × 12 ; 1	80 × 8 ; 2
1330 × 1330	8	150 × 12 ; 2	100 × 10 ; 2

9.2.2

The upper edge of the hatchway coamings is to be suitably reinforced by a horizontal section, generally not more than 170 to 190 mm from the upper edge of the coamings.

9.2.3

For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement are to comply with [5.2].

9.2.4
For small hatch covers constructed of materials other than steel, the required scantlings are to provide equivalent strength.

9.3 Weathertightness

9.3.1
The hatch cover is to be fitted with a gasket of elastic material. This is to be designed to allow a metal to metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged. The metal-to-metal contacts are to be arranged close to each securing device in accordance with Fig 6 and a sufficient capacity to withstand the bearing force.

9.4 Primary securing devices

9.4.1
Small hatches located on exposed fore deck are to be fitted with primary securing devices such their hatch covers can be secured in place and weather-tight by means of a mechanism employing any one of the following methods:

a) butterfly nuts tightening onto forks (clamps)
b) quick acting cleats
c) central locking device.

Dogs (twist tightening handles) with wedges are not acceptable.

9.4.2
The primary securing method is to be designed and manufactured such that the designed compression pressure is achieved by one person without the need of any tools.

9.4.3
For a primary securing method using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed to minimize the risk of butterfly nuts being dislodged while in use; by means of curving the forks upward, a raised surface on the free end, or a similar method. The plate thickness of unstiffened steel forks is to be not less than 16 mm. An example arrangement is shown in Fig 7.

9.4.4
For small hatch covers located on the exposed deck forward of the fore-most cargo hatch, the hinges are to be fitted such that the predominant direction of green seas will cause the cover to close, which means that the hinges are normally to be located on the fore edge.

9.4.5
On small hatches located between the main hatches, for example between Nos. 1 and 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green water in beam sea and bow quartering conditions.

9.5 Secondary securing devices

9.5.1

Small hatches on the fore deck are to be fitted with an independent secondary securing device e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

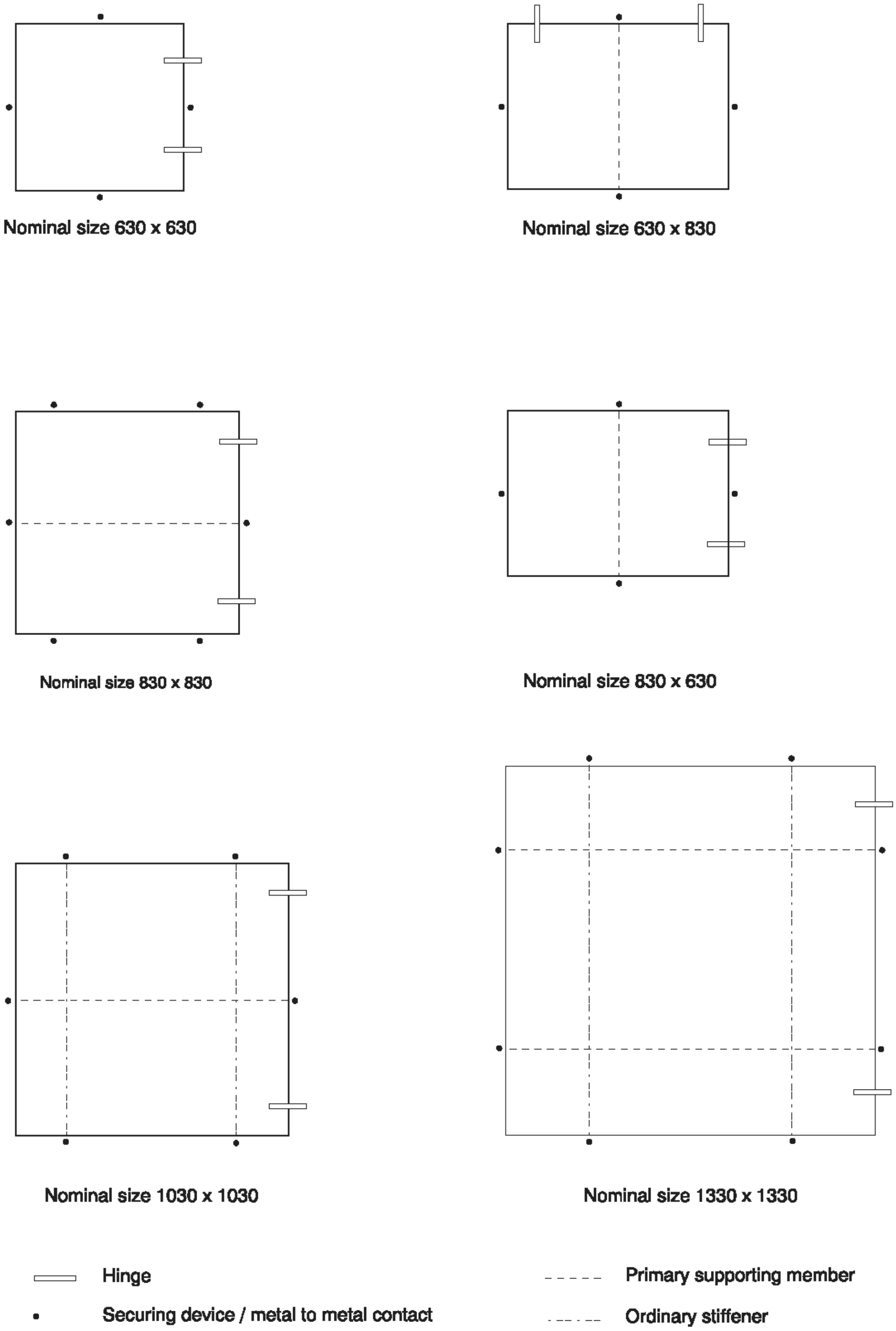
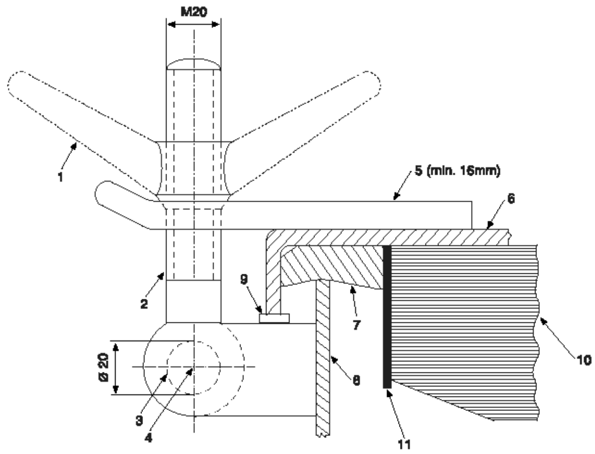


Figure 6: Arrangement of stiffeners



1) Butterfly nut
2) Bolt
3) Pin
4) Centre of pin
5) Fork (clamp) plate
6) Hatch cover
7) Gasket
8) Hatch coaming
9) Bearing pad welded on the bracket of a toggle bolt for metal to metal contact
10) Stiffener
11) Inner edge stiffener.

Figure 7: Example of a primary securing method

Section 6 – ARRANGEMENT OF HULL AND SUPERSTRUCTURE OPENINGS

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

p : Lateral pressure for glasses, in kN/m^2, defined in [3.3.2].

1. General

1.1 Application

1.1.1

The requirements of this Section apply to the arrangement of hull and superstructure openings excluding hatchways, for which the requirements in Ch 9, Sec 5 apply.

1.2 Definitions

1.2.1 Standard height of superstructure

The standard height of superstructure is that defined in Ch 1, Sec 4.

1.2.2 Standard sheer

The standard sheer is that defined according to the International Load Line Convention, as amended.

1.2.3 Exposed zones

Exposed zones are the boundaries of superstructures or deckhouses set in from the ship's side at a distance equal to or less than 0.04*B*.

1.2.4 Unexposed zones

Unexposed zones are the boundaries of deckhouses set in from the ship's side at a distance greater than 0.04*B*.

2. External openings

2.1 General

2.1.1

Ref. SOLAS Reg.II-1/25-10 .1

All external openings leading to compartments assumed intact in the damage analysis, which are below the final damage waterline, are required to be watertight.

2.1.2

Ref. SOLAS Reg.II-1/25-10 .2

External openings required to be watertight in accordance with [2.1.1] are to be of sufficient strength and, except for cargo hatch covers, are to be fitted with indicators on the bridge.

2.1.3
No openings, be they permanent openings or temporary openings such as shell doors, windows or ports, are allowed on the side shell between the embarkation station of the marine evacuation system and the waterline in the lightest seagoing condition. Windows and side scuttles of the non-opening type are allowed if the Society's applicable criteria for fire integrity are complied with.

2.1.4
Ref. SOLAS Reg.II-1/25-10 .5

Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of external openings are to be provided with a notice affixed to each appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

2.2 Gangway, cargo and coaling ports

2.2.1
Ref. SOLAS Reg.II-1/17-1 & Reg.II-1/17 .10.1 & .10.2 and ILLC, as amended (Resolution MSC.143(77) Reg. 21(2))

Gangway, cargo and coaling ports fitted below the freeboard deck are to be of sufficient strength. They are to be effectively closed and secured watertight before the ship leaves port, and to be kept closed during navigation.

Such ports are in no case to be so fitted as to have their lowest point below the deepest subdivision load line.

Unless otherwise permitted by the Society, the lower edge of openings is not to be below a line drawn parallel to the freeboard deck at side, which is at its lowest point at least 230 mm above the upper edge of the uppermost load line.

3. Side scuttles, windows and skylights

3.1 General

3.1.1 Application
The requirements in [3.1] to [3.4] apply to side scuttles and rectangular windows providing light and air, located in positions which are exposed to the action of sea and/or bad weather.

3.1.2 Side scuttle definition
Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(2))

Side scuttles are round or oval openings with an area not exceeding 0.16 m^2. Round or oval openings having areas exceeding 0.16 m^2 are to be treated as windows.

3.1.3 Window definition
Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(3))

Windows are rectangular openings generally, having a radius at each corner relative to the window size in accordance with recognised national or international standards, and round or oval openings with an area exceeding 0.16 m^2.

3.1.4 Number of openings in the shell plating

Ref. SOLAS Reg.II-1/17-1& Reg.II-1/17 .1

The number of openings in the shell plating are to be reduced to the minimum compatible with the design and proper working of the ship.

3.1.5 Material and scantlings

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(1))

Side scuttles and windows together with their glasses, deadlights and storm covers, if fitted, are to be of approved design and substantial construction in accordance with, or equivalent to, recognised national or international standards.

Non-metallic frames are not acceptable. The use of ordinary cast iron is prohibited for side scuttles below the freeboard deck.

3.1.6 Means of closing and opening

Ref. SOLAS Reg.II-1/17-1& Reg.II-1/17 .2

The arrangement and efficiency of the means for closing any opening in the shell plating are to be consistent with its intended purpose and the position in which it is fitted is to be generally to the satisfaction of the Society.

3.1.7 Opening of side scuttles

Ref. SOLAS Reg.II-1/17-1& Reg.II-1/17 .3.2

All side scuttles, the sills of which are below the freeboard deck, are to be of such construction as to prevent effectively any person opening them without the consent of the Master of the ship.

3.2 Opening arrangement

3.2.1 General

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(5))

Side scuttles are not be fitted in such a position that their sills are below a line drawn parallel to the freeboard deck at side and having its lowest point 0.025B or 0.5 m, whichever is the greater distance, above the summer load waterline (or timber summer load waterline if assigned).

3.2.2 Side scuttles below (1.4 + 0.025*B*) m above the water

Ref. SOLAS Reg.II-1/17-1& Reg.II-1/17 .3.3.1 and .3.3.3

Where in 'tween decks the sills of any of the side scuttles are below a line drawn parallel to the freeboard deck at side and having its lowest point 1.4+0.025B m above the water when the ship departs from any port, all the side scuttles in that 'tween decks are to be closed watertight and locked before the ship leaves port, and they may not be opened before the ship arrives at the next port. In the application of this requirement, the appropriate allowance for fresh water may be made when applicable.

For any ship that has one or more side scuttles so placed that the above requirements apply when it is floating at its deepest subdivision load line, the Society may indicate the limiting mean draught at which these side scuttles are to have their sills above the line drawn parallel to the freeboard deck at side, and having its lowest point 1.4+0.025B above the waterline corresponding to the limiting mean draught, and at which it is therefore permissible to depart from port without previously closing and locking them and to open them at sea under the

responsibility of the Master during the voyage to the next port. In tropical zones as defined in the International Convention on Load Lines in force, this limiting draught may be increased by 0.3 m.

3.2.3 Cargo spaces

Ref. SOLAS Reg.II-1/17-1& Reg.II-1/17 .6.1 to .6.3

No side scuttles may be fitted in any spaces which are appropriated exclusively for the carriage of cargo or coal. Side scuttles may, however, be fitted in spaces appropriated alternatively for the carriage of cargo or passengers, but they are to be of such construction as to prevent effectively any person opening them or their deadlights without the consent of the Master.

If cargo is carried in such spaces, the side scuttles and their deadlights are to be closed watertight and locked before the cargo is shipped. The Society, at its discretion, may prescribe that the time of closing and locking is to be recorded in a log book.

3.2.4 Non-opening type side scuttles

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(6))

Side scuttles are to be of the non-opening type where they become immersed by any intermediate stage of flooding or the final equilibrium waterline in any required damage case for ships subject to damage stability regulations.

3.2.5 Manholes and flush scuttles

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 18(1))

Manholes and flush scuttles in positions 1 or 2, or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

3.2.6 Automatic ventilating scuttles

Ref. SOLAS Reg.II-1/17-1& Reg.II-1/17 .7

Automatic ventilating side scuttles, fitted in the shell plating below the freeboard deck, are considered by the Society on a case by case basis.

3.2.7 Window arrangement

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(7))

Windows are not to be fitted below the freeboard deck, in first tier end bulkheads or sides of enclosed superstructures and in first tier deckhouses considered buoyant in the stability calculations or protecting openings leading below.

3.2.8 Skylights

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(12))

Fixed or opening skylights are to have glass thickness appropriate to their size and position as required for side scuttles and windows. Skylight glasses in any position are to be protected from mechanical damage and, where fitted in positions 1 or 2, to be provided with permanently attached robust deadlights or storm covers.

3.3 Glasses

3.3.1 General

In general, toughened glasses with frames of special type are to be used in compliance with, or equivalent to, recognised national or international standards. The use of clear plate glasses is considered by the Society on a case by case basis.

3.3.2 Design loads

The design load is to be determined in accordance with the applicable requirements of Ch 9, Sec 4.

3.3.3 Materials

Toughened glasses are to be in accordance with ISO 1095 for side scuttles and ISO 3254 for windows.

3.3.4 Thickness of toughened glasses in side scuttles

The thickness of toughened glasses in side scuttles is to be not less than that obtained, in mm, from the following formula:

$$t = \frac{d}{358}\sqrt{p}$$

where:

d : Side scuttle diameter, in mm.

3.3.5 Thickness of toughened glasses in rectangular windows

The thickness of toughened glasses in rectangular windows is to be not less than that obtained, in mm, from the following formula:

$$t = \frac{b}{200}\sqrt{\beta\, p}$$

where:

β : Coefficient defined in Tab 1. β is to be obtained by linear interpolation for intermediate values of a/b

a : Length, in mm, of the longer side of the window

b : Length, in mm, of the shorter side of the window.

Table 1: Coefficient β

a/b	β
1.0	0.284
1.5	0.475
2.0	0.608
2.5	0.684
3.0	0.716
3.5	0.734
≥ 4.0	0.750

The Society may require both limitations on the size of rectangular windows and the use of glasses of increased thickness in way of front bulkheads which are particularly exposed to heavy sea.

3.4 Deadlight arrangement

3.4.1 General

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(4))

Side scuttles to the following spaces are to be fitted with hinged inside deadlights:

- *spaces below freeboard deck*
- *spaces within the first tier of enclosed superstructures*
- *first tier deckhouses on the freeboard deck protecting openings leading below or considered buoyant in stability calculations.*

Deadlights are to be capable of being closed and secured watertight if fitted below the freeboard deck and weathertight if fitted above.

3.4.2 Openings at the side shell in the second tier

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(8))

Side scuttles and windows at the side shell in the second tier are to be provided with efficient, hinged inside deadlights capable of being closed and secured weathertight, if the superstructure protects direct access to an opening leading below or is considered buoyant in the stability calculations.

3.4.3 Openings set inboard in the second tier

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(9) and .23(10))

Side scuttles and windows in side bulkheads set inboard from the side shell in the second tier which protect direct access below to spaces listed in [3.4.1], are to be provided with either hinged inside deadlights or, where they are accessible, permanently attached external storm covers of approved design and substantial construction *capable of being closed and secured weathertight.*

Cabin bulkheads and doors in the second tier and above separating side scuttles and windows from a direct access leading below or the second tier considered buoyant in the stability calculations may be accepted in place of deadlights or storm covers fitted to the side scuttles and windows.

Note 1: Deadlights in accordance with recognised standards are fitted to the inside of windows and side scuttles, while storm covers of comparable specifications to deadlights are fitted to the outside of windows, where accessible, and may be hinged or portable.

3.4.4 Deckhouses on superstructures of less than standard height

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(11))

Deckhouses situated on a raised quarter deck or on the deck of a superstructure of less than standard height may be regarded as being in the second tier as far as the requirements for deadlights are concerned, provided the height of the raised quarterdeck or superstructure is equal to or greater than the standard quarter deck height.

3.4.5 Openings protected by a deckhouse

Where an opening in a superstructure deck or in the top of a deckhouse on the freeboard deck which gives access to a space below the freeboard deck or to a space within an enclosed superstructure is protected by a deckhouse, then it is considered that only those side scuttles fitted in spaces which give direct access to an open stairway need to be fitted with deadlights.

4. Discharges

4.1 Arrangement of discharges

4.1.1 Inlets and discharges

Ref. SOLAS Reg.II-1/17-1 & Reg.II-1/17 .9.1

All inlets and discharges in the shell plating are to be fitted with efficient and accessible arrangements for preventing the accidental admission of water into the ship.

4.1.2 Inboard opening of ash-shoot, rubbish-shoot, etc.

Ref. SOLAS Reg.II-1/17-1 & Reg.II-1/17 .11.1 and .11.2

The inboard opening of each ash-shoot, rubbish-shoot, etc. is to be fitted with an efficient cover.

If the inboard opening is situated below the freeboard deck, the cover is to be watertight, and in addition an automatic non-return valve is to be fitted in the shoot in an easily accessible position above the deepest subdivision load line. When the shoot is not in use, both the cover and the valve are to be kept closed and secured.

4.2 Arrangement of garbage chutes

4.2.1 Inboard end above the waterline

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 22-1(1, b))

The inboard end is to be located above the waterline formed by an 8.5° heel, to port or starboard, at a draft corresponding to the assigned summer freeboard, but not less than 1000 mm above the summer load waterline.

Where the inboard end of the garbage chute exceeds 0.01L above the summer load waterline, valve control from the freeboard deck is not required, provided the inboard gate valve is always accessible under service conditions.

4.2.2 Inboard end below the waterline

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 22-1(4))

Where the inboard end of a garbage chute is below the waterline corresponding to the deepest draught after damage in a ship of more than 100 m in length, then:

- *the inboard end hinged cover/valve is to be watertight*
- *the valve is to be a screw-down non-return valve fitted in an easily accessible position above the deepest subdivision load line*
- *the screw-down non-return valve is to be controlled from a position above the freeboard deck and provided with open/shut indicators. The valve control is to be clearly marked: «Keep closed when not in use».*

4.2.3 Gate valves

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 22-1(1, a))

For garbage chutes, two gate valves controlled from the working deck of the chute may be accepted instead of a non-return valve with a positive means of closing it from a position above the freeboard deck. In addition, the lower gate valve is to be controlled from a position above the freeboard deck. An interlock system between the two valves is to be arranged.

The distance between the two gate valves is to be adequate to allow the smooth operation of the interlock system.

4.2.4 Hinged cover and discharge flap

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 22-1(1, c))

The upper and lower gate valves, as required in [4.2.3], may be replaced by a hinged weathertight cover at the inboard end of the chute together with a discharge flap.

The cover and discharge flap are to be arranged with an interlock so that the flap cannot be operated until the hopper cover is closed.

4.2.5 Marking of valve and hinged cover

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 22-1(3))

The controls for the gate valves and/or hinged covers are to be clearly marked: «Keep closed when not in use».

4.3 Scantlings of garbage chutes

4.3.1 Material

The chute is to be constructed of steel. Other equivalent materials are considered by the Society on a case by case basis.

4.3.2 Wall thickness

The wall thickness of the chute up to and including the cover is to be not less than that obtained, in mm, from Tab 2.

Table 2: Wall thickness of garbage chutes

External diameter d, in mm	Thickness, in mm
$d \leq 80$	7.0
$80 < d < 180$	$7.0 + 0.03(d - 80)$
$180 \leq d \leq 220$	$10.0 + 0.063(d - 180)$
$d > 220$	12.5

5. Freeing ports

5.1 General provisions

5.1.1 General

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (1, a) and Reg.3 (15))

Where bulwarks on the weather portions of freeboard or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of water and for draining them.

A well is any area on the deck exposed to the weather, where water may be entrapped. Wells are considered to be deck areas bounded on four sides by deck structures; however, depending on their configuration, deck areas bounded on three or even two sides by deck structures may be deemed wells.

5.1.2 Freeing port areas

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24)

The minimum required freeing port areas in bulwarks on the freeboard deck are specified in Tab 3.

Table 3: Freeing port area in bulwark located on freeboard deck

Ship types or ship particulars	Area A of freeing ports, in m^2	Applicable requirement
Type B-100	$0.33\ell_B h_B$	[5.5.2]
Type B-60	$0.25\ell_B h_B$	[5.5.1]
Ships fitted with a trunk included in freeboard calculation and/ or breadth ≥ 0.6B	$0.33\ell_B h_B$	[5.3.1]
Ships fitted with a trunk not included in freeboard calculation and/or continuous or substantially continuous hatch coamings	A_2	[5.3.1]
Ships fitted with non-continuous trunk and/ or hatch coamings	A_3	[5.3.2]
Ships fitted with open superstructure	A_S for superstructures	[5.4.2]
	A_W for wells	[5.4.3]
Other ships	A_1	[5.2.1]

where:

ℓ_B : Length, in m, of bulwark in a well at one side of the ship

h_B : Mean height, in m, of bulwark in a well of length ℓ_B.

5.1.3 Freeing port arrangement

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (5))

Where a sheer is provided, two thirds of the freeing port area required is to be provided in the half of the well nearer the lowest point of the sheer curve.

One third of the freeing port area required is to be evenly spread along the remaining length of the well. With zero or little sheer on the exposed freeboard deck or an exposed superstructure deck the freeing port area is to be evenly spread along the length of the well.

However, bulwarks may not have substantial openings or accesses near the breaks of superstructures, unless they are effectively detached from the superstructure sides.

5.1.4 Freeing port positioning

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (5) and 24 (6))

The lower edge of freeing ports is to be as near the deck as practicable.

All the openings in the bulwark are to be protected by rails or bars spaced approximately 230 mm apart.

5.1.5 Freeing port closures

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (6))

If shutters or closures are fitted to freeing ports, ample clearance is to be provided to prevent jamming. Hinges are to have pins or bearings of non-corrodible material. If shutters are fitted with securing appliances, these appliances are to be of approved construction.

5.2 Freeing port area in a well not adjacent to a trunk or hatchways

5.2.1 Freeing port area

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (1, b and c))

Where the sheer in way of the well is standard or greater than the standard, the freeing port area on each side of the ship for each well is to be not less than that obtained, in m², in Tab 4.
In ships with no sheer, the above area is to be increased by 50%. Where the sheer is less than the standard, the percentage of increase is to be obtained by linear interpolation.

Table 4: Freeing port area in a well not adjacent to a trunk or hatchways

Location	Area A_1 of freeing ports, in m²	
	$\ell_B \le 20$	$\ell_B > 20$
Freeboard deck and raised quarterdecks	$0.7 + 0.035\ell_B + A_C$	$0.07\ell_B + A_C$
Superstructure decks	$0.35 + 0.0175\ell_B + 0.5A_C$	$0.035\ell_B + 0.5A_C$

where:

ℓ_B : Length, in m, of bulwark in the well, but need in no case to be taken as greater than $0.7L_{LL}$

A_C : Area, in m², to be taken, with its sign, equal to:

$$A_C = \frac{\ell_B}{25}(h_B - 1.2) \quad \text{for} \quad h_B > 1.2$$
$$A_C = 0 \quad \text{for} \quad 0.9 \le h_B \le 1.2$$
$$A_C = \frac{\ell_B}{25}(h_B - 0.9) \quad \text{for} \quad h_B < 0.9$$

h_B : Mean height, in m, of the bulwark in a well of length ℓ_B.

5.2.2 Minimum freeing port area for a deckhouse having breadth not less than 0.8*B*

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (1, d))

Where a flush deck ship is fitted amidships with a deckhouse having breadth not less than 0.8 B and the width of the passageways along the side of the ship less than 1.5 m, the freeing port area is to be calculated for two separate wells, before and abaft the deckhouse. For each of these wells, the freeing port area is to be obtained from Tab 4, where ℓ_B is to be taken equal to the actual length of the well considered.

5.2.3 Minimum freeing port area for screen bulkhead

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (1, e))

Where a screen bulkhead is fitted across the full breadth of the ship at the fore end of a midship deckhouse, the weather deck is to be considered as divided into two wells, irrespective of the width of the deckhouse, and the freeing port area is to be obtained in accordance with [5.1.2].

5.3 Freeing port area in a well contiguous to a trunk or hatchways

5.3.1 Freeing area for continuous trunk or continuous hatchway coaming

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (2))

Where the ship is fitted with a continuous trunk not included in the calculation of freeboard or where continuous or substantially continuous hatchway side coamings are fitted between detached superstructures, the freeing port area is to be not less than that obtained, in m², from Tab 5.

Table 5: Freeing port area in a well contiguous to a continuous trunk or hatchway

Breadth B_H, in m, of hatchway or trunk	**Area A_2 of freeing ports, in m^2**
$B_H \leq 0.4B$	$0.2\ell_B h_B$
$0.4B < B_H < 0.75B$	$\left[0.2-0.286\left(\frac{B_H}{B}-0.4\right)\right]\ell_B h_B$
$B_H \geq 0.75B$	$0.1\ell_B h_B$

where:

ℓ_B : Length, in m, of bulwark in a well at one side of the ship

h_B : Mean height, in m, of bulwark in a well of length ℓ_B.

Where the ship is fitted with a continuous trunk having breadth not less than $0.6B$, included in the calculation of freeboard, and where open rails on the weather parts of the freeboard deck in way of the trunk for at least half the length of these exposed parts are not fitted, the freeing port area in the well contiguous to the trunk is to be not less than 33% of the total area of the bulwarks.

5.3.2 Freeing area for non-continuous trunk or hatchway coaming

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (3))

Where the free flow of water across the deck of the ship is impeded due to the presence of a non-continuous trunk, hatchway coaming or deckhouse in the whole length of the well considered, the freeing port area in the bulwark of this well is to be not less than that obtained, in m^2, from Tab 6.

Table 6: Freeing port area in a well contiguous to a non-continuous trunk or hatchway

Free flow area f_P, in m^2	**Freeing port area A_3, in m^2**
$f_P \leq A_1$	A_2
$A_1 < f_P < A_2$	$A_1 + A_2 - f_P$
$f_P \geq A_2$	A_1

where:

f_P : Free flow area on deck, equal to the net area of gaps between hatchways, and between hatchways and superstructures and deckhouses up to the actual height of the bulwark

A_1 : Area of freeing ports, in m^2, to be obtained from Tab 4

A_2 : Area of freeing ports, in m^2, to be obtained from Tab 5.

5.4 Freeing port area in an open space within superstructures

5.4.1 General

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (4))

In ships having superstructures on the freeboard or superstructure decks, which are open at either or both ends to wells formed by bulwarks on the open decks, adequate provision for freeing the open spaces within the superstructures is to be provided.

5.4.2 Freeing port area for open superstructures

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (4))

The freeing port area on each side of the ship for the open superstructure is to be not less than that obtained, in m², from the following formula:

$$A_S = A_1 C_{SH}\left[1-\left(\frac{\ell_W}{\ell_T}\right)^2\right]\left(\frac{b_0 h_s}{2\ell_T h_W}\right)$$

where:

ℓ_T : *Total well length, in m, to be taken equal to:*

$$\ell_T = \ell_W + \ell_S$$

ℓ_W : *Length, in m, of the open deck enclosed by bulwarks*

ℓ_S : *Length, in m, of the common space within the open superstructures*

A_1 : *Freeing port area, in m^2, required for an open well of length ℓ_T, in accordance with Tab 4, where A_C is to be taken equal to zero*

C_{SH} : *Coefficient which accounts for the absence of sheer, if applicable, to be taken equal to:*

C_{SH} = 1.0 in the case of standard sheer or sheer greater than standard sheer

C_{SH} = 1.5 in the case of no sheer

b_0 : *Breadth, in m, of the openings in the end bulkhead of enclosed superstructures*

h_S : *Standard superstructure height, in m, defined in [1.2.1]*

h_W : *Distance, in m, of the well deck above the freeboard deck.*

5.4.3 Freeing port area for open well

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (4))

The freeing port area on each side of the ship for the open well is to be not less than that obtained, in m^2, from the following formula:

$$A_W = A_1 c_{SH}\left(\frac{h_S}{2h_W}\right)$$

A_1 : *Freeing port area, in m^2, required for an open well of length ℓ_W, in accordance with Tab 4*

c_{SH}, h_S, h_W, ℓ_W: *Defined in [5.4.2].*

The resulting freeing port areas for the open superstructure A_S and for the open well A_W are to be provided along each side of the open space covered by the open superstructure and each side of the open well, respectively.

5.5 Freeing port area in bulwarks of the freeboard deck for ships of types B-100 and B-60

5.5.1 Freeing arrangement for type B-60

For type B-60 ships, the freeing port area in the lower part of the bulwarks of the freeboard deck is to be not less than 25% of the total area of the bulwarks in the well considered.

The upper edge of the sheer strake is to be kept as low as possible.

5.5.2 Freeing arrangement for type B-100 ships with trunks

For type B-100 ships, open rails are to be fitted on the weather parts of the freeboard deck in way of the trunk for at least half the length of these exposed parts.

Alternatively, if a continuous bulwark is fitted, the freeing port area in the lower part of the bulwarks of the freeboard deck is to be not less than 33% of the total area of the bulwarks in the well considered.

6. Machinery space openings

6.1 Engine room skylights

6.1.1

Engine room skylights in positions 1 or 2 are to be properly framed, securely attached to the deck and efficiently enclosed by steel casings of suitable strength. Where the casings are not protected by other structures, their strength will be considered by the Society on a case by case basis.

6.2 Closing devices

6.2.1 Machinery casings

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 17 (1)and 12 (1))

Openings in machinery space casings in positions 1 or 2 are to be fitted with doors of steel or other equivalent materials, permanently and strongly attached to the bulkhead, and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead and weathertight when closed. The doors are to be capable of being operated from both sides and generally to open outwards to give additional protection against wave impact.

Other openings in such casings are to be fitted with equivalent covers, permanently attached in their proper position.

6.2.2 Height of the sill of the door

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 17 (1 and 2))

The height of the sill of the door is to be not less than:

- *600 mm above the deck if in position 1*
- *380 mm above the deck if in position 2*
- *230 mm in all other cases.*

6.2.3 Double doors

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 17 (1 and 2))

Where casings are not protected by other structures, double doors (i.e. inner and outer doors) are required for ships assigned freeboard less than that based on Table B of the International Load Line Convention, as amended. An inner sill of 230 mm in conjunction with the outer sill of 600 mm is to be provided.

6.2.4 Fiddly openings

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 17 (5))

Fiddly openings are to be fitted with strong covers of steel or other equivalent material permanently attached in their proper positions and capable of being secured weathertight.

6.3 Coamings

6.3.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 17 (3))

Coamings of any fiddly, funnel or machinery space ventilator in an exposed position on the freeboard deck or superstructure deck are to be as high above the deck as is reasonable and practicable.

In general, ventilators necessary to continuously supply the machinery space and, on demand, the emergency generator room are to have coamings whose height is in compliance with [8.1.3], but need not be fitted with weathertight closing appliances.

6.3.2

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 17 (4))

Where, due to the ship's size and arrangement, this is not practicable, lesser heights for machinery space and emergency generator room ventilator coamings, fitted with weathertight closing appliances in accordance with [8.1.2], may be permitted by the Society in combination with other suitable arrangements to ensure an uninterrupted, adequate supply of ventilation to these spaces.

7. Companionway

7.1 General

7.1.1 Openings in freeboard deck

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 18 (2))

Openings in freeboard deck other than hatchways, machinery space openings, manholes and flush scuttles are to be protected by an enclosed superstructure or by a deckhouse or companionway of equivalent strength and weathertightness.

7.1.2 Openings in superstructures

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 18 (2))

Openings in an exposed superstructure deck or in the top of a deckhouse on the freeboard deck which give access to a space below the freeboard deck or a space within an enclosed superstructure are to be protected by an efficient deckhouse or companionway.

7.1.3 Openings in superstructures having height less than standard height

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 18 (3))

Openings in the top of a deckhouse on a raised quarterdeck or superstructure of less than standard height, having a height equal to or greater than the standard quarterdeck height are to be provided with an acceptable means of closing but need not be protected by an efficient deckhouse or companionway provided the height of the deckhouse is at least the height of the superstructure. Openings in the top of the deckhouse on a deckhouse of less than a standard superstructure height may be treated in a similar manner.

7.2 Scantlings

7.2.1

Companionways on exposed decks protecting openings leading into enclosed spaces are to be of steel and strongly attached to the deck and are to have adequate scantlings.

7.3 Closing devices

7.3.1 Doors

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 18 (2))

Doorways in deckhouses or companionways leading to or giving access to spaces below the freeboard deck or to enclosed superstructures are to be fitted with weathertight doors. The doors are to be made of steel, to be capable of being operated from both sides and generally to open outwards to give additional protection against wave impact.

Alternatively, if stairways within a deckhouse are enclosed within properly constructed companionways fitted with weathertight doors, the external door need not be weathertight.

Where the closing appliances of access openings in superstructures and deckhouses are not weathertight, interior deck openings are to be considered exposed, i.e. situated in the open deck.

7.3.2 Height of sills

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 18 (4 to 6))

The height above the deck of sills to the doorways in companionways is to be not less than:

- *600 mm in position 1*
- *380 mm in position 2.*

Where access is provided from the deck above as an alternative to access from the freeboard deck, the height of the sills into the bridge or poop is to be 380 mm. This also applies to deckhouses on the freeboard deck.

Where access is not provided from above, the height of the sills to doorways in deckhouses on the freeboard deck is to be 600 mm.

8. Ventilators

8.1 Closing appliances

8.1.1 General

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 19 (4))

Ventilator openings are to be provided with efficient weathertight closing appliances of steel or other equivalent material.

8.1.2 Closing appliance exemption

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 19 (3))

Ventilators need not be fitted with closing appliances, unless specifically required by the Society, if the coamings extend for more than:

- *4.5 m above the deck in position 1*

- *2.3 m above the deck in position 2.*

8.1.3 Closing appliances for ships of not more than 100 m in length

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 19 (4))

In ships of not more than 100 m in length, the closing appliances are to be permanently attached to the ventilator coamings.

8.1.4 Closing appliances for ships of more than 100 m in length

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 19 (4))

Where, in ships of more than 100 m in length, the closing appliances are not permanently attached, they are to be conveniently stowed near the ventilators to which they are to be fitted.

8.1.5 Ventilation of machinery spaces and emergency generator room

In order to satisfactorily ensure, in all weather conditions:

- the continuous ventilation of machinery spaces,
- and, when necessary, the immediate ventilation of the emergency generator room,

the ventilators serving such spaces are to comply with [8.1.2], i.e. their openings are to be so located that they do not require closing appliances.

8.1.6 Reduced height of ventilator coamings for machinery spaces and emergency generator room

Where, due to the ship's size and arrangement, the requirements in [8.1.5] are not practicable, lesser heights may be accepted for machinery space and emergency generator room ventilator coamings fitted with weathertight closing appliances in accordance with [8.1.1], [8.1.3] and [8.1.4] in combination with other suitable arrangements, such as separators fitted with drains, to ensure an uninterrupted, adequate supply of ventilation to these spaces.

8.1.7 Closing arrangements of ventilators led overboard or through enclosed superstructures

Closing arrangements of ventilators led overboard to the ship side or through enclosed superstructures are considered by the Society on a case by case basis. If such ventilators are led overboard more than 4.5 m above the freeboard deck, closing appliances may be omitted provided that satisfactory baffles and drainage arrangements are fitted.

8.2 Coamings

8.2.1 General

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 19 (1 and 2))

Ventilators in positions 1 or 2 to spaces below freeboard decks or decks of enclosed superstructures are to have coamings of steel or other equivalent material, substantially constructed and efficiently connected to the deck.

Ventilators passing through superstructures other than enclosed superstructures are to have substantially constructed coamings of steel or other equivalent material at the freeboard deck.

8.2.2 Scantlings

The scantlings of ventilator coamings exposed to the weather are to be not less than those obtained from Tab 7.

In exposed locations or for the purpose of compliance with buoyancy calculations, the height of coamings may be required to be increased to the satisfaction of the Society.

Table 7: Scantlings of ventilator coamings

Feature	Scantlings
Height of the coaming, in mm, above the deck	$h = 900$ in position 1 $h = 760$ in position 2
Thickness of the coaming, in mm (1)	$t = 5.5 + 0.01\ d_V$ with $7.5 \le t \le 10$
Support	If $h > 900$ mm, the coaming is to be suitably stiffened or supported by stays.
where: d_V : External diameter of the ventilator, in mm. (1) Where the height of the ventilator exceeds the height h, the thickness of the coaming may be gradually reduced, above that height, to a minimum of 6.5 mm.	

9. Tank cleaning openings

9.1 General

9.1.1

Ullage plugs, sighting ports and tank cleaning openings may not be arranged in enclosed spaces.

Chapter 10

Hull Outfitting

Section 1 – RUDDER AND MANOEUVRING ARRANGEMENT

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

C_R : Rudder force, in N

Q_R : Rudder torque, in N.m

A : Total movable area of the rudder, in m^2, measured at the mid-plane of the rudder

For nozzle rudders, A is not to be taken less than 1.35 times the projected area of the nozzle.

A_t : Area equal to A + area of a rudder horn, if any, in m^2

A_f : Portion of rudder area located ahead of the rudder stock axis, in m^2

b : Mean height of rudder area, in m

c : Mean breadth of rudder area, in m, see Fig 1

Λ : Aspect ratio of rudder area A_t, taken equal to:

$$\Lambda = \frac{b^2}{A_t}$$

V_0 : Maximum ahead speed, in knots, as defined in Ch 1, Sec 4. If this speed is less than 10, V_0 is to be replaced by:

$$V_{\min} = \frac{(V_0 + 20)}{3}$$

V_a : Maximum astern speed, in knots, to be taken not less than $0.5V_0$. For greater astern speeds special evaluation of rudder force and torque as a function of the rudder angle may be required. If no limitations for the rudder angle at astern condition is stipulated, the factor κ_2 is not to be taken less than given in Tab 1 for astern condition.

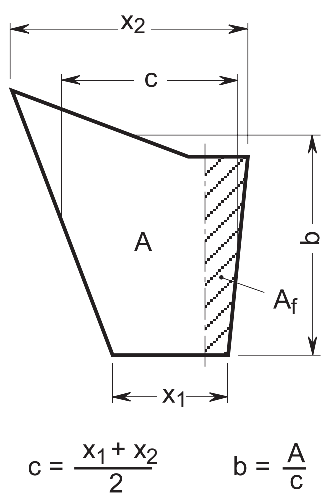


Figure 1: Dimensions of rudder

1. General

1.1 Manoeuvring arrangement

1.1.1

The manoeuvring arrangement includes all parts from the rudder and steering gear to the steering position necessary for steering the ship.

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1.1.2

Rudder stock, rudder coupling, rudder bearings and the rudder body are dealt with in this Section. The steering gear is to comply with the appropriate Rules of the Society.

1.1.3

The steering gear compartment shall be readily accessible and, as far as practicable, separated from the machinery space.

Note: Concerning the use of non-magnetisable material in the wheel house in way of a magnetic compass, the requirements of the national Administration concerned are to be observed.

1.2 Structural details

1.2.1

Effective means are to be provided for supporting the weight of the rudder body without excessive bearing pressure, e.g. by a rudder carrier attached to the upper part of the rudder stock. The hull structure in way of the rudder carrier is to be suitably strengthened.

1.2.2

Suitable arrangements are to be provided to prevent the rudder from lifting.

1.2.3

Connections of rudder blade structure with solid parts in forged or cast steel, which are used as rudder stock housing, are to be suitably designed to avoid any excessive stress concentration at these areas.

1.2.4

The rudder stock is to be carried through the hull either enclosed in a watertight trunk, or glands are to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided.

1.3 (void)

(void)

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1.4 Materials

1.4.1

For materials for rudder stock, pintles, coupling bolts etc. refer to the Society's Rules for Materials.

1.4.2

In general, materials having R_{eH} of less than 200 N/mm^2 and R_m of less than 400 N/mm^2 or more than 900 N/mm^2 are not to be used for rudder stocks, pintles, keys and bolts. The requirements of this Section are based on a with R_{eH} of 235 N/mm^2. If material is used having a R_{eH} differing from 235 N/mm^2, the material factor k_r is to be determined as follows:

$$k_r = \left(\frac{235}{R_{eH}}\right)^{0.75} \quad \text{for } R_{eH} > 235$$

$$k_r = \frac{235}{R_{eH}} \quad \text{for } R_{eH} \le 235$$

where:

R_{eH} : Minimum yield stress of material used, in N/mm^2. R_{eH} is not to be taken greater than $0.7R_m$ or 450 N/mm^2, whichever is less.

1.4.3

Before significant reductions in rudder stock diameter due to the application of steels with R_{eH} exceeding 235 N/mm^2 are accepted, the Society may require the evaluation of the elastic rudder stock deflections. Large deflections should be avoided in order to avoid excessive edge pressures in way of bearings.

1.4.4

The permissible stresses given in [5.1] are applicable for normal strength steel. When higher strength steels are used, higher values may be used for the permissible stresses, on a case by case basis.

2. Rudder force and torque

2.1 Rudder force and torque for normal rudders

2.1.1

The rudder force is to be determined, in N, according to the following formula:

$$C_R = 132\, A V^2 \kappa_1\, \kappa_2\, \kappa_3\, \kappa_t$$

where:

V : V_0 for ahead condition

V_a for astern condition

κ_1 : Coefficient, depending on the aspect ratio Λ, taken equal to:

$\kappa_1 = (\Lambda + 2)/3$, where Λ need not be taken greater than 2

κ_2 : Coefficient, depending on the type of the rudder and the rudder profile according to Tab 1

Table 1: Coefficient κ_2

Profile / type of rudder	κ_2	
	Ahead	**Astern**
NACA-00 series Göttingen profiles	1.10	0.80
Flat side profiles	1.10	0.90
Mixed profiles (e. g. HSVA)	1.21	0.90
Hollow profiles	1.35	0.90
High lift rudders	1.70	to be specially considered; if not known: 1.30
Fish tail	1.40	0.80
Single plate	1.00	1.00

κ_3 : Coefficient, depending on the location of the rudder, taken equal to:

$\kappa_3 = 0.80$ for rudders outside the propeller jet

$\kappa_3 = 1.00$ elsewhere, including also rudders within the propeller jet

$\kappa_3 = 1.15$ for rudders aft of the propeller nozzle

κ_t : Coefficient equal to 1.0 for rudders behind propeller. Where a thrust coefficient $C_{Th} > 1.0$, the Society may consider a coefficient κ_t different from 1.0, on a case by case basis.

2.1.2

The rudder torque, in Nm, is to be determined by the following formula:

$Q_R = C_R\, r$

where:

r : Lever of the force C_R, in m, taken equal to:

$r = c(\alpha - k_{bc})$, without being less than $0.1c$ for ahead condition

α : Coefficient taken equal to:

$\alpha = 0.33$ for ahead condition

$\alpha = 0.66$ for astern condition (general)

$\alpha = 0.75$ for astern condition (hollow profiles)

For parts of a rudder behind a fixed structure such as a rudder horn:

$\alpha = 0.25$ for ahead condition

$\alpha = 0.55$ for astern condition

For high lift rudders α is to be specially considered. If not known, $\alpha = 0.40$ may be used for the ahead condition

k_{bc} : Balance factor as follows:

$$k_{bc} = \frac{A_f}{A}$$

$k_{bc} = 0.08$ for unbalanced rudders

2.1.3

Effects of the provided type of rudder/profile on choice and operation of the steering gear are to be observed.

2.2 Rudder force and torque for rudder blades with cut-outs (semi-spade rudders)

2.2.1

The total rudder force C_R is to be calculated according to [2.1.1]. The pressure distribution over the rudder area, upon which the determination of rudder torque and rudder blade strength are to be based, is to be obtained as follows:

- the rudder area may be divided into two rectangular or trapezoidal parts with areas A_1 and A_2, see Fig 2.
- the resulting force, in N, of each part may be taken as:

$$C_{R1} = C_R \frac{A_1}{A}$$

$$C_{R2} = C_R \frac{A_2}{A}$$

2.2.2

The resulting torque, in N.m, of each part is to be taken as:

$$Q_{R1} = C_{R1}\, r_1$$

$$Q_{R2} = C_{R2}\, r_2$$

where:

$r_1 = c_1(\alpha - k_{b1})$, in m

$r_2 = c_2(\alpha - k_{b2})$, in m

$$k_{b1} = \frac{A_{1f}}{A_1}$$

$$k_{b2} = \frac{A_{2f}}{A_2}$$

A_{1f}, A_{2f} : As defined in Fig 2

$$c_1 = \frac{A_1}{b_1}$$

$$c_2 = \frac{A_2}{b_2}$$

b_1, b_2 : Mean heights of the partial rudder areas A_1 and A_2 (see Fig 2).

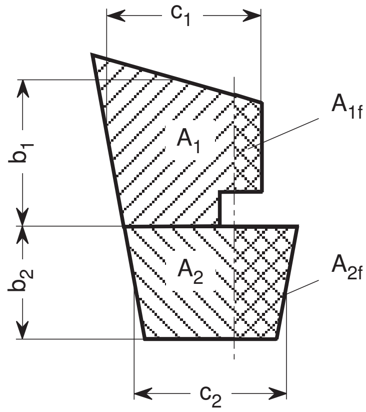

Figure 2: Areas A_1 and A_2

2.2.3

The total rudder torque, in N.m, is to be determined according to the following formulae:

$Q_R = Q_{R1} + Q_{R2}$, without being less than $Q_{R\min} = C_R \, r_{1,2\min}$

where:

$r_{1,2\min} = \frac{0.1}{A}(c_1 A_1 + c_2 A_2)$, in m.

3. Scantlings of the rudder stock

3.1 Rudder stock diameter

3.1.1

The diameter of the rudder stock, in mm, for transmitting the rudder torque is not to be less than:

$D_t = 4.2 \sqrt[3]{Q_R \, k_r}$

where:

Q_R : As defined in [2.1.2], [2.2.2] and [2.2.3]

The related torsional stress, in N/mm², is:

$\tau_t = \frac{68}{k_r}$

where:

k_r : As defined in [1.4.2] an[1.4.3].

3.1.2

The diameter of the rudder stock determined according to [3.1.1] is decisive for the steering gear, the stopper and the locking device.

3.1.3

In case of mechanical steering gear the diameter of the rudder stock in its upper part which is only intended for transmission of the torsional moment from the auxiliary steering gear may be $0.9D_t$. The length of the edge of the quadrangle for the auxiliary tiller must not be less than $0.77D_t$ and the height not less than $0.8D_t$.

3.1.4

The rudder stock is to be secured against axial sliding. The degree of the permissible axial clearance depends on the construction of the steering engine and on the bearing.

3.2 Strengthening of rudder stock

3.2.1

If the rudder is so arranged that additional bending stresses occur in the rudder stock, the stock diameter has to be suitably increased. The increased diameter is, where applicable, decisive for the scantlings of the coupling.

For the increased rudder stock diameter the equivalent stress of bending and torsion, in N/mm^2, is not to exceed the following value:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\tau^2} \leq \frac{118}{k_r}$$

where:

σ_b : Bending stress, in N/mm^2, equal to:

$$\sigma_b = \frac{10.2 M_b}{D_1^3}$$

M_b : Bending moment at the neck bearing, in N.m

τ : Torsional stress, in N/mm^2, equal to:

$$\tau = \frac{5.1 Q_R}{D_1^3}$$

D_1 : Increased rudder stock diameter, in cm, equal to:

$$D_1 = 0.1 D_t \sqrt[6]{1 + \frac{4}{3}\left(\frac{M_b}{Q_R}\right)^2}$$

Q_R : As defined in [2.1.2], [2.2.2] and [2.2.3]

D_t : As defined in [3.1.1].

Note: Where a double-piston steering gear is fitted, additional bending moments may be transmitted from the steering gear into the rudder stock. These additional bending moments are to be taken into account for determining the rudder stock diameter.

3.3 Analysis

3.3.1 General

The bending moments, shear forces and support forces for the system rudder - rudder stock are to be obtained from [3.3.2] and [3.3.3], for rudder types as shown in Fig 3 to Fig 7.

3.3.2 Data for the analysis

ℓ_{10} ,.., ℓ_{50} : Lengths, in m, of the individual girders of the system

I_{10} ,.., I_{50} : Moments of inertia of these girders, in cm^4

For rudders supported by a sole piece the length ℓ_{20} is the distance between lower edge of rudder body and centre of sole piece, and I_{20} is the moment of inertia of the pintle in the sole piece.

Load on rudder body, in kN/m, (general):

$$p_R = \frac{C_R}{\ell_{10} \cdot 10^3}$$

Load on semi-spade rudders, in kN/m:

$$p_{R10} = \frac{C_{R2}}{\ell_{10} \cdot 10^3}$$

$$p_{R20} = \frac{C_{R1}}{\ell_{20} \cdot 10^3}$$

C_R, C_{R1}, C_{R2} : As defined in [2.1] and [2.2]

Z : Spring constant, in kN/m, of support in the sole piece or rudder horn respectively:

for the support in the sole piece (see Fig 3):

$$Z = \frac{6.18\, I_{50}}{\ell_{50}^3}$$

for the support in the rudder horn (see Fig 4):

$$Z = \frac{1}{f_b + f_t}$$

f_b : Unit displacement of rudder horn, in m/kN, due to a unit force of 1 kN acting in the centre of support

$$f_b = \frac{1.3\, d^3\, 10^8}{3\, E\, I_n}$$

$$f_b = 0.21 \frac{d^3}{I_n} \quad \text{(guidance value for steel)}$$

I_n : Moment of inertia of rudder horn, in cm^4, around the x-axis at $d/2$ (see Fig 4)

f_t : Unit displacement due to a torsional moment of the amount 1, in m/kN

$$f_t = \frac{d\, e^2}{G\, J_t}$$

$$f_t = \frac{d e^2 \sum u_i / t_i}{3.14 \cdot 10^8\, F_T^2} \qquad \text{for steel}$$

G : Modulus of rigity, kN/m^2:

$G = 7.92 \cdot 10^7$ for steel

J_t : Torsional moment of inertia, in m^4

F_T : Mean sectional area of rudder horn, in m^2

u_i : Breadth, in mm, of the individual plates forming the mean horn sectional area

t_i : Plate thickness of individual plate having breadth u_i, in mm

e, d : Distances, in m, according to Fig 4

K_{11}, K_{22}, K_{12} : Rudder horn compliance constants calculated for rudder horn with 2-conjugate elastic supports (Fig 5).The 2-conjugate elastic supports are defined in terms of horizontal displacements, y_i, by the following equations:

at the lower rudder horn bearing:

$y_1 = - K_{12}\, B_2 - K_{22}\, B_1$

at the upper rudder horn bearing:

$y_2 = - K_{11}\, B_2 - K_{12}\, B_1$

where

y_1, y_2 : Horizontal displacements, in m, at the lower and upper rudder horn bearings, respectively

B_1, B_2 : Horizontal support forces, in kN, at the lower and upper rudder horn bearings, respectively

K_{11}, K_{22}, K_{12} : Obtained, in m/kN, from the following formulae:

$$K_{11} = 1.3 \frac{\lambda^3}{3EJ_{1h}} + \frac{e^2 \lambda}{GJ_{th}}$$

$$K_{12} = 1.3 \left[\frac{\lambda^3}{3EJ_{1h}} + \frac{\lambda^2 (d - \lambda)}{2EJ_{1h}} \right] + \frac{e^2 \lambda}{GJ_{th}}$$

$$K_{22} = 1.3 \left[\frac{\lambda^3}{3EJ_{1h}} + \frac{\lambda^2 (d - \lambda)}{EJ_{1h}} + \frac{\lambda (d - \lambda)^2}{EJ_{1h}} + \frac{(d - \lambda)^3}{3EJ_{2h}} \right] + \frac{e^2 d}{GJ_{th}}$$

d : Height of the rudder horn, in m, defined in Fig 5. This value is measured downwards from the upper rudder horn end, at the point of curvature transition, till the mid-line of the lower rudder horn pintle

λ : Length, in m, as defined in Fig 5. This length is measured downwards from the upper rudder horn end, at the point of curvature transition, till the mid-line of the upper rudder horn bearing. For $\lambda = 0$, the above formulae converge to those of spring constant Z for a rudder horn with 1-elastic support, and assuming a hollow cross section for this part

e : Rudder-horn torsion lever, in m, as defined in Fig 5 (value taken at $z = d/2$)

J_{1h} : Moment of inertia of rudder horn about the x axis, in m^4, for the region above the upper rudder horn bearing. Note that J_{1h} is an average value over the length λ (see Fig 5)

J_{2h} : Moment of inertia of rudder horn about the x axis, in m^4, for the region between the upper and lower rudder horn bearings. Note that J_{2h} is an average value over the length $d - \lambda$ (see Fig 5)

J_{th} : Torsional stiffness factor of the rudder horn, in m^4

For any thin wall closed section

$$J_{th} = \frac{4F_T^2}{\sum_i \frac{u_i}{t_i}}$$

F_T : Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn, in m^2

u_i : Length, in mm, of the individual plates forming the mean horn sectional area

t_i : Thickness, in mm, of the individual plates mentioned above.

Note that the J_{th} value is taken as an average value, valid over the rudder horn height.

3.3.3 Moments and forces to be evaluated

a) The bending moment M_R and the shear force Q_1 in the rudder body, the bending moment M_b in the neck bearing and the support forces B_1, B_2, B_3 are to be evaluated.

The so evaluated moments and forces are to be used for the stress analyses required by [3.2], [5], [9.1] and [9.2]

b) For spade rudders (see Fig 6) the moments, in N.m, and forces, in N, may be determined by the following formulae:

$$M_b = C_R\left(\ell_{20} + \frac{\ell_{10}(2x_1 + x_2)}{3(x_1 + x_2)}\right)$$

$$B_3 = \frac{M_b}{\ell_{30}}$$

$$B_2 = C_R + B_3$$

c) For spade rudders with rudders trunks (see Fig 7) the moments, in N.m, and forces, in N, may be determined by the following formulae:

M_R is the greatest of the following values:

$M_R = C_{R2}\ (\ell_{10} - CG_{2Z})$

$M_R = C_{R1}\ (CG_{1Z} - \ell_{10})$

where :

C_{R1} : Rudder force over the rudder blade area A_1

C_{R2} : Rudder force over the rudder blade area A_2

CG_{1Z} : Vertical position of the centre of gravity of the rudder blade area A_1

CG_{2Z} : Vertical position of the centre of gravity of the rudder blade area A_2

$M_B = C_{R2}\ (\ell_{10} - CG_{2Z})$

$B_3 = (M_B + M_{CR1})\ /\ (\ell_{20} + \ell_{30})$

$B_2 = C_R + B_3$

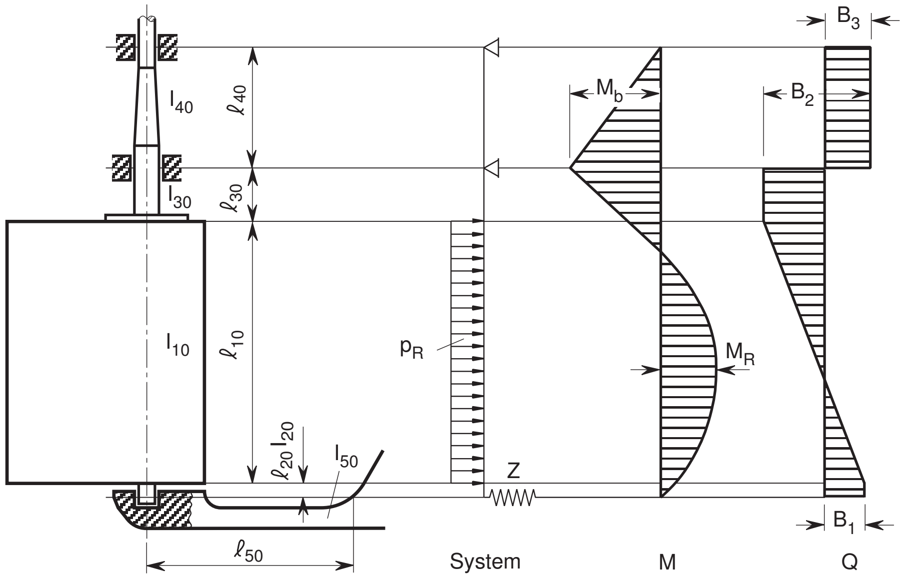

Figure 3: Rudder supported by sole piece

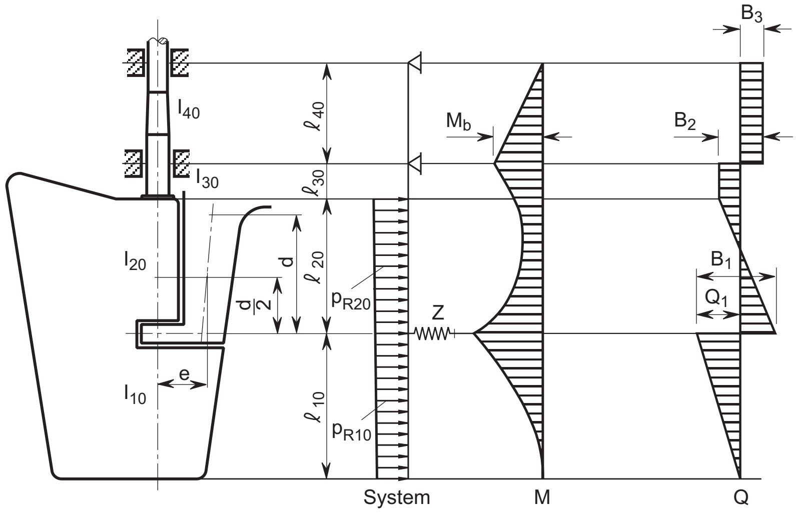

Figure 4: Semi-spade rudder (with 1-elastic support)

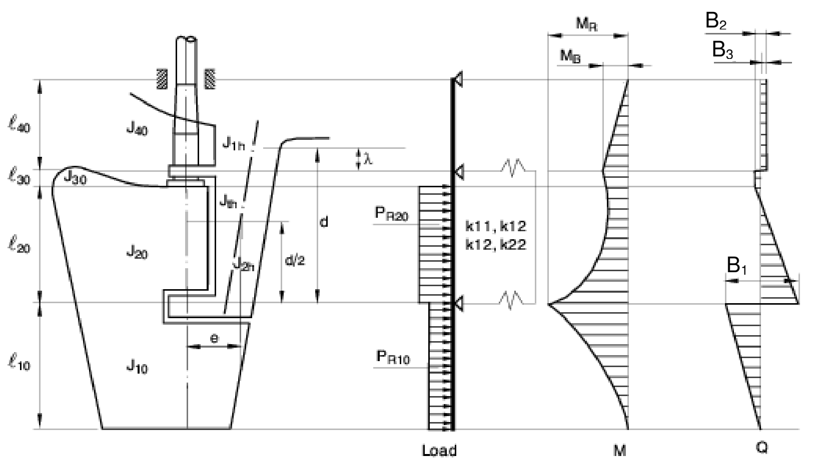

Figure 5: Semi-spade rudder (with 2-conjugate elastic supports)

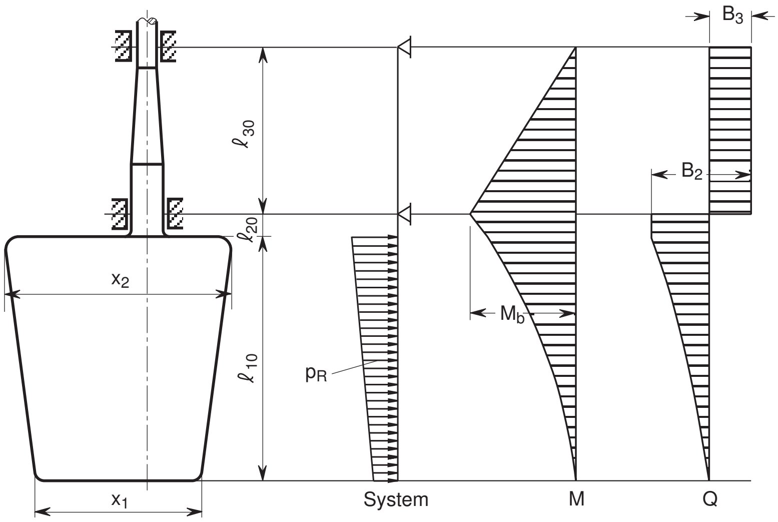

Figure 6: Spade rudder

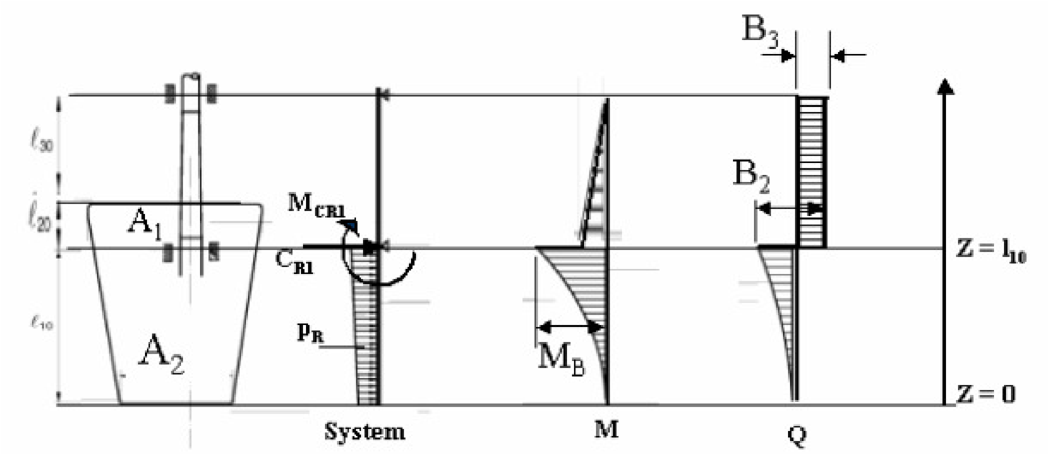

Figure 7: Spade rudders with rudder trunks

3.4 Rudder trunk

3.4.1

Where the rudder stock is arranged in a trunk in such a way that the trunk is stressed by forces due to rudder action, the scantlings of the trunk are to be as such that the equivalent stress due to bending and shear does not exceed $0.35\,R_{eH}$ of the material used.

3.4.2

In case where the rudder stock is fitted with a rudder trunk welded in such a way the rudder trunk is loaded by the pressure induced on the rudder blade, as given in [2.1.1], the bending stress in the rudder trunk, in N/mm^2, is to be in compliance with the following formula:

$\sigma \leq 80 / k$

where the material factor k for the rudder trunk is not to be taken less than 0.7.

For the calculation of the bending stress, the span to be considered is the distance between the mid-height of the lower rudder stock bearing and the point where the trunk is clamped into the shell or the bottom of the skeg.

3.4.3
The steel used for the rudder trunk is to be of weldable quality, with a carbon content not exceeding 0.23% on ladle analysis and a carbon equivalent CEQ not exceeding 0.41.

3.4.4
The weld at the connection between the rudder trunk and the shell or the bottom of the skeg is to be full penetration.

The fillet shoulder radius r, in mm, is to be as large as practicable and to comply with the following formulae:

$r = 60$ when $\sigma \geq 40 / k$ N/mm^2

$r = 0.1D_1$, without being less than 30, when $\sigma < 40 / k$ N/mm^2

where D_1 is defined in [3.2.1].

The radius may be obtained by grinding. If disk grinding is carried out, score marks are to be avoided in the direction of the weld.

The radius is to be checked with a template for accuracy. Four profiles at least are to be checked. A report is to be submitted to the Surveyor.

3.4.5
Before welding is started, a detailed welding procedure specification is to be submitted to the Society covering the weld preparation, welding positions, welding parameters, welding consumables, preheating, post weld heat treatment and inspection procedures. This welding procedure is to be supported by approval tests in accordance with the applicable requirements of materials and welding sections of the rules.

The manufacturer is to maintain records of welding, subsequent heat treatment and inspections traceable to the welds. These records are to be submitted to the Surveyor.

3.4.6
Non destructive tests are to be conducted at least 24 hours after completion of the welding. The welds are to be 100% magnetic particle tested and 100% ultrasonic tested. The welds are to be free from cracks, lack of fusion and incomplete penetration. The non destructive tests reports are to be handed over to the Surveyor.

3.4.7
Rudder trunks in materials other than steel are to be specially considered by the Society.

3.4.8
The thickness of the shell or of the bottom plate is to be compatible with the trunk thickness.

4. Rudder couplings

4.1 General

4.1.1
The couplings are to be designed in such a way as to enable them to transmit the full torque of the rudder stock.

4.1.2
The distance of the bolt axis from the edges of the flange is not to be less than 1.2 times the diameter of the bolt. In horizontal couplings, at least 2 bolts are to be arranged forward of the stock axis.

4.1.3
The coupling bolts are to be fitted bolts. The bolts and nuts are to be effectively secured against loosening.

4.1.4
For spade rudders, horizontal couplings according to [4.2] are permitted only where the required thickness of the coupling flanges t_f is less than 50 mm, otherwise cone coupling according to [4.4] or [4.5], as applicable, is to be applied. For spade rudders of the high lift type, only cone coupling according to [4.4] or [4.5], as applicable, is permitted.

4.2 Horizontal couplings

4.2.1
The diameter of coupling bolts, in mm, is not to be less than:

$$d_b = 0.62\sqrt{\frac{D^3 k_b}{k_r\, n\, e}}$$

where:

D : Rudder stock diameter according to [6], in mm

n : Total number of bolts, which is not to be less than 6

e : Mean distance of the bolt axes from the centre of bolt system, in mm

k_r : Material factor for the rudder stock as defined in [1.4.2]

k_b : Material factor for the bolts, obtained according to [1.4.2].

4.2.2
The thickness of the coupling flanges, in mm, is not to be less than determined by the following formulae:

$$t_f = 0.62\sqrt{\frac{D^3 k_f}{k_r\, n e}}$$, without being less than $0.9 d_b$

where:

k_f : Material factor for the coupling flanges, obtained according to [1.4.2]

The thickness of the coupling flanges clear of the bolt holes is not to be less than $0.65 t_f$.

The width of material outside the bolt holes is not to be less than $0.67 d_b$.

4.2.3
The coupling flanges are to be equipped with a fitted key according to DIN 6885 or equivalent standard for relieving the bolts.

The fitted key may be dispensed with if the diameter of the bolts is increased by 10%.

4.2.4

Horizontal coupling flanges are to be either forged together with the rudder stock or welded to the rudder stock, according to [10.1.3].

4.2.5

For the connection of the coupling flanges with the rudder body, see also [10].

4.3 Vertical couplings

4.3.1

The diameter of the coupling bolts, in mm, is not to be less than:

$$d_b = \frac{0.81D}{\sqrt{n}}\sqrt{\frac{k_b}{k_r}}$$

where:

D, k_b, k_r, n are defined in [4.2.1], where n is not to be less than 8.

4.3.2

The first moment of area of the bolts, in cm^3, about the centre of the coupling is not to be less than:

$$S = 0.00043D^3$$

4.3.2

The thickness of the coupling flanges, in mm, is not to be less than $t_f = d_b$

The width of material outside the bolt holes is not to be less than $0.67d_b$.

4.4 Cone couplings with key

4.4.1

Cone couplings should have a taper c on diameter of $1:8$ to $1:12$, where $c = (d_0 - d_u)/\ell$ (see Fig 8).

The cone shapes are to fit very exact. The nut is to be carefully secured, e.g. by a securing plate as shown in Fig 8.

4.4.2

The coupling length ℓ is to be, in general, not less than $1.5d_0$.

4.4.3

For couplings between stock and rudder a key is to be provided, the shear area of which, in cm^2, is not to be less than:

$$a_s = \frac{17.55Q_F}{d_k R_{eH1}}$$

where:

Q_F : Design yield moment of rudder stock, in Nm according to [6]

d_k : Diameter of the conical part of the rudder stock, in mm, at the key

R_{eH1} : Minimum yield stress of the key material, in N/mm^2

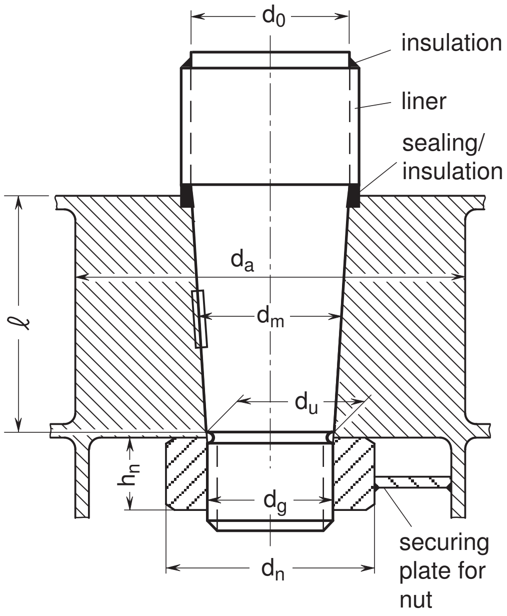

Figure 8: Cone coupling with key

4.4.4

The effective surface area, in cm^2, of the key (without rounded edges) between key and rudder stock or cone coupling is not to be less than:

$$a_k = \frac{5Q_F}{d_k R_{eH2}}$$

where:

R_{eH2} : Minimum yield stress of the key, stock or coupling material, in N/mm^2, whichever is less.

4.4.5

The dimensions of the slugging nut are to be as follows (see Fig 8):

- height: $h_n = 0.6 d_g$
- outer diameter, the greater value of: $d_n = 1.2\ d_u$ or $d_n = 1.5\ d_g$
- external thread diameter: $d_g = 0.65\ d_0$

4.4.6

It is to be proved that 50% of the design yield moment will be solely transmitted by friction in the cone couplings. This can be done by calculating the required push-up pressure and push-up length according to [0] for a torsional moment $Q'_F = 0.5 Q_F$.

4.5 Cone couplings with special arrangements for mounting and dismounting the couplings

4.5.1

Where the stock diameter exceeds 200 mm, the press fit is recommended to be effected by a hydraulic pressure connection. In such cases the cone is to be more slender, $c \approx 1:12$ to $\approx 1:20$.

4.5.2

In case of hydraulic pressure connections the nut is to be effectively secured against the rudder stock or the pintle. A securing plate for securing the nut against the rudder body is not to be provided (see Fig 9).

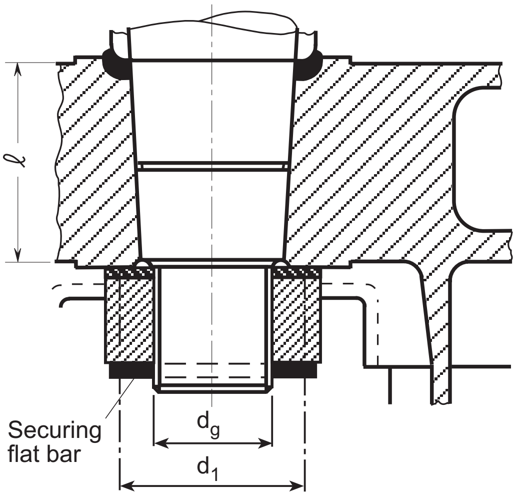

Figure 9: Cone coupling without key

Note: A securing flat bar will be regarded as an effective securing device of the nut, if its shear area, in mm², is not less than:

$$A_s = \frac{P_s \cdot \sqrt{3}}{R_{eH}}$$

where:

Ps : Shear force, in N, as follows:

$$P_S = \frac{P_e}{2}\mu_1\left(\frac{d_1}{d_g} - 0.6\right)$$

P_e : Push-up force according to [4.5.3], in N

μ_1 : Frictional coefficient between nut and rudder body, normally $\mu_1 = 0.3$

d_1 : Mean diameter of the frictional area between nut and rudder body

d_g : Thread diameter of the nut

R_{eH} : Minimum yield stress, in N/mm², of the securing flat bar material.

4.5.3 Push-up pressure and push-up length

For the safe transmission of the torsional moment by the coupling between rudder stock and rudder body the push-up length and the push-up pressure are to be determined according to [4.5.4] and [4.5.5].

4.5.4 Push-up pressure

The push-up pressure is not to be less than the greater of the two following values:

$$p_{req1} = \frac{2Q_F}{d_m^2\,\ell\,\pi\,\mu_0}10^3$$

$$p_{req2} = \frac{6 \cdot M_b}{\ell^2\,d_m}10^3$$

where:

Q_F : Design yield moment of rudder stock according to [6], in N.m

d_m : Mean cone diameter, in mm

ℓ : Cone length, in mm

μ_0 : Frictional coefficient, equal to about 0.15

M_b : Bending moment in the cone coupling (e.g. in case of spade rudders), in N.m

It has to be proved that the push-up pressure does not exceed the permissible surface pressure in the cone. The permissible surface pressure is to be determined by the following formula:

$$p_{perm} = \frac{0.8 R_{eH} \left(1 - \alpha^2\right)}{\sqrt{3 + \alpha^4}}$$

where:

R_{eH} : Minimum yield stress, in N/mm^2, of the material of the gudgeon

$$\alpha = \frac{d_m}{d_a}$$

d_m : Diameter, in mm, as defined in Fig 8

d_a : Outer diameter of the gudgeon (see Fig 8), in mm, to be not less than $1.5 d_m$.

4.5.5 Push-up length

The push-up length, in mm, is not to be less than:

$$\Delta\ell_1 = \frac{p_{req} d_m}{E\left(\frac{1 - \alpha^2}{2}\right)c} + \frac{0.8 R_{tm}}{c}$$

where:

R_{tm} : Mean roughness, in mm , taken equal to about 0.01

c : Taper on diameter according to [4.5.1]

The push-up length, in mm, is, however, not to be taken greater than:

$$\Delta\ell_2 = \frac{1.6\, R_{eH}\; d_m}{E\, c \sqrt{3 + \alpha^4}} + \frac{0.8 R_{tm}}{c}$$

Note: In case of hydraulic pressure connections the required push-up force P_e for the cone, in N, may be determined by the following formula:

$$P_e = p_{req}\; d_m \pi\, \ell \left(\frac{c}{2} + 0.02\right)$$

The value 0.02 is a reference for the friction coefficient using oil pressure. It varies and depends on the mechanical treatment and roughness of the details to be fixed.

Where due to the fitting procedure a partial push-up effect caused by the rudder weight is given, this may be taken into account when fixing the required push-up length, subject to approval by the Society.

4.5.6 Push-up pressure for pintle bearings

The required push-up pressure for pintle bearings, in N/mm^2, is to be determined by the following formula:

$$p_{req} = 0.4 \frac{B_1 d_0}{d_m^2\, \ell}$$

where:

B_1 : Supporting force in the pintle bearing, in N (see Fig 4)

d_m, ℓ : As defined in [4.5.3]

d_0 : Pintle diameter, in mm, according to Fig 8.

5. Rudder body, rudder bearings

5.1 Strength of rudder body

5.1.1

The rudder body is to be stiffened by horizontal and vertical webs in such a manner that the rudder body will be effective as a beam. The rudder should be additionally stiffened at the aft edge.

5.1.2

The strength of the rudder body is to be proved by direct calculation according to [3.3]

5.1.3

For rudder bodies without cut-outs the permissible stress are limited to:

- bending stress, in N/mm^2, due to M_R defined in [3.3.3]:

  $\sigma_b = 110$

- shear stress, in N, due to Q_1 defined in [3.3.3]:

  $\tau_t = 50$

- equivalent stress due to bending and shear:

  $\sigma_v = \sqrt{\sigma_b{}^2 + 3\tau^2} = 120$

In case of openings in the rudder plating for access to cone coupling or pintle nut the permissible stresses according to [5.1.4] apply. Smaller permissible stress values may be required if the corner radii are less than $0.15h_o$, where h_o is the height of opening.

5.1.4

In rudder bodies with cut-outs (semi-spade rudders) the following stress values are not to be exceeded:

- bending stress, N/mm^2, due to M_R:

  $\sigma_b = 75$

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- shear stress, N/mm^2, due to Q_1:

  $\tau = 50$

- torsional stress, N/mm^2,due to M_t:

  $\tau_t = 50$

- equivalent stress, in N/mm^2, due to bending and shear and equivalent stress due to bending and torsion:

  $\sigma_{v1} = \sqrt{\sigma_b^2 + 3\tau^2} = 100$

  $\sigma_{v2} = \sqrt{\sigma_b^2 + 3\tau_t^2} = 100$

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where:

$M_R = C_{R2} f_1 + B_1 \dfrac{f_2}{2}$, in N.m

$Q_1 = C_{R2}$, in N

f_1, f_2 : As defined in Fig 10

τ_t : Torsional stress, in N/mm^2, taken equal to:

$$\tau_t = \frac{M_t}{2 \ell h t}$$

$M_t = C_{R2}\, e$, in N.m

C_{R2} : Partial rudder force, in N, of the partial rudder area A_2 below the cross section under consideration

e : Lever for torsional moment, in m (horizontal distance between the centre of pressure of area A_2 and the centre line a-a of the effective cross sectional area under consideration, see Fig 10. The centre of pressure is to be assumed at $0.33c_2$ aft of the forward edge of area A_2, where c_2 is the mean breadth of area A_2).

h, ℓ, t : Dimensions, in cm, as defined in Fig 10.

The distance ℓ between the vertical webs should not exceed $1.2h$.

The radii in the rudder plating are not to be less than 4 to 5 times the plate thickness, but in no case less than 50 mm.

Note: It is recommended to keep the natural frequency of the fully immersed rudder and of local structural components at least 10 % above the exciting frequency of the propeller (number of revolutions × number of blades) or if relevant above higher order.

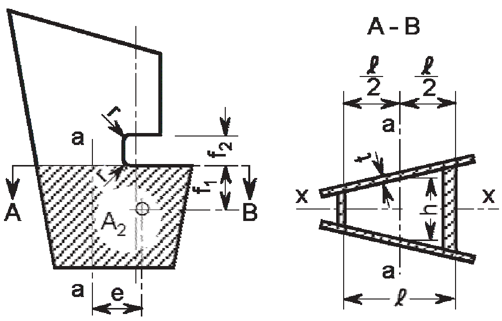


Figure 10: Geometry of rudder

5.2 Rudder plating

5.2.1

The thickness of the rudder plating, in mm, is to be determined according to the following formula:

$t_P = 1.74 a \beta \sqrt{p_R\, k} + 2.5$

where:

$p_R = 10T + \dfrac{C_R}{10^3 A}$, in kN/m^2

a : Smaller unsupported width of a plate panel, in m.

$\beta = \sqrt{1.1 - 0.5\left(\frac{a}{b}\right)^2}$ max, 1.00, if $\frac{b}{a} \geq 2.5$

b : greatest unsupported width of a plate panel, in m.

However, the thickness is to be not less than the thickness of the shell plating at aft part according to Ch 9, Sec 2. Regarding dimensions and welding, [10.1.1] is to be comply with.

5.2.2

For connecting the side plating of the rudder to the webs tenon welding is not to be used. Where application of fillet welding is not practicable, the side plating is to be connected by means of slot welding to flat bars which are welded to the webs.

5.2.3

The thickness of the webs, in mm, is not to be less than 70 % of the thickness of the rudder plating according to [5.2.1], but not less than:

$$t_{min} = 8\sqrt{k}$$

Webs exposed to seawater are to be dimensioned according to [5.2.1].

5.3 Connections of rudder blade structure with solid parts in forged or cast steel

5.3.1 General

Solid parts in forged or cast steel which ensure the housing of the rudder stock or of the pintle are in general to be connected to the rudder structure by means of two horizontal web plates and two vertical web plates.

5.3.2 Minimum section modulus of the connection with the rudder stock housing

The section modulus of the cross-section of the structure of the rudder blade which is connected with the solid part where the rudder stock is housed, which is made by vertical web plates and rudder plating, is to be not less than that obtained, in cm^3, from the following formula:

$$w_S = c_S\, d_1^3 \left(\frac{H_E - H_X}{H_E}\right)^2 \frac{k}{k_1} 10^{-4}$$

where:

c_S : Coefficient, to be taken equal to:

c_S = 1.0 if there is no opening in the rudder plating or if such openings are closed by a full penetration welded plate

c_S = 1.5 if there is an opening in the considered cross-section of the rudder

D_1 : Rudder stock diameter, in mm, defined in [3.2.1]

H_E : Vertical distance, in m, between the lower edge of the rudder blade and the upper edge of the solid part

H_X : Vertical distance, in m, between the considered cross-section and the upper edge of the solid part

k, k_1 : Material factors, defined for the rudder blade plating and the rudder stock, respectively.

5.3.3 Calculation of the actual section modulus of the connection with the rudder stock housing

The actual section modulus of the cross-section of the structure of the rudder blade which is connected with the solid part where the rudder stock is housed is to be calculated with respect to the symmetrical axis of the rudder.

The breadth of the rudder plating to be considered for the calculation of this actual section modulus is to be not greater than that obtained, in m, from the following formula:

$$b = s_V + 2\frac{H_X}{m}$$

where:

s_V : Spacing, in m, between the two vertical webs (see Fig 11)

H_X : Distance defined in [5.3.2]

m : Coefficient to be taken, in general, equal to 3.

Where openings for access to the rudder stock nut are not closed by a full penetration welded plate, they are to be deducted (see Fig 11).

5.3.4 Thickness of horizontal web plates

In the vicinity of the solid parts, the thickness of the horizontal web plates, as well as that of the rudder blade plating between these webs, is to be not less than the greater of the values obtained, in mm, from the following formulae:

$t_H = 1.2\, t_P$

$$t_H = 0.045\frac{d_S^2}{s_H}$$

where:

t_P : Defined in [5.2.1]

d_S : Diameter, in mm, to be taken equal to:

$d_S = D_1$ for the solid part connected to the rudder stock

$d_S = d_a$ for the solid part connected to the pintle

D_1 : Rudder stock diameter, in mm, defined in [3.2.1]

d_a : Pintle diameter, in mm, defined in [5.5.1]

s_H : Spacing, in mm, between the two horizontal web plates.

Different thickness may be accepted when justified on the basis of direct calculations submitted to the Society for approval.

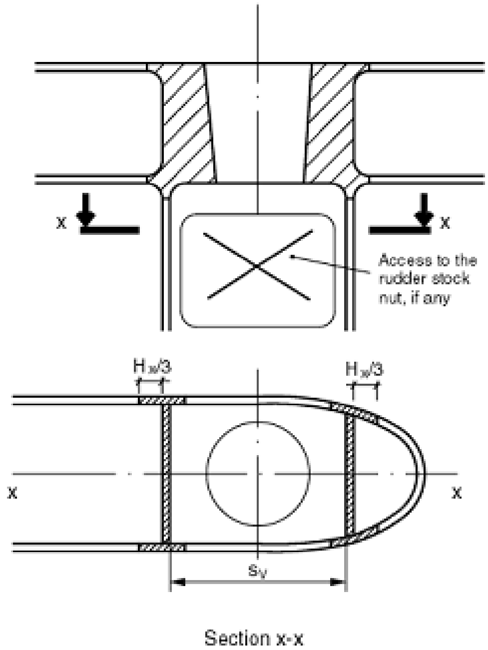


Figure 11: Cross-section of the connection between rudder blade structure and rudder stock housing

5.3.5 Thickness of side plating and vertical web plates welded to the solid part

The thickness of the vertical web plates welded to the solid part where the rudder stock is housed as well as the thickness of the rudder side plating under this solid part is to be not less than the values obtained, in mm, from Tab 2.

Table 2: Thickness of side plating and vertical web plates

Type of rudder	Thickness of vertical web plates, in mm		Thickness of rudder plating, in mm	
	Rudder blade without opening	At opening boundary	Rudder blade without opening	Area with opening
Rudder supported by sole piece (Fig 3)	$1.2t_P$	$1.6t_P$	$1.2t_P$	$1.4t_P$
Semi-spade and spade rudders (Fig 4 to Fig 7)	$1.4t_P$	$2.0t_P$	$1.3t_P$	$1.6t_P$
t_P : Defined in [5.2.1]				

5.3.6 Solid part protrusions

The solid parts are to be provided with protrusions. Vertical and horizontal web plates of the rudder are to be butt welded to these protrusions.

These protrusions are not required when the web plate thickness is less than:

- 10 mm for web plates welded to the solid part on which the lower pintle of a semi-spade rudder is housed and for vertical web plates welded to the solid part of the rudder stock coupling of spade rudders
- 20 mm for the other web plates.

5.3.7

If the torque is transmitted by a prolonged shaft extended into the rudder, the latter must have the diameter D_t or D_1, whichever is greater, at the upper 10 % of the intersection length. Downwards it may be tapered to $0.6D_t$, in spade rudders to 0.4 times the strengthened diameter, if sufficient support is provided for.

5.4 Rudder bearings

5.4.1

In way of bearings liners and bushes are to be fitted.

Their minimum thickness is equal to:

- t_{min} = 8 mm for metallic materials and synthetic material
- t_{min} = 22 mm for lignum material

Where in case of small ships bushes are not fitted, the rudder stock is to be suitably increased in diameter in way of bearings enabling the stock to be re-machined later.

5.4.2

An adequate lubrication is to be provided.

5.4.3

The bearing forces result from the direct calculation mentioned in [3.3]. As a first approximation the bearing force may be determined without taking account of the elastic supports. This can be done as follows:

- normal rudder with two supports:

  The rudder force C_R is to be distributed to the supports according to their vertical distances from the centre of gravity of the rudder area.
- semi-spade rudders:

  support force in the rudder horn, in N:

  $$B_1 = C_R \frac{b}{c}$$

  support force in the neck bearing, in N:

  $$B_2 = C_R - B_1$$

For b and c see Fig 14.

5.4.4

The projected bearing surface A_b (“bearing height” × “external diameter of liner”), in mm^2, is not to be less than

$$A_b = \frac{B}{q}$$

where:

B : Support force, in N

q : Permissible surface pressure according to Tab 3.

5.4.5

Stainless and wear resistant steels, bronze and hot-pressed bronze-graphit materials have a considerable difference in potential to non-alloyed steel. Respective preventive measures are required.

5.4.6
The bearing height is to be equal to the bearing diameter, however, is not to exceed 1.2 times the bearing diameter. Where the bearing depth is less than the bearing diameter, higher specific surface pressures may be allowed.

Table 3: Surface pressure *q* of bearing materials

Bearing material	q, in N/mm^2
Lignum vitae	2.5
White metal, oil lubricated	4.5
Synthetic material (1)	5.5
Steel (2), bronze and hot-pressed bronze-graphite materials	7.0

(1) Synthetic materials to be of approved type.
Surface pressures exceeding 5.5 N/mm^2 may be accepted in accordance with bearing manufacturer's specification and tests, but in no case more than 10 N/mm^2.
(2) Stainless and wear resistant steel in an approved combination with stock liner. Higher surface pressures than 7 N/mm^2 may be accepted if verified by tests.

The wall thickness of pintle bearings in sole piece and rudder horn is to be approximately equal to one fourth of the pintle diameter.

5.5 Pintles

5.5.1
Pintles are to have scantlings complying with the conditions given in [4.4] and [4.6]. The pintle diameter, in mm, is not to be less than:

$$d_a = 0.35\sqrt{B_1 k_r}$$

where:

B_1 : Support force, in N

k_r : Material factor defined in [1.4.2].

5.5.2
The thickness of any liner or bush, in mm, is neither to be less than:

$$t = 0.01\sqrt{B_1}$$

nor than the minimum thickness defined in [5.4.1].

5.5.3
Where pintles are of conical shape, the taper on diameter is to comply with the following:

- $1:8$ to $1:12$, if keyed by slugging nut
- $1:12$ to $1:20$, if mounted with oil injection and hydraulic nut

5.5.4
The pintles are to be arranged in such a manner as to prevent unintentional loosening and falling out.

For nuts and threads the requirements of [4.4.5] and [4.5.2] apply accordingly.

5.6 Criteria for bearing clearances

5.6.1

For metallic bearing material the bearing clearance, in mm, is to be not less:

$$\frac{d_b}{1000} + 1.0$$

where:

d_b : Inner diameter of bush, in mm.

5.6.2

If non-metallic bearing material is applied, the bearing clearance is to be specially determined considering the material's swelling and thermal expansion properties.

5.6.3

The clearance is not to be taken less than 1.5 mm on diameter. In case of self lubricating bushes going down below this value can be agreed to on the basis of the manufacturer's specification.

6. Design yield moment of rudder stock

6.1 General

6.1.1

The design yield moment of the rudder stock is to be determined by the following formula:

$$Q_F = 0.02664 \frac{D_t^3}{k_r}$$

D_t : Stock diameter, in mm, according to [3.1].

Where the actual diameter D_{ta} is greater than the calculated diameter D_t, the diameter D_{ta} is to be used. However, D_{ta} applied to the above formula need not be taken greater than $1.145 D_t$.

7. Stopper, locking device

7.1 Stopper

7.1.1

The motions of quadrants or tillers are to be limited on either side by stoppers. The stoppers and their foundations connected to the ship's hull are to be of strong construction so that the yield point of the applied materials is not exceeded at the design yield moment of the rudder stock.

7.2 Locking device

7.2.1

Each steering gear is to be provided with a locking device in order to keep the rudder fixed at any position. This device as well as the foundation in the ship's hull are to be of strong construction so that the yield point of the applied materials is not exceeded at the design yield moment of the rudder stock as specified in [6]. Where the

ship's speed exceeds 12 knots, the design yield moment need only be calculated for a stock diameter based on a speed V_0 = 12 knots.

7.3

7.3.1

Regarding stopper and locking device see also the applicable requirements of the Society’s Rules for Machinery Installations.

8. Propeller nozzles

8.1 General

8.1.1

The following requirements are applicable to propeller nozzles having an inner diameter of up to 5 m. Nozzles with larger diameters will be specially considered.

8.1.2

Special attention is to be given to the support of fixed nozzles at the hull structure.

8.2 Design pressure

8.2.1

The design pressure for propeller nozzles, in kN/m^2, is to be determined by the following formula:

$$p_d = c\, p_{d0}$$

$$p_{d0} = \varepsilon \frac{N}{Ap}$$

where:

N : Maximum shaft power, in kW

A_p : Propeller disc area, in m^2, taken equal to:

$$A_p = D^2 \frac{\pi}{4}$$

D : Propeller diameter, in m

ε : Factor obtained from the following formula:

$$\varepsilon = 0.21 - 2 \cdot 10^{-4} \frac{N}{A_p}$$, without being taken less than 0.1

c : Coefficient taken equal to (see Fig 12):

c = 1.0 in zone 2 (propeller zone)

c = 0.5 in zones 1 and 3

c = 0.35 in zone 4.

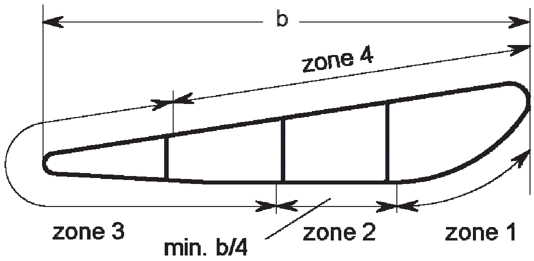


Figure 11: Zones of propeller nozzle

8.3 Plate thickness

8.3.1

The thickness of the nozzle shell plating, in mm, is not to be less than:

$t = t_0 + t_k$, without being taken less than 7.5

where:

t_0 : Thickness, in mm, obtained from the following formula:

$$t_0 = 5a\sqrt{p_d}$$

a : Spacing of ring stiffeners, in m

t_k : Corrosion allowance, in mm, taken equal to:

$$t_k = 1.5 \qquad \text{if } t_0 \le 10$$

$$t_k = \min\left[0.1\left(\frac{t_0}{\sqrt{k}} + 0.5\right), 3.0\right] \qquad \text{if } t_0 > 10$$

8.3.2

The web thickness of the internal stiffening rings is not to be less than the nozzle plating for zone 3, however, in no case be less than 7.5 mm.

8.4 Section modulus

8.4.1

The section modulus of the cross section shown in Fig 12 around its neutral axis, in cm^3, is not to be less than:

$w = n\,d^2\,b\,V_0^2$

where:

d : Inner diameter of nozzle, in m

b : Length of nozzle, in m

n : Coefficient taken equal to:

$n = 1.0$, for rudder nozzles

$n = 0.7$, for fixed nozzles.

8.5 Welding

8.5.1

The inner and outer nozzle shell plating is to be welded to the internal stiffening rings as far as practicable by double continuous welds. Plug welding is only permissible for the outer nozzle plating.

9. Rudder horn and sole piece scantlings

9.1 Sole piece

9.1.1

The section modulus of the sole piece related to the z-axis, in cm^3, is not to be less than:

$$W_z = \frac{B_1\, x\, k}{80}$$

where:

B_1 : As defined in [3.3]. For rudders with two supports the support force is approximately $B_1 = C_R/2$, when the elasticity of the sole piece is ignored.

x : Distance, in m, of the respective cross section from the rudder axis, with:

$x_{min} = 0.5\,\ell_{50}$

$x_{max} = \ell_{50}$

ℓ_{50} : As defined in Fig 13 and [3.3.2].

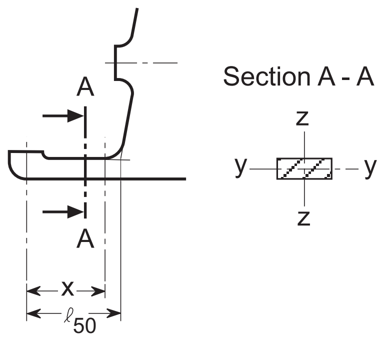


Figure 13: Sole piece

9.1.2

The section modulus related to the y-axis is not to be less than:

- where no rudder post or rudder axle is fitted

$$W_y = \frac{W_z}{2}$$

- where a rudder post or rudder axle is fitted

$$W_y = \frac{W_z}{3}$$

9.1.3

The sectional area, in mm^2, at the location $x = \ell_{50}$ is not to be less than:

$$A_s = \frac{B_1}{48} k$$

9.1.4

The equivalent stress taking into account bending and shear stresses, in N/mm^2, at any location within the length ℓ_{50} is not to exceed:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\tau^2} = \frac{115}{k}$$

where:

$$\sigma_b = \frac{B_1 x}{W_z}$$

$$\tau = \frac{B_1}{A_s}$$

9.2 Rudder horn of semi spade rudders (case of 1-elastic support)

9.2.1

The distribution of the bending moment, in N.m, shear force, in N, and torsional moment, in N.m, is to be determined according to the following formulae:

- bending moment: $M_b = B_1 z$

  $M_{b\max} = B_1 d$
- shear force: $Q = B_1$
- torsional moment: $M_T = B_1 \, e_{(z)}$

For determining preliminary scantlings the flexibility of the rudder horn may be ignored and the supporting force B_1, in N, be calculated according to the following formula:

$$B_1 = C_R \frac{b}{c}$$

where b, c, d, $e_{(z)}$ and z are defined in Fig 14 and Fig 15.

b results from the position of the centre of gravity of the rudder area.

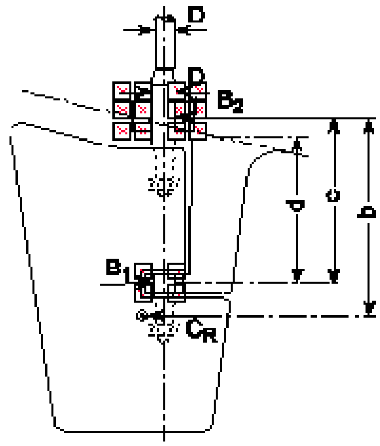


Figure 14: Dimensions of rudder horn

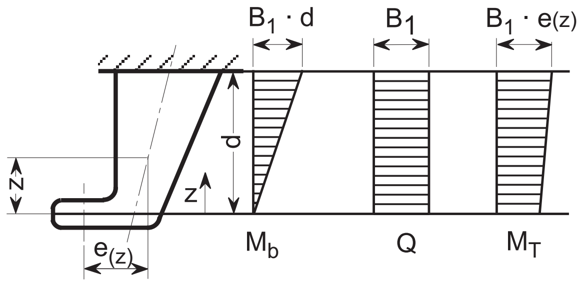


Figure 15: Rudder horn loads

9.2.2

The section modulus of the rudder horn in transverse direction related to the horizontal x-axis is at any location z, in cm^3, not to be less than:

$$W_x = \frac{M_b\,k}{67}$$

9.2.3

At no cross section of the rudder horn the shear stress, in N/mm^2, due to the shear force Q is to exceed the value:

$$\tau = \frac{48}{k}$$

The shear stress, in N/mm^2, is to be determined by the following formula:

$$\tau = \frac{B_1}{A_h}$$

where:

A_h : Effective shear area of the rudder horn, in mm^2, in y-direction

9.2.4

The equivalent stress, in N/mm^2, at any location z of the rudder horn is not to exceed the following value:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\left(\tau^2 + \tau_T^2\right)} = \frac{120}{k}$$

where:

$$\sigma_b = \frac{M_b}{W_x}$$

$$\tau_T = \frac{M_T}{2A_T t_h} 10^3$$

A_T : Sectional area, in mm^2, enclosed by the rudder horn at the location considered

t_h : Thickness of the rudder horn plating, in mm.

9.2.5

When determining the thickness of the rudder horn plating the provisions of [5.2] to [5.4] are to be complied with. The thickness, in mm, is, however, not to be less than $2.4\sqrt{LK}$.

9.2.6

The rudder horn plating is to be effectively connected to the aft ship structure, e.g. by connecting the plating to longitudinal girders, in order to achieve a proper transmission of forces, see Fig 16.

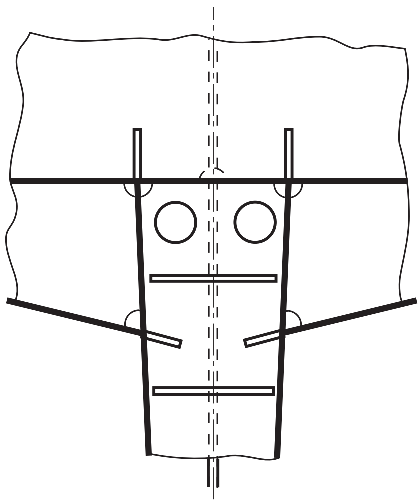


Figure 16: Connection of rudder horn to aft ship structure

9.2.7

Transverse webs of the rudder horn are to be led into the hull up to the next deck in a sufficient number and must be of adequate thickness.

9.2.8

Strengthened plate floors are to be fitted in line with the transverse webs in order to achieve a sufficient connection with the hull. The thickness of these plate floors is to be increased by 50% above the bottom thickness determined according to Ch 6, Sec 1 or Ch 9, Sec 2.

9.2.9

The centre line bulkhead (wash-bulkhead) in the after peak is to be connected to the rudder horn.

9.2.10

Where the transition between rudder horn and shell is curved, about 50% of the required total section modulus of the rudder horn is to be formed by the webs in a section A - A located in the centre of the transition zone, i.e. 0.7r above the beginning of the transition zone (See Fig. 17).

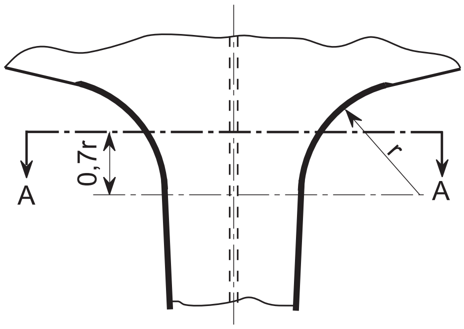


Figure 17: Transition between rudder horn and shell

9.3 Rudder horn of semi spade rudders (case of 2-conjugate elastic supports)

9.3.1 Bending moment

The bending moment acting on the generic section of the rudder horn is to be obtained, in N.m, from the following formulae:

- between the lower and upper supports provided by the rudder horn:

  $M_H = F_{A1}\, z$

- above the rudder horn upper-support:

  $M_H = F_{A1}\, z + F_{A2}\, (z - d_{lu})$

where:

F_{A1} : Support force at the rudder horn lower-support, in N, to be obtained according to Fig 5, and taken equal to B_1

F_{A2} : Support force at the rudder horn upper-support, in N, to be obtained according to Fig 5, and taken equal to B_2

z : Distance, in m, defined in Fig 19, to be taken less than the distance d, in m, defined in the same figure

d_{lu} : Distance, in m, between the rudder-horn lower and upper bearings (according to Fig 18, $d_{lu} = d - \lambda$).

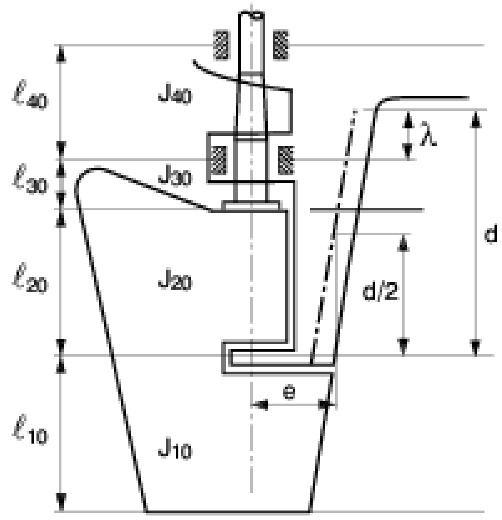


Figure 18: Geometrical parameters for the calculation of the bending moment in rudder horn

9.3.2 Shear force

The shear force Q_H acting on the generic section of the rudder horn is to be obtained, in N, from the following formulae:

- between the lower and upper rudder horn bearings:

  $Q_H = F_{A1}$

- above the rudder horn upper-bearing:

  $Q_H = F_{A1} + F_{A2}$

where:

F_{A1}, F_{A2} : Support forces, in N.

9.3.3 Torque

The torque acting on the generic section of the rudder horn is to be obtained, in N.m, from the following formulae:

- between the lower and upper rudder horn bearings:

  $M_T = F_{A1}\, e_{(z)}$

- above the rudder horn upper-bearing:

  $M_T = F_{A1}\, e_{(z)} + F_{A2}\, e_{(z)}$

where:

F_{A1}, F_{A2} : Support forces, in N

$e_{(z)}$: Torsion lever, in m, defined in Fig 19.

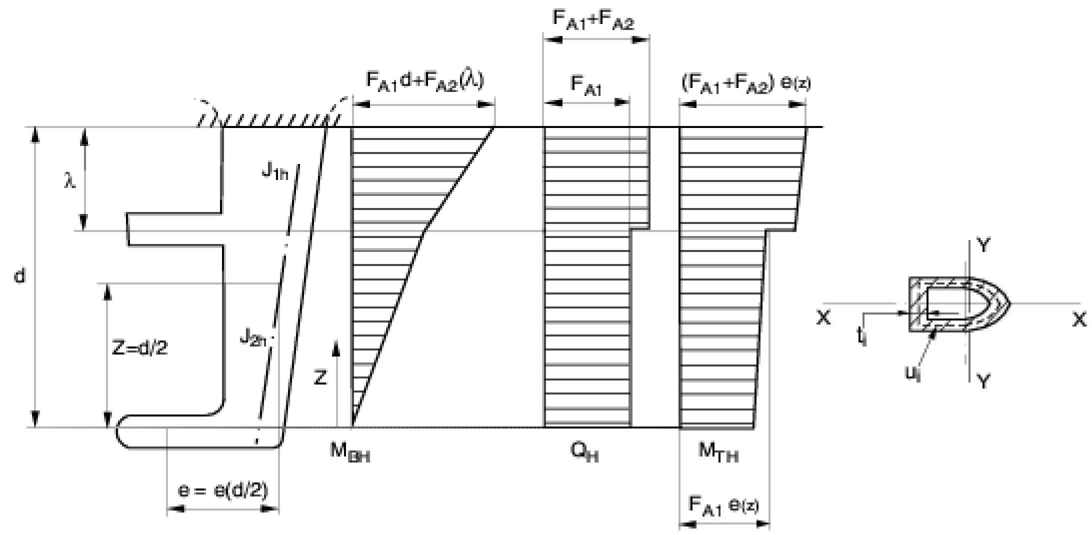


Figure 19: Geometry of rudder horn

9.3.4 Shear stress calculation

a) For a generic section of the rudder horn, located between its lower and upper bearings, the following stresses are to be calculated:

τ_S : Shear stress, in N/mm^2, to be obtained from the following formula:

$$\tau_S = \frac{F_{A1}}{A_H}$$

τ_T : Torsional stress, in N/mm^2, to be obtained for hollow rudder horn from the following formula:

$$\tau_T = \frac{M_T 10^3}{2 F_T t_H}$$

For solid rudder horn, τ_T is to be considered by the Society on a case by case basis

b) For a generic section of the rudder horn, located in the region above its upper bearing, the following stresses are to be calculated:

τ_S : Shear stress, in N/mm^2, to be obtained from the following formula:

$$\tau_S = \frac{F_{A1} + F_{A2}}{A_H}$$

τ_T : Torsional stress, in N/mm^2, to be obtained for hollow rudder horn from the following formula:

$$\tau_T = \frac{M_T 10^3}{2 F_T t_H}$$

For solid rudder horn, τ_T is to be considered by the Society on a case by case basis

where:

F_{A1}, F_{A2} : Support forces, in N

A_H : Effective shear sectional area of the rudder horn, in mm^2, in y-direction

M_T : Torque, in N.m

F_T : Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn, in m^2

t_H : Plate thickness of rudder horn, in mm. For a given cross section of the rudder horn, the maximum value of τ_T is obtained at the minimum value of t_H.

9.3.5 Bending stress calculation

For the generic section of the rudder horn within the length *d*, defined in Fig 14, the following stresses are to be calculated:

σ_B : Bending stress, in N/mm^2, to be obtained from the following formula:

$$\sigma_B = \frac{M_H}{W_X}$$

M_H : Bending moment at the section considered, in N.m

W_X : Section modulus, in cm^3, around the X-axis (see Fig 19).

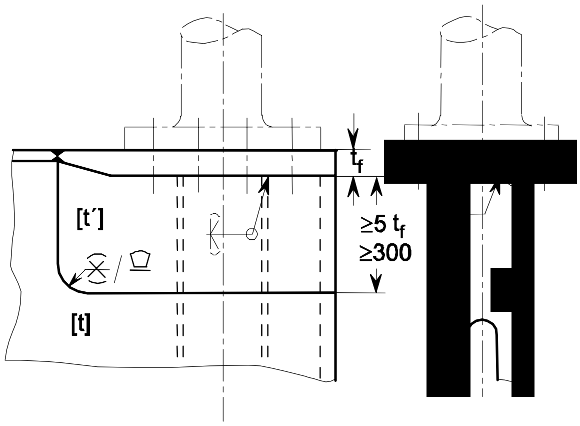
9.3.6 General remarks

Requirements [9.2.5] to [9.2.10] also apply to rudder horn with 2-conjugate elastic supports.

10. Rudder coupling flanges

10.1.1

Unless forged or cast steel flanges with integrally forged or cast welding flanges are used, horizontal rudder coupling flanges are to be joined to the rudder body by plates of graduated thickness and full penetration single or double-bevel welds as prescribed in Ch 11, Sec 1 (see Fig 20).



t = thickness of rudder plating, in mm

t_f = actual flange thickness in [mm]

$t' = \frac{t_f}{3} + 5$ [mm] where $t_f < 50$mm

$t' = 3\sqrt{t_f}$ [mm] where $t_f \geq 50$mm

Figure 20: Horizontal rudder coupling flanges

10.1.2

Allowance is to be made for the reduced strength of the coupling flange in the thickness direction. In case of doubt, proof by calculation of the adequacy of the welded connection shall be produced.

10.1.3
The welded joint between the rudder stock (with thickened collar, see Ch 11, Sec 2) and the flange is to be made in accordance with Fig 21.

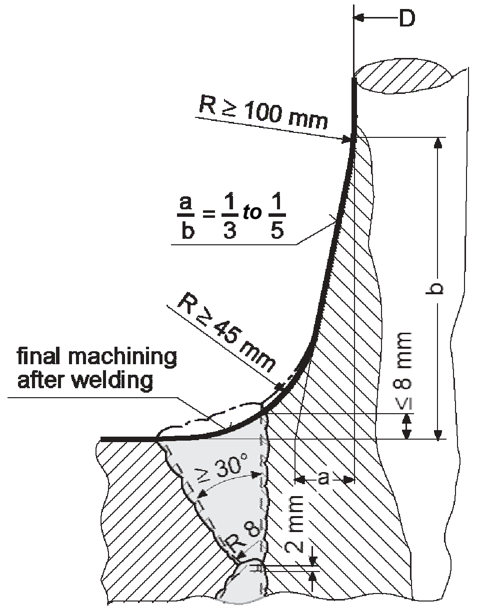


Figure 20: Welded joint between rudder stock and coupling flange

11. Azimuth propulsion system

11.1 General

11.1.1 Arrangement
The azimuth propulsion system is constituted by the following sub-systems (see Fig 22):

- the steering unit
- the bearing
- the hull supports
- the rudder part of the system
- the pod, which contains the electric motor in the case of a podded propulsion system.

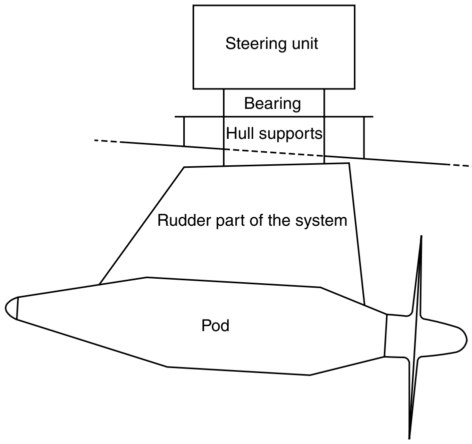


Figure 22: Azimuth propulsion system

11.1.2 Application

The requirements of this Article apply to the scantlings of the hull supports, the rudder part and the pod.

The steering unit and the bearing are to comply with the relevant requirements of the Society's Rules.

11.1.3 Operating conditions

The maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed is to be specified by the Designer. Such maximum angle is generally to be less than 35° on each side.

In general, orientations greater than this maximum angle may be considered by the Society for azimuth propulsion systems during manoeuvres, provided that the orientation values together with the relevant speed values are submitted to the Society for approval.

11.2 Arrangement

11.2.1 Plans to be submitted

In addition to the plans showing the structural arrangement of the pod and the rudder part of the system, the plans showing the arrangement of the azimuth propulsion system supports are to be submitted to the Society for approval. The scantlings of the supports and the maximum loads which act on the supports are to be specified in these drawings.

11.2.2 Locking device

The azimuth propulsion system is to be mechanically lockable in a fixed position, in order to avoid rotations of the system and propulsion in undesirable directions in the event of damage.

11.3 Design loads

11.3.1

The lateral pressure to be considered for scantling of plating and ordinary stiffeners of the azimuth propulsion system is to be determined for an orientation of the system equal to the maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed.

- The total force which acts on the azimuth propulsion system is to be obtained by integrating the lateral pressure on the external surface of the system.
- The calculations of lateral pressure and total force are to be submitted to the Society for information.

11.4 Plating

11.4.1 Plating of the rudder part of the azimuth propulsion system

The thickness of plating of the rudder part of the azimuth propulsion system is to be not less than that obtained, in mm, from the formulae in [5.2.1], in which the term C_R/A is to be replaced by the lateral pressure calculated according to [11.3].

11.4.2 Plating of the pod

The thickness of plating of the pod is to be not less than that obtained, in mm, from the formulae in Ch 6, Sec 1 or Ch 9, Sec 2, where the lateral pressure is to be calculated according to [11.3].

11.4.3 Webs

The thickness of webs of the rudder part of the azimuth propulsion system is to be determined according to [5.2.3], where the lateral pressure is to be calculated according to [11.3].

11.5 Ordinary stiffeners

11.5.1 Ordinary stiffeners of the pod

The scantlings of ordinary stiffeners of the pod are to be not less than those obtained from the formulae in Ch 6, Sec 2 or Ch 9, Sec 2, where the lateral pressure is to be calculated according to [11.3].

11.6 Primary supporting members

11.6.1 Analysis criteria

The scantlings of primary supporting members of the azimuth propulsion system are to be obtained by the Designer through direct calculations, to be carried out according to the following requirements:

- the structural model is to include the pod, the rudder part of the azimuth propulsion system, the bearing and the hull supports
- the boundary conditions are to represent the connections of the azimuth propulsion system to the hull structures
- the loads to be applied are those defined in [11.6.2].
- The direct calculation analyses (structural model, load and stress calculation, strength checks) carried out by the Designer are to be submitted to the Society for information.

11.6.2 Loads

The following loads are to be considered by the Designer in the direct calculation of the primary supporting members of the azimuth propulsion system:

- gravity loads
- buoyancy
- maximum loads calculated for an orientation of the system equal to the maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed
- maximum loads calculated for the possible orientations of the system greater than the maximum angle at the relevant speed (see [11.1.3])
- maximum loads calculated for the crash stop of the ship obtained through inversion of the propeller rotation
- maximum loads calculated for the crash stop of the ship obtained through a 180° rotation of the pod.

11.6.3 Strength check

It is to be checked that the Von Mises equivalent stress σ_E in primary supporting members, calculated, in N/mm^2, for the load cases defined in [11.6.2], is in compliance with the following formula:

$$\sigma_E \le \sigma_{ALL}$$

where:

σ_{ALL} : Allowable stress, in N/mm^2, to be taken equal to the lesser of the following values:

$$\sigma_{ALL} = 0.275 R_m$$

$$\sigma_{ALL} = 0.55 R_{eH}$$

11.7 Hull supports of the azimuth propulsion system

11.7.1 Analysis criteria

The scantlings of hull supports of the azimuth propulsion system are to be obtained by the Designer through direct calculations, to be carried out in accordance with the requirements in [11.6.1].

11.7.2 Loads

The loads to be considered in the direct calculation of the hull supports of the azimuth propulsion system are those specified in [11.6.2].

11.7.3 Strength check

It is to be checked that the Von Mises equivalent stress σ_E in hull supports, in N/mm^2, calculated for the load cases defined in [11.6.2], is in compliance with the following formula:

$$\sigma_E \le \sigma_{ALL}$$

where:

σ_{ALL} : Allowable stress, in N/mm^2, equal to 65 / k_r

k_r : Material factor, defined in [1.4.2]

Values of σ_E greater than σ_{ALL} may be accepted by the Society on a case by case basis, depending on the localisation of σ_E and on the type of direct calculation analysis.

Section 2 – BULWARKS AND GUARD RAILS

1. General

1.1 Introduction

1.1.1

The requirements of this Section apply to the arrangement of bulwarks and guard rails provided at boundaries of the freeboard deck, superstructure decks and tops of the first tier of deckhouses located on the freeboard deck.

1.2 General

1.2.1

Efficient bulwarks or guard rails are to be fitted at the boundaries of all exposed parts of the freeboard deck and superstructure decks directly attached to the freeboard deck, as well as the first tier of deckhouses fitted on the freeboard deck and the superstructure ends.

1.2.2

The height of the bulwarks or guard rails is to be at least 1 m from the deck. However, where their height would interfere with the normal operation of the ship, a lesser height may be accepted, if adequate protection is provided and subject to any applicable statutory requirement.

1.2.3

Where superstructures are connected by trunks, open rails are to be fitted for the whole length of the exposed parts of the freeboard deck.

1.2.4

In type B-100 ships, open rails on the weather parts of the freeboard deck for at least half the length of the exposed parts are to be fitted.

Alternatively, freeing ports complying with Ch 9, Sec 6, [5.5.2] are to be fitted.

1.2.5

In ships with bulwarks and trunks of breadth not less than $0.6B$, which are included in the calculation of freeboard, open rails on the weather parts of the freeboard deck in way of the trunk for at least half the length of the exposed parts are to be fitted.

Alternatively, freeing ports complying with Ch 9, Sec 6, [5.3.1] are to be fitted.

1.2.6

In ships having superstructures which are open at either or both ends, adequate provision for freeing the space within such superstructures is to be provided.

1.2.7

The freeing port area in the lower part of the bulwarks is to be in compliance with the applicable requirements of Ch 9, Sec 6, [5].

2. Bulwarks

2.1 General

2.1.1
As a rule, plate bulwarks are to be stiffened at the upper edge by a suitable bar and supported either by stays or plate brackets spaced not more than 2.0 m apart.

The free edge of the stay or the plate bracket is to be stiffened.

Stay and brackets of bulwarks are to be aligned with the beams located below or are to be connected to them by means of local transverse stiffeners.

As an alternative, the lower end of the stay and bracket may be supported by a longitudinal stiffener.

2.1.2
In type B-60 and B-100 ships, the spacing forward of 0.07L from the fore end of brackets and stays is to be not greater than 1.2 m.

2.1.3
Where bulwarks are cut completely, the scantlings of stays or brackets are to be increased with respect to those given in [2.2].

2.1.4
As a rule, bulwarks are not to be connected either to the upper edge of the sheerstrake plate or to the stringer plate.

Failing this, the detail of the connection will be examined by the Society.

2.2 Scantlings

2.2.1
The gross thickness of bulwarks on the freeboard deck not exceeding 1 m in height is to be not less than 6.5 mm.

Where the height of the bulwark is equal to or greater than 1.8 m, its thickness is to be equal to that calculated for the side of a superstructure situated in the same location as the bulwark.

For bulwarks between 1 m and 1.8 m in height, their thickness is to be calculated by linear interpolation.

2.2.2
Bulwark plating and stays are to be adequately strengthened in way of eye plates used for shrouds or other tackles in use for cargo gear operation, as well as in way of hawser holes or fairleads provided for mooring or towing.

2.2.3
At the ends of partial superstructures and for the distance over which their side plating is tapered into the bulwark, the latter is to have the same thickness as the side plating. Where openings are cut in the bulwark at these positions, adequate compensation is to be provided either by increasing the thickness of the plating or by other suitable means.

2.2.4
The gross section modulus of stays in way of the lower part of the bulwark is to be not less than the value obtained, in cm^3, from the following formula:

$$w = 77 s h_B^2$$

where:

s : Spacing of stays, in m

h_B : Height of bulwark, in m, measured from the top of the deck plating to the upper edge.

The actual section of the connection between stays and deck structures is to be taken into account when calculating the above section modulus.

To this end, the bulb or face plate of the stay may be taken into account only where welded to the deck; in this case the beam located below is to be connected by double continuous welding.

For stays with strengthening members not connected to the deck, the calculation of the required section modulus is considered by the Society on a case by case basis.

At the ends of the ship, where the bulwark is connected to the sheerstrake, an attached plating having a width not exceeding 600 mm may also be included in the calculation of the actual gross section modulus of stays.

2.2.5
Openings in bulwarks are to be arranged so that the protection of the crew is to be at least equivalent to that provided by the horizontal courses in [3.1.2].

For this purpose, vertical rails or bars spaced approximately 230 mm apart may be accepted in lieu of rails or bars arranged horizontally.

2.2.6
In the case of ships intended for the carriage of timber deck cargoes, the specific provisions of the freeboard regulations are to be complied with.

3. Guard rails

3.1 General

3.1.1
Where guard rails are provided, the upper edge of sheerstrake is to be kept as low as possible.

3.1.2
The opening below the lowest course is to be not more than 230 mm. The other courses are to be not more than 380 mm apart.

3.1.3
In the case of ships with rounded gunwales or sheerstrake, the stanchions are to be placed on the flat part of the deck.

3.1.4
Fixed, removable or hinged stanchions are to be fitted about 1.5 m apart. At least every third stanchion is to be supported by a bracket or stay.

Removable or hinged stanchions are to be capable of being locked in the upright position.

3.1.5

Wire ropes may only be accepted in lieu of guard rails in special circumstances and then only in limited lengths. Wires are to be made taut by means of turnbuckles.

3.1.6

Chains may only be accepted in short lengths in lieu of guard rails if they are fitted between two fixed stanchions and/or bulwarks.

Section 3 - EQUIPMENT

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

EN : Equipment number defined in [2.1]

1. General

1.1 General

1.1.1

The requirements in this Section apply to temporary mooring of a ship within or near harbour, or in a sheltered area, when the ship is awaiting a berth, the tide, etc..

Therefore, the equipment complying with the requirements in this Section is not intended for holding a ship off fully exposed coasts in rough weather or for stopping a ship which is moving or drifting.

1.1.2

The equipment complying with the requirements in this Section is intended for holding a ship in good holding ground, where the conditions are such as to avoid dragging of the anchor. In poor holding ground the holding power of the anchors is to be significantly reduced.

1.1.3

The equipment number *EN* formula for anchoring equipment required here under is based on an assumed current speed of 2.5 m/s, wind speed of 25 m/s and a scope of chain cable between 6 and 10, the scope being the ratio between length of chain paid out and water depth.

1.1.4

It is assumed that under normal circumstances a ship will use one anchor only.

2. Equipment number

2.1 Equipment number

2.1.1 General

All ships are to be provided with equipment in anchors and chain cables (or ropes according to [3.3.5]), to be obtained from Tab 1, based on their equipment number *EN*.

In general, stockless anchors are to be adopted.

For ships with *EN* greater than 16000, the determination of the equipment will be considered by the Society on a case by case basis.

Table 1: Equipment

Equipment number EN $A < EN \le B$		Stockless anchors		Stud link chain cables for anchors			
		N (1)	Mass per anchor, in kg	Total length, in m	Diameter, in mm		
A	B				Grade 1	Grade 2	Grade 3
50	70	2	180	220.0	14.0	12.5	
70	90	2	240	220.0	16.0	14.0	
90	110	2	300	247.5	17.5	16.0	
110	130	2	360	247.5	19.0	17.5	
130	150	2	420	275.0	20.5	17.5	
150	175	2	480	275.0	22.0	19.0	
175	205	2	570	302.5	24.0	20.5	
205	240	3	660	302.5	26.0	22.0	20.5
240	280	3	780	330.0	28.0	24.0	22.0
280	320	3	900	357.5	30.0	26.0	24.0
320	360	3	1020	357.5	32.0	28.0	24.0
360	400	3	1140	385.0	34.0	30.0	26.0
400	450	3	1290	385.0	36.0	32.0	28.0
450	500	3	1440	412.5	38.0	34.0	30.0
500	550	3	1590	412.5	40.0	34.0	30.0
550	600	3	1740	440.0	42.0	36.0	32.0
600	660	3	1920	440.0	44.0	38.0	34.0
660	720	3	2100	440.0	46.0	40.0	36.0
720	780	3	2280	467.5	48.0	42.0	36.0
780	840	3	2460	467.5	50.0	44.0	38.0
840	910	3	2640	467.5	52.0	46.0	40.0
910	980	3	2850	495.0	54.0	48.0	42.0
980	1060	3	3060	495.0	56.0	50.0	44.0
1060	1140	3	3300	495.0	58.0	50.0	46.0
1140	1220	3	3540	522.5	60.0	52.0	46.0
1220	1300	3	3780	522.5	62.0	54.0	48.0
1300	1390	3	4050	522.5	64.0	56.0	50.0
1390	1480	3	4320	550.0	66.0	58.0	50.0
1480	1570	3	4590	550.0	68.0	60.0	52.0
1570	1670	3	4890	550.0	70.0	62.0	54.0
1670	1790	3	5250	577.5	73.0	64.0	56.0
1790	1930	3	5610	577.5	76.0	66.0	58.0
1930	2080	3	6000	577.5	78.0	68.0	60.0
2080	2230	3	6450	605.0	81.0	70.0	62.0
2230	2380	3	6900	605.0	84.0	73.0	64.0
2380	2530	3	7350	605.0	87.0	76.0	66.0
2530	2700	3	7800	632.5	90.0	78.0	68.0
2700	2870	3	8300	632.5	92.0	81.0	70.0
2870	3040	3	8700	632.5	95.0	84.0	73.0
3040	3210	3	9300	660.0	97.0	84.0	76.0
3210	3400	3	9900	660.0	100.0	87.0	78.0
3400	3600	3	10500	660.0	102.0	90.0	78.0
3600	3800	3	11100	687.5	105.0	92.0	81.0

Equipment number *EN* *A* < *EN* ≤ *B*		Stockless anchors		Stud link chain cables for anchors			
		N (1)	Mass per anchor, in kg	Total length, in m	Diameter, in mm		
A	*B*				Grade 1	Grade 2	Grade 3
3800	4000	3	11700	687.5	107.0	95.0	84.0
4000	4200	3	12300	687.5	111.0	97.0	87.0
4200	4400	3	12900	715.0	114.0	100.0	87.0
4400	4600	3	13500	715.0	117.0	102.0	90.0
4600	4800	3	14100	715.0	120.0	105.0	92.0
4800	5000	3	14700	742.5	122.0	107.0	95.0
5000	5200	3	15400	742.5	124.0	111.0	97.0
5200	5500	3	16100	742.5	127.0	111.0	97.0
5500	5800	3	16900	742.5	130.0	114.0	100.0
5800	6100	3	17800	742.5	132.0	117.0	102.0
6100	6500	3	18800	742.5		120.0	107.0
6500	6900	3	20000	770.0		124.0	111.0
6900	7400	3	21500	770.0		127.0	114.0
7400	7900	3	23000	770.0		132.0	117.0
7900	8400	3	24500	770.0		137.0	122.0
8400	8900	3	26000	770.0		142.0	127.0
8900	9400	3	27500	770.0		147.0	132.0
9400	10000	3	29000	770.0		152.0	132.0
10000	10700	3	31000	770.0			137.0
10700	11500	3	33000	770.0			142.0
11500	12400	3	35500	770.0			147.0
12400	13400	3	38500	770.0			152.0
13400	14600	3	42000	770.0			157.0
14600	16000	3	46000	770.0			162.0
(1) See [3.2.4].							

2.1.2 Equipment number

The equipment number *EN* is to be obtained from the following formula:

$EN = \Delta^{2/3} + 2\, h\, B + 0.1\, A$

where:.

Δ : Moulded displacement of the ship, in t, to the summer load waterline

h : Effective height, in m, from the summer load waterline to the top of the uppermost house, to be obtained in accordance with the following formula:

$h = a + \Sigma\, h_n$

When calculating h, sheer and trim are to be disregarded

a : Freeboard amidships from the summer load waterline to the upper deck, in m

h_n : Height, in m, at the centreline of tier "*n*" of superstructures or deckhouses having a breadth greater than $B/4$. Where a house having a breadth greater than $B/4$ is above a house with a breadth of $B/4$ or less, the upper house is to be included and the lower ignored

A : Area, in m^2, in profile view, of the parts of the hull, superstructures and houses above the summer load waterline which are within the length L and also have a breadth greater than $B/4$

Fixed screens or bulwarks 1.5 m or more in height are to be regarded as parts of houses when determining h and A. In particular, the hatched area shown in Fig 1 is to be included.

The height of hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining h and A.

3. Equipment

3.1 General

3.1.1

All anchoring equipment, towing bitts, mooring bollards, fairlead cleats and eyebolts are to be so constructed and attached to the hull that, in use up to design loads, the integrity of the ship will not be impaired.

3.1.2

The anchoring arrangement is to be such as to prevent the cable from being damaged and fouled. Adequate arrangement is to be provided to secure the anchor under all operational conditions.

3.2 Anchors

3.2.1 General

The scantlings of anchors are to be in compliance with the following requirements.

Anchors are to be constructed and tested in compliance with approved plans.

3.2.2 Ordinary anchors

The required mass for each anchor is to be obtained from Tab 1.

The individual mass of a main anchor may differ by ±7% from the mass required for each anchor, provided that the total mass of anchors is not less than the total mass required in Tab 1.

The mass of the head of an ordinary stockless anchor, including pins and accessories, is to be not less than 60% of the total mass of the anchor.

Where a stock anchor is provided, the mass of the anchor, excluding the stock, is to be not less than 80% of the mass required in Tab 1 for a stockless anchor. The mass of the stock is to be not less than 25% of the mass of the anchor without the stock but including the connecting shackle.

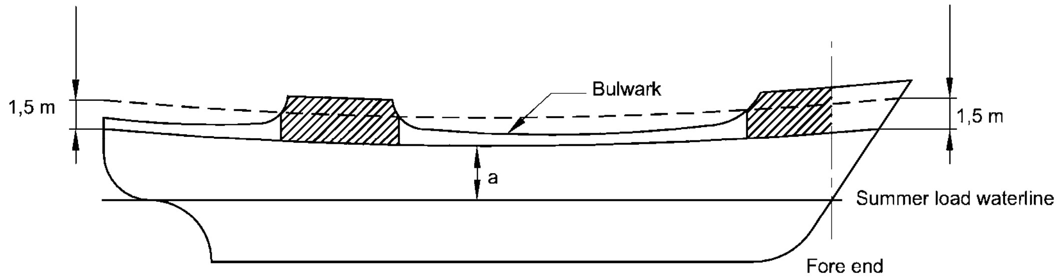


Figure 1: Effective area of bulwarks or fixed screen to be included in the equipment number

3.2.3 High and very high holding power anchors

High holding power (HHP) and very high holding power (VHHP) anchors, i.e. anchors for which a holding power higher than that of ordinary anchors has been proved according to the applicable requirements of the Society's Rules for Materials, do not require prior adjustment or special placement on the sea bottom.

Where HHP or VHHP anchors are used as bower anchors, the mass of each anchor is to be not less than 75% or 50%, respectively, of that required for ordinary stockless anchors in Tab 1.

The mass of VHHP anchors is to be, in general, less than or equal to 1500 kg.

3.2.4 Third anchor

Where three anchors are provided, two are to be connected to their own chain cables and positioned on board always ready for use.

The third anchor is intended as a spare and is not required for the purpose of classification.

3.2.5 Test for high holding power anchors approval

For approval and/or acceptance as a HHP anchor, comparative tests are to be performed on various types of sea bottom.

Such tests are to show that the holding power of the HHP anchor is at least twice the holding power of an ordinary stockless anchor of the same mass.

For approval and/or acceptance as a HHP anchor of a whole range of mass, such tests are to be carried out on anchors whose sizes are, as far as possible, representative of the full range of masses proposed. In this case, at least two anchors of different sizes are to be tested. The mass of the maximum size to be approved is to be not greater than 10 times the maximum size tested. The mass of the smallest is to be not less than 0.1 times the minimum size tested.

3.2.6 Test for very high holding power anchors approval

For approval and/or acceptance as a VHHP anchor, comparative tests are to be performed at least on three types of sea bottom: soft mud or silt, sand or gravel and hard clay or similar compounded material. Such tests are to show that the holding power of the VHHP anchor is to be at least four times the holding power of an ordinary stockless anchor of the same mass or at least twice the holding power of a previously approved HHP anchor of the same mass. The holding power test load is to be less than or equal to the proof load of the anchor, specified in the applicable requirements of the Society's Rules for Materials.

For approval and/or acceptance as a VHHP anchor of a whole range of mass, such tests are to be carried out on anchors whose sizes are, as far as possible, representative of the full range of masses proposed. In this case, at least three anchors of different sizes are to be tested, relevant to the bottom, middle and top of the mass range.

3.2.7 Specification for test on high holding power and very high holding power anchors

Tests are generally to be carried out from a tug. Shore based tests may be accepted by the Society on a case by case basis.

Alternatively, sea trials by comparison with a previous approved anchor of the same type (HHP or VHHP) of the one to be tested may be accepted by the Society on a case by case basis.

For each series of sizes, the two anchors selected for testing (ordinary stockless and HHP anchors for testing HHP anchors, ordinary stockless and VHHP anchors or, when ordinary stockless anchors are not available, HHP and VHHP anchors for testing VHHP anchors) are to have the same mass.

The length of chain cable connected to each anchor, having a diameter appropriate to its mass, is to be such that the pull on the shank remains practically horizontal. For this purpose a value of the ratio between the length of the chain cable paid out and the water depth equal to 10 is considered normal. A lower value of this ratio may be accepted by the Society on a case by case basis.

Three tests are to be carried out for each anchor and type of sea bottom.

The pull is to be measured by dynamometer; measurements based on the RPM/bollard pull curve of tug may, however, be accepted instead of dynamometer readings.

Note is to be taken where possible of the stability of the anchor and its ease of breaking out.

3.3 Chain cables for anchors

3.3.1 Material

The chain cables are classified as grade 1, 2 or 3 depending on the type of steel used and its manufacture.

The characteristics of the steel used and the method of manufacture of chain cables are to be approved by the Society for each manufacturer. The material from which chain cables are manufactured and the completed chain cables themselves are to be tested in accordance with the applicable requirements of the Society's Rules for Materials.

Chain cables made of grade 1 may not be used with high holding power and very high holding power anchors.

3.3.2 Scantlings of stud link chain cables

The mass and geometry of stud link chain cables, including the links, are to be in compliance with the requirements in the applicable requirements of the Society's Rules for Materials.

The diameter of stud link chain cables is to be not less than the value in Tab 1.

3.3.3 Studless link chain cables

For ships with *EN* less than 90, studless short link chain cables may be accepted by the Society as an alternative to stud link chain cables, provided that the equivalence in strength is based on proof load, defined in the applicable requirements of the Society's Rules for Materials and that the steel grade of the studless chain is equivalent to the steel grade of the stud chains it replaces, as defined in [3.3.1].

3.3.4 Chain cable arrangement

Chain cables are to be made by lengths of 27.5 m each, joined together by Dee or lugless shackles.

The total length of chain cable, required in Tab 1, is to be divided in approximately equal parts between the two anchors ready for use.

Where different arrangements are provided, they are considered by the Society on a case by case basis.

Where the ship may anchor in areas with current speed greater than 2.5 m/s, the Society may require a length of heavier chain cable to be fitted between the anchor and the rest of the chain in order to enhance anchor bedding.

3.3.5 Wire ropes

As an alternative to the stud link or short link chain cables mentioned, wire ropes may be used in the following cases:

- wire ropes for both the anchors, for ship length less than 30 m
- wire rope for one of the two anchors, for ship length between 30 m and 40 m.

The wire ropes above are to have a total length equal to 1.5 times the corresponding required length of stud link chain cables, obtained from Tab 1, and a minimum breaking load equal to that given for the corresponding stud link chain cable (see [3.3.2]).

A short length of chain cable is to be fitted between the wire rope and the anchor, having a length equal to 12.5m or the distance from the anchor in the stowed position to the winch, whichever is the lesser.

3.4 Attachment pieces

3.4.1 General

Where the lengths of chain cable are joined to each other by means of shackles of the ordinary Dee type, the anchor may be attached directly to the end link of the first length of chain cable by a Dee type end shackle.

A detachable open link in two parts riveted together may be used in lieu of the ordinary Dee type end shackle; in such case the open end link with increased diameter, defined in [3.4.2], is to be omitted.

Where the various lengths of chain cable are joined by means of lugless shackles and therefore no special end and increased diameter links are provided, the anchor may be attached to the first length of chain cable by a special pear-shaped lugless end shackle or by fitting an attachment piece.

3.4.2 Scantlings

The diameters of the attachment pieces, in mm, are to be not less than the values indicated in Tab 2.

Attachment pieces may incorporate the following items between the increased diameter stud link and the open end link:

- swivel, having a diameter equal to $1.2d$
- increased stud link, having a diameter equal to $1.1d$

Where different compositions are provided, they will be considered by the Society on a case by case basis.

Table 2: Diameters of attachment pieces

Attachment piece	Diameter, in mm
End shackle	1.4d
Open end link	1.2d
Increased stud link	1.1d
Common stud link	d
Lugless shackle	d
where: d : Diameter, in mm, of the common link.	

3.4.3 Material

Attachment pieces, joining shackles and end shackles are to be of such material and design as to provide strength equivalent to that of the attached chain cable, and are to be tested in accordance with the applicable requirements of the applicable requirements of the Society's Rules for Materials.

3.4.4 Spare attachment pieces

A spare pear-shaped lugless end shackle or a spare attachment piece is to be provided for use when the spare anchor is fitted in place.

3.5 Towlines and mooring lines

3.5.1 General

The towlines having the characteristics defined in Tab 3 are intended as those belonging to the ship to be towed by a tug or another ship.

3.5.2 Materials

Towlines and mooring lines may be of wire, natural or synthetic fibre or a mixture of wire and fibre.

The breaking loads defined in Tab 3 refer to steel wires or natural fibre ropes.

Steel wires and fibre ropes are to be tested in accordance with the applicable requirements in the applicable requirements of the Society's Rules for Materials.

3.5.3 Steel wires

Steel wires are to be made of flexible galvanised steel and are to be of types defined in Tab 4.

Where the wire is wound on the winch drum, steel wires to be used with mooring winches may be constructed with an independent metal core instead of a fibre core. In general such wires are to have not less than 186 threads in addition to the metallic core.

Table 3: Towlines and mooring lines

Equipment number *EN* *A< EN ≤B*		**Towline (1)**		**Mooring lines**		
A	***B***	**Minimum length, in m**	**Breaking load, in kN**	***N* (2)**	**Length of each line, in m**	**Breaking load, in kN**
50	70	180	98.1	3	80	34
70	90	180	98.1	3	100	37
90	110	180	98.1	3	110	39
110	130	180	98.1	3	110	44
130	150	180	98.1	3	120	49
150	175	180	98.1	3	120	54
175	205	180	112	3	120	59
205	240	180	129	4	120	64
240	280	180	150	4	120	69
280	320	180	174	4	140	74
320	360	180	207	4	140	78
360	400	180	224	4	140	88
400	450	180	250	4	140	98
450	500	180	277	4	140	108
500	550	190	306	4	160	123
550	600	190	338	4	160	132
600	660	190	371	4	160	147
660	720	190	406	4	160	157
720	780	190	441	4	170	172
780	840	190	480	4	170	186
840	910	190	518	4	170	201
910	980	190	550	4	170	216
980	1060	200	603	4	180	230
1060	1140	200	647	4	180	250
1140	1220	200	692	4	180	270
1220	1300	200	739	4	180	284
1300	1390	200	786	4	180	309
1390	1480	200	836	4	180	324
1480	1570	220	889	5	190	324
1570	1670	220	942	5	190	333
1670	1790	220	1024	5	190	353
1790	1930	220	1109	5	190	378
1930	2080	220	1168	5	190	402
2080	2230	240	1259	5	200	422
2230	2380	240	1356	5	200	451
2380	2530	240	1453	5	200	481
2530	2700	260	1471	6	200	481
2700	2870	260	1471	6	200	490
2870	3040	260	1471	6	200	500
3040	3210	280	1471	6	200	520
3210	3400	280	1471	6	200	554
3400	3600	280	1471	6	200	588

Equipment number *EN* *A*< *EN* ≤*B*		Towline (1)		Mooring lines		
A	*B*	Minimum length, in m	Breaking load, in kN	*N* (2)	Length of each line, in m	Breaking load, in kN
3600	3800	300	1471	6	200	612
3800	4000	300	1471	6	200	647
4000	4200	300	1471	7	200	647
4200	4400	300	1471	7	200	657
4400	4600	300	1471	7	200	667
4600	4800	300	1471	7	200	677
4800	5000	300	1471	7	200	686
5000	5200	300	1471	8	200	686
5200	5500	300	1471	8	200	696
5500	5800	300	1471	8	200	706
5800	6100	300	1471	9	200	706
6100	6500			9	200	716
6500	6900			9	200	726
6900	7400			10	200	726
7400	7900			11	200	726
7900	8400			11	200	735
8400	8900			12	200	735
8900	9400			13	200	735
9400	10000			14	200	735
10000	10700			15	200	735
10700	11500			16	200	735
11500	12400			17	200	735
12400	13400			18	200	735
13400	14600			19	200	735
14600	16000			21	200	735

(1) The towline is not compulsory. It is recommended for ships having length not greater than 180 m.
(2) See [3.5.4].

Table 4: Steel wire composition

Breaking load *BL*, in kN	Steel wire components		
	Number of threads	Ultimate tensile strength of threads, in N/mm^2	Composition of wire
BL< 216	72	1420 ÷ 1570	6 strands with 7-fibre core
216 < *BL*< 490	144	1570 ÷ 1770	6 strands with 7-fibre core
BL > 490	216 or 222	1770 ÷ 1960	6 strands with 1-fibre core

3.5.4 Number of mooring lines

When the breaking load of each mooring line is greater than 490 kN, either a greater number of mooring lines than those required in Tab 3 having lower strength, or a lower number of mooring lines than those required in

Tab 3 having greater strength may be used, provided the total breaking load of all lines aboard the ship is greater than the value defined in Tab 3.

In any case, the number of lines is to be not less than 6 and the breaking load of each line is to be greater than 490 kN.

3.5.5 Length of mooring lines

The length of individual mooring lines may be reduced by up to 7% of the length defined in Tab 3, provided that the total length of mooring lines is greater than that obtained by adding the lengths of the individual lines defined in Tab 3.

3.5.6 Equivalence between the breaking loads of synthetic and natural fibre ropes

Generally, fibre ropes are to be made of polyamide or other equivalent synthetic fibres.

The equivalence between the breaking loads of synthetic fibre ropes B_{LS} and of natural fibre ropes B_{LN} is to be obtained, in kN, from the following formula:

$$B_{LS} = 7.4\,\delta\left(B_{LN}\right)^{8/9}$$

where:

δ : Elongation to breaking of the synthetic fibre rope, to be assumed not less than 30%.

3.6 Hawse pipes

3.6.1

Hawse pipes are to be built according to sound marine practice.

Their position and slope are to be so arranged as to create an easy lead for the chain cables and efficient housing for the anchors, where the latter are of the retractable type, avoiding damage to the hull during these operations.

For this purpose chafing lips of suitable form with ample lay-up and radius adequate to the size of the chain cable are to be provided at the shell and deck. The shell plating in way of the hawse pipes is to be reinforced as necessary.

3.6.2

In order to obtain an easy lead of the chain cables, the hawse pipes may be provided with rollers. These rollers are to have a nominal diameter not less than 10 times the size of the chain cable where they are provided with full imprints, and not less than 12 times its size where provided with partial imprints only.

3.6.3

All mooring units and accessories, such as timbler, riding and trip stoppers are to be securely fastened to the Surveyor's satisfaction.

3.7 Windlass

3.7.1 General

The windlass, which is generally single, is to be power driven and suitable for the size of chain cable and the mass of the anchors.

The windlass is to be fitted in a suitable position in order to ensure an easy lead of the chain cables to and through the hawse pipes. The deck in way of the windlass is to be suitably reinforced.

3.7.2 Assumptions for the calculation of the continuous duty pull

The calculation of the continuous duty pull P_C that the windlass unit prime mover is to be able to supply is based on the following assumptions:

- ordinary stockless anchors
- wind force equal to 6 on Beaufort Scale
- water current velocity 3 knots
- anchorage depth 100 m
- P_C includes the influences of buoyancy and hawse pipe efficiency; the latter is assumed equal to 70%
- the anchor masses assumed are those defined in the applicable requirements of the Society's Rules for Materials, excluding tolerances
- only one anchor is assumed to be raised at a time.

Owing to the buoyancy, the chain masses assumed are smaller than those defined in the applicable requirements of the Society's Rules for Materials, and are obtained, per unit length of the chain cable, in kg/m, from the following formula:

$m_L = 0.0218\ d^2$

where d is the chain cable diameter, in mm.

3.7.3 Calculation of the continuous duty pull

According to the assumptions in [3.7.2], the windlass unit prime mover is to be able to supply for a least 30 minutes a continuous duty pull P_C to be obtained, in kN, from Tab 5.

Table 5: Continuous duty pull

Material of chain cables	Continuous duty pull, in kN
Mild steel	$P_C = 0.0375\ d^2$
High tensile strength steel	$P_C = 0.0425\ d^2$
Very high tensile strength steel	$P_C = 0.0475\ d^2$
where: d : Chain cable diameter, in mm.	

3.7.4 Temporary overload capacity

The windlass unit prime mover is to provide the necessary temporary overload capacity for breaking out the anchor.

The temporary overload capacity, or short term pull, is to be not less than 1,5 times the continuous duty pull P_C and it is to be provided for at least two minutes.

The speed in this overload period may be lower than the nominal speed specified in [3.7.5].

3.7.5 Nominal hoisting speed

The nominal speed of the chain cable when hoisting the anchor and cable, to be assumed as an average speed, is to be not less than 0.15 m/s.

The speed is to be measured over two shots of chain cable during the entire trip; the trial is to commence with 3 shots (82.5 m) of chain fully submerged.

3.7.6 Windlass brake

A windlass brake is to be provided having sufficient capacity to stop the anchor and chain cable when paying out the latter with safety, in the event of failure of the power supply to the prime mover. Windlasses not actuated by steam are also to be provided with a non-return device.

A windlass with brakes applied and the cable lifter declutched is to be able to withstand a pull of 45% of the breaking load of the chain without any permanent deformation of the stressed parts or brake slip.

3.7.7 Chain stoppers

Where a chain stopper is fitted, it is to be able to withstand a pull of 80% of the breaking load of the chain.

Where a chain stopper is not fitted, the windlass is to be able to withstand a pull of 80% of the breaking load of the chain without any permanent deformation of the stressed part or brake slip.

3.7.8 Green sea loads

Where the height of the exposed deck in way of the item is less than $0.1L$ or 22 m above the summer load waterline, whichever is the lesser, the securing devices of windlasses located within the forward quarter length of the ship are to resist green sea forces.

The green sea pressure and associated areas are to be taken equal to (see Fig 2):

- 200 kN/m^2 normal to the shaft axis and away from the forward perpendicular, over the projected area in this direction
- 150 kN/m^2 parallel to the shaft axis and acting both inboard and outboard separately, over the multiple of f times the projected area in this direction,

where:

f : Coefficient taken equal to

$$f = 1 + \frac{B}{H} \text{, but not greater than 2.5}$$

B : Width of windlass measured parallel to the shaft axis,

H : Overall height of windlass.

Where mooring winches are integral with the anchor windlass, they are to be considered as part of the windlass.

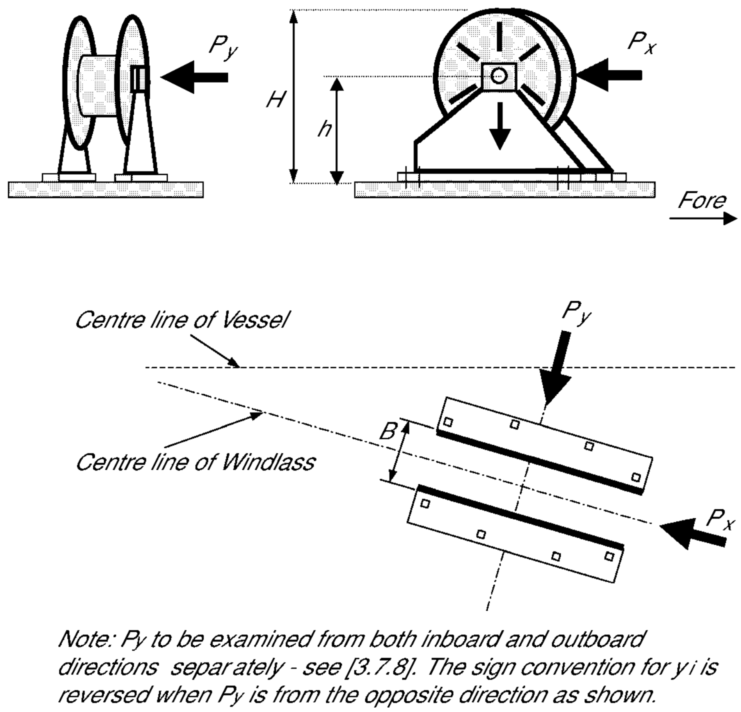


Figure 2: Direction of forces and weight

3.7.9 Forces in the securing devices of windlasses due to green sea loads

Forces in the bolts, chocks and stoppers securing the windlass to the deck are to be calculated by considering the green sea loads specified in [3.7.8].

The windlass is supported by *N* bolt groups, each containing one or more bolts (see also Fig 3).

The axial force R_i in bolt group (or bolt) *i*, positive in tension, is to be obtained, in kN, from the following formulae:

- $R_{xi} = P_x \, h x_i \, A_i / I_x$
- $R_{yi} = P_y \, h y_i \, A_i / I_y$
- $R_i = R_{xi} + R_{yi} - R_{si}$

where:

Px : Force, in kN, acting normal to the shaft axis

Py : Force, in kN, acting parallel to the shaft axis, either inboard or outboard, whichever gives the greater force in bolt group *i*

h : Shaft height, in cm, above the windlass mounting

x_i, y_i : *X* and *Y* co-ordinates, in cm, of bolt group *i* from the centroid of all *N* bolt groups, positive in the direction opposite to that of the applied force

A_i : Cross-sectional area, in cm^2, of all bolts in group *I*

I_x, I_y : Inertias, for *N* bolt groups, equal to:

$I_x = \Sigma A_i \, x_i^2$

$I_y = \Sigma A_i \, y_i^2$

R_{si} : Static reaction force, in kN, at bolt group *i*, due to weight of windlass.

Shear forces F_{xi} , F_{yi} applied to the bolt group i, and the resultant combined force F_i are to be obtained, in kN, from the following formulae:

- $F_{xi} = (P_x - \alpha\, g\, M) / N$
- $F_{yi} = (P_y - \alpha\, g\, M) / N$
- $F_i = (F_{xi}^2 + F_{yi}^2)^{0,5}$

where:

α : Coefficient of friction, to be taken equal to 0.5

M : Mass, in t, of windlass

N : Number of bolt groups.

Axial tensile and compressive forces and lateral forces calculated according to these requirements are also to be considered in the design of the supporting structure.

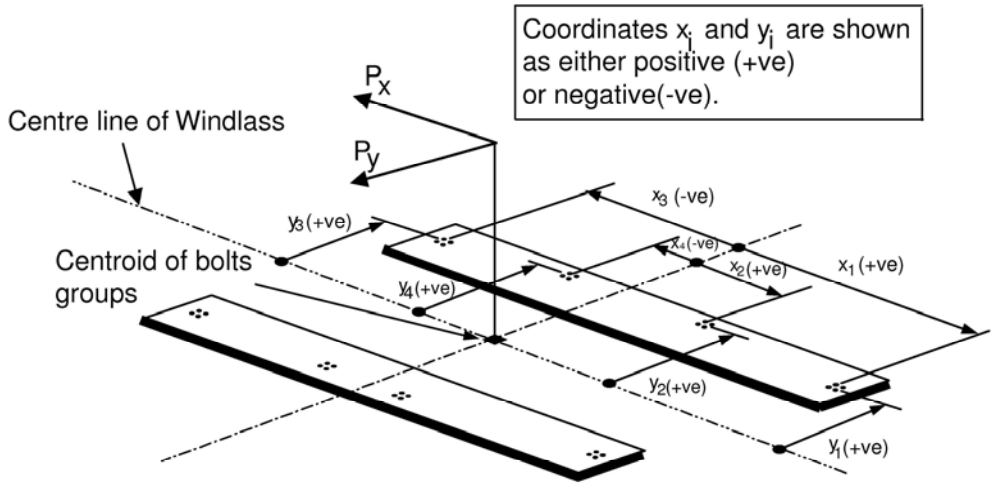


Figure 3: Sign convention

3.7.10 Strength criteria for windlass subject to anchor and chain loads

The stresses on the parts of the windlass, its frame and stopper are to be less than the yield stress of the material used.

For the calculation of the above stresses, special attention is to be paid to:

- stress concentrations in keyways and other stress raisers
- dynamic effects due to sudden starting or stopping of the prime mover or anchor chain
- calculation methods and approximation.

3.7.11 Strength criteria for securing devices of windlass

Tensile axial stresses in the individual bolts in each bolt group i are to be calculated according to the requirements specified in [3.7.9]. The horizontal forces F_{xi} and F_{yi}, to be calculated according to the requirements specified in [3.7.9], are normally to be reacted by shear chocks.

Where "fitted" bolts are designed to support these shear forces in one or both directions, the equivalent Von Mises stress σ, in N/mm^2, in the individual bolt is to comply with following formula:

$\sigma \leq 0.5\ \sigma_{BPL}$

where σ_{BPL} is the stress in the bolt considered as being loaded by the proof load.

Where pourable resins are incorporated in the holding down arrangements, due account is to be taken in the calculations.

3.7.12 Connection with deck

The windlass, its frame and the stoppers are to be efficiently bedded to the deck.

3.8 Chain stoppers

3.8.1

A chain stopper is generally to be fitted between the windlass and the hawse pipe in order to relieve the windlass of the pull of the chain cable when the ship is at anchor. A chain stopper is to be capable of withstanding a pull of 80% of the breaking load of the chain cable. The deck at the chain stopper is to be suitably reinforced.

For the same purpose, a piece of chain cable may be used with a rigging screw capable of supporting the weight of the anchor when housed in the hawse pipe or a chain tensioner. Such arrangements are not to be considered as chain stoppers.

3.8.2

Where the windlass is at a distance from the hawse pipes and no chain stoppers are fitted, suitable arrangements are to be provided to lead the chain cables to the windlass.

3.9 Chain locker

3.9.1

The capacity of the chain locker is to be adequate to stow all chain cable equipment and provide an easy direct lead to the windlass.

3.9.2

Where two chains are used, the chain lockers are to be divided into two compartments, each capable of housing the full length of one line.

3.9.3

The inboard ends of chain cables are to be secured to suitably reinforced attachments in the structure by means of end shackles, whether or not associated with attachment pieces.

Generally, such attachments are to be able to withstand a force not less than 15% of the breaking load of the chain cable.

In an emergency, the attachments are to be easily released from outside the chain locker.

3.9.4

Where the chain locker is arranged aft of the collision bulkhead, its boundary bulkheads are to be watertight and a drainage system is to be provided.

3.10 Fairleads and bollards

3.10.1

Fairleads and bollards of suitable size and design are to be fitted for towing, mooring and warping operations.

Chapter 11

Construction and Testing

Section 1 - CONSTRUCTION

1. Structural details

1.1 Cut-outs, plate edges

1.1.1

The free edges (cut surfaces) of cut-outs, hatch corners, etc. are to be properly prepared and are to be free from notches. As a general rule, cutting draglines, etc. are not to be welded out, but are to be smoothly ground. All edges are to be broken or in cases of highly stressed parts, be rounded off.

Free edges on flame or machine cut plates or flanges are not to be sharp cornered and are to be finished off as laid down in above. This also applies to cutting drag lines, etc., in particular to the upper edge of shear strake and analogously to weld joints, changes in sectional areas or similar discontinuities.

1.1.2

The hatch opening corners are to be machine cut.

1.2 Cold forming

1.2.1

For cold forming (bending, flanging, beading) of corrugated bulkhead the inside bending radius is to be not less than $2t$ (t = as-built thickness).

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In order to prevent cracking, flame cutting flash or sheering burrs are to be removed before cold forming. After cold forming all structural components and, in particular, the ends of bends (plate edges) are to be examined for cracks. Except in cases where edge cracks are negligible, all cracked components are to be rejected. Repair welding is not permissible.

1.3 Assembly, alignment

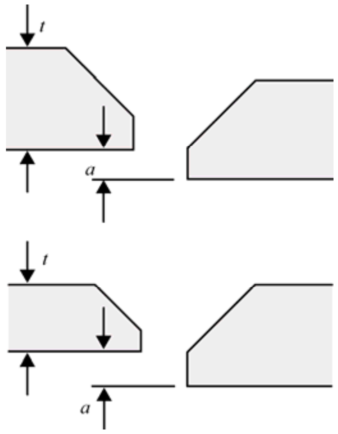
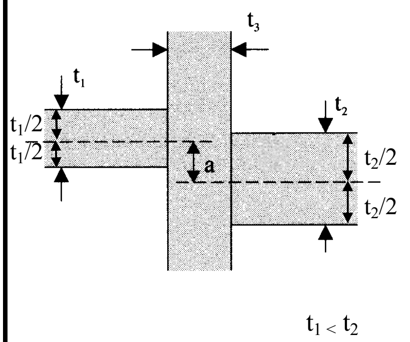
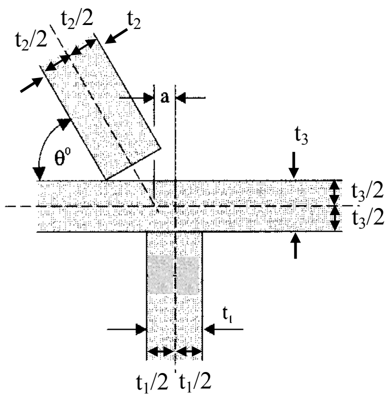
1.3.1

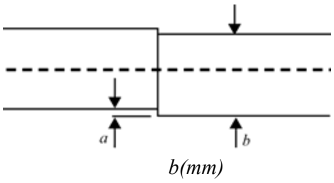
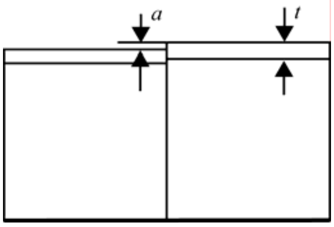
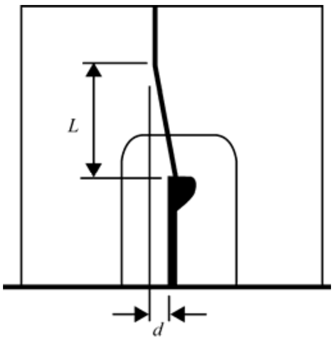
The use of excessive force is to be avoided during the assembly of individual structural components or during the erection of sections. As far as possible, major distortions of individual structural components are to be corrected before further assembly.

Structural members are to be aligned following the IACS recommendation No.47 provisions given in Tab 1 or according to the requirements of a recognised fabrication standard that has been accepted by the Classification Society. In the case of critical components, control drillings are to be made where necessary, which are then to be welded up again on completion.

After completion of welding, straightening and aligning are to be carried out in such a manner that the material properties are not influenced significantly. In case of doubt, the Society may require a procedure test or a working test to be carried out.

Table 1: **Alignment** (t, t_1 and t_2: as-built thickness)

Detail	Standard	Limit	Remarks
Alignment of butt welds 		$a \le 0.15t$ strength member $a \le 0.2t$ other but maximum 4.0 mm	t is the lesser plate thickness
Alignment of fillet welds 		Strength member and higher stress member: $a \le t_1/3$ Other: $a \le t_1/2$	Alternatively, heel line can be used to check the alignment. Where t_3 is less than t_1, then t_3 should be substituted for t_1.
Alignment of fillet welds 		Strength member and higher stress member: $a \le t_1/3$ Other: $a \le t_1/2$	Alternatively, heel line can be used to check the alignment. Where t_3 is less than t_1, then t_3 should be substitute for t_1.
Note: "strength" means the following elements: strength deck, inner bottom, bottom, lower stool, lower part of transverse bulkhead, bilge hopper and side frames of single side bulk carriers.			

Detail	Standard	Limit	Remarks
Alignment of face plates of T longitudinal 	Strength member $a \leq 0.04b$	$a = 8.0$ mm	
Alignment of height of T-bar, L-angle bar or bulb 	Strength member $a \leq 0.15\ t$ Other $a \leq 0.2\ t$	$a = 3.0$ mm	
Alignment of panel stiffener 	$d \leq L\ /\ 50$		
Note: "strength" means the following elements: strength deck, inner bottom, bottom, lower stool, lower part of transverse bulkhead, bilge hopper and side frames of single side bulk carriers.			

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Section 2 – WELDING

1. General

1.1 Application

1.1.1
The requirements of this Section apply to the preparation, execution and inspection of welded connections in hull structures.

1.1.2
Welding of hull parts is to be carried out by approved welders only.

1.1.3
Welding procedures and welding consumables approved for the types of connection and parent material in question are to be used.

1.1.4
Welding of connections is to be executed according to the approved plans.

1.1.5
The quality standard adopted by the shipyard is to be submitted to the Society and it applies to all welded connections unless otherwise specified on a case by case basis.

1.1.6
Completed weld joints are to be to the satisfaction of the attending Surveyor.

1.1.7
Non destructive examination (NDE) for weld is to be carried out at the position indicated by the test plan in order to ensure that the welds are free from cracks and internal harmful imperfections and defects.

1.2 Welding consumables and procedures

1.2.1
Welding consumables adopted are to be approved by the Society. The requirements for the approval of welding consumables are given in the Society's Rules or guide for welding.

1.2.2
The welding procedures adopted are to be approved by the Society. The requirements for the approval of welding procedures are given in the Society's Rules or guide for welding.

1.2.3
Suitable welding consumables are to be selected depending on the kind and grade of materials. The requirements of the selection of welding consumables are given in the Society's Rules or guide for welding.

1.3 Welders and NDE operators

1.3.1 Welders

Manual and semi-automatic welding is to be performed by welders certified by the Society as specified in the Society's Rules or guide for welding.

1.3.2 Automatic welding operators

Personnel manning automatic welding machines and equipment are to be competent and sufficiently trained and certified by the Society as specified in the Society's Rules or guide for welding.

1.3.3 NDE operator

NDE is to be carried out by qualified personnel certified by the Society or by recognized bodies in compliance with appropriate standards.

1.4 Documentation to be submitted

1.4.1

The welding application plan to be submitted for approval has to contain the necessary data relevant to the fabrication by welding of the structures, kinds of welding procedure applied, welding position, etc.

1.4.2

The NDE plan to be submitted for approval has to contain the necessary data relevant to the locations and number of examinations, welding procedure(s) applied, method of NDE applied, etc.

2. Types of welded connections

2.1 General

2.1.1

The type of welded connections and the edge preparation are to be appropriate to the welding procedure adopted.

2.2 Butt welding

2.2.1 General

Butt connections of plating are to be full penetration, welded on both sides except where special welding procedures approved by the Society is applied.

2.2.2 Welding of plates with different thicknesses

In the case of welding of plates with a difference in as-built thickness greater than 4 mm, the thicker plate is normally to be tapered. The taper has to have a length of not less than 3 times the difference in as-built thickness.

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2.2.3 Edge preparation, root gap

Edge preparations and root gaps are to be in accordance with the adopted welding procedure and relevant bevel preparation.

2.3 Tee or cross joints

2.3.1 General

The connections of primary supporting members and stiffener webs to plating as well as plating abutting on another plating, are to be made by fillet welding or deep penetration weld, as shown in Fig 1.

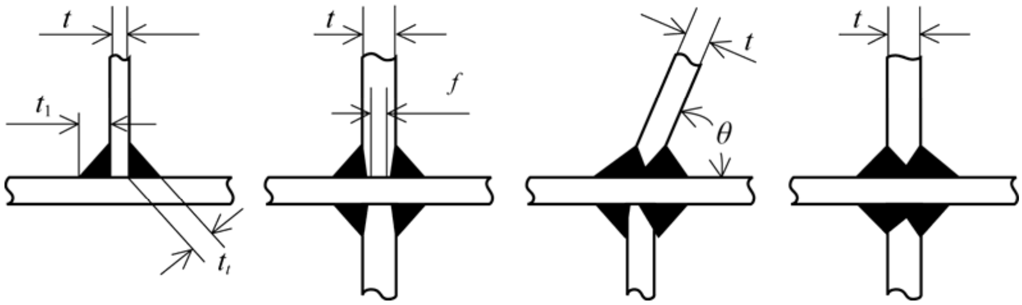

Figure 1: Tee or cross joints

t : As-built thickness of abutting plate, in mm

f : Unwelded root face, in mm, taken as $f \le t/3$

t_ℓ : Leg length of the fillet weld, in mm

t_t : Throat thickness, in mm.

2.4 Full penetration welds

2.4.1 Application

Full penetration welds are to be used in the following connections:

- rudder horns and shaft brackets to shell structure
- rudder side plating to rudder stock connection areas
- vertical corrugated bulkhead to inner bottom plating that are situated in the cargo area and arranged without transverse lower stool
- vertical corrugated bulkhead to top plating of transverse lower stool
- pillars to plating member, in case the stress acting on the pillar is tension (i.e. engine room, fore peak and deckhouses)
- edge reinforcement or pipe penetrations both to strength deck, sheer strake and bottom plating within 0.6L amidships, when the dimension of the opening exceeds 300 mm
- abutting plate panels with as-built thickness less than or equal to 12mm, forming boundaries to the sea below the summer load water line. For as-built thickness greater than 12mm, deep penetration weld with a maximum root face length f = T/3 is acceptable (see Fig.2).

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2.4.2

In case where shedder plates are fitted at the lower end of corrugated bulkhead, the shedder plates are to be welded to the corrugation and the top plate of the transverse lower stool by one side penetration welds or equivalent.

2.4.3

The transverse lower stool side plating is to be connected to the transverse lower stool top plating and the inner bottom plating by full penetration welds. Deep penetration welds may be accepted.

2.4.4

The supporting floors are to be connected to the inner bottom plating by full penetration welds. Deep penetration welds may be accepted.

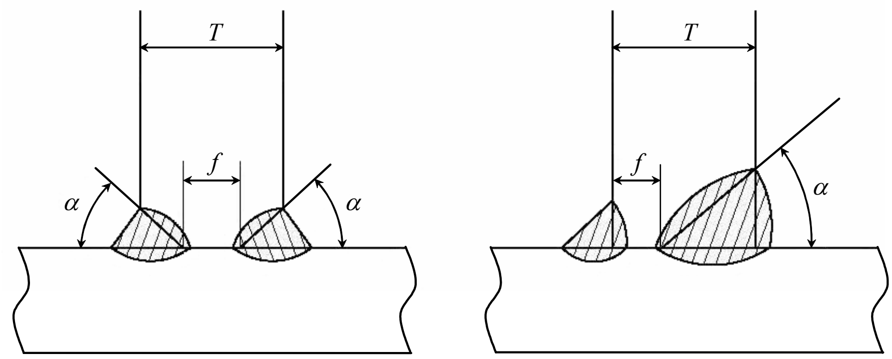
2.4.5

Generally, adequate groove angle between 40 and 60 degrees and root opening is to be taken and if necessary back gouging for both side welding is required.

2.5 Deep penetration weld

2.5.1

Deep penetration weld is defined as Fig 2.



- Root face (f) : 3 mm to T/3 mm
- Groove angle (α) : 40º to 60º

Figure 2: Deep penetration weld

2.6 Fillet welds

2.6.1 Kinds and size of fillet welds and their applications

Kinds and size of fillet welds for as-built thickness of abutting plating up to 50 mm are classed into 5 categories as given in Tab 1 and their application to hull construction is to be as required by Tab 2.

In addition, for zones "*a*" and "*b*" of side frames as shown in Ch 3, Sec 6, Fig 19, the weld throats are to be respectively 0.44t and 0.4t, where t is as-built thickness of the thinner of two connected members.

Table 1: Categories of fillet welds

Category	Kinds of fillet welds	As-built thickness of abutting plate, t, in mm [(1)]	Leg length of fillet weld, in mm [(2)]	Length of fillet welds, in mm	Pitch, in mm
F0	Double continuous weld	t	$0.7t$	-	-
F1	Double continuous weld	$t \le 10$	$0.5t + 1.0$	-	-
		$10 \le t < 20$	$0.4t + 2.0$	-	-
		$20 \le t$	$0.3t + 4.0$	-	-
F2	Double continuous weld	$t \le 10$	$0.4t + 1.0$	-	-
		$10 \le t < 20$	$0.3t + 2.0$	-	-
		$20 \le t$	$0.2t + 4.0$	-	-
F3	Double continuous weld	$t \le 10$	$0.3t + 1.0$	-	-
		$10 \le t < 20$	$0.2t + 2.0$		
		$20 \le t$	$0.1t + 4.0$		
F4	Intermittent weld	$t \le 10$	$0.5t + 1.0$	75	300
		$10 \le t < 20$	$0.4t + 2.0$		
		$20 \le t$	$0.3t + 4.0$		

(1) t is as-built thickness of the abutting plate, in mm. In case of cross joint as specified in Fig 1, t is the thinner thickness of the continuous member and the abutting plate, to be considered independently for each abutting plate.

(2) Leg length of fillet welds is made fine adjustments corresponding to the corrosion addition t_C specified in Ch 3, Sec 3, Tab 1 as follows:

+ 1.0 mm for $t_C > 5$

+ 0.5 mm for $5 \ge t_C > 4$

+ 0.0 mm for $4 \ge t_C > 3$

- 0.5 mm for $t_C \le 3$

(3) Leg length is rounded to the nearest half millimetre.

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Table 2: Application of fillet welds

Hull area	Connection: Of		Connection: To		Category
General, unless otherwise specified in the table(1)	Watertight plate		Boundary plating		F1
	Brackets at ends of members				F1
	Ordinary stiffener and collar plates		Deep tank bulkheads		F3
			Web of primary supporting members and collar plates		F2
	Web of ordinary stiffener		Plating (Except deep tank bulkhead)		F4
			Face plates of built-up stiffeners	At ends (15% of span)	F2
				Elsewhere	F4
	End of primary supporting members and ordinary stiffeners without brackets		Deck plate, shell plate, inner bottom plate, bulkhead plate		F0
	End of primary supporting members and ordinary stiffeners with brackets		Deck plate, shell plate, inner bottom plate, bulkhead plate		F1
Bottom and double bottom	Ordinary stiffener		Bottom and inner bottom plating		F3
	Center girder		Shell plates in strengthened bottom forward		F1
			Inner bottom plate and shell plate except the above		F2
	Side girder including intercostal plate		Bottom and inner bottom plating		F3
	Floor		Shell plates and inner bottom plates	At ends, on a length equal to two frame spaces	F2
			Center girder and side girders in way of hopper tanks		F2
			Elsewhere		F3
	Bracket on center girder		Center girder, inner bottom and shell plates		F2
	Web stiffener		Floor and girder		F3
Side and inner side in double side structure	Web of primary supporting members		Side plating, inner side plating and web of primary supporting members		F2
Side frame of single side structure	Side frame and end bracket		Side shell plate		See Ch.3 Sec 6 Fig.19
	Tripping bracket		Side shell plate and side frame		F1
Deck	Strength deck	$t \geq 13$	Side shell plating within 0.6L midship		Deep penetration
			Elsewhere		F1
		$t < 13$	Side shell plating		F1
	Other deck		Side shell plating		F2
			Ordinary stiffeners		F4
	Ordinary stiffener and intercostal girder		Deck plating		F3
	Hatch coamings		Deck plating	At corners of hatchways for 15% of the hatch length	F1
				Elsewhere	F2
	Web stiffeners		Coaming webs		F4

Hull area	**Connection**			**Category**
	Of	**To**		
Bulkheads	Non-watertight bulkhead structure	Boundaries	Swash bulkheads	F3
	Ordinary stiffener	Bulkhead plating	At ends (25% of span), where no end brackets are fitted	F1
Primary supporting members[(1)]	Web plate	Shell plating, deck plating, inner bottom plating, bulkhead	At end (15% of span)	F1
			Elsewhere	F2
		Face plate	In tanks, and located within $0.125L$ from fore peak	F2
			Face area exceeds 65 cm^2	F2
			Elsewhere	F3
After peak	Internal members	Boundaries and each other		F2
Seating	Girder and bracket	Bed plate	In way of main engine, thrust bearing, boiler bearers and main generator engines	F1
		Girder plate	In way of main engine and thrust bearing	F1
		Inner bottom plate and shell	In way of main engine and thrust bearing	F2
Super-structure and deck houses	External bulkhead	Deck		F1
	Ordinary stiffeners	Side wall and deck plate	At end (15% of span)	F3
			Elsewhere	F4[(2)]
	End section of ordinary stiffener and Primary supporting member	Without brackets	Side wall and web of primary supporting members	F1
		With bracket		F2
Pillar	Pillar	Heel and head		F1
Ventilator	Coaming	Deck		F1
Rudder	Rudder frame	Vertical frames forming main piece		F1
		Rudder plate		F3
		Rudder frames except above		F2

(1) For Hatch cover, weld sizes F1, F2 and F3 instead of F0, F1 and F2, respectively, are to be used.

(2) Where the one side continuous welding is applied, the weld size F3 is to be applied.

(3) The interior bulkheads are not included in this category. The welding of the interior bulkheads is to be subjected to the discretion of the Society.

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2.6.2 Intermittent welds

Where double continuous fillet welds in lieu of intermittent welds are applied, leg length of fillet welds is to be of category F3.

2.6.3 Size of fillet weld for abutting plating with small angle

Where the angle between an abutting plate and the connected plate is not 90 degrees as shown in Fig 3, the size of fillet welds for the side of larger angle is to be increased in accordance with the following formula:

$$t_\ell{}' = t_\ell \frac{1}{\sqrt{2}\sin\left(\frac{\varphi}{2}\right)}$$

where:

t_ℓ : Leg length of the fillet weld, in mm, as defined in [2.3.1]

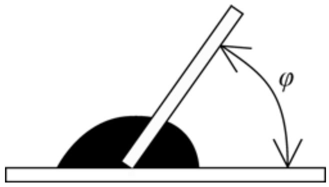

Figure 3: Connecting angle

2.6.4 Deep penetration welds

The leg length of fillet welds of deep penetration type may be reduced by 15% of that required in Tab 1, depending on the welding procedure test.

2.7 Lap joint welds

2.7.1 General

Lap joint welds may be adopted in very specific cases subject to the approval of the Society. Lap joint welds may be adopted for the followings:

- peripheral connections of doublers
- internal structural elements subject to very low stresses.

2.7.2 Fillet welds

Lap joints are to have the fillet size of category F1.

2.8 Slot welds

2.8.1 General

Slot welds may be adopted in very specific cases subject to the approval of the Society. However, slot welds of doublers on the outer shell and strength deck are not permitted within 0.6*L* amidships.

2.8.2 Size of fillet welds

The slot welds are to have adequate shape to permit a thoroughly fused bead to be applied all around the bottom edge of the opening. The size of fillet welds is to be category F1 and spacing of slots is to be as determined by the Society on a case by case basis.

3. Connection details

3.1 Bilge keel connection

3.1.1

The intermediate flat, through which the bilge keel is connected to the shell, according to Ch 3, Sec 6, [6.5.2], is to be welded to bilge plating and bilge keel.

3.1.2

The butt welds of the intermediate flat and bilge keel are to be full penetration and shifted from the shell butts.

The butt welds of the bilge plating and those of the intermediate flat are to be flush in way of crossing, respectively, with the intermediate flat and with the bilge keel.

3.1.3

Along the longitudinal edges, the intermediate flat is to be continuously fillet welded with a throat thickness "*a*" of 0.3 times its thickness. At the ends of intermediate flat, the throat thickness "*a*" at the end faces is to be increased to 0.5 times the intermediate flat thickness but is to be less than the bilge plating thickness (see Fig 4). The welded transition at the end faces of the doubling plates to the plating should form with the latter an angle of 45° or less.

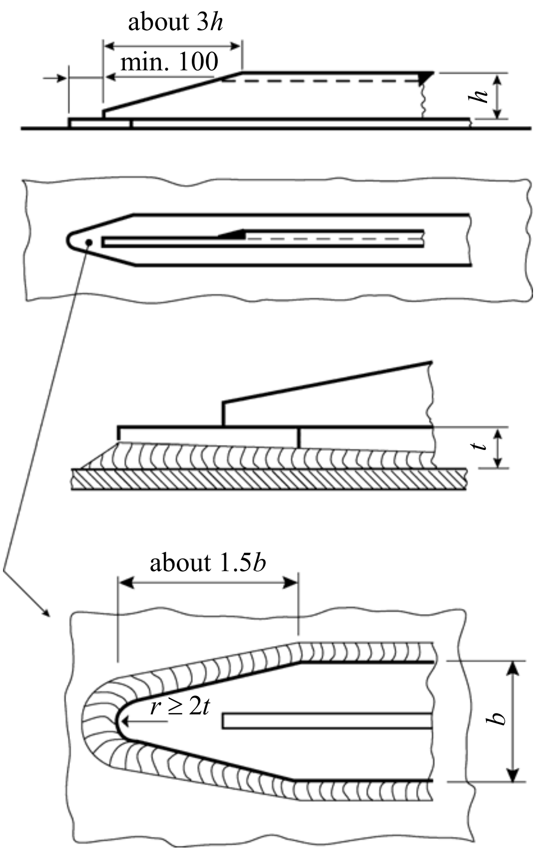

Figure 4: Bilge keel welding arrangement

Section 3 – TESTING OF COMPARTMENTS

1. General

1.1 Definitions

1.1.1 Shop primer
Shop primer is a thin coating applied after surface preparations and prior to fabrication as a protection against corrosion during fabrication.

1.1.2 Protective coating
Protective coating is a final coating protecting the structure from corrosion.

1.1.3 Structural testing
Structural testing is a hydrostatic test carried out to demonstrate the tightness of the tanks and the structural adequacy of the design. Where practical limitations prevail and hydrostatic testing is not feasible (for example when it is difficult, in practice, to apply the required head at the top of tank), hydropneumatic testing may be carried out instead. When hydropneumatic testing is performed, the conditions should simulate, as far as practicable, the actual loading of the tank.

1.1.4 Hydropneumatic testing
Hydropneumatic testing is a combination of hydrostatic and air testing, consisting in filling the tank with water up to its top and applying an additional air pressure. The value of additional air pressure is at the discretion of the Society, but is to be at least as defined in [2.2].

1.1.5 Leak testing
Leak testing is an air or other medium test carried out to demonstrate the tightness of the structure.

1.1.6 Hose testing
Hose testing is carried out to demonstrate the tightness of structural items not subjected to hydrostatic or leak testing and to other compartments which contribute to the watertight integrity of the hull.

1.2 Application

1.2.1
The following requirements determine the testing conditions for:

- tanks, including independent tanks,
- watertight or weathertight structures.

1.2.2
The purpose of these tests is to check the tightness and/or the strength of structural elements at time of ship construction and on the occasion of major repairs.

1.2.3
Tests are to be carried out in the presence of the Surveyor at a stage sufficiently close to completion so that any subsequent work not impair the strength and tightness of the structure.

2. Testing methods

2.1 Structural testing

2.1.1
Structural testing may be carried out after application of the shop primer.

2.1.2
Structural testing may be carried out after the protective coating has been applied, provided that one of the following two conditions is satisfied:

- all the welds are completed and carefully inspected visually to the satisfaction of the Surveyor prior to the application of the protective coating,
- leak testing is carried out prior to the application of the protective coating.

2.1.3
In absence of leak testing, protective coating should be applied after the structural testing of:

- all erection welds, both manual and automatic,
- all manual fillet weld connections on tank boundaries and manual penetration welds.

2.2 Leak testing

2.2.1
Where leak testing is carried out, in accordance with Tab 1, an air pressure of $0.15 \cdot 10^5$ Pa is to be applied during the test.

2.2.2
Prior to inspection, it is recommended that the air pressure in the tank is raised to $0.20 \cdot 10^5$ Pa and kept at this level for about 1 hour to reach a stabilized state, with a minimum number of personnel in the vicinity of the tank, and then lowered to the test pressure.

2.2.3
The Society may accept that the test is conducted after the pressure has reached a stabilized state at $0.20 \cdot 10^5$ Pa, without lowering pressure, provided they are satisfied of the safety of the personnel involved in the test.

2.2.4
Welds are to be coated with an efficient indicating liquid.

2.2.5
A U-tube filled with water up to a height corresponding to the test pressure is to be fitted to avoid overpressure of the compartment tested and verify the test pressure. The U-tube should have a cross section larger than that of the pipe supplying air.
In addition, test pressure is also to be verified by means of one master pressure gauge. The Society may accept alternative means which are considered to equivalently reliable.

2.2.6
Leak testing is to be carried out, prior to the application of protective coating, on all fillet weld connections on tank boundaries, penetrations and erection welds on tank boundaries excepting welds may be automatic processes. Selected locations of automatic erection welds and pre-erection manual or automatic welds may be required to be similarly tested at the discretion of the Surveyor taking account of the quality control procedures operating in the shipyard. For other welds, leak testing may be carried out, after the protective coating has been applied, provided that these welds were carefully inspected visually to the satisfaction of the Surveyor.

2.2.7
Any other recognized method may be accepted to the satisfaction of the Surveyor.

2.3 Hose testing

2.3.1
When hose testing is required to verify the tightness of the structures, as defined in Tab 1, the minimum pressure in the hose, at least equal to $2 \cdot 10^5$ Pa, is to be applied at a maximum distance of 1.5 m. The nozzle diameter is not to be less than 12 mm.
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2.4 Hydropneumatic testing

2.4.1
When hydropneumatic testing is performed, the same safety precautions as for leak testing are to be adopted.

2.5 Other testing methods

2.5.1
Other testing methods may be accepted, at the discretion of the Society, based upon equivalency considerations.

3. Testing requirements

3.1 General

3.1.1
General testing requirements for testing are given in Tab 1.

Table 1: General testing requirements

Item number	Structural to be tested	Type of testing	Structural test pressure	Remarks
1	Double bottom tanks	Structural testing [(1)]	The greater of the following: • head of water up to the top of overflow • head of water up to the bulkhead deck	Tank boundaries tested from at least one side
2	Double side tanks	Structural testing [(1)]	The greater of the following: • head of water up to the top of overflow • 2.4 m head of water above highest point of tank	Tank boundaries tested from at least one side
3	Tank bulkheads, deep tanks	Structural testing [(1)]	The greater of the following: [(2)] • head of water up to the top of overflow • 2.4 m head of water above highest point of tank • setting pressure of the safety relief valves, where relevant	Tank boundaries tested from at least one side
	Fuel oil tanks	Structural testing		
4	Ballast holds	Structural testing [(1)]	The greater of: • top of overflow, or • top of hatch coaming	
5	Fore peak and after peak used as tank	Structural testing	The greater of the following: • head of water up to the top of overflow • 2.4 m head of water above highest point of tank	Tank of the after peak carried out after the stern tube has been fitted
	Fore peak not used as tank	Refer to SOLAS Ch II.1 Reg.14		
	Aft peak not used as tank	Leak testing		
6	Cofferdams	Structural testing [(3)]	The greater of the following: • head of water up to the top of overflow • 2.4 m head of water above highest point of tank	

Item number	Structural to be tested	Type of testing	Structural test pressure	Remarks
7	Watertight bulkheads	Refer to SOLAS Ch II.1 Reg.14 [(4)]		
8	Watertight doors below freeboard or bulkhead deck	Refer to SOLAS Ch II.1 Reg.18		
9	Double plate rudder	Leak testing		
10	Shaft tunnel clear of deep tanks	Hose testing		
11	Shell doors	Hose testing		
12	Watertight hatchcovers of tanks	Hose testing		
13	Watertight hatchcovers and closing appliances	Hose testing		
14	Chain locker, located aft of collision bulkhead	Structural testing	Head of water up to the top	
15	Independent tanks	Structural testing	Head of water up to the top of overflow, but not less than 0.9 m	
16	Ballast ducts	Structural testing	Ballast pump maximum pressure	

[(1)] Leak or hydropneumatic testing may be accepted under the conditions specified in [2.2], provided that at least one tank for each type is structurally tested, to be selected in connection with the approval of the design. In general, structural testing need not be repeated for subsequent vessels of series of identical newbuildings. This relaxation does not apply to cargo space boundaries in tankers and combination carriers and tanks for segregated cargoes or pollutants. If the structural test reveals weakness or severe faults not detected by the leak test, all tanks are to be structurally tested.

[(2)] Where applicable, the highest point of tank is to be measured to the deck and excluding hatches. In holds for liquid cargo or ballast with large hatch covers, the highest point of tanks is to be taken at the top of hatch.

[(3)] Leak or hydropneumatic testing may be accepted under the conditions specified in [2.2] when, at the Society discretion, the latter is considered significant also in relation to the construction techniques and the welding procedures adopted.

[(4)] When hose test cannot be performed without damaging possible outfitting (machinery, cables, switchboards, insulation, etc.) already installed, it may be replaced, at the Society discretion, by a careful visual inspection of all the crossings and weld joints; where necessary, dye penetrant test or ultrasonic test may be required.

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Chapter 12

Additional Class Notations

Section 1 GRAB Additional Class Notation

Section 1 – GRAB ADDITIONAL CLASS NOTATION

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

M_{GR} : Mass of unladen grab, in tons

s : Spacing, in m, of ordinary stiffeners, measured at mid-span

1. Basic concepts

1.1 Application

1.1.1

The additional class notation GRAB [X] is assigned, in accordance with Ch 1, Sec 1, [3.2], to ships with holds designed for loading/unloading by grabs having a maximum specific weight up to [X] tons, in compliance with the requirements of this Section.

1.1.2

It is to be noted that this additional class notation does not negate the use of heavier grabs, but the owner and operators are to be made aware of the increased risk of local damage and possible early renewal of inner bottom plating if heavier grabs are used regularly or occasionally to discharge cargo.

2. Scantlings

2.1 Plating

2.1.1

The net thickness of plating of inner bottom, hopper tank sloping plate, transverse lower stool, transverse bulkhead plating and inner hull up to a height of 3.0m above the lowest point of the inner bottom, excluding bilge wells, is to be taken as the greater of the following values:

- t , as obtained according to requirements in Ch 6 and Ch 7
- t_{GR} , as defined in [2.1.2] and [2.1.3].

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2.1.2

The net thickness t_{GR}, in mm, of the inner bottom plating is to be obtained from the following formula:

$$t_{GR} = 0.28(M_{GR} + 50)\sqrt{sk}$$

2.1.3

The net thickness t_{GR}, in mm, of hopper tank sloping plate, transverse lower stool, transverse bulkhead plating and inner hull up to a height of 3.0m above the lowest point of the inner bottom, excluding bilge wells, is to be obtained from the following formula:

$$t_{GR} = 0.28(M_{GR} + 42)\sqrt{sk}$$ *RCN 1 to July 2008 version (effective from 1 July 2009)*

Chapter 13

Ships in Operation, Renewal Criteria

Section 1 - MAINTENANCE OF CLASS

1. General

1.1 Application

1.1.1

The survey requirements for the maintenance of class of bulk carriers are given in UR Z10.2 for single side skin bulk carriers and UR Z10.5 for double side skin bulk carriers.

Thickness measurements are a major part of surveys to be carried out for the maintenance of class, and the analysis of these measurements is a prominent factor in the determination and extent of the repairs and renewals of the ship's structure.

1.1.2

(Void)

Corrigenda 1 to July 2012 version (effective from 1July 2012)

1.1.3

(Void)

Corrigenda 1 to July 2012 version (effective from 1July 2012)

1.2 Definitions

1.2.1 Local corrosion

Local corrosion is pitting corrosion, grooving, edge corrosion, necking effect or other corrosions of very local aspect.

1.2.2 Substantial corrosion

Substantial corrosion is an extent of corrosion such that assessment of the corrosion pattern indicates gauged (or measured) thickness between $t_{renewal}$ and $t_{renewal} + t_{reserve}$.

(RCN 2, effective from 1 July 2008)

1.2.3 Deck zone

The deck zone includes all the following items contributing to the hull girder strength above the horizontal strake of the topside tank or above the level corresponding to 0.9D above the base line if there is no topside tank:

- strength deck plating
- deck stringer
- sheer strake
- side shell plating
- top side tank sloped plating, including horizontal and vertical strakes
- longitudinal stiffeners connected to the above mentioned platings.

Corrigenda 1 to July 2012 version (effective from 1July 2012)

1.2.4 Bottom zone

The bottom zone includes the following items contributing to the hull girder strength up to the upper level of the hopper sloping plating or up to the inner bottom plating if there is no hopper tank:

- keel plate
- bottom plating
- bilge plate
- bottom girders
- inner bottom plating
- hopper tank sloping plating
- side shell plating
- longitudinal stiffeners connected to the above mentioned platings.

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1.2.5 Neutral axis zone

The neutral axis zone includes the plating only of the items between the deck zone and the bottom zone, as for example:

- side shell plating
- inner hull plating, if any.

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Section 2 - Acceptance criteria

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

$t_{renewal}$: Renewal thickness; Minimum allowable thickness, in mm, below which renewal of structural members is to be carried out

$t_{renewal} = t_{as\_built} - t_C - t_{voluntary\_addition}$

$t_{reserve}$: Reserve thickness; Thickness, in mm, to account for anticipated thickness diminution that may occur during a survey interval of 2.5 year. ($t_{reserve}$ = 0.5 mm)

t_C : Corrosion addition, in mm, defined in Ch 3, Sec3

t_{as_built} : As built thickness, in mm, including $t_{voluntary\_addition}$, if any

$t_{voluntary\_addition}$: Voluntary thickness addition; Thickness, in mm, voluntarily added as the Owner's extra margin for corrosion wastage in addition to t_C

t_{gauged} : Gauged thickness, in mm, on one item, i.e average thickness on one item using the various measurements taken on this same item during periodical ship's in service surveys.

1. Local strength criteria

1.1 Application

1.1.1

The items to be considered for the local strength criteria are those defined in UR Z10.2 for single side skin bulk carriers and UR Z10.5 for double side skin bulk carriers.

1.2 Renewal thickness for corrosion other than local corrosion

1.2.1

For each item, steel renewal is required when the gauged thickness t_{gauged} is less than the renewal thickness, as specified in the following formula:

$t_{gauged} < t_{renewal,}$

Where the gauged thickness t_{gauged} is such as:

$t_{renewal} < t_{gauged} < t_{renewal} + t_{reserve}$

coating applied in accordance with the coating manufacturer's requirements or annual gauging may be adopted as an alternative to the steel renewal. The coating is to be maintained in good condition.

1.3 Renewal thickness for local corrosion

1.3.1

If pitting intensity in an area where coating is required, according to Ch 3, Sec 5, is higher than 15% (see Fig 1), thickness measurements are to be performed to check the extent of pitting corrosion. The 15% is based on pitting or grooving on only one side of a plate.

In cases where pitting is exceeding 15%, as defined above, an area of 300 mm or more, at the most pitted part of the plate, is to be cleaned to bare metal and the thickness is to be measured in way of the five deepest pits within the cleaned area. The least thickness measured in way of any of these pits is to be taken as the thickness to be recorded.

The minimum remaining thickness in pits, grooves or other local areas as defined in Ch 13, Sec1, [1.2.1] is to be greater than:

- 75% of the as-built thickness, in the frame and end brackets webs and flanges
- 70% of the as-built thickness, in the side shell, hopper tank and topside tank plating attached to the each side frame, over a width up to 30 mm from each side of it,

without being greater than $t_{renewal}$.

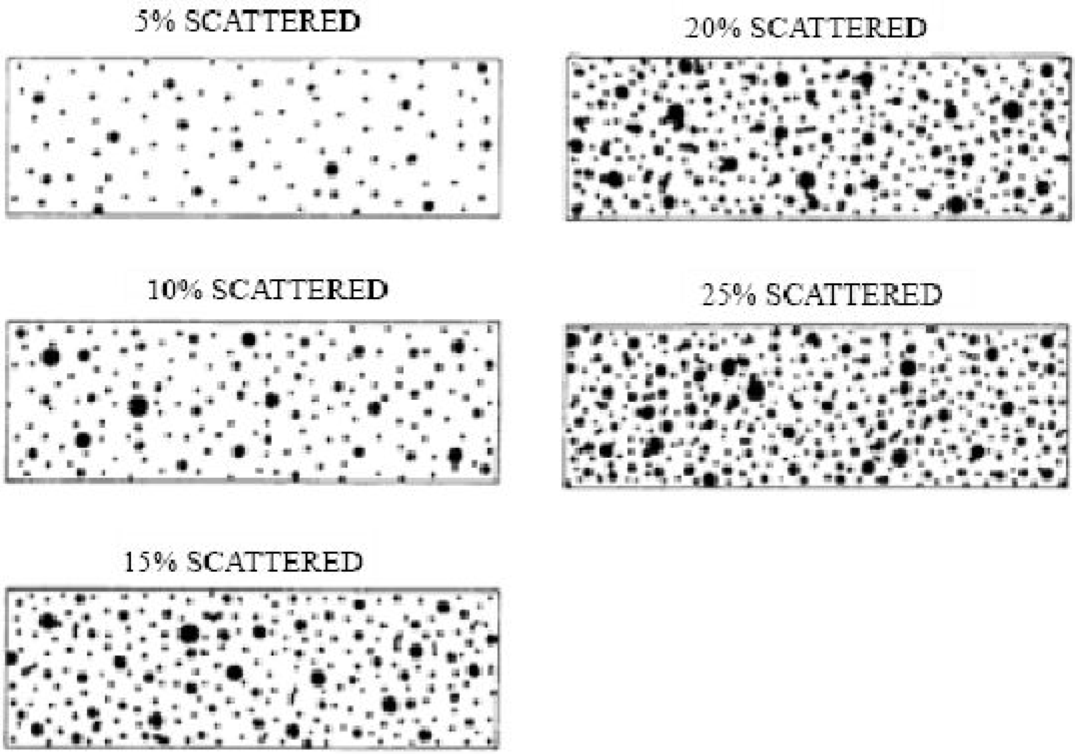

Figure 1: Pitting intensity diagrams (from 5% to 25% intensity)

1.4 Global strength criteria

1.4.1 Items for the global strength criteria

The items to be considered for the global strength criteria are those of the deck zone, the bottom zone and the neutral axis zone, as defined in Ch 13, Sec 1, [1.2].

1.4.2 Renewal thickness

The global strength criteria is defined by the assessment of the bottom zone, deck zone and neutral axis zone, as detailed below.

a) bottom zone and deck zone:

The current hull girder section modulus determined with the thickness measurements is not to be less than 90% of the section modulus calculated according to Ch 5, Sec 1 with the gross offered thicknesses.

Alternatively, the current sectional areas of the bottom zone and of the deck zone which are the sum of the gauged items area of the considered zones, are not to be less than 90% of the sectional area of the corresponding zones determined with the gross offered thicknesses.

b) neutral axis zone:

The current sectional area of the neutral axis zone, which is the sum of the gauged platings area of this zone, is not to be less than 85% of the gross offered sectional area of the neutral axis zone.

If the actual wastage of all items, of a given transverse section, which contribute to the hull girder strength is less than 10% for the deck and bottom zones and 15% for the neutral axis zone, the global strength criteria of this transverse section is automatically satisfied and its checking is no more required.

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Common Structural Rules for Double Hull Oil Tankers

Sections 1 to 7

July 2013

Lloyd's Register

COMMON STRUCTURAL RULES FOR DOUBLE HULL OIL TANKERS

Foreword

1. This version of the Rules is effective as of 1st July 2012.

2. This version incorporates changes made to the 1 July 2010 consolidated edition.

3. The Rules contain two parts, one part that is for information and does not constitute specific requirements and one part giving structural rules for double hull oil tankers of 150m or greater.

Subjects for information are given in *Section 1 – Introduction* and *Section 2 – Rule Principles*.

Specific rule requirements are given in *Sections 3* to *12* and the Appendices.

4. The following table provides a revision history of the Rules.

	Amendment Type / No.	**Approval Date**	**Effective Date ***	**Reference Rule Edition**
1	Corrigenda 1	7 Apr 2006	1 Apr 2006	1 Jan 2006 edition
2	Corrigenda 2	27 July 2006	1 Apr 2006	1 Jan 2006 edition
3	Rule Change Notice 1	29 Sept 2006	1 Apr 2007	1 Jan 2006 edition
4	Corrigenda 3	19 Nov 2007	1 Apr 2006	1 Jan 2006 edition
5	Rule Change Notice 2	25 Feb 2008	1 July 2008	1 Jan 2006 edition
6	Corrigenda 1 (1 July 2008 consolidated edition)	2 July 2008	1 July 2008	1 July 2008 consolidated edition
7	Rule Change Notice 1 (1 July 2008 consolidated edition)	11 Nov 2009 (Amended version) 1)	1 Feb 2010	1 July 2008 consolidated edition
8	Rule Change Notice 1 (1 July 2008 consolidated edition)	12 Apr 2010	1 July 2010	1 July 2008 consolidated edition

	Amendment Type / No.	Approval Date	Effective Date *	Reference Rule Edition
9	Rule Change Notice 1 (1 July 2010 consolidated edition)	30 Dec 2011	1 July 2012	1 July 2010 consolidated edition

* For effective date, refer to the implementation statements of relevant Corrigenda / Rule Changes.

1) RCN 1 to July 2008 edition was originally approved on 28 January 2009, however following input from industry, IACS Council decided to postpone the original implementation date of 1 July 2009 until such time as a technical study was completed.
In November 2009, following further technical review, IACS Council agreed an amended version of RCN 1 to enter into force on 1 February 2010.

Note: When the word '(void)' appears in the text, it means that the concerned part has been deleted. This is to keep the numbering of the remainder unchanged.

SECTION 4 BASIC INFORMATION

SECTION 5 STRUCTURAL ARRANGEMENT

SECTION 6 MATERIALS AND WELDING

APPENDIX B STRUCTURAL STRENGTH ASSESSMENT

APPENDIX C FATIGUE STRENGTH ASSESSMENT

APPENDIX D BUCKLING STRENGTH ASSESSMENT

SECTION 1

INTRODUCTION

1 INTRODUCTION TO COMMON STRUCTURAL RULES FOR OIL TANKERS

1.1 General

1.1.1 Applicability

1.1.1.1 These Rules apply to double hull oil tankers of 150m length, *L*, and upward classed with the Society and contracted for construction(1) on or after 1 April 2006. The definition of the rule length, *L*, is given in *Section 4/1.1.1.1*.

1.1.1.2 Generally, for double hull tankers of less than 150m in length, *L*, the Rules of the individual Classification Society are to be applied.

1.1.1.3 Ships contracted for construction before the effective date of these Rules are to comply with the Rules of the individual Classification Society.

Note

The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contracted for construction", see *IACS Procedural Requirement (PR) No. 29*.

1.2 Application of Individual Classification Rules

1.2.1 Regions of the ship which these Rules do not cover

1.2.1.1 For regions of the structure which these Rules do not cover, the relevant requirements of the individual Classification Society's Rules are to be applied.

1.3 Guidance on Rule Structure

1.3.1 Framework

1.3.1.1 The Rules are structured in Sections giving instructions for detailed application and requirements which are applied in order to satisfy the Rule objectives. The acceptable procedures for the structural analysis required by the Rules are given in the Appendices.

1.3.2 Numbering and cross-references

1.3.2.1 The system for numbering of Sections and Sub-Sections is given in *Table 1.1.1*.

Table 1.1.1
Section Numbering

Order	Levels	Example
1	Section name (displayed in the header)	SECTION 1 - INTRODUCTION
2	Sub-Section	1 INTRODUCTION TO THE COMMON STRUCTURAL…
3	Sub-Section 2	1.1 General
4	Sub-Section 3	1.1.1 Development of the rules
5	Paragraph number	1.1.1.1 An important part of the classification process is the development of rule…

1.3.2.2 The system for the numbering of Tables and Figures is given in *Table 1.1.2*.

Table 1.1.2 Numbering of Tables and Figures	
Table location in document	**Example of numbering**
Section 5, Sub-Section 1, 2nd table in sub-section	Table 5.1.2
Section 1, Sub-Section 12, 5th table in sub-section	Table 1.12.5
Section 10, Sub-Section 4, 3rd table in sub-section	Table 10.4.3
Figure location in document	
Section 5, Sub-Section 1, 2nd figure in sub-section	Figure 5.1.2
Section 1, Sub-Section 12, 5th figure in sub-section	Figure 1.12.5
Section 10, Sub-Section 4, 3rd figure in sub-section	Figure 10.4.3

1.3.2.3 Cross-references are given in *italics* throughout the document.

1.3.2.4 Cross-references within a Section (local) are represented as a Sub-Section or Paragraph number, e.g. *4.2* or *4.2.1.1*. See *Table 1.1.3*.

1.3.2.5 Cross-references outside a Section (global) are represented as Section no./Sub-Section or Paragraph number, e.g. *Section 4/2.1.1.3*. See *Table 1.1.3*.

Table 1.1.3 How Cross-References are Applied		
Location of reference	**Example of cross-reference**	
Local (within a Section)		
Text in Sub-Section 4.2	See *4.2*	in *4.2*
Text in Sub-Section 6.2.2	See *6.2.2*	in *6.2.2*
Text in Paragraph 5.1.2.1	See *5.1.2.1*	in *5.1.2.1*
Global (outside a section)		
Text in Section 6, Sub-Section 4.2	*Section 6/4.2*	
Text in Section 6, Sub-Section 6.2.2	*Section 6/6.2.2*	
Text in Section 6, Paragraph 5.1.2.1	*Section 6/5.1.2.1*	

1.3.3 General organization of the Rules

1.3.3.1 The general organisation of the Rules is shown in *Figure 1.1.1*

Figure 1.1.1
Schematic Layout of the Rules

Topic	Sections
Introduction	1
Rule Principles	2
Rule Application	3
Basic Information	4
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Loads	7

Aft end
& Machinery Room

Cargo Area

Fore end

Topic	Sections
Machinery general structure	8/4.1
Machinery bottom structure	8/4.2
Machinery side structure	8/4.3
Machinery deck structure	8/4.4
Machinery internal structure	8/4.5-4.8
Aft end general structure	8/5.1
Aft end bottom structure	8/5.2
Aft end shell structure	8/5.3
Aft end deck structure	8/5.4
Aft end internal structure	8/5.5-5.7

Topic	Sections
Hull girder strength	8/1
Hull envelope plating	8/2.2
Hull envelope framing	8/2.3
Inner bottom	8/2.4
Bulkheads	8/2.5
Primary support members	8/2.6
Sloshing	8/6.2
Hull girder ultimate strength	9/1
Strength assessment (FEM)	9/2
Fatigue strength	9/3

Topic	Sections
General structure	8/3.1
Bottom structure	8/3.2
Side structure	8/3.3
Deck structure	8/3.4
Internal structure	8/3.5-3.9
Bottom slamming	8/6.3
Bow impact	8/6.4

Topic	Sections
Hull openings and closing arrangements	11/1
Crew protection	11/2
Support structure and structural appendages	11/3
Equipment	11/4
Testing procedures	11/5
Ship in operation renewal criteria	12

SECTION 2

RULE PRINCIPLES

1 INTRODUCTION

1.1 Rule Principles

1.1.1 Rule objectives

1.1.1.1 The objectives of the Rules are to establish requirements to reduce the risks of structural failure in order to help improve the safety of life, environment and property and to provide adequate durability of the hull structure for the design life.

1.1.2 General

1.1.2.1 The sub-sections contain:

(a) the General Assumptions; pertaining to the design, construction and operation of the ship and gives information on the responsibilities of Classification Societies, builders and owners

(b) the Design Basis; which specifies the premises that the design principles of the Rules are based on, in terms of design parameters and assumptions about the ship operation

(c) the Design Principles; which define the fundamental principles used for the structural requirements in the Rules with respect to loads, structural capacity and assessment criteria

(d) the Application of the Design Principles; which describes how the design principles and methods are applied and what criteria are used to demonstrate that the structure meets the objective.

2 GENERAL ASSUMPTIONS

2.1 General

2.1.1 International and national regulations

2.1.1.1 Ships are to be designed, constructed and operated in compliance with the regulatory framework prescribed internationally by the International Maritime Organisation and implemented by National Administrations.

2.1.1.2 The Rules are based on the assumptions that all applicable statutory requirements are complied with.

2.1.1.3 The Rules incorporate the IACS unified requirements as shown in *Table 2.2.1*.

2.1.2 Classification Societies

2.1.2.1 Classification Societies develop and publish the standards for the hull structure and essential engineering systems. Classification Societies verify compliance with the classification requirements and the applicable international regulations when authorised by a National Administration during design, construction and operation of a ship.

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Table 2.2.1
IACS Unified Requirements Applicable to Oil Tankers

Number	Title
A1	*Equipment*
A2	*Shipboard fittings and supporting hull structures associated with towing and mooring on conventional vessels*
S1	*Requirements for Loading Conditions, Loading Manuals and Loading Instruments*
S2	*Definitions of ship's length L and block coefficient C_b*
S3	*Strength of end bulkheads of superstructures and deckhouses*
S4	*Criteria for use of high tensile steel with yield points of 315 N/mm² and 355N/mm² (with respect to longitudinal strength)*
S5	*Calculation of midship section moduli for conventional ship for ship's scantlings*
S6	*Use of steel grades for various hull members – ships of 90m in length and above*
S7	*Minimum longitudinal strength Standards*
S11	*Longitudinal strength Standard*
S13	*Strength of bottom forward in oil tankers*
S14	*Testing procedures of Watertight Compartments*
S26	*Strength and securing of Small Hatches on the Exposed Fore Deck*
S27	*Strength Requirements for Fore Deck Fittings and Arrangements*

2.1.3 Responsibilities of Classification Societies, builders and owners

2.1.3.1 These Rules address the hull structural aspects of classification and do not include requirements related to the verification of compliance with the Rules during construction and operation. The verification of compliance with these Rules is the

responsibility of all parties and requires that proper care and conduct is shown by all parties involved in its implementation. These responsibilities include:

(a) general aspects:

- relevant information and documentation involved in the design, construction and operation is to be communicated between all parties in a clear and efficient manner. The builder is responsible for providing design documentation according to requirements specified in the Rules. Other requirements for information and documentation are specified by the requirements and approval procedures of the individual Classification Societies
- quality systems are applied to the design, construction, operation and maintenance activities to assist compliance with the requirements of the Rules.

(b) design aspects:

- it is the responsibility of the owner to specify the intended use of the ship, and the responsibility of the builder to ensure that the operational capability of the design fulfils the owner's requirements as well as the structural requirements given in the Rules
- the builder shall identify and document the operational limits for the ship so that the ship can be safely and efficiently operated within these limits
- verification of the design is performed by the builder to check compliance with provisions contained in the Rules in addition to national and international regulations
- the design is performed by appropriately qualified, competent and experienced personnel
- the classification society is responsible for a technical appraisal of the design plans and related documents for a ship to verify compliance with the appropriate classification rules.

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(c) construction aspects:

- the builder is responsible for ensuring that adequate supervision and quality control is provided during the construction
- construction is to be carried out by qualified and experienced personnel
- workmanship, including alignment and tolerances, is to be in accordance with acceptable shipbuilding standards
- the Classification Society is responsible for surveying to verify that the construction and quality control are in accordance with the plans and procedures.

(d) operational aspects:

- the owner is to ensure that the operations personnel are aware of, and comply with, the operational limitations of the ship
- the owner is to provide operations personnel with sufficient training such that the ship is properly handled to ensure that the loads and resulting stresses imposed on the structure are minimised
- the owner is to ensure that the ship is maintained in good condition and in accordance with the Classification Society survey scheme and also in accordance with the international and national regulations and requirements

- the Classification Society is responsible for surveying to verify that the vessel maintains its condition of class in accordance with the Classification Society survey scheme.

3 DESIGN BASIS

3.1 General

3.1.1 The design basis

3.1.1.1 This Sub-Section specifies the design parameters and the assumptions about the ship operation that are used as the basis of the design principles of the Rules.

3.1.1.2 The Rules are applicable for ships in compliance with the specified design basis. Special consideration will be given to deviations from this design basis.

3.1.1.3 The design basis used for the design of each ship is to be documented and submitted to the Classification Society as part of the design review and approval. All deviations from the design basis are to be formally advised to the Classification Society.

3.1.2 Arrangement and layout

3.1.2.1 The Rules cover typical double hull tankers of greater than or equal to 150m in length and with arrangements as follows:

(a) engine room and deck house located aft of the cargo tank region, and
(b) in addition to the inner skin two longitudinal oil-tight bulkheads with no centreline longitudinal bulkhead, or
(c) in addition to the inner skin one centreline longitudinal oil-tight bulkhead.

3.1.2.2 The ship's structure is assumed to be:

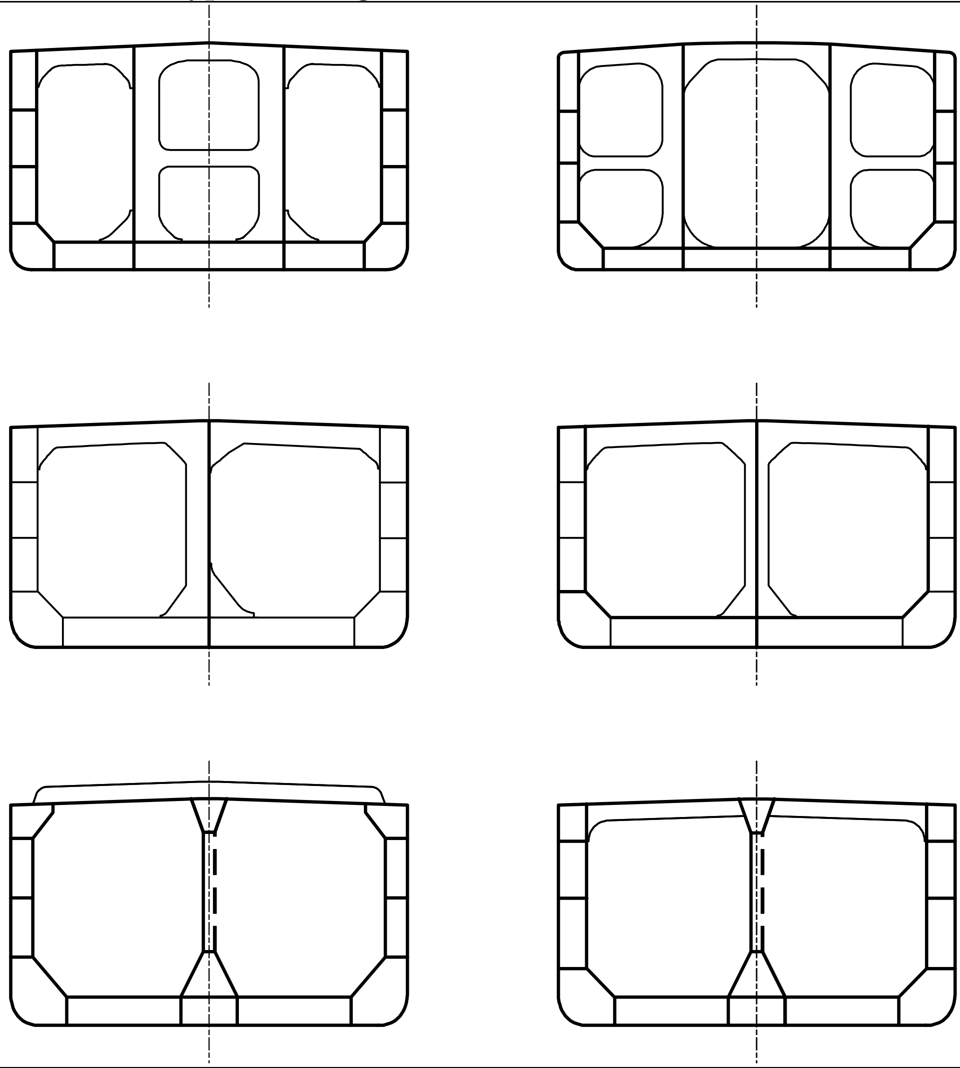
(a) constructed of welded steel structures
(b) composed of stiffened plate panels
(c) longitudinally framed with full transverse bulkheads and intermediate web frames.

3.1.2.3 The typical arrangements covered by the Rules are shown in *Figure 2.3.1* and assume that the structural arrangements include:

(a) narrow double side structure and double bottom structure with breadth/depth in accordance with statutory requirements
(b) single deck ships
(c) side longitudinal, centreline longitudinal or transverse bulkheads of plane, corrugated or double skin construction
(d) the number and location of bulkheads are arranged to comply with the statutory requirements.

The cross sections shown in *Figure 2.3.1* are typical examples only and other variations of cross tie and web frame arrangements are also covered

Figure 2.3.1
Typical Arrangements of Double Hull Tankers



3.1.2.4 The Rules assume the following hull form with respect to environmental loading:

(a) full form ship with block coefficient (C_b) greater than 0.7

(b) the ship length breadth ratio (L/B) greater than 5

(c) ship breadth depth ratio (B/D) less than 2.5

(d) the metacentric height (GM) not greater than 0.12B for homogeneously full load conditions, and 0.33B for ballast conditions.

3.1.3 Design life

3.1.3.1 A nominal design life of 25 years is assumed for selecting appropriate ship design parameters. The specified design life is the nominal period that the ship is assumed to be exposed to operating conditions. However, the ship's actual service life may be longer or shorter depending on the actual operating conditions and maintenance of the ship throughout its life cycle.

3.1.4 Design speed

3.1.4.1 The design maximum service speed is to be specified by the designer. The Rules assume that the ship is able to operate at this service speed on a continuous basis, but this does not relieve the responsibilities of the owner and personnel to properly

handle the ship and reduce speed or change heading in severe weather, see *2.1.3.1(d)*.

3.1.5 Operating conditions

3.1.5.1 The ship is to be capable of carrying the intended cargo with the necessary flexibility in operation to fulfil its design role. Specification of cargo loading conditions as required by the Rules and any additional cargo loading conditions required by the owner are the responsibility of the designer.

3.1.5.2 The Rules assume the following:

(a) a minimum set of specified loading conditions as defined in the Rules are examined. These are to include both seagoing and harbour loading conditions

(b) in addition to the minimum set of specified loading conditions, all relevant additional loading conditions covering the intended ship's service which result in increased still water shear force, bending moments or increased local static loadings are to be submitted for review

(c) the Trim and Stability Booklet, Loading Manual and loading computer systems specify the operational limitations to the ship and these comply with the appropriate statutory and classification requirements

(d) all cargo tanks are from a local strength point of view including sloshing designed for unrestricted filling for a cargo density as specified in *3.1.8*. Limitations to loading patterns resulting in full or empty adjacent tanks as specified in the Rules and the Loading Manual do however apply for primary support members and hull girder shear force and bending moments.

3.1.6 Operating draughts

3.1.6.1 The design operating draughts are to be specified by the designer and are to be used to derive the appropriate structural scantlings. All operational loading conditions in the Loading Manual are to comply with the specified design operating draughts. The following design operating draughts are as a minimum to be considered:

(a) the maximum and minimum mean operational draughts

(b) maximum scantling draught for the assessment of structure

(c) minimum draughts forward for the assessment of bottom slamming, with and without ballast tanks in way filled

(d) maximum mean draught for a condition with all cargo tanks abreast empty

(e) maximum mean draught for a condition with empty centre or wing cargo tank.

3.1.7 External environment

3.1.7.1 To cover worldwide trading operations and also to deal with the uncertainty in the future trading pattern of the ship and the corresponding wave conditions that will be encountered, a severe wave environment is used for the design assessment. The rule requirements are based on a ship trading in the North Atlantic wave environment for its entire design life.

3.1.7.2 The effects of wind and current on the structure are considered to be negligible and hence are not explicitly included.

3.1.7.3 The Rules do not include the effects of ice.

3.1.7.4 The Rules assume that the structural assessment of hull strength members is valid for the following design temperatures:

(a) lowest daily mean temperature in air is -10 ˚C

(b) lowest daily mean temperature in sea water is 0 ˚C

Ships operating for long periods in areas with lower daily mean air temperature may be subject to additional requirements as specified by the individual Classification Society.

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3.1.8 Internal environment (cargo and water ballast tanks)

3.1.8.1 A specific gravity (SG) of 1.025, or a higher value if specified by the designer, is to be used for oil cargoes for the strength assessment of cargo tank structures.

3.1.8.2 For the fatigue assessment of cargo tank structures, a representative mean cargo density throughout the ship's life is to be used. The representative mean density is to be taken as 0.9 tonnes/m^3 or the cargo density from the homogeneous full load condition at the full load design draught T_{full}, if this is higher.

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3.1.8.3 A SG of 1.025 is to be used for water ballast.

3.1.8.4 The Rules are based on the following design temperatures for the cargo:

(a) maximum cargo temperature is 80 ˚C

(b) minimum cargo temperature is 0 ˚C.

3.1.8.5 The design aspects and assumption upon which corrosion additions in the Rules are specified are as follows:

(a) the corrosion additions are based on a combination of experience and a statistical evaluation of historical corrosion measurements. The corrosion additions are based on the carriage of a mixture of crude and other oil products with various degrees of corrosive properties

(b) the corrosion additions are based on the design life, see *3.1.3.1*

(c) ballast tanks are coated. Requirements for coating application and maintenance are excluded from the Rules.

3.1.8.6 The values for corrosion additions and wastage allowance are specified in *Section 6/3* and *Section 12* respectively.

3.1.9 Structural construction and inspection

3.1.9.1 The structural requirements included in the Rules are developed with the assumption that construction and repair will follow acceptable shipbuilding and repair standards and tolerances. The Rules may require that additional attention is paid during construction and repair of critical areas of the structure.

3.1.9.2 Tank strength and tightness testing are to be carried out as a part of the verification scheme.

3.1.9.3 The Rules define the renewal criteria for the individual structural items. The structural requirements included are developed on the assumption that the structure will be subject to periodical survey in accordance with individual Classification Society Rules and Regulations. All structural elements are to be arranged to allow access for inspection, see *Section 5/5*. It is assumed that close-up inspection of the critical areas will be carried out on a regular basis.

3.1.10 Owner's extras

3.1.10.1 Owner's specification of requirements above the general classification or statutory requirements may affect the structural design. Owner's extras may include requirements for:

(a) vibration analysis

(b) maximum percentage of high strength steel

(c) additional scantling dimensions above that required by the Rules

(d) additional design margin on the loads specified by the Rules, etc

(e) improved fatigue resistance, in the form of a specified increase in design fatigue life or equivalent

(f) combinations of cargo loading patterns and draughts exceeding the Rule specified conditions

(g) higher cargo density for fatigue evaluation for ships intended to carry high density cargo in part load conditions on a regular basis.

Owner's extras are not covered by these Rules. Owner's extras that may affect the structural design are to be clearly specified in the design documentation.

4 DESIGN PRINCIPLES

4.1 Overall Principles

4.1.1 Introduction

4.1.1.1 This Sub-Section defines the underlying design principles of the Rules in terms of loads, structural capacity models and assessment criteria and also construction and in-service aspects.

4.1.2 General

4.1.2.1 The Rules are based on the following overall principles:

(a) the safety of the structure can be demonstrated by addressing the potential structural failure mode(s) when the vessel is subjected to operational loads and environmental loads/conditions

(b) the design complies with the design basis, see *Sub-Section 3*

(c) the structural requirements are based on a consistent set of loads that represent typical worst possible loading scenarios

(d) the structural requirements with respect to loads, capacity models and assessment criteria are presented in a modular format so that each component of the requirement is clearly identified.

4.1.2.2 The ship's structure is designed such that:

(a) it has inherent redundancy. The ship's structure works in a hierarchical manner and, as such, failure of structural elements lower down in the hierarchy should not result in immediate consequential failure of elements higher up in the hierarchy

(b) permanent deformations are minimised. Permanent deformations of local panel or individual stiffened plate members may be acceptable provided that this does not affect the structural integrity, containment integrity or the performance of structural or other systems

(c) the incidence of in-service cracking is minimised, particularly in locations which; affect the structural integrity or containment integrity, affect the performance of structural or other systems or are difficult to inspect and repair

(d) it has adequate structural redundancy to survive in the event that the structure is accidentally damaged; for example, minor impact leading to flooding of any compartment.

4.2 Loads

4.2.1 Load scenarios

4.2.1.1 The loads used for assessment of the structure covers the load scenarios encountered by the ship during operation at sea and in harbour.

4.2.2 Design load combinations

4.2.2.1 Design load combinations combine local and global load components to represent identified load scenarios. The design load combinations should be sufficiently severe and varied so as to encompass all scenarios that can reasonably occur during normal operation.

4.2.2.2 The design load combinations for the hull and structural members consider the most unfavourable combination of load effects in order to maintain a consistent safety level for all combinations.

4.2.2.3 The design load combinations are based on one of the following combinations of static and dynamic loads depending on the type of load and the load scenario being considered:

(a) Static design load combinations (S)
covers application of all relevant static loads and typically covers load scenarios in harbour, tank testing or similar operations

(b) Static plus Dynamic design load combination (S+D)
covers application of all relevant static loads plus a realistic combination of simultaneously occurring dynamic load components and typically covers load scenarios for seagoing operations

(c) Impact design load combination
covers application of impact loads such as bottom slamming and bow impact encountered during seagoing operation. It is usually sufficient to ignore other static and dynamic load components in association with an impact load event.

(d) Sloshing design load combination
covers application of sloshing loads encountered during seagoing operations

(e) Fatigue design load
covers application of all relevant dynamic loads

(f) Accidental design load combination (A)
covers application of accidental loads where these loads are not considered as occurring during normal operations

4.2.3 Load categorisation

4.2.3.1 The design load combinations are composed of many different types of loads, which are categorised as shown in *Table 2.4.1.*

Table 2.4.1
Load Categorisations

Operational Loads	Lightship weight	Steel weight and outfit Machinery and permanent equipment
	Buoyancy loads	Buoyancy of the ship
	Variable loads	Cargo Ballast water Stores and consumables Personnel Temporary equipment
	Other loads	Tug and berthing loads Towing loads Anchor and mooring loads Lifting appliance loads
Environmental loads	Cyclic loading due to wave action including inertia loads	Dynamic wave pressures
		Dynamic loads and dynamic tank pressures due to ship accelerations
	Impact loads or resonant loads	Wave impacts Bottom slamming Liquid sloshing in tanks Green sea loads
Accidental loads		Flooding of compartments
Deformation loads		Thermal loads Deformations due to construction

4.2.3.2 Operational loads generally are static loads. They are grouped into lightship weight, buoyancy loads, variable loads and other loads. The operational loads occur as a consequence of the operation and handling of the ship.

4.2.3.3 Environmental loads are dynamic loads due to external influences. The environmental loads covered by the Rules are loads due to wave action.

4.2.3.4 Accidental loads include loads that result as a consequence of an accident or operational mishandling of the ship. The accidental loads covered by the Rules are increased tank pressures due to flooding of compartments.

4.2.3.5 Deformation loads are caused by thermal loads and residual stresses. The load effects from deformation loads are not covered by the Rules.

4.2.4 Characteristic load values

4.2.4.1 The characteristic values of the load components that are applied in the Rules are dependant on the design load combination being considered. The characteristic loads are typical values and are given by:

(a) for operational loads the characteristic loads are the expected or specified values

(b) for environmental loads the characteristic load is typically a load value which has a low probability of occurrence, i.e. an 'extreme' value.

4.2.5 Operational loads

4.2.5.1 The characteristic values of the static sea pressure on the hull due to the buoyancy are based on the draught at the loading condition under consideration.

4.2.5.2 The characteristic values of the static tank pressure are based on the filling height and the specific gravity of the cargo/ballast, and include allowances for possible overpressure due to the height of air pipes, pressure relief valve settings and capacity of pumps.

4.2.5.3 The characteristic values of the loads due to personnel, stores and consumables, temporary equipment and permanent equipment are based on specified values.

4.2.5.4 The characteristic values for tug, berthing, towing and mooring loads are based on specified values.

4.2.6 Environmental loads

4.2.6.1 The Rule formulations for wave loads, as given in *Section 7/3*, are based on the envelope values calculated in accordance with *4.2.6.2* and calibrated with feedback from service experience and model tests.

4.2.6.2 The general principles for the derivation of the wave load values are:

(a) the application of load values is consistent for all similar load scenarios

(b) the characteristic load value is selected to suit the purpose of the application of the load and the selected structural assessment method, e.g. for strength assessment the expected lifetime maximum load is applied while for fatigue assessment an average value representing the expected load history is applied

(c) load calculations are performed using 3-D linear hydrodynamic computational tools. The effects of speed are considered

(d) the derivation of characteristic wave loads is based on a long term statistical approach which includes representation of the wave environment (North Atlantic scatter diagram), probability of ship/wave heading and probability of load value exceedance based on IACS Rec. 34. All of which result in envelope values

(e) non-linear effects are considered for the expected lifetime maximum loads.

4.2.6.3 The combination of dynamic loads considers all simultaneously occurring dynamic load components. In deriving the simultaneously occurring loads, one particular load component is maximised or minimised and the relative magnitude of all simultaneously occurring dynamic load components is specified by the application of dynamic load combination factors (DLCF) based on the envelope load value. These dynamic load combination factors are based on the application of the equivalent design wave approach and are given as tabulated values.

4.2.6.4 The formulations of the load values for bottom slamming, bow impact loads and green sea loads take account of the following factors:

(a) vessel draught

(b) hull form

(c) heading

(d) forward speed

(e) location of deck houses/superstructure

(f) geometry of structural elements.

4.2.6.5 A slamming impact load results in a transient dynamic response in the structure. The formulation of the impact loads considers the impact load as an equivalent static load acting on the associated exposed hull surface.

4.2.6.6 The effect of green water on the deck structure along the entire vessel's length is considered. The green water loads on fore and parallel mid bodies of a ship are

determined based on model tests, ship motion analysis and service experience. The green sea loads for the aft body are consistent with the derivation for the fore and mid body green sea loads.

4.2.7 Accidental loads

4.2.7.1 The accidental load scenarios cover loads acting on local structure as a consequence of flooding in accordance with the assumptions made in IMO regulations. This relates to the assessment of the watertight subdivision boundaries.

4.2.7.2 Only static loads corresponding to the draught in the flooded condition are considered.

4.2.8 Deformation loads

4.2.8.1 Thermal loads within the limits specified by the design basis are considered negligible. It is assumed that care is taken to account for, and allow for, expected thermal expansion.

4.3 Structural Capacity Assessment

4.3.1 General

4.3.1.1 The basic principle in structural design is to apply the defined design loads, identify possible failure modes and employ appropriate capacity models to determine the required structural scantlings.

4.3.2 Capacity models for strength

4.3.2.1 The strength assessment method is to be capable of analysing the failure mode in question to the required degree of accuracy. Several assessment methods may be applicable, even for the same failure modes.

4.3.2.2 The following aspects are the basis for selection of strength capacity models:

(a) whether the structural member is also assessed at a higher level in the hierarchy and/or at a later stage by more accurate methods or by more accurate response calculations

(b) simplified capacity models where some of the stress components are neglected are to always give conservative results

(c) appropriate methodology to assess the failure mode

(d) probability level of the load

(e) capability of response calculations to represent the physical behaviour of the structure up to the given load level

(f) complexity of structure

(g) complexity of loads

(h) criticality of the structural member. This will primarily have an impact on the assessment criteria, but needs to be considered in conjunction with selection of the appropriate methodology for structural assessment.

4.3.2.3 The structural capacity assessment methods are in either a prescriptive format or require the use of more advanced calculations such as finite element analysis methods.

4.3.2.4 The formulae used to determine stresses, deformations and capacity are appropriate for the selected capacity assessment method and the type and magnitude of the design load set.

4.3.3 Capacity models for fatigue

4.3.3.1 The fatigue assessment method provides Rule requirements to safeguard structural details against fatigue failure.

4.3.3.2 The fatigue capacity model is based on a linear cumulative damage summation (Palmgren-Miner's rule) in combination with S-N curves, a characteristic stress range and an assumed long-term stress distribution curve.

4.3.3.3 The fatigue capacity assessment models are in either a prescriptive format or require the use of more advanced calculations such as finite element analysis methods. These methods account for the combined effects of global and local dynamic loads.

4.3.4 Net thickness approach

4.3.4.1 The philosophy behind the net thickness approach is to:

(a) provide a direct link between the thickness used for strength calculations during the new building stage and the minimum thickness accepted during the operational phase

(b) enable the status of the structure with respect to corrosion to be clearly ascertained throughout the life of the ship.

4.3.4.2 The net thickness approach distinguishes between local and global corrosion. Local corrosion is defined as uniform corrosion of local structural elements, such as a single plate or stiffener. Global corrosion is defined as the overall average corrosion of larger areas such as primary support members and the hull girder. Both the local and overall corrosion are used as a basis for the new building review and are to be confirmed during operation of the vessel.

4.3.4.3 The net thickness approach for the local corrosion is shown in *Figure 2.4.1 (a)* and is in terms of new building thicknesses, given by:

(a) the local strength requirements are given by the net thickness ($t_{net\text{-}req}$) after rounding

(b) the required gross thickness ($t_{grs\text{-}req}$) is given by adding the corrosion addition (t_{corr}) to the required rounded net thickness ($t_{net\text{-}req}$)

(c) the gross thickness (t_{grs}) is the actual thickness selected by the designer to fulfil the gross required thickness($t_{grs\text{-}req}$) and is to be equal or greater than the required gross thickness ($t_{grs\text{-}req}$)

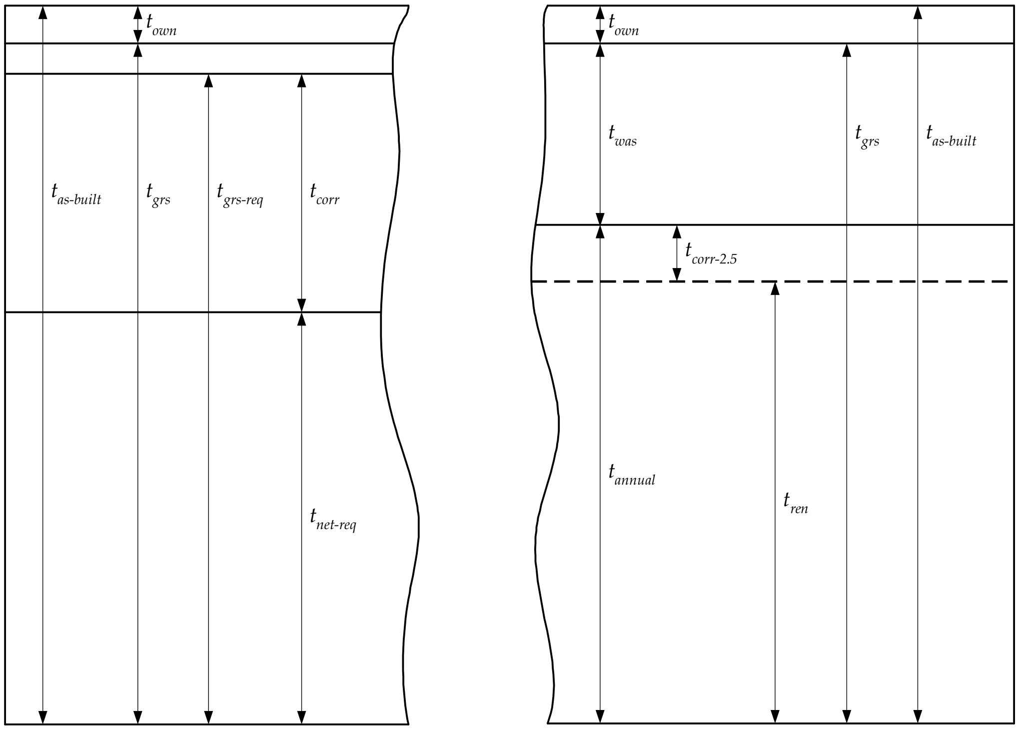
(d) the as built thickness is equal to the gross thickness (t_{grs}) plus any additional owners extra margin (t_{own})

(e) any additional thicknesses specified by the owner, as owners extra margin (t_{own}) are not to be included in the assessment of the required gross thickness ($t_{grs\text{-}req}$).

Figure 2.4.1
Net Thickness Approach for Local Wastage

(a) application to scanting requirements

(b) application to ship in operation requirements



4.3.4.4 The net thickness approach for determining the local renewal thickness during the ship in operation phase is shown in *Figure 2.4.1 (b)* and is given by:

(a) the thickness at which annual surveys are required, t_{annual}, is obtained by subtracting the total wastage allowance (t_{was}) and the owners extra margin (t_{own}) from the as-built thickness ($t_{as\text{-}built}$)

(b) thickness at which renewal is required, t_{ren}, is obtained by subtracting the total wastage allowance (t_{was}), the thickness $t_{corr\text{-}2.5}$ and the owners extra margin (t_{own}) from the as-built thickness ($t_{as\text{-}built}$). Where $t_{corr\text{-}2.5}$ is the wastage allowance in reserve for corrosion occurring in the two and half years between Intermediate and Special surveys

(c) the total wastage allowance given is the rule specified wastage allowance (t_{was}) plus the wastage allowance in reserve ($t_{corr\text{-}2.5}$) plus any additional owners extra margin (t_{own})

(d) the rule specified wastage allowance (t_{was}) available before annual surveys are required is obtained by deducting the thickness $t_{corr\text{-}2.5}$ from the corrosion addition (t_{corr}).

The approach calls for a general 2.5 year survey interval when the gauged thickness is greater than the “thickness at which annual surveys are required” (t_{annual}), and a 1 year survey interval when the gauged thickness is less than the “thickness at which annual surveys are required” (t_{annual}).

4.3.4.5 The overall average corrosion for primary support members and the hull girder cross-section is given by deducting half the local corrosion addition ($0.5t_{corr}$) from all structural elements comprising the respective cross-sections.

4.3.4.6 The assessment of local scantlings is performed based on the hull girder stresses given by the net hull girder properties, e.g. based on a global overall average

corrosion of the hull girder, and the local stresses based on the net thickness of the local member under consideration, e.g. based on full local corrosion. It is assumed that the structure may corrode locally to the maximum allowed and that the hull girder may reduce to the maximum allowed overall hull girder corrosion.

4.3.4.7 The assessment of global (hull girder and primary support member) scantlings is based on the overall global corrosion, e.g. half the full local corrosion for all structural members simultaneously. The assumption is that the full local corrosion will not occur globally and hence a lesser average value of assumed corrosion is appropriate. Individual structural elements may corrode to the maximum corrosion addition and this is taken into account in the buckling assessment.

4.3.4.8 As fatigue is an accumulative assessment the scantlings and stresses used for the assessment are to be taken as the representative mean value over the design life. The mean corrosion over the design life is given as half the corrosion assumed for scantling strength assessment. Local stresses are thus calculated based on half the full local corrosion addition and hull girder stresses are calculated based on half the overall global corrosion. Half the global overall corrosion is found by deduction of one quarter of the full local corrosion addition of all structural elements simultaneously.

4.3.4.9 The actual amount of wastage allowed in service is taken as:

(a) locally: the full corrosion addition less an amount for typical wastage between the survey periods

(b) globally: the full global overall corrosion addition less an amount for typical wastage between the survey periods. The global wastage is monitored in service by evaluating the current global characteristics of the vessel.

4.3.5 Intact structure

4.3.5.1 All strength calculations are based on the assumption that the structure is intact. The residual strength of the ship in a structurally damaged condition is not assessed.

4.3.5.2 No benefit is given in the assessment of structural capability for the presence of coatings or similar corrosion protection systems.

4.4 Materials and Welding

4.4.1 Materials

4.4.1.1 The Rule requirements associated with the selection of materials for structural components is based on the location, design temperature (see *3.1.7.4* and *3.1.8.4)*, membrane, through thickness forces and criticality of the component. The requirements comply with *IACS UR S6.*

4.4.1.2 The Rule requirements are based on the assumption that the material is manufactured in accordance with the allowable under thickness rolling tolerances specified in *IACS UR W13*.

4.4.2 Welding

4.4.2.1 The Rule requirements for weld type, size and materials are based on the following considerations:

(a) joint type

(b) criticality of the joint

(c) magnitude, type and direction of the stresses in the joint

(d) material properties of the parent and weld material

(e) weld gap size.

4.5 Assessment/Acceptance Criteria

4.5.1 Design methods

4.5.1.1 The criteria for the assessment of the scantlings are based on one of the following design methods:

(a) Working Stress Design (WSD) method, also known as the permissible or allowable stress method

(b) Partial safety Factor (PF) method, also known as Load and Resistance Factor Design (LRFD).

4.5.1.2 For both WSD and PF, two design assessment conditions and corresponding acceptance criteria are given. These conditions are associated with the probability level of the combined loads, A and B:

(a) condition A is applicable to design load combinations based on 'expected' characteristic load values, typically covered by the static design load combinations

(b) condition B is applicable to design load combinations based on 'extreme' characteristic load values, typically covered by the static + dynamic load combinations.

4.5.1.3 The WSD method has the following composition:

$$W_{stat} \le \eta_1 R \quad \text{for condition A}$$

$$W_{stat} + W_{dyn} \le \eta_2 R \quad \text{for condition B}$$

Where:

W_{stat} simultaneously occurring static loads (or load effects in terms of stresses)

W_{dyn} simultaneously occurring dynamic loads. The dynamic loads are typically a combination of local and global load components

R characteristic structural capacity (e.g. yield stress or buckling capacity)

η_i permissible utilisation factor (resistance factor). The utilisation factor includes consideration of uncertainties in loads, structural capacity and the consequence of failure

4.5.1.4 The PF method has the following composition:

$$\gamma_{stat-1} W_{stat} + \gamma_{dyn-1} W_{dyn} \le \frac{R}{\gamma_R} \quad \text{for condition A}$$

$$\gamma_{stat-2} W_{stat} + \gamma_{dyn-2} W_{dyn} \le \frac{R}{\gamma_R} \quad \text{for condition B}$$

Where:

γ_{stat-i} partial safety factor that accounts for the uncertainties related to static loads

W_{stat}	simultaneously occurring static loads (or load effects in terms of stresses)
γ_{dyn-i}	partial safety factor that accounts for the uncertainties related to dynamic loads
W_{dyn}	simultaneously occurring dynamic loads. The dynamic loads are typically a combination of local and global load components
R	characteristic structural capacity (e.g. yield stress, ultimate hull girder stress)
γ_R	partial safety factor that accounts for the uncertainties related to structural capacity

4.5.1.5 The acceptance criteria for both the WSD method and PF method are calibrated for the various requirements such that consistent and acceptable safety level for all combinations of static and dynamic load effects are achieved.

4.6 Principle of Safety Equivalence

4.6.1 General

4.6.1.1 Novel designs deviating from the design basis or structural arrangements covered by the Rules will be subject to special consideration. The principle of equivalence is to be applied to the novel design, hence it must be demonstrated that the structural safety of the novel design is at least equivalent to that intended by the Rules.

4.6.1.2 The principle of equivalence may be applied to alternative calculation methods.

4.6.1.3 A systematic review process was undertaken in developing these Rules. This identified and evaluated the likely consequences of hazards due to operational and environmental influences on tanker structural configurations and arrangements covered by these Rules. For novel designs, dependent on the nature of the deviation, it may be necessary to conduct an independent systematic review to document equivalence with the Rules.

5 APPLICATION OF PRINCIPLES

5.1 Overview of the Application of Principles

5.1.1 General

5.1.1.1 This Sub-Section shows how the design principles described in *Sub-Section 4* have been applied in the development of the rule requirements.

5.2 Structural Design Process

5.2.1 Overview of the structural design process

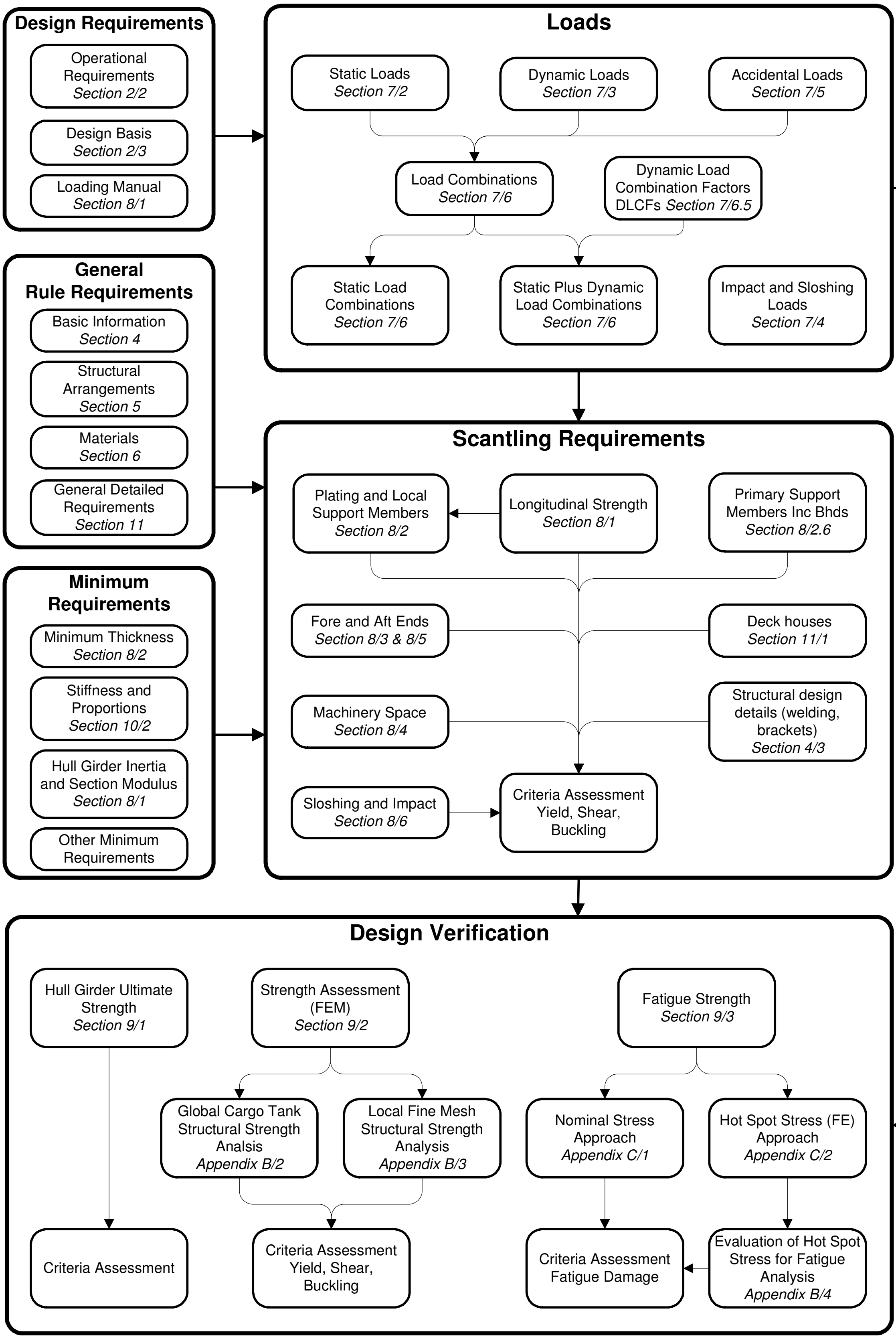
5.2.1.1 An overview of the structural design process applied in the Rules is shown in *Figure 2.5.1*.

5.2.1.2 The strength and acceptable safety of the hull and the structural elements is verified through the application of the following Rule requirements:

(a) prescriptive scantling requirements
- minimum requirements
- load-capacity based requirements

(b) design verification requirements based on load-capacity methods
- hull girder ultimate strength
- strength assessment using the Finite Element (FE) analysis
- fatigue assessment

Figure 2.5.1
Overview of Structural Design Process



5.3 Minimum Requirements

5.3.1 General

5.3.1.1 The minimum requirements are usually in one of the following forms:

(a) minimum thickness, which is independent of the yield stress, these are based on service experience and are usually expressed in the following format:

$t = A + B\,L$

Where:

A, B constants

L rule length, as defined in *Section 4/1.1.1.1*

(b) minimum stiffness and proportion, which are based on prescriptive buckling requirements

5.4 Load-capacity Based Requirements

5.4.1 General

5.4.1.1 In general, the Working Stress Design (WSD) method is applied in the requirements, except for the hull girder ultimate strength criteria where the Partial safety Factor (PF) method is applied. The partial safety factor format is applied for this highly critical failure mode to better account for uncertainties related to static loads, dynamic loads and capacity formulations.

5.4.1.2 The identified load scenarios are addressed by the Rules in terms of design loads, design format and acceptance criteria set, as given in *Table 2.5.3*. The table is schematic and only intended to give an overview.

5.4.1.3 The load scenarios addressed by the rules cover operations such as seagoing conditions, loading and unloading, tank testing conditions, ballast water exchange situations, special operations in harbour (e.g. propeller inspection afloat condition) and accidental flooding.

5.4.1.4 The design load combinations that represent the identified load scenarios are given in *Section 7/6* and are denoted by S (static loads), S+D (static+dynamic loads), and A (accidental loads). In addition, the Rules address impact loads and sloshing loads as given in *Section 7/4* and fatigue loads as given in *Section 7/3*.

5.4.1.5 For the strength requirements, the considered loads cover the most severe operational loads that occur, hence the cargo tank finite element analysis and load-capacity based scantling requirements are based on rule loading conditions which simulate the worst possible loading conditions within the operating limits of the vessel.

5.4.1.6 For the fatigue requirements the considered loads cover an expected load history and representative loading conditions covering the ships' intended service are applied.

5.4.1.7 The acceptance criteria are categorised into three acceptance criteria sets. These are explained below and shown in *Tables 2.5.2* and *2.5.3*. The specific acceptance criteria set that is applied in the WSD rule requirements is dependent on the probability level of the characteristic combined load.

5.4.1.8 The acceptance criteria set AC1 is applied when the combined characteristic loads are frequently occurring, typically for the static design load combinations, but also applied for the sloshing design loads. This means that the loads occur on a frequent

or regular basis. The allowable stress for a frequent load is lower than for an extreme load to take into account effects of:

(a) repeated yield

(b) allowance for some dynamics

(c) margins for operational mistakes.

5.4.1.9 The acceptance criteria set AC2 is typically applied when the combined characteristic loads are extreme values, e.g. typically for the static+dynamic design load combinations. High utilisation (η_i in *Table 2.5.1*) of the structural capacity (R_i in *Table 2.5.1*) is allowed in such cases because the considered loads are extreme loads with a low probability of occurrence.

5.4.1.10 The acceptance criteria set AC3 is typically applied for capacity formulations based on the plastic collapse models such as those that are applied to address bottom slamming and bow impact loads.

Table 2.5.1
Load Scenarios and Corresponding Rule Requirements

Load Scenarios		Rule Requirements			
Operation	**Loads** (that the vessel is exposed to and is to withstand)	**Design Load Combination** (specified in *Section 7/6*) **Ref. no**	**Notation**	**Design Format** (specified in *Sections 8* and *9*) see Note 1	**Acceptance Criteria Set** (specified in *Sections 8* and *9*)
Seagoing operations					
Transit	Static and dynamic loads in heavy weather	1	S + D	1. $S_G + S_L + D_G + D_L \leq \eta_2 R_1$	AC2
				2. $\gamma_S S_G + \gamma_D D_G \leq R_2/\gamma_{R2}$	AC2
	Impact loads in heavy weather	2	Impact	$S_L + D_{imp} \leq \eta_3 R_p$	AC3
	Internal sloshing loads	3	Sloshing	$S_G + D_{slh} \leq \eta_1 R_1$	AC1
	Cyclic wave loads	4	Fatigue	$DM \leq \Sigma\eta_i / N_i$	-
BWE by flow through or sequential methods	Static and dynamic loads in heavy weather	5	S + D	$S_G + S_L + D_G + D_L \leq \eta_2 R_1$	AC2
Harbour and sheltered operations					
Loading, unloading and ballasting	Typical maximum loads during loading, unloading and ballasting operations	6	S	$S_G + S_L \leq \eta_1 R_1$	AC1
Tank testing	Typical maximum loads during tank testing operations	7	S	$S_G + S_{L1} \leq \eta_1 R_1$	AC1
Special conditions in harbour	Typical maximum loads during special operations in harbour, e.g. propeller inspection afloat or dry-docking loading conditions	8	S	$S_G + S_L \leq \eta_1 R_1$	AC1
Accidental condition					
Accidental flooding	Typically maximum loads on internal watertight subdivision structure due to accidental flooding	9	A	for water tight boundaries 1. $S_L \leq \eta_2 R_1$	AC2
				for collision bulkhead 2. $S_L \leq \eta_1 R_1$	AC1
Note 1. The symbols defined in this column are defined in the text of *5.4*					

Where:

D_G	dynamic global load
D_L	dynamic local load
DM	cumulative fatigue damage ratio
S_G	static global load
S_L	static local load
R_i	structural capacity

5.4.2 Design loads for scantling requirements and strength assessment (FEM)

5.4.2.1 The structural assessment of compartment boundaries, e.g. bulkheads, is based on the worst possible loading, hence conditions are assessed with a full tank on one side and an empty tank on the other side. The situation with the tank content reversed is also considered. Similarly the shell envelope is assessed for conditions at the deepest draught without internal filling and at the lowest draught with internal filling.

5.4.2.2 The standard loading patterns to be used in the strength assessment (FEM) are given in *Appendix B*, *Tables B.2.3* and *B.2.4* for tankers with two oil-tight longitudinal bulkheads and one centreline oil-tight longitudinal bulkhead respectively. The corresponding information for the scantling requirements is given in *Section 8*.

5.4.2.3 To ensure consistency of approach, standardised rule values for parameters such as GM, R_{roll}, T_{sc} and C_b. are applied to calculate the rule load values.

5.4.2.4 The probability level of the dynamic global and local loads (D_G, D_L and D_{imp} in *Table 2.5.1*) is 10^{-8} and are derived using the long term statistical approach specified in *4.2.6.2*.

5.4.2.5 The probability level of the sloshing loads (D_{slh} in *Table 2.5.1*) is 10^{-4} which is a load that occurs frequently.

5.4.2.6 The design load combinations corresponding to the identified load scenarios produce realistic design load sets suitable for the design and verification of the structural capability. Design load sets apply all the applicable simultaneously acting static and dynamic local load components (S_L and D_L in *Table 2.5.1*, which are usually pressure load components) and static and dynamic global load components (S_G and D_G in *Table 2.5.1*, which is usually hull girder bending moment) for the design of a particular or group of structural members. The relevant design load sets for the scantling requirements are given in *Sections 8/2* to *8/5*. The design load sets for the Finite Element analysis are referred to as load cases and are given in *Appendix B*.

5.4.2.7 The simultaneously occurring dynamic loads are specified by applying a dynamic load combination factor to the envelope dynamic load values given in *Section 7/3.* The dynamic load combination factors that define the dynamic load cases are given in *Section 7/6.4* for the structural strength assessment (FE) and in *Section* 7/*6.5* for the scantling requirements.

5.4.2.8 The dynamic load combination factors have been derived using the equivalent design wave approach to provide realistic simultaneously occurring dynamic loads components suitable for structural assessment.

5.4.2.9 For the determination of design loads for the hull girder ultimate strength requirement given in *Section 9/1*, the operational loads (i.e. ship loading conditions) and the environmental loads (i.e. hull girder wave bending moments) are maximised for sagging conditions for seagoing conditions. The characteristic value for the still water hull girder sagging bending moments M_{sw} is based on the maximum value from the seagoing conditions specified in *Section 8/1*. The characteristic value for the wave hull girder sagging bending moments M_{WV} is given in *Section 7/3.*

5.4.3 Design loads for fatigue requirements

5.4.3.1 For the fatigue requirements given in *Section 9/3* and *Appendix C*, the load assessment is based on the expected load history and an average approach is

applied. The expected load history for the design life is characterised by the 10^{-4} probability level of the dynamic load value, the load history for each structural member is represented by Weibull probability distributions of the corresponding stresses.

5.4.3.2 The considered wave-induced loads include:

(a) hull girder loads (i.e., vertical and horizontal bending moments)

(b) dynamic wave pressures

(c) dynamic tank pressures.

5.4.3.3 The fatigue analysis is calculated for two representative loading conditions covering the ship's intended operation. These two conditions are:

(a) full load homogeneous conditions at design draught

(b) normal ballast condition.

The proportion of the ship's sailing life in the full load condition is 50% and in ballast 50%. It is assumed that 15% of the ships' life is in harbour/sheltered water. It is consequently assumed that the ship will be sailing in open waters in full load condition for 42.5% of the ship's life and in the ballast condition for 42.5% of the ship's life.

5.4.3.4 The load values are based on actual parameters corresponding to the applied loading conditions, e.g. *GM*, C_b, etc., and the applicable draughts at amidships is used. The actual values are taken from specified loading conditions in the loading manual.

5.4.3.5 The simultaneously occurring dynamic loads are accounted for by combination of stresses due to the various dynamic load components. The stress combination procedure is given in *Appendix C*.

5.4.3.6 Still water loads and static sea and tank pressures from the actual loading conditions are used to determine the mean stress effect.

5.4.4 Structural response analysis

5.4.4.1 In general, the following approaches are applied for determination of the structural response to the applied design load combinations

(a) Beam theory

- used for prescriptive requirements

(b) FE analysis

- coarse mesh for cargo hold model
- fine mesh for local models
- very fine mesh for fatigue assessment

5.4.5 Structural capacity assessment

5.4.5.1 The considered failure modes in the Rules are yield (plastic deformation), buckling, brittle fracture and fatigue. Structural failure due to yield and buckling is primarily controlled by the strength requirements, brittle fracture is primarily controlled by the requirements for material selection and welding, and fatigue failure is primarily controlled by the high cycle fatigue requirements.

5.4.5.2 Generally, the capacity models applied in the prescriptive rules, i.e., the scantling requirements in *Section 8*, are based on simple beam theory and include elastic yield and plastic capacity models. The buckling capacity is assessed using simplified buckling capacity models or by a more theoretical non-linear analysis procedure.

5.4.5.3 The design verification requirements are based on a linear elastic finite element analysis, a detailed prescriptive fatigue assessment procedure and a simplified ultimate strength assessment procedure. There is also a finite element based fatigue assessment procedure for some structural members, such as the hopper knuckle.

5.4.5.4 The application of the net thickness approach to assess the structural capacity is specified in *Section 6/3.3*.

5.4.6 Acceptance criteria

5.4.6.1 The acceptance criteria applied in the working stress design requirements are given as acceptance criteria sets shown in *Tables 2.5.2* and *2.5.3.* There are slight variations within each set depending on the relative contribution of local and global loads, static and dynamic loads and the structural member being considered. The specific acceptance criteria are given in the detailed rule requirements in *Section 8* and *9/2*.

Table 2.5.2
Principal Acceptance Criteria - Rule Requirements

	Plate panels and Local Support Members		Primary Support Members		Hull girder members	
Acceptance criteria set	Yield	Buckling	Yield	Buckling	Yield	Buckling
AC1:	70-80% of yield stress	Control of stiffness and proportions. Usage factor typically 0.8	70-75% of yield stress	Control of stiffness and proportions. Pillar buckling	75% of yield stress	NA
AC2:	90-100% of yield stress	Control of stiffness and proportions. Usage factor typically 1.0	85% of yield stress	Control of stiffness and proportions. Pillar buckling	90-100% of yield stress	Usage factor typically 0.9
AC3:	Plastic criteria	Control of stiffness and proportions	Plastic criteria	Control of stiffness and proportions	NA	NA

Table 2.5.3
Principal Acceptance Criteria - Design Verification - FE Analysis

	Global cargo tank analysis		Local fine mesh analysis
Acceptance criteria set	**Yield**	**Buckling**	**Yield**
AC1:	60-80% of yield stress	Control of stiffness and proportions. Usage factor typically 0.8	local mesh as 136% of yield stress averaged stresses as global analysis
AC2:	80-100% of yield stress	Control of stiffness and proportions. Usage factor typically 1.0	local mesh as 170% of yield stress averaged stresses as global analysis

5.4.6.2 The purpose of applying different sets is to achieve a consistent and acceptable safety level for all combinations of static and dynamic loads and to account for different capacity models.

5.5 Materials

5.5.1 General

5.5.1.1 Higher material properties are selected for highly critical structural elements which are subjected to high loads in order to reduce the risk of propagation of brittle fracture.

5.6 Application of Rule Requirements

5.6.1 Minimum requirements

5.6.1.1 These specify the minimum scantling requirements which are to be applied irrespective of all other requirements, hence thickness below the minimum are not allowed.

5.6.2 Load based prescriptive requirements

5.6.2.1 These provide scantling requirements for all plating, local support members, most primary support members and the hull girder and cover all structural elements including deckhouses, foundations for deck equipment, etc.

5.6.2.2 In general, these requirements explicitly control one particular failure mode and hence several requirements may be applied to assess one particular structural member.

5.6.3 Design verification - hull girder ultimate strength

5.6.3.1 The requirements for the ultimate strength of the hull girder are based on a Partial safety Factor (PF) method, see *4.5*. A safety factor is assigned to each of the basic variables, the still water bending moment, wave bending moment and ultimate capacity. The safety factors were determined using a structural reliability assessment approach, the long term load history distribution of the wave bending moment was derived using ship motion analysis techniques suitable for determining extreme wave bending moments.

5.6.3.2 The purpose of the hull girder ultimate strength verification is to demonstrate that one of most critical failure modes of a double hull tanker is controlled.

5.6.4 Design verification - global finite element analysis

5.6.4.1 The global finite element analysis is used to verify the scantlings given by the load-capacity based prescriptive requirements. The analysis is required because the prescriptive requirements do not take into account the complex interactions between the ship's structural components, complex local structural geometry, change in thicknesses and member section properties as well as the complex load regime with sufficient accuracy. Hence the global finite element analysis is necessary to verify the proposed scantlings.

5.6.4.2 A linear elastic three dimensional finite element analysis of the cargo region (a FE model length of three tanks is required) is carried out to assess and verify the structural response of the proposed hull girder and primary support members and assist in specifying the scantling requirements for the primary support members. The purpose with the finite element analysis is to verify that the stresses and buckling capability of the primary support members are within acceptable limits for the applied design loads.

5.6.5 Design verification - fatigue assessment

5.6.5.1 The fatigue assessment is required to verify that the fatigue life of critical structural details is adequate. A prescriptive fatigue requirement is applied to details such as end connections of longitudinal stiffeners using an SN curve approach based on geometric details, i.e. Class F, F2, etc. A hot spot fatigue assessment procedure using finite element analysis is applied to details such as the hopper knuckle. In both cases, the fatigue assessment method is based on the Palmgren-Miner linear damage model.

5.6.6 Relationship between the prescriptive scantling requirements and the strength assessment (FEM)

5.6.6.1 The prescriptive minimum requirements define the minimum acceptable scantlings. These may not to be reduced by any form of alternative calculations such as load-capacity prescriptive requirements or strength analysis such as FEM.

5.6.6.2 The section modulus and/or shear area of a primary support member and/or the cross sectional area of a primary support member cross tie may be reduced to 85% of the prescriptive requirements provided that the reduced scantlings comply with the strength assessment (FEM).

5.6.6.3 The philosophy is that a coarse approach should be more conservative than a detailed approach. Hence, the prescriptive requirements are generally more conservative than the corresponding requirements based on strength assessment (FEM).

SECTION 3

RULE APPLICATION

1 NOTATIONS

1.1 Notations

1.1.1 General

1.1.1.1 Ships fully complying with the requirements of these Rules and the specific requirements of the assigning Classification Society relating to construction, survey and equipment will be eligible to be assigned with character symbols and a ship type notation appropriate to the assigning Classification Society.

1.1.1.2 In addition to *1.1.1.1*, ships fully complying with the requirements of these Rules will also be assigned the notation **CSR**.

2 DOCUMENTATION, PLANS AND DATA REQUIREMENTS

2.1 Documentation and Data Requirements

2.1.1 Loading information

2.1.1.1 Loading guidance information containing sufficient information to enable the master of the ship to maintain the ship within the stipulated operational limitations is to be provided onboard the ship. The loading guidance information is to include an approved loading manual and loading computer system complying with the requirements given in *Sections 8/1.1.2* and *8/1.1.3* respectively.

2.1.2 Submission of calculation data and results

2.1.2.1 Where calculations have been carried out in accordance with the procedures given in the Appendices of these Rules, one copy of the following supporting information is to be submitted as applicable:

(a) reference to the calculation procedure and technical program used

(b) a description of the structural modelling

(c) a summary of the analysis parameters including properties and boundary conditions

(d) details of the loading conditions and the means of applying loads

(e) a comprehensive summary of calculation results

(f) sample calculations where appropriate.

2.1.2.2 In general, submission of large volumes of input and output data associated with programs, such as finite element analysis, will not be required.

2.1.2.3 The responsibility for error free specification and input of program data and the subsequent correct transposal of output resides with the designer.

2.1.3 Use of computer software for rule calculations

2.1.3.1 In general, any rule computation program recognised by the Classification Society may be employed to determine scantlings according to these Rules provided the implementation given in *5.1* is complied with.

2.1.3.2 A computer program that has been demonstrated to produce reliable results to the satisfaction of the Classification Society is regarded as a recognised program. Where the computer programs employed are not supplied or recognised by the Classification Society, full particulars of the computer program, including example calculation output, are to be submitted. It is recommended that the designers consult the Classification Society on the suitability of the computer programs intended to be used prior to the commencement of any analysis work.

2.2 Submission of Plans and Supporting Calculations

2.2.1 General

2.2.1.1 In general, the main categories and lists of information required are given in *2.2.2*. Additional requirements for some items are also given in subsequent sections as applicable.

2.2.1.2 Plans are generally to be submitted in triplicate, but one copy only is necessary for supporting documents and calculations. Additional copies may be required according to the individual Classification Society requirements.

2.2.1.3 Plans are to contain all necessary information to fully define the structure, including construction details, materials, welding and loads imposed on the structure by equipment and systems as appropriate.

2.2.1.4 Plans are to include information related to the renewal thickness as specified in *Section 12*.

2.2.2 Plans and supporting calculations

2.2.2.1 In general, plans covering the following items are to be submitted:

(a) main scantling plans:
- midship sections showing longitudinal and transverse structural members
- construction profiles/plans showing all main longitudinal structural elements along the ships length including decks, inner bottom, bulkheads, double side stringers and double bottom girders
- shell expansion
- main oil-tight and watertight transverse bulkheads including primary support members

(b) loading guidance information:
- preliminary loading manual
- final loading manual
- details of the design basis, see *Section 8/1.1.2*
- test conditions for the loading instrument

(c) detailed construction plans:
- cargo tank construction plans showing the variations in detail arrangements and scantlings of double bottom floors, double side webs and other transverse primary support members
- fore end
- aft end
- engine room construction including the engine and thrust bearing seating
- deckhouses and superstructures

(d) detail design plans except where the information is already included on plans listed in (a) and (c):
- sternframe
- hull penetration plans
- welding
- bilge keels
- booklet of standard design details
- anchoring and mooring equipment
- pillar and girder support arrangements for decks
- access arrangements through double bottom and side skin spaces in the cargo tank region
- details and arrangements of openings and attachments to the hull structure for means of access for inspection purposes

(e) plans detailing support structures except where the information is already included on plans listed in (a) to (d):

- anchoring windlass and chain stopper
- mooring winches
- masts, derrick posts or cranes
- emergency towing equipment
- other deck equipment or fittings

2.2.2.2 The following supporting documents are to be submitted:

(a) general arrangement

(b) capacity plan

(c) lines plan or equivalent

(d) dry-docking plan, where developed

(e) freeboard plan or equivalent, showing freeboards and items relative to the conditions of assignment

2.2.2.3 The following supporting calculations are to be submitted:

(a) calculation of the equipment number.

2.2.2.4 Plans of items not covered by these Rules are to be submitted according to the individual Classification Society requirements.

2.2.3 Plans to be supplied onboard the ship

2.2.3.1 One copy of the following plans indicating the new-building and renewal thickness for each structural item:

(a) main scantling plans as given in *2.2.2.1(a)*

(b) one copy of the final approved loading manual, see *2.1.1*

(c) one copy of the final loading instrument test conditions, see *Section 8/1.1.3*

(d) detailed construction plans as given in *2.2.2.1(c)*

(e) welding

(f) details of the extent and location of higher tensile steel together with details of the specification and mechanical properties, and any recommendations for welding, working and treatment of these steels

(g) details and information on use of special materials, such as aluminium alloy, used in the hull construction.

(h) towing and mooring arrangements plan, see *Section 11/3.1.6.16*

3 SCOPE OF APPROVAL

3.1 General

3.1.1 Rule application

3.1.1.1 Further to the information contained in *Section 1/1.1.2* and *Section 1/1.2.1*, the Rules cover the scantling requirements for the classification of new double hull tankers of 150m or greater in length.

3.1.1.2 The attention of owners, designers, and builders is directed to the regulations of international, national, canal, and other authorities dealing with those requirements which may affect structural aspects, in addition to or in excess of the classification requirements.

3.1.1.3 Other aspects of the structural design not covered by these Rules are to be addressed using the rules of the individual Classification Society.

3.2 Classification

3.2.1 General

3.2.1.1 The documentation, plans and data requirements specified in *Sub-Section 2* are to be submitted. Each individual Classification Society will review such documentation to verify compliance with the requirements.

3.2.1.2 An appropriate term to indicate that the plans, reports or documents have been reviewed for compliance with these Rules will be used according to the procedures of the individual Classification Society.

3.3 Requirements of National and International Regulations

3.3.1 Responsibility

3.3.1.1 It is the responsibility of the designer to ensure that the design complies with the current National and International regulations applicable to the vessel.

3.3.1.2 Classification Societies are not responsible for assessing compliance with International and National regulations as part of the general classification approval process. However, a Classification Society may enter into an agreement under which they are explicitly instructed to review and approve a vessel design for compliance with specified regulations. This approval may be accepted as proof of compliance on behalf of a Flag Administration provided the Classification Society has been designated as a suitable recognised by that Flag Administration in accordance with *SOLAS* Regulations XI/1.

3.3.2 Review procedure

3.3.2.1 When compliance is reviewed by the Flag Administration, the vessel is to be issued with certificates indicating compliance with National and International regulations by the Flag Administration. For ships with arrangements and equipment that are required to comply with the following requirements, and applicable amendments thereto, and where not issued by the Flag Administration, the applicable convention certificates are to be issued by the Classification Society or by an IACS member when authorised:

(a) *International Convention on Load Lines*, 1966

(b) *International Convention for the Safety of Life at Sea*, 1974, and its Protocol of 1978

(c) *International Convention for the Prevention of Pollution from Ships, 1973*, and as modified by the Protocol of 1978 relating thereto.

For dual class ships, convention certificates may be issued by either Classification Society with which the ship is classed, provided this is recognised in a formal dual class agreement with the Classification Societies classing the ship and that both societies are authorised by the Flag Administration.

4 EQUIVALENCE PROCEDURE

4.1 General

4.1.1 Rule applications

4.1.1.1 These Rules apply in general to double hull oil tankers of normal form, proportions, speed and structural arrangements. Relevant design parameters defining the assumptions made are given in *Section 2/3*.

4.1.1.2 The Rules are applicable to steel ships of welded construction. Other materials for use in hull construction will be specially considered.

4.1.1.3 Special consideration will be given to the application of the Rules incorporating design parameters which are outside the design basis of *Section 2/3*, for example:

(a) increased fatigue life

(b) increased corrosion additions

(c) increased cargo density.

4.1.2 Novel designs

4.1.2.1 Ships of novel design, i.e. those of unusual form, proportions, speed and structural arrangements outside those reflected in *Section 2/3.1.2* of these Rules will be specially considered according to the contents of this sub-section.

4.1.2.2 Information is be submitted to the Classification Society to demonstrate that the structural safety of the novel design is at least equivalent to that intended by the Rules.

4.1.2.3 In such cases, the Classification Society is to be contacted at an early stage in the design process to establish the applicability of the Rules and additional information required for submission.

4.1.2.4 Dependent on the nature of the deviation, a systematic review may be required to document equivalence with the Rules.

4.1.3 Alternative calculation methods

4.1.3.1 Where indicated in specific sections of the Rules, alternative calculation methods to those shown in the Rules may be accepted provided it is demonstrated that the scantlings and arrangements are of at least equivalent strength to those derived using the Rule calculation method.

5 CALCULATION AND EVALUATION OF SCANTLING REQUIREMENTS

5.1 Determination of Scantling Requirements for Plates

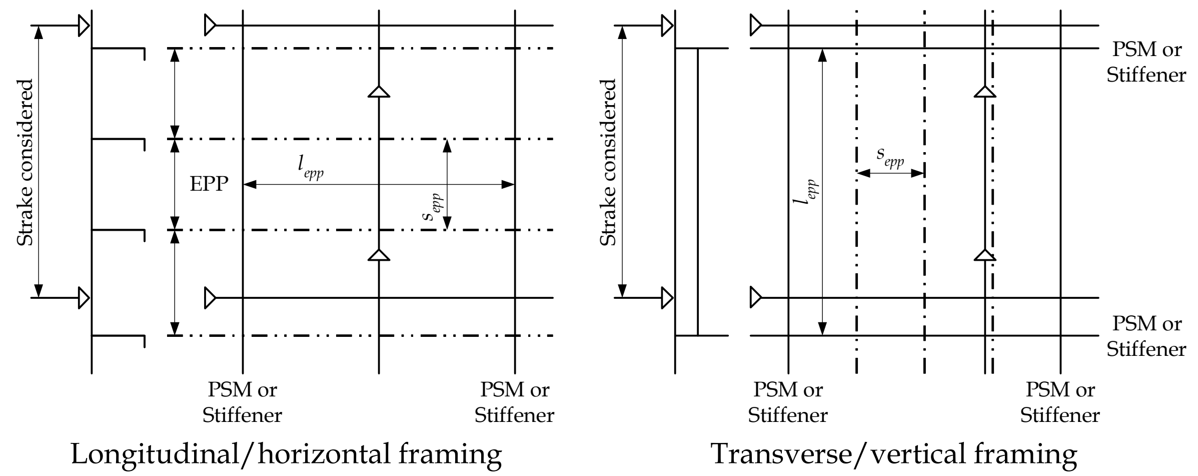
5.1.1 Determination of scantlings of plate strakes - idealisation of plate panels

5.1.1.1 Scantlings of plate strakes are to be derived based on the idealisation of the as-built structure as a series of Elementary Plate Panels (EPP).

5.1.1.2 An EPP is the unstiffened part of the plating between stiffeners. The plate panel length, l_{epp}, and breadth, s_{epp}, of the EPP are defined in relation to the longest and shortest plate edges respectively, as shown in *Figure 3.5.1*.

5.1.1.3 For strength assessment, the idealisation of EPP may be different and take into account the mesh arrangement in the FEM model.

Figure 3.5.1
Elementary Plate Panel Definition



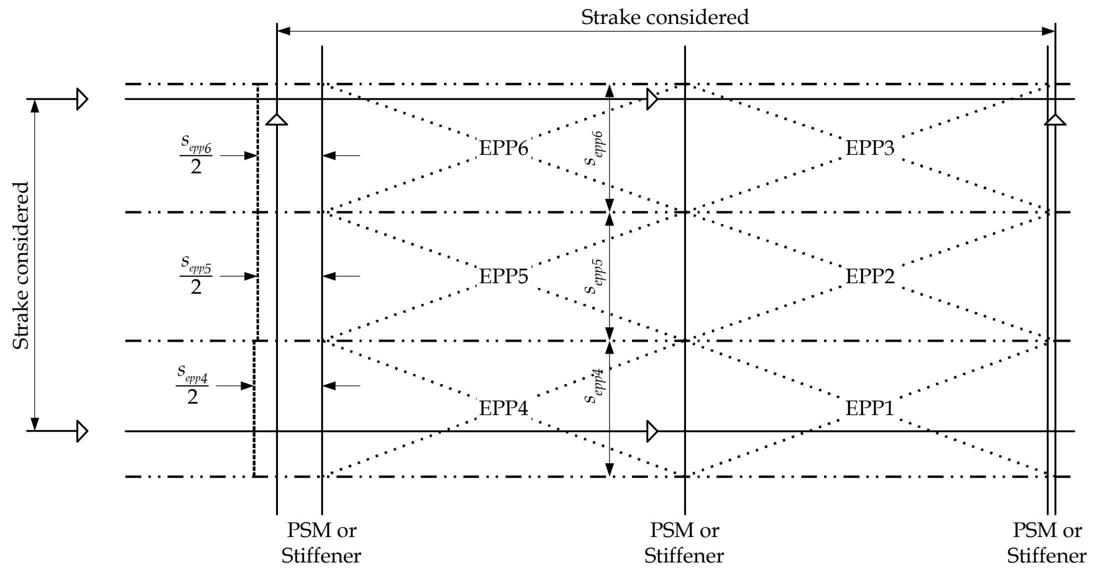
5.1.1.4 The required scantling of a plate strake is to be taken as the greatest value required for each EPP within that strake as given by:

(a) an EPP positioned entirely within the strake boundaries, e.g. EPP2 in *Figure 3.5.2*

(b) an EPP with a strake boundary weld seam bisecting it predominantly in the direction of the long edge of the EPP, e.g. EPP1, 3, 4 and 6 in *Figure 3.5.2*

(c) an EPP with a strake boundary weld seam bisecting it predominantly in the direction of the short edge of the EPP within more than half the EPP breadth, s_{epp}, from the edge, e.g. EPP1 and EPP2 in *Figure 3.5.3(a)*.

Figure 3.5.2
Determining Elementary Plate Panels for a Strake



5.1.2 Determination of scantlings of elementary plate panels for scantling requirements

5.1.2.1 The required scantling of each elementary plate panel is to be calculated based on a Load Calculation Point (LCP) defined as:

(a) for longitudinal framing, at the mid length of the EPP measured along the global x-axis at its lower edge. For horizontal plating the load calculation point is to be taken at the outboard y-value of the EPP. See *Figure 3.5.3(a)*

(b) for transverse framing, at the mid length of the EPP measured along the global x-axis at the lower edge of strake. For horizontal plating the load calculation point is to be taken at the outboard y-value of the EPP. See *Figure 3.5.3(b)*

(c) for horizontal framing on vertical transverse structure, at the lower edge of the elementary plate panel at the point of outboard y-value of the EPP. See *Figure 3.5.3(c)*

(d) for vertical framing on vertical transverse structure, at the greatest y-value of the lower edge of the EPP or at the lower edge of strake. See *Figure 3.5.3(d)*

5.1.2.2 Both the local pressure and hull girder stress used for the calculation of the local scantling requirements are to be taken at the LCP.

5.1.3 Determination of scantlings of elementary plate panels for hull girder strength

5.1.3.1 The required scantlings of the elementary plate panels are to satisfy the hull girder bending and hull girder shear requirements of *Section 8/1*.

5.1.3.2 The required thickness of each elementary plate panel, with respect to buckling, is to be calculated based on stresses taken at the mid length of the EPP measured along the global x-axis.

5.1.3.3 The buckling evaluation is to be calculated using the stress distribution across the width of the panel defined with a reference stress taken at the edge with maximum stress and reduced stress at the other edge given as a fraction, Ψ, defined in *Table 10.3.1*, of the reference stress.

5.1.3.4 The required scantling of a plate strake is to be taken as the greatest value required for each EPP within that strake as given by:

(a) an EPP positioned entirely within the strake boundaries, e.g. EPP2 in *Figure 3.5.2*

(b) an EPP with a strake boundary weld seam bisecting it predominantly in the direction of the long edge of the EPP, e.g. EPP 1, 3, 4 and 6 in *Figure 3.5.2*

(c) an EPP with a strake boundary weld seam bisecting it predominantly in the direction of the short edge of the EPP within more than half the EPP breadth, S_{epp}, from the edge, e.g. EPP 1 and 2 in *Figure 3.5.3(a)*.

5.1.4 Determination of scantlings of elementary plate panels for FEM strength assessment

5.1.4.1 The required scantlings of elementary plate panels are to be derived from the plate mesh element with maximum utilisation, see *Section 9/2*.

Figure 3.5.3
Example of Load Calculation Point for Typical Structural Configurations

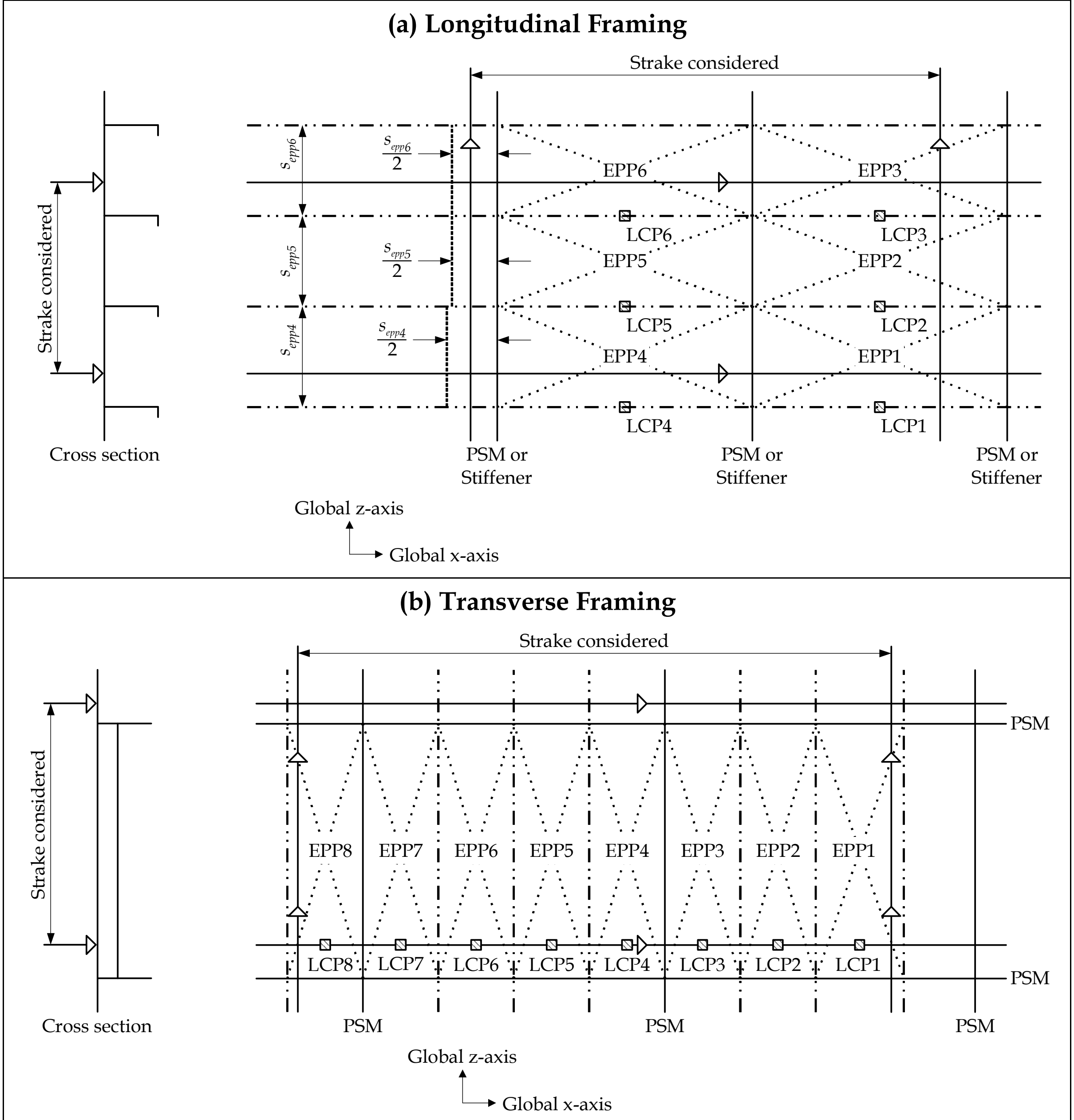
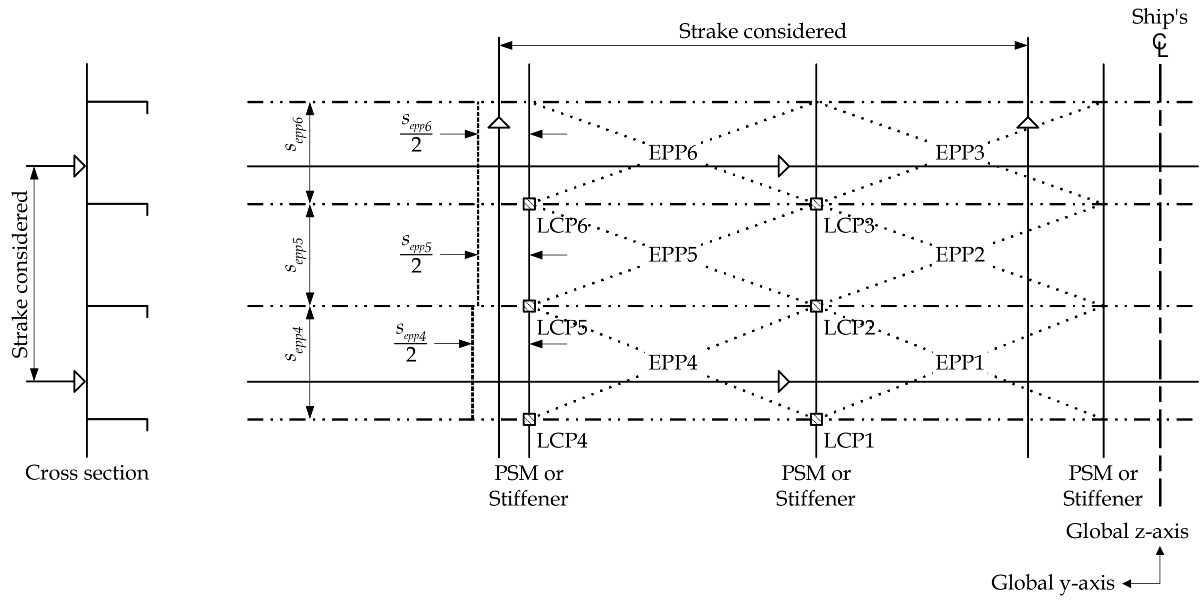
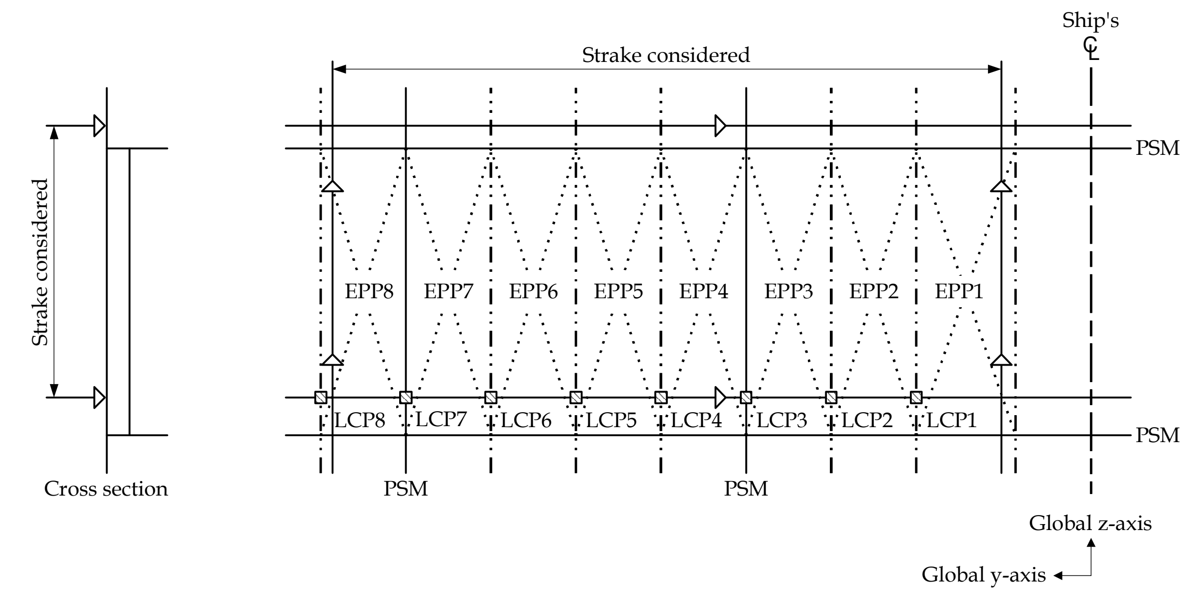


Figure 3.5.3 (Continued)
Example of Load Calculation Point for Typical Structural Configurations

(c) Horizontal Framing on Transverse Structure



(d) Vertical Framing on Transverse Structure



5.2 Determination of Scantlings of Stiffeners

5.2.1 Determination of scantlings of stiffeners - idealisation of stiffeners

5.2.1.1 Scantlings of individual stiffeners are to be derived based on the idealisation of the as-built structure as a series of stiffened panels.

5.2.1.2 A stiffened panel consists of a single idealised stiffener profile and effective plate flange supporting a boundary of one or more elementary plate panels. The arrangement of stiffened panels is based on the idealisation of the structure according to the elementary plate panel definition in *5.1.1*.

5.2.1.3 Scantlings of stiffeners based on requirements in *Section 8* may be decided based on the concept of grouping designated sequentially placed stiffeners of equal scantlings. The scantling of the group is to be taken as the greater of the following:

(a) the average of the required scantling of all stiffeners within a group

(b) 90% of the maximum scantling required for any one stiffener within the group.

The concept of grouping is not applicable to fatigue requirements as given in *Section 9/3* and *Appendix C.*

5.2.2 Determination of scantlings of stiffened panels for scantling requirements and fatigue

5.2.2.1 The required scantling of a stiffened panel is to be based on a pressure load calculation point defined as:

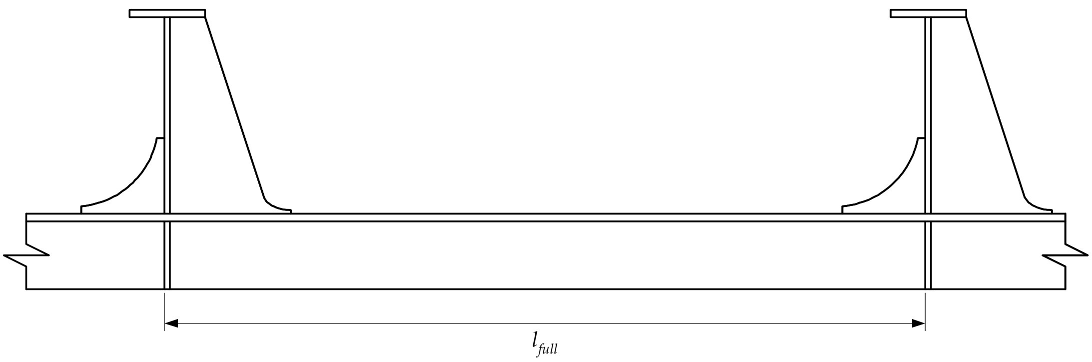
(a) mid point of the overall span, l_{full}, of the stiffener between primary support members, see *Figure 3.5.4*

(b) at the connection of the stiffener to the plating.

Figure 3.5.4
Definition of Overall Span of Stiffeners, l_{full}

Double Skin Construction

Single Skin Construction



5.2.2.2 For longitudinal and horizontal framing the design pressure is to be taken as the pressure at the mid point of the overall span.

5.2.2.3 For transverse and vertical framing the design pressure is to be taken as the greater of the following:

P_{ms} kN/m²

$\frac{(P_{end-1}+P_{end-2})}{2}$ kN/m²

Where:

P_{ms} calculated pressure at mid point of overall span, l_{full}, in kN/m²

P_{end-1} calculated pressure at 1st end of overall span, in kN/m²

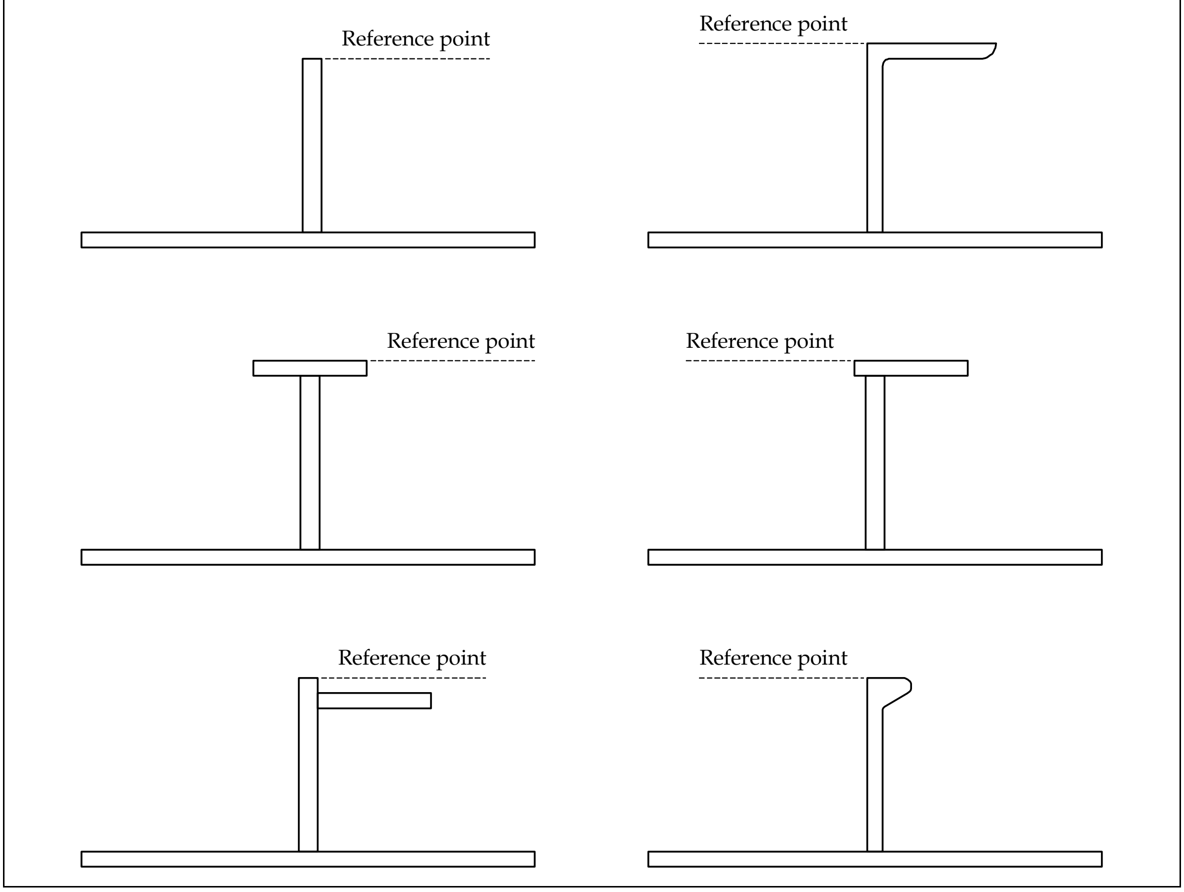
P_{end-2} calculated pressure at 2nd end of overall span, in kN/m²

l_{full} overall span, in m, see *Figure 3.5.4*

5.2.2.4 The section modulus requirements given in these Rules relate to the reference point giving the minimum section modulus. In general, this will be on the outer surface of the faceplate. The reference point for calculation of section modulus for typical profiles is shown in *Figure 3.5.5*.

5.2.2.5 The hull girder stress used for calculation of local scantling requirements for stiffeners is to be taken at the reference point as shown in *Figure 3.5.5*

Figure 3.5.5
Reference Point for Calculation of Section Modulus and Hull Girder Stress for Local Scantling Assessment



5.2.3 Determination of scantlings of stiffened panels for hull girder buckling strength

5.2.3.1 The required scantling of a stiffened panel, with respect to buckling, is to be based on the axial stress calculated at the attachment point of the stiffener to the plate and at the mid length of the stiffener measured along the global x-axis.

5.2.3.2 The required scantling as given in *5.2.3.1* applies to stiffeners outside of a distance s from the support, where *s* is the stiffener spacing.

5.2.4 Determination of scantlings of stiffened panels for FEM strength assessment

5.2.4.1 The required scantlings of the stiffened panel are to be based on the derivation of applied stresses in accordance with *Section 9/2*.

5.2.5 Shear area requirements of stiffeners

5.2.5.1 Requirements for the shear area and/or web thickness of stiffeners are given in *Section 8*.

5.2.5.2 The requirements in *Section 8* are to be calculated based on the load point defined in *5.2.2* and the effective span as given in *Section 4/2.1.2*.

5.2.5.3 The requirements in *Section 8* are to be evaluated against the actual shear area of the stiffener, based on the effective shear height of the stiffener as given in *Section 4/2.4.2* and based on the specified minimum yield of the stiffener.

5.2.5.4 The effect of brackets may be included in the calculation of the effective span, but no part of the bracket is to be included in the calculation of the actual shear area.

5.2.6 Bending requirements of stiffeners

5.2.6.1 Requirements for the section modulus and moment of inertia of stiffeners are given in *Section 8*.

5.2.6.2 The requirements in *Section 8* are to be calculated based on the load point defined in *5.2.1* and the effective span as given in *Section 4/2.1.1*.

5.2.6.3 The requirements in *Section 8* are to be evaluated against the actual section modulus/moment of inertia of the stiffener. The stiffener web and flanges are to be included in the calculation of actual sectional properties.

5.2.6.4 The effect of brackets may be included in the calculation of the effective span, but no part of the bracket is to be included in the calculation of section modulus/moment of inertia.

5.2.6.5 When the stiffener is of a higher strength material than the attached plate, the yield stress used for the calculation of the section modulus requirements in *Section 8* is in general not to be greater than 1.35 times the minimum specified yield stress of the attached plate. If the yield stress of the stiffener exceeds this limitation the following criterion is to be satisfied:

$$\sigma_{yd-stf} \leq \left(\sigma_{yd-plt} - |\sigma_{hg}|\right)\frac{Z_{net-plt}}{Z_{net}} + |\sigma_{hg}| \quad \text{N/mm}^2$$

Where:

$\sigma_{yd\text{-}stf}$ specified minimum yield stress of the material of the stiffener, in N/mm^2

$\sigma_{yd\text{-}plt}$ specified minimum yield stress of the material of the attached plate, in

N/mm²

σ_{hg} maximum hull girder stress of sagging and hogging (S+D), in N/mm², as defined in *Table 8.2.5* and *Table 8.4.3* for stiffeners in cargo tank region and machinery spaces respectively and not to be taken as less than 0.4 $\sigma_{yd\text{-}plt}$

Z_{net} net section modulus, in way of face plate/free edge of the stiffener, in cm³

$Z_{net\text{-}plt}$ net section modulus, in way of the attached plate of stiffener, in cm³

5.2.7 Evaluation of slanted stiffeners

5.2.7.1 The shear area and section modulus requirements for local support members are valid about an axis parallel to the plate flange. If the angle φ_w between the stiffener web and the attached plating is less than 75 degrees, see *Figure 4.2.14*, then the actual shear area and section modulus is to be adjusted in accordance with *Sections 4/2.4.2* and *2.4.3*. The angle between the stiffener web, φ_w, and the attached plating is not to be less than 50 degrees.

5.3 Calculation and Evaluation of Scantling Requirements for Primary Support Members

5.3.1 Load application point for primary support members

5.3.1.1 The design pressure for primary support members is generally taken at the mid point of the load area. The design pressures for the primary support members are defined for individual members as given in *Section 8*.

5.3.2 Shear requirements of primary support members

5.3.2.1 Requirements for shear area and/or web thickness of primary support members are given in *Section 8*.

5.3.2.2 These requirements are to be calculated based on the load point defined in *5.3.1* and the effective span as given in *Section 4/2.1.5*.

5.3.2.3 These requirements are to be evaluated against the actual shear area and the specified minimum yield of the web plate of the primary support member. The actual shear area of the primary support member is defined in *Section 4/2.5.1*. The effect of brackets may be included in the calculation of effective span, but are not to be included in the calculation of actual shear area.

5.3.3 Bending requirements of primary support members

5.3.3.1 Requirements for section modulus and moment of inertia of primary support members are given in *Section 8* and *Section 10*, respectively.

5.3.3.2 These requirements are to be calculated based on the load point defined in *5.3.1* and the effective span as given in *Section 4/2.1.4*.

5.3.3.3 These requirements are to be evaluated against the actual section modulus/moment of inertia of the primary support member. Web and flanges are included in the calculation of actual sectional properties. The effect of brackets may be included in calculation of effective span, but are not to be included in the calculation of section modulus/moment of inertia.

5.3.3.4 Where it is impracticable to fit a primary support member with the required web depth, then it is permissible to fit a member with reduced depth provided that the fitted member has equivalent moment of inertia or deflection to the required

member. The required equivalent moment of inertia is to be based on an equivalent section given by the effective width of plating at mid span with required plate thickness, web of required depth and thickness and face plate of sufficient width and thickness to satisfy the required mild steel section modulus. All other rule requirements, such as minimum thicknesses, slenderness ratio, section modulus and shear area, are to be satisfied for the member of reduced depth. The equivalent moment of inertia may be also demonstrated by an equivalent member having the same deflection as the required member.

5.4 Rounding of Calculated Thickness

5.4.1 Required gross thickness

5.4.1.1 The minimum required gross thickness of any member to be fitted at the new-building stage, exclusive of any owners' extras, is to be taken as the rounded net thickness required plus the appropriate corrosion addition.

5.4.1.2 The required net thickness is given by rounding the calculated net thickness to the nearest half millimetre. For example:

(a) for $10.75 \le t_{calc\text{-}net} < 11.25$ mm the Rule required thickness is 11mm

(b) for $11.25 \le t_{calc\text{-}net} < 11.75$ mm the Rule required thickness is 11.5mm.

SECTION 4

BASIC INFORMATION

1 DEFINITIONS

1.1 Principal Particulars

1.1.1 *L*, rule length

1.1.1.1 *L*, the rule length, is the distance on the waterline at the scantling draught, from the forward side of the stem to the centreline of the rudder stock, in metres. *L* is not to be less than 96%, and need not be greater than 97%, of the extreme length on the summer load waterline. In ships with an unusual stern and bow arrangement the length, *L*, will be specially considered.

1.1.2 L_L, load line length

1.1.2.1 L_L, the load line length is defined in the *International Convention on Load Lines*.

1.1.3 Moulded breadth

1.1.3.1 *B*, the moulded breadth, is the maximum breadth of the ship, measured amidships to the moulded line of the frame, in metres.

1.1.4 Moulded depth

1.1.4.1 *D*, the moulded depth, is the vertical distance, in metres, amidships, from the moulded baseline to the moulded deck line of the uppermost continuous deck measured at deck at side. On vessels with a rounded gunwale, *D* is to be measured to the continuation of the moulded deck line.

1.1.5 Draughts

1.1.5.1 *T*, the draught in metres, is the summer load line draught for the ship in operation, measured from the moulded base line at amidships. Note this may be less than the maximum permissible summer load waterline draught.

1.1.5.2 T_{bal}, is the minimum design ballast draught, in metres, at which the strength requirements for the scantlings of the ship are met. The minimum design ballast draught is not to be greater than the minimum draught of ballast conditions including ballast water exchange operation, measured from the moulded base line at amidships, for any ballast loading condition in the loading manual including both departure and arrival conditions.

1.1.5.3 T_{bal-n}, the normal ballast draught in metres, is the draught at departure given for the normal ballast condition in the loading manual, measured from the moulded base line at amidships, see *Section 8/1.1.2.3*. The normal ballast condition is the ballast condition in compliance with condition specified in *Section 8/1.1.2.2 a)*.

1.1.5.4 T_{full}, the full load design draught in metres, is the draught at departure given for the homogeneous full load condition in the loading manual, measured from the moulded base line at amidships, see *Section 8/1.1.2.3*.

1.1.5.5 T_{sc}, is the maximum design draught, in metres, at which the strength requirements for the scantlings of the ship are met.

1.1.6 Amidships

1.1.6.1 Amidships is to be taken as the middle of the rule length, *L*.

1.1.7 Moulded displacement

1.1.7.1 Δ, the moulded displacement, in tonnes, corresponding to the underwater volume of the ship, at draught T_{sc}, in sea water with a density of 1.025t/m^3.

1.1.8 Maximum service speed

1.1.8.1 V, the maximum ahead service speed, in knots, means the greatest speed which the ship is designed to maintain in service at her deepest sea-going draught at the maximum propeller RPM and corresponding engine MCR (Maximum Continuous Rating).

1.1.9 Block coefficient

1.1.9.1 C_b, the block coefficient at the scantling draught, is defined as:

$$C_b = \frac{\nabla}{L B_{WL} T_{sc}}$$

Where:

∇	moulded displacement volume at the scantling draught, in m^3
L	rule length, as defined in *1.1.1.1*
B_{WL}	moulded breadth measured amidships, in m, at the scantling draught waterline
T_{sc}	scantling draught, as defined in *1.1.5.5*

1.1.9.2 C_{b-LC}, the block coefficient at considered loading condition, is defined as:

$$C_{b-LC} = \frac{\nabla_{LC}}{L B_{WL} T_{LC}}$$

Where:

∇_{LC}	moulded displacement volume at the T_{LC}, in m^3
L	rule length, as defined in 1.1.1.1
B_{WL}	moulded breadth measured amidships, in m, at the T_{LC}
T_{LC}	draught at amidships, in m, in the loading condition being considered.

1.1.10 Length between perpendiculars

1.1.10.1 L_{pp}, the length between perpendiculars, is the distance, in metres, on the scantling draught waterline from the fore side of the stem to the after side of the rudder post, or to the centre of the rudder stock if there is no rudder post.

1.1.11 The forward perpendicular

1.1.11.1 F.P., the forward perpendicular, is the perpendicular at the intersection of the scantling draught waterline with the fore side of the stem. The F.P. is the forward end of the rule length, L.

1.1.12 The aft perpendicular

1.1.12.1 A.P., the aft perpendicular, is the perpendicular at the aft end of the rule length, L, measured from the F.P.

1.1.13 Load line block coefficient

1.1.13.1 C_{bL}, the load line block coefficient, is defined in the *International Convention on Load Lines* as follows:

$$C_{bL} = \frac{\nabla_L}{L_L B T_L}$$

Where:

∇_L	moulded displacement volume at the moulded draught, T_L, in m^3
L_L	load line length, as defined in *1.1.2.1*
B	moulded breadth, in m, as defined in *1.1.3.1*
T_L	the moulded draught measured to the waterline at 85 per cent of the least moulded depth, in m

1.1.14 Deadweight

1.1.14.1 DWT, is the deadweight of the ship, in tonnes, floating in water with a specific gravity of 1.025, at the summer load line draught.

1.2 Position 1 and Position 2

1.2.1 Position 1

1.2.1.1 Position 1 is defined as any location upon exposed freeboard and raised quarterdecks, and exposed superstructure decks within the forward $0.25L_L$.

1.2.2 Position 2

1.2.2.1 Position 2 is defined as any location upon exposed superstructure decks abaft the forward $0.25L_L$.

1.3 Type 'A' and Type 'B' Freeboard Ships

1.3.1 ICLL definition

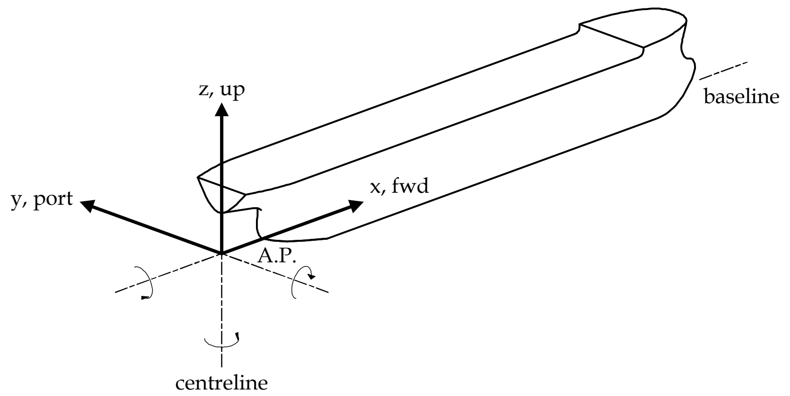
1.3.1.1 A Type 'A' or Type 'B' freeboard ship is as defined in the *International Convention on Load Lines*.

1.4 Coordinate System

1.4.1 Origin and orientation

1.4.1.1 The coordinate system used within these Rules is shown in *Figure 4.1.1*. Motions and displacements are considered positive in the forward, up and to port direction. Angular motions are considered positive in the clockwise direction about the x, y or z axis.

Figure 4.1.1
Coordinate System



1.5 Naming Convention

1.5.1 Bulkhead nomenclature

1.5.1.1 *Figures 4.1.2*, *4.1.3* and *4.1.4* show the common structural nomenclature used within these Rules.

Figure 4.1.2
Corrugated Transverse Bulkhead Nomenclature

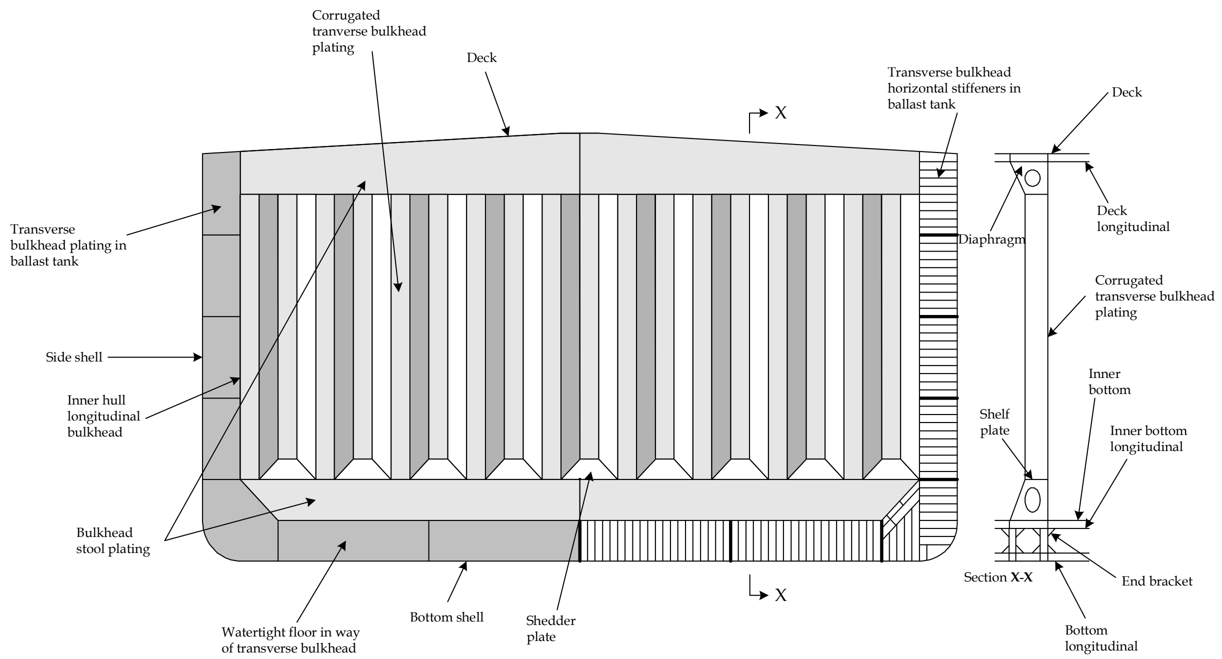


Figure 4.1.3
Flat Transverse Bulkhead Nomenclature

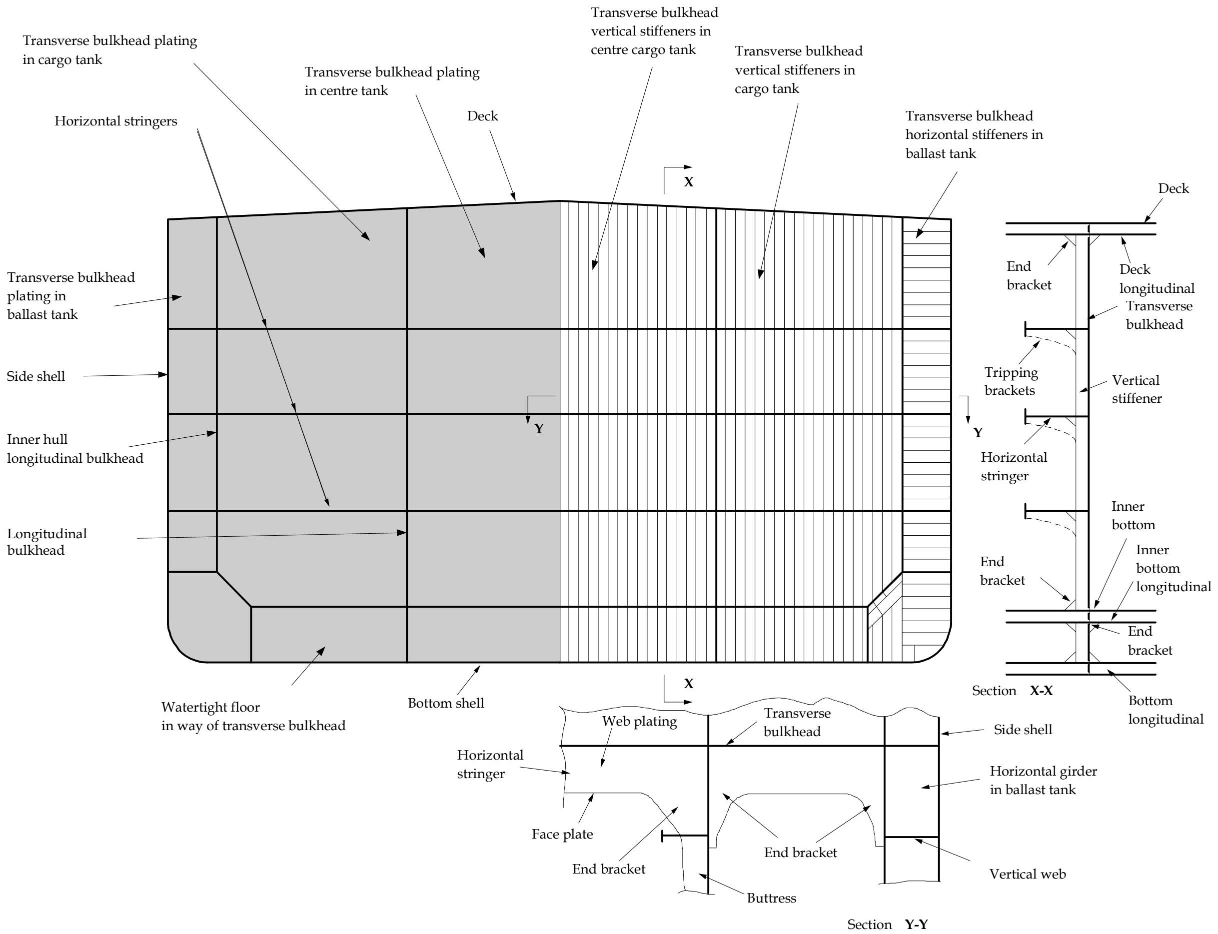
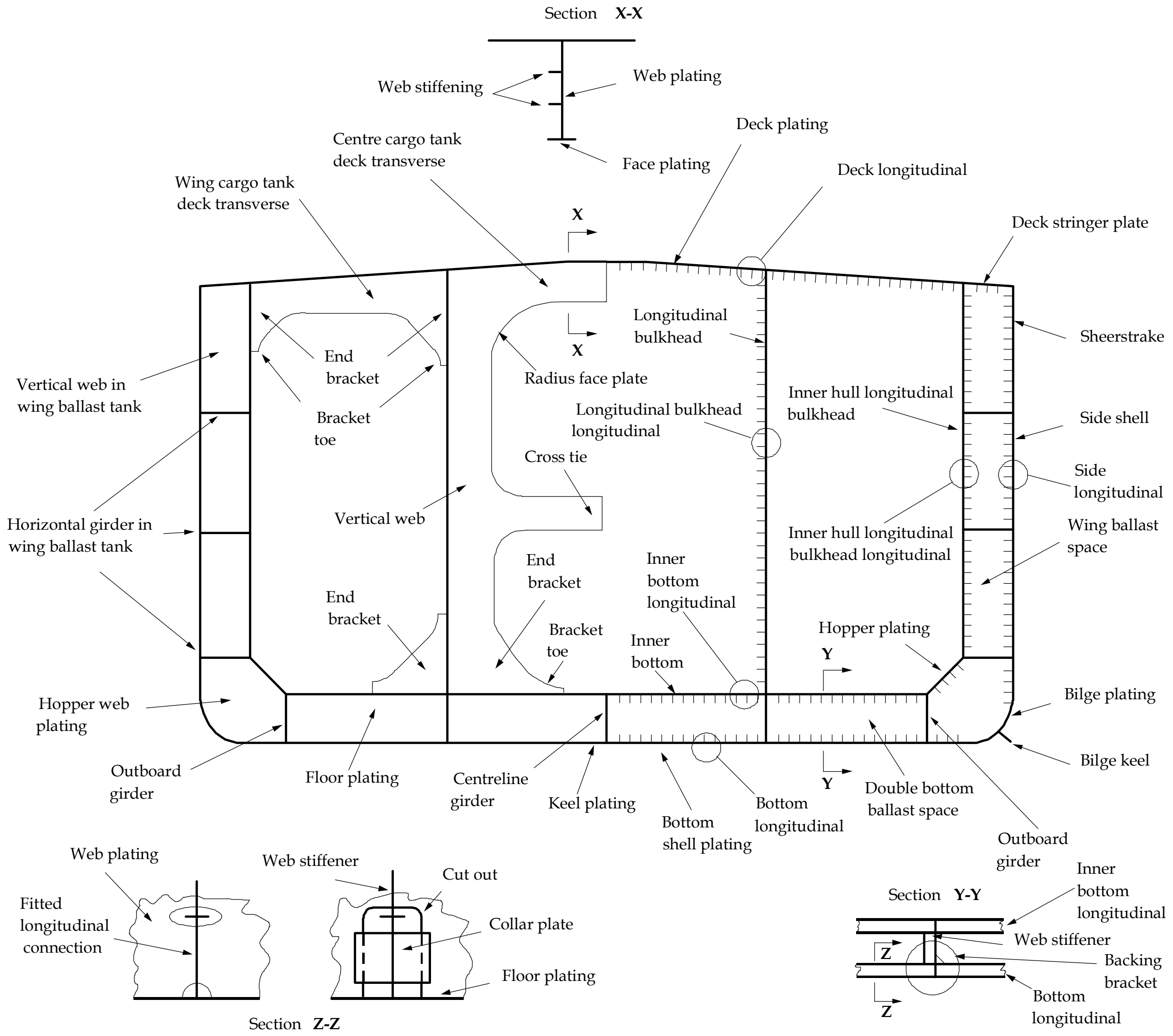


Figure 4.1.4
Mid Cargo Hold Transverse Section



1.6 Symbols

1.6.1 General

1.6.1.1 The symbols and subscripts used within these Rules are defined locally. The principal particulars, as defined in *1.1*, may be referred to within text without reference.

1.7 Units

1.7.1 General

1.7.1.1 The following units are used within these Rules. The units to be used within equations are given locally.

(a) General:

- dimensions/distances	m
- primary spacings	m
- secondary spacings	mm
- area	m^2

- volume m^3
- mass t
- velocity m/s
- acceleration m/s^2

(b) Hull girder properties:

- dimensions m
- area m^2
- section modulus m^3
- moment of inertia m^4
- moment of area m^3

(c) Stiffener properties:

- dimensions mm
- area cm^2
- section modulus cm^3
- inertia cm^4
- length/effective length m
- span m

(d) Plating dimensions:

- breadth mm
- length m
- thickness mm

(e) Loads:

- pressures kN/m^2
- loads kN
- bending moment kNm
- shear force kN

(f) Miscellaneous:

- yield strength N/mm^2
- stress N/mm^2
- deflections mm
- modulus of elasticity N/mm^2
- density t/m^3
- displacement t
- angle deg
- calculated angle rad
- period s
- frequency Hz
- ship speed knots

1.8 Glossary

1.8.1 Definitions of terms

1.8.1.1 The terms in *Table 4.1.1* are used within these Rules to describe the items which their respective definitions describe.

Table 4.1.1
Definitions of Terms

Terms	Definition
Accommodation deck	A deck used primarily for the accommodation of the crew
Accommodation ladder	A portable set of steps on a ship's side for people boarding from small boats or from a pier
Aft peak	The area aft of the aft peak bulkhead
Aft peak bulkhead	The first main transverse watertight bulkhead forward of the stern
Aft peak tank	The compartment in the narrow part of the stern aft of the aft peak bulkhead
Anchor	a device which is attached to anchor chain at one end and lowered into the sea bed to hold a ship in position; it is designed to grip the bottom when it is dragged by the ship trying to float away under the influence of wind and current; usually made of heavy casting or casting
Ballast tank	A compartment used for the storage of water ballast
Bay	The area between adjacent transverse frames or transverse bulkheads
Bilge keel	A piece of plate set perpendicular to a ship's shell along the bilges to reduce the rolling motion
Bilge plating	The area of curved plating between the bottom shell and side shell. To be taken as follows: From the start of the curvature at the lower turn of bilge on the bottom to the lesser of, the end of curvature at the upper turn of the bilge on the side shell or 0.2D above the baseline/local centreline elevation
Bilge strake	The lower strake of bilge plating
Boss	The boss of propeller is the central part to which propeller blades are attached and through which the shaft end passes
Bottom shell	The shell envelope plating forming the predominantly flat bottom portion of the shell envelope including the keel plate
Bow	The structural arrangement and form of the forward end of the ship
Bower Anchor	An anchor carried at the bow of the ship
Bracket	An extra structural component used to increase the strength of a joint between two structural members
Bracket toe	The narrow end of a tapered bracket
Breakwater	Inclined and stiffened plate structure on a weather deck to break and deflect the flow of water coming over the bow
Breast hook	A triangular plate bracket joining port and starboard side structural members at the stem
Bridge	An elevated superstructure having a clear view forward and at each side, and from which a ship is steered
Bulb profile	A stiffener utilising an increase in steel mass on the outer end of the web instead of a separate flange
Bulkhead	A structural partition wall sub-dividing the interior of the ship into compartments
Bulkhead deck	The uppermost continuous deck to which transverse watertight bulkheads and shell are carried
Bulkhead stool	The lower or upper base of a corrugated bulkhead

Table 4.1.1 (Continued)
Definitions of Terms

Terms	Definition
Bulkhead structure	The transverse or longitudinal bulkhead plating with stiffeners and girders
Bulwark	The vertical plating immediately above the upper edge of the ship's side surrounding the exposed deck(s)
Bunker	A compartment for the storage of fuel oil used by the ship's machinery
Cable	A rope or chain attached to the anchor
Camber	The upward rise of the weather deck from both sides towards the centreline of the ship
Cargo tank bulkhead	A boundary bulkhead separating cargo tanks
Cargo area	The part of the ship that contains cargo tanks and cargo/slop tanks and adjacent areas including ballast tanks, fuel tanks, cofferdams, void spaces and also including deck areas throughout the entire length and breadth of the part of the ship over the mentioned spaces. It includes the collision bulkhead and the transverse bulkhead at the aft end of the cargo block.
Carlings	A stiffening member used to supplement the regular stiffening arrangement
Casing	The covering or bulkhead around or about any space for protection
Cellular construction	A structural arrangement where there are two closely spaced boundaries and internal diaphragm plates arranged in such a manner to create small compartments
Centreline girder	A longitudinal member located on the centreline of the ship
Chain	Connected metal rings or links used for holding anchor, fastening timber cargoes, etc.
Chain locker	A compartment usually at the forward end of a ship which is used to store the anchor chain
Chain pipe	A section of pipe through which the anchor chain enters or leaves the chain locker
Chain stopper	A device for securing the chain cable when riding at anchor as well as securing the anchor in the housed position in the hawse pipe, thereby relieving the strain on the windlass
Coaming	The vertical boundary structure of a hatch or skylight
Cofferdams	The spaces between two bulkheads or decks primarily designed as a safeguard against leakage of oil from one compartment to another
Collar plate	A patch used to, partly or completely, close a hole cut for a longitudinal stiffener passing through a transverse web
Collision bulkhead	The foremost main transverse watertight bulkhead
Companionway	A weathertight entrance leading from a ship's deck to spaces below
Compartment	An internal space bounded by bulkheads or plating
Confined space	A space identified by one of the following characteristics: limited openings for entry and exit, unfavourable natural ventilation or not designed for continuous worker occupancy
Corrugated bulkhead	A bulkhead comprised of plating arranged in a corrugated fashion
Cross ties	Large transverse structural members joining longitudinal bulkheads and used to support them against hydrostatic and hydrodynamic loads
Deck	A horizontal structure element that defines the upper or lower boundary of a compartment
Deck house	A decked structure other than a superstructure, located on the freeboard deck or above.
Deck structure	The deck plating with stiffeners, girders and supporting pillars

Table 4.1.1 (Continued)
Definitions of Terms

Terms	Definition
Deep tank	any tank which extends between two decks or the shell/inner bottom and the deck above or higher
Discharges	Any piping leading through the ship's sides for conveying bilge water, circulating water, drains etc.
Docking bracket	A bracket located in the double bottom to locally strengthen the bottom structure for the purposes of docking
Double bottom structure	The shell plating with stiffeners below the top of the inner bottom and other elements below and including the inner bottom plating
Doubler	Small piece of plate which is attached to a larger area of plate that requires strengthening in that location. Usually at the attachment point of a stiffener
Double skin member	Double skin member is defined as a structural member where the idealized beam comprises webs, with top and bottom flanges formed by attached plating
Duct keel	A keel built of plates in box form extending the length of the cargo tank. It is used to house ballast and other piping leading forward which otherwise would have to run through the cargo tanks
Enclosed superstructure	The superstructure with bulkheads forward and/or aft fitted with weather tight doors and closing appliances
Engine room bulkhead	A transverse bulkhead either directly forward or aft of the engine room
Face plate	The section of a stiffening member attached to the plate via a web and is usually parallel to the plated surface
Flange	The section of a stiffening member, typically attached to the web, but is sometimes formed by bending the web over. It is usually parallel to the plated surface
Flat bar	A stiffener comprising only of a web
Floor	A bottom transverse member
Forecastle	A short superstructure situated at the bow
Fore peak	The area of the ship forward of the collision bulkhead
Fore peak deck	A short raised deck extending aft from the bow of the ship
Freeboard deck	Generally the uppermost complete deck exposed to weather and sea, which has permanent means of closing all exposed openings
Freeing port	An opening in the bulwarks to allow water shipped on deck to run freely overboard
Gangway	The raised walkway between superstructure, such as between the forecastle and bridge, or between the bridge and poop
Girder	A collective term for primary supporting structural members
Gudgeon	A block with a hole in the centre to receive the pintle of a rudder; located on the stern post, it supports and allows the rudder to swing
Gunwale	The upper edge of the ship's sides
Gusset	A plate, usually fitted to distribute forces at a strength connection between two structural members
Hatch ways	Openings, generally rectangular, in a ship's deck affording access into the compartment below
Hawse pipe	Steel pipe through which the hawser or cable of anchor passes, located in the ship's bow on either side of the stem, also known as spurling pipe
Hawser	Large steel wire or fibre rope used for towing or mooring
Hopper plating	Plating running the length of a compartment sloping between the inner bottom and vertical portion of inner hull longitudinal bulkhead
HP	Holland Profile

Table 4.1.1 (Continued)
Definitions of Terms

Terms	Definition
Independent tank	A self supporting tank
Inner hull	The innermost plating forming a second layer to the hull of the ship
Intercostal	Longitudinal member between the floors or frames of a ship; it is non-continuous
JIS	Japanese industrial standard profile
Keel	The main structural member or backbone of a ship running longitudinal along centreline of bottom. Usually a flat plate stiffened by a vertical plate on its centreline inside the shell
Knuckle	A discontinuity in a structural member
Lightening hole	A hole cut in a structural member to reduce its weight
Limber hole	A small drain hole cut in a frame or plate to prevent water or oil from collecting
Local support members	Local support members are defined as local stiffening members which only influence the structural integrity of a single panel, e.g. deck beams
Longitudinal centreline bulkhead	A longitudinal bulkhead located on the centreline of the ship
Longitudinal hull girder structural members	Structural members that contribute to the longitudinal strength of the hull girder, including: deck, side, bottom, inner bottom, inner hull longitudinal bulkheads including upper sloped plating where fitted, hopper, bilge plate, longitudinal bulkheads, double bottom girders and horizontal girders in wing ballast tanks
Longitudinal hull girder shear structural members	Structural members that contribute to strength against hull girder vertical shear loads, including: side, inner hull longitudinal bulkheads, hopper, longitudinal bulkheads and double bottom girders
Manhole	A round or oval hole cut in decks, tanks, etc., for the purpose of providing access
Margin plate	The outboard strake of the inner bottom and when turned down at the bilge the margin plate (or girder) forms the outer boundary of the double bottom
Notch	A discontinuity in a structural member caused by welding
Oil fuel tank	A tank used for the storage of fuel oil
Pillar	A vertical support placed between decks where the deck is unsupported by the shell or bulkhead
Pintle	Vertical pin on a rudder's forward edge that enables the rudder to hang onto the stern post and swing when it fits into the gudgeon
Pipe tunnel	The void space running in the midships fore and aft lines between the inner bottom and shell plating forming a protective space for bilge, ballast and other lines extending from the engine room to the tanks
Poop	The space below an enclosed superstructure at the extreme aft end of a ship
Poop deck	The first deck above the shelter deck at the aft end of a ship
Primary support members	Members of the beam, girder or stringer type which ensure the overall structural integrity of the hull envelope and tank boundaries, e.g. double bottom floors and girders, transverse side structure, deck transverses, bulkhead stringers and vertical webs on longitudinal bulkheads
Rudder	A device, usually of an aerofoil or flat section, that is used to steer a ship. A common type has a vertical fin at the stern and is able to move from 35 degrees port to 35 degrees starboard; rudders are characterised by their area, aspect ratio, and shape

Table 4.1.1 (Continued)
Definitions of Terms

Terms	Definition
Scallop	A hole cut into a stiffening member to allow continuous welding of a plate seam
Scarfing bracket	A bracket used between two offset structural items
Scantlings	The physical dimensions of a structural item
Scupper	Any opening for carrying off water from a deck, either directly or through piping
Scuttle	A small opening in a deck or elsewhere, usually fitted with a cover or lid or a door for access to a compartment
Shedder plates	Slanted plates that are fitted to minimise pocketing of residual cargo in way of corrugated bulkheads
Sheer strake	The top strake of a ship’s side shell plating
Shelf plate	A horizontal plate located on the top of a bulkhead stool
Shell envelope plating	The shell plating forming the effective hull girder
Side shell	The shell envelope plating forming the side portion of the shell envelope above the bilge plating
Single skin member	Single skin member is defined as a structural member where the idealized beam comprises a web, with a top flange formed by attached plating and a bottom flange formed by a face plate
Skylight	A deck opening fitted with or without a glass port light and serving as a ventilator for engine room, quarters, etc.
Slop tank	A tank in an oil tanker which is used to collect the oil and water mixtures from cargo tanks after tank washing
Spaces	Separate compartments including tanks
Stay	Bulwark and hatch coaming brackets
Stem	The piece of bar or plating at which a ship's outside plating terminates at forward end
Stern frame	The heavy strength member in single or triple screw ships, combining the rudder post
Stern tube	A tube through which the shaft passes to the propeller; and acts as an after bearings for the shafting and may be water or oil lubricated
Stiffener	A collective term for secondary supporting structural members
Stool	A structure supporting tank bulkheads
Strake	A course, or row, of shell, deck, bulkhead, or other plating
Strength deck	The uppermost continuous deck
Stringer	Horizontal girders linking vertical web frames
Stringer plate	The outside strake of deck plating
Superstructure	A decked structure on the freeboard deck, extending from side to side of the ship or with the side plating not being inboard of the shell plating more than 0.04B.
Tank top	The horizontal plating forming the bottom of a cargo tank
Towing pennant	A long rope which is used to effect the tow of a ship
Transom	The structural arrangement and form of the aft end of the ship
Transverse ring	All transverse material appearing in a cross-section of the ship's hull, in way of a double bottom floor, vertical web and deck transverse girder
Transverse web frame	The primary transverse girders which join the ships longitudinal structure
Tripping bracket	A bracket used to strengthen a structural member under compression, against torsional forces
‘Tween deck	An abbreviation of between decks, placed between the upper deck and the tank top in the cargo tanks

Table 4.1.1 (Continued)
Definitions of Terms

Terms	Definition
Ullage	The quantity represented by the unoccupied space in a tank
Void	An enclosed empty space in a ship
Wash bulkhead	A perforated or partial bulkhead in a tank
Watertight	Watertight means capable of preventing the passage of water through the structure under a head of water for which the surrounding structure is designed
Weather deck	A deck or section of deck exposed to the elements which has means of closing weathertight, all hatches and openings
Weathertight	Weathertight means that in any sea conditions water will not penetrate into the ship
Web	The section of a stiffening member attached perpendicular to the plated surface
Wind and water strakes	The strakes of a ship's side shell plating between the ballast and the deepest load waterline
Windlass	A machine for lifting and lowering the anchor chain
Wing tank	The space bounded by the inner hull longitudinal bulkhead and side shell

RCN 2 to July 2008 version (effective from 1 July 2010)

2 STRUCTURAL IDEALISATION

2.1 Definition of Span

2.1.1 Effective bending span of local support members

2.1.1.1 The effective bending span, l_{bdg}, of a stiffener is defined for typical arrangements in *2.1.1.3* to *2.1.1.7*. Where arrangements differ from those shown in *Figure 4.2.1* through *Figure 4.2.8*, span definition may be specially considered.

2.1.1.2 The effective bending span may be reduced due to the presence of brackets, provided the brackets are effectively supported by the adjacent structure, otherwise the effective bending span is to be taken as the full length of the stiffener between primary member supports.

2.1.1.3 If the web stiffener is sniped at the end or not attached to the stiffener under consideration, the effective bending span is to be taken as the full length between primary member supports unless a backing bracket is fitted, see *Figure 4.2.2*.

2.1.1.4 The effective bending span may only be reduced where brackets are fitted to the flange or free edge of the stiffener. Brackets fitted to the attached plating on the side opposite to that of the stiffener are not to be considered as effective in reducing the effective bending span.

2.1.1.5 The effective bending span, l_{bdg}, for stiffeners forming part of a double skin arrangement is to be taken as shown in *Figure 4.2.1*.

2.1.1.6 The effective bending span, l_{bdg}, for stiffeners forming part of a single skin arrangement is to be taken as shown in *Figure 4.2.2*.

2.1.1.7 For stiffeners supported by a bracket on one side of primary support members, the effective bending span is to be taken as the full distance between primary support members as shown in *Figure 4.2.2(a)*. If brackets are fitted on both sides of the primary support member, the effective bending span is to be taken as in *Figures 4.2.2(b), (c)* and (*d*).

Figure 4.2.1
Effective Bending Span of Stiffeners Supported by Web Stiffeners
(Double Skin Construction)

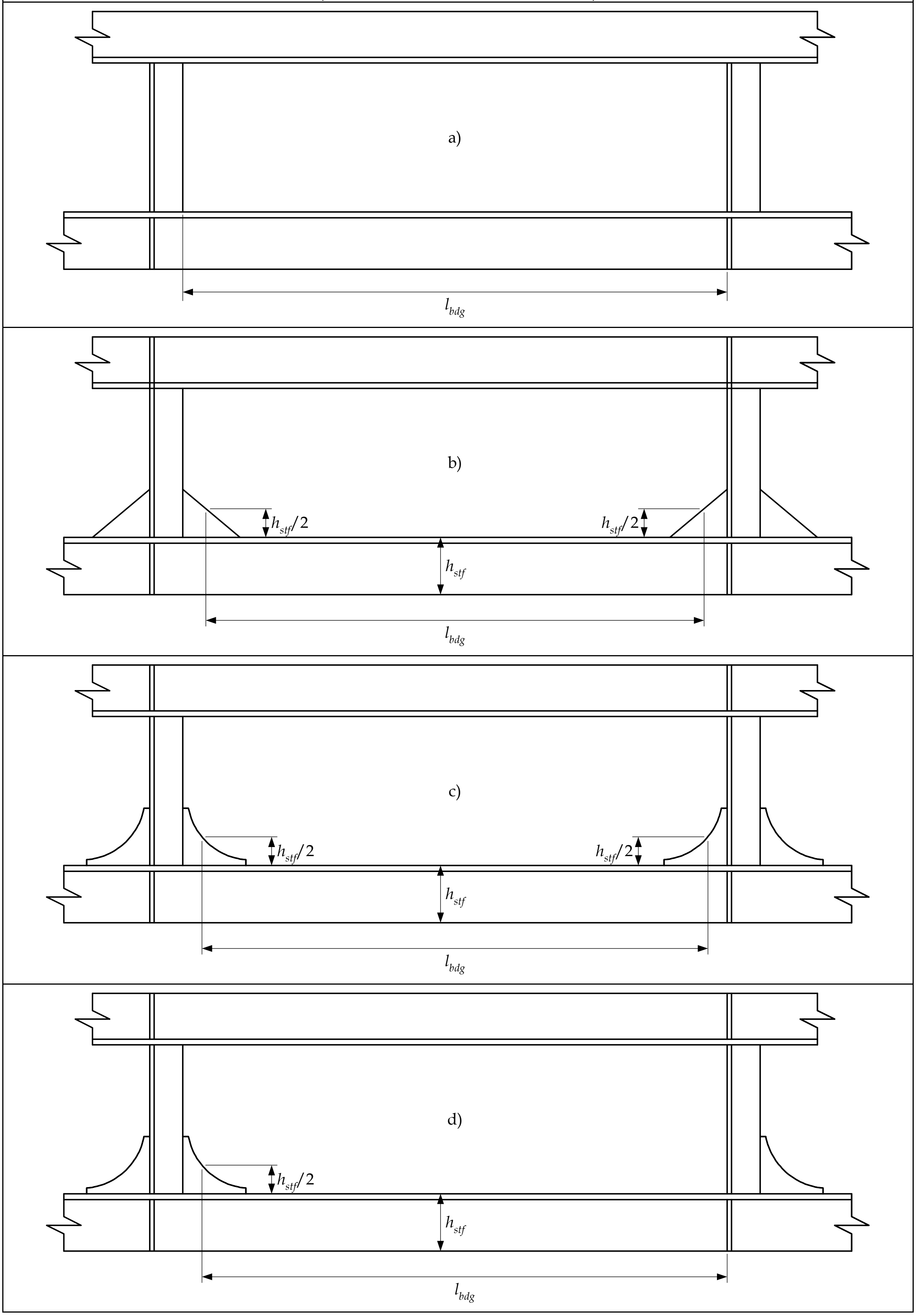
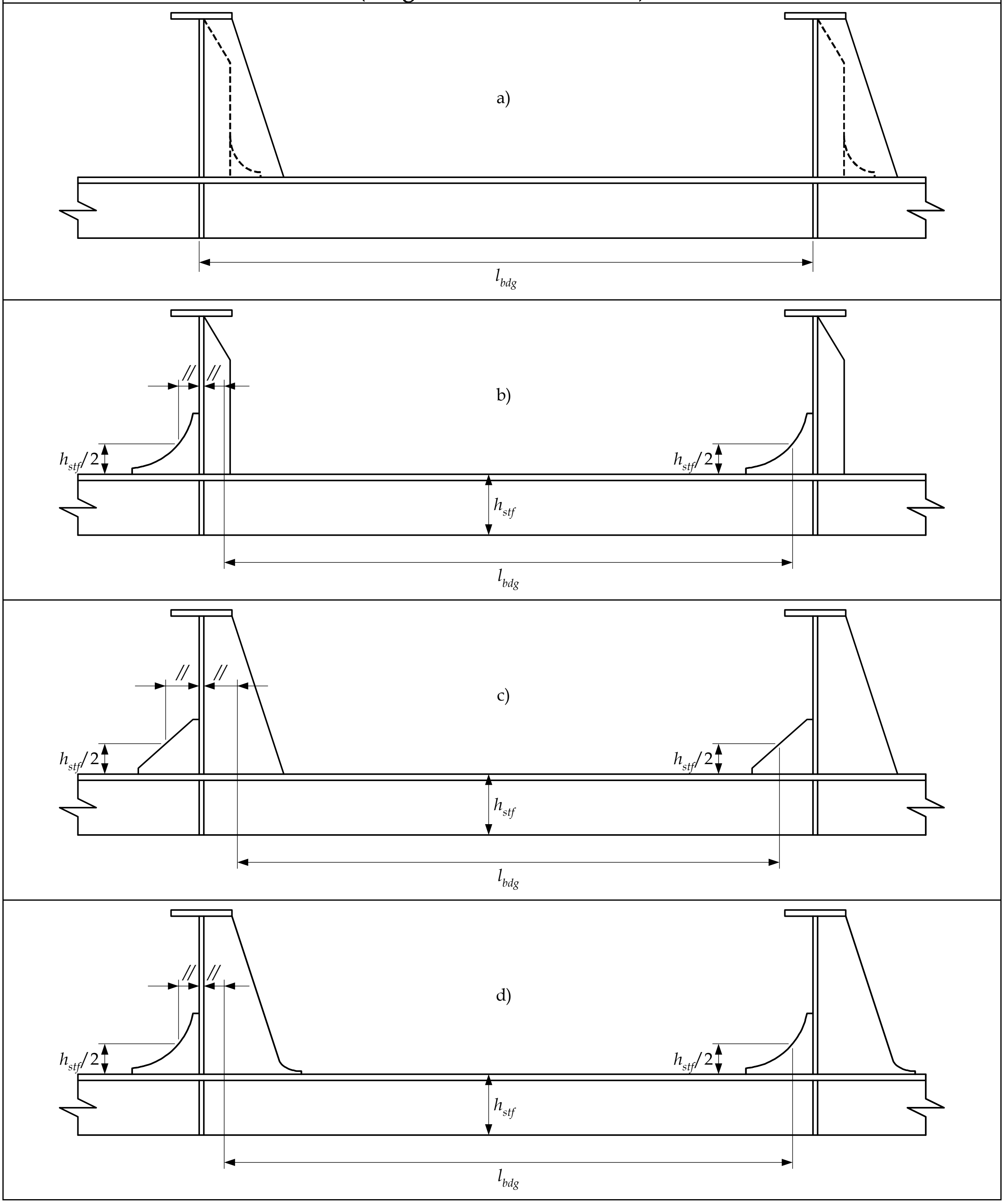
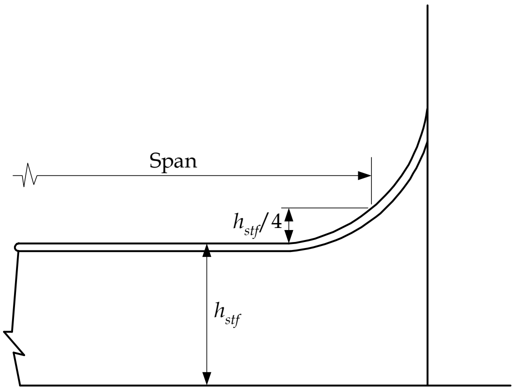


Figure 4.2.2
Effective Bending Span of Stiffeners Supported by Web Stiffeners
(Single Skin Construction)



2.1.1.8 Where the face plate of the stiffener is continuous along the edge of the bracket, the effective bending span is to be taken to the position where the depth of the bracket is equal to one quarter of the depth of the stiffener, see *Figure 4.2.3*.

Figure 4.2.3
Effective Bending Span for Local Support Members with Continuous Face Plate along Bracket Edge



2.1.1.9 For the calculation of the span point, the bracket length is not to be taken greater than 1.5 times the length of the arm on the bulkhead or base.

2.1.2 Effective shear span of local support members

2.1.2.1 The effective shear span, l_{shr}, of a stiffener is defined for typical arrangements in *2.1.2.5* to *2.1.2.7*. Effective bending span for other arrangements will be specially considered.

2.1.2.2 The effective shear span may be reduced due to the presence of brackets provided the brackets are effectively supported by the adjacent structure, otherwise the effective shear span is to be as the full length as given in *2.1.2.4*.

2.1.2.3 The effective shear span may be reduced for brackets fitted on either the flange or the free edge of the stiffener, or for brackets fitted to the attached plating on the side opposite to that of the stiffener. If brackets are fitted at both the flange or free edge of the stiffener, and to the attached plating on the side opposite to that of the stiffener the effective shear span may be calculated using the longer effective bracket arm.

2.1.2.4 The effective shear span may be reduced by a minimum of $s/4000$ m at each end of the member, regardless of support detail, hence the effective shear span, l_{shr}, is not to be taken greater than:

$$l_{shr} \le l - \frac{s}{2000} \quad \text{m}$$

Where:

l full length of the stiffener between primary support members, in m

s stiffener spacing, in mm, as defined in *2.2.1*

2.1.2.5 The effective shear span, l_{shr}, for stiffeners forming part of a double skin arrangement is to be taken as shown in *Figure 4.2.4*.

2.1.2.6 The effective shear span, l_{shr}, for stiffeners forming part of a single skin arrangement is to be taken as shown in *Figure 4.2.5*.

Figure 4.2.4
Effective Shear Span of Stiffeners Supported by Web Stiffeners (Double Skin Construction)

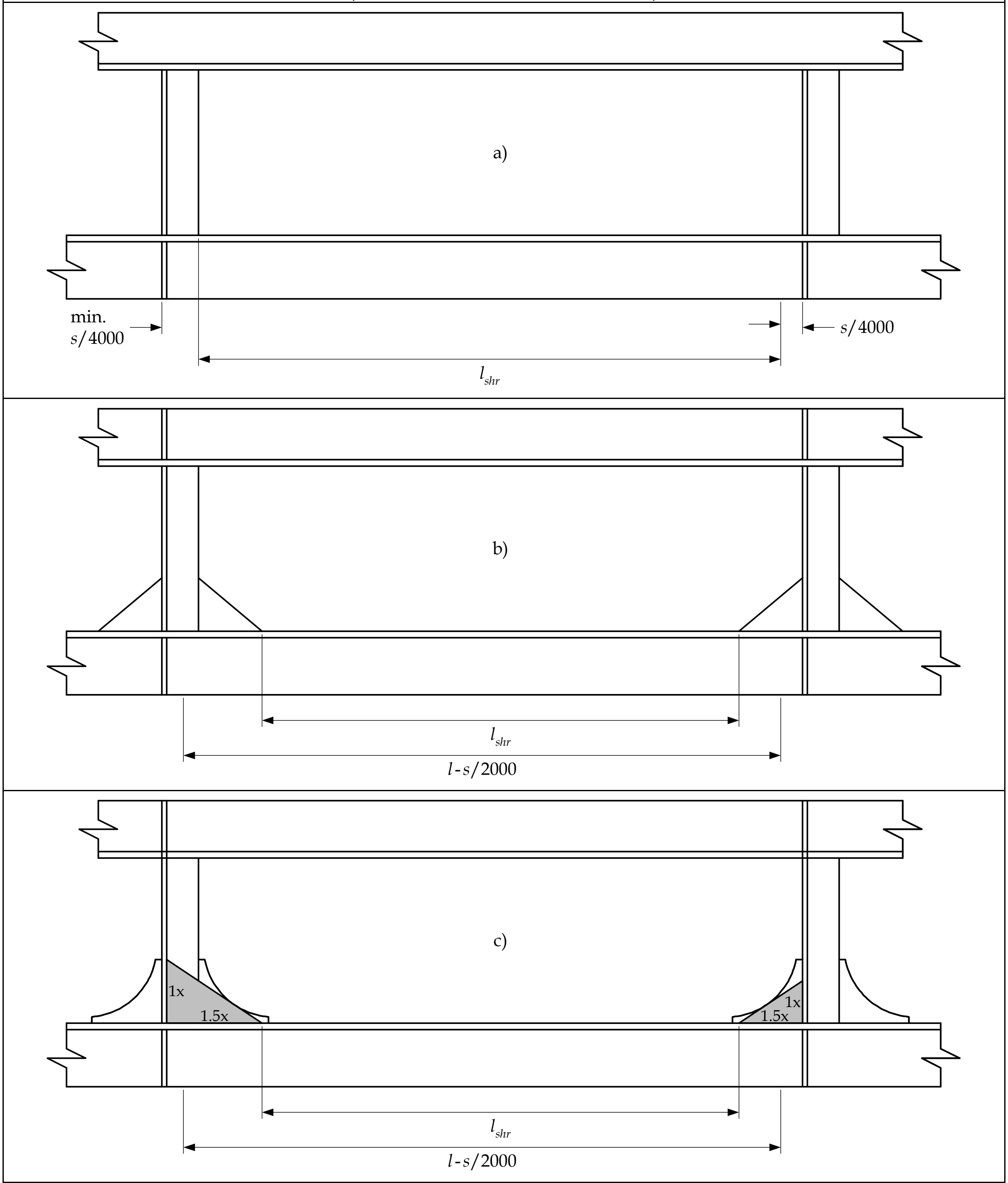


Figure 4.2.5
Effective Shear Span of Stiffeners Supported by Web Stiffeners (Single Skin Construction)

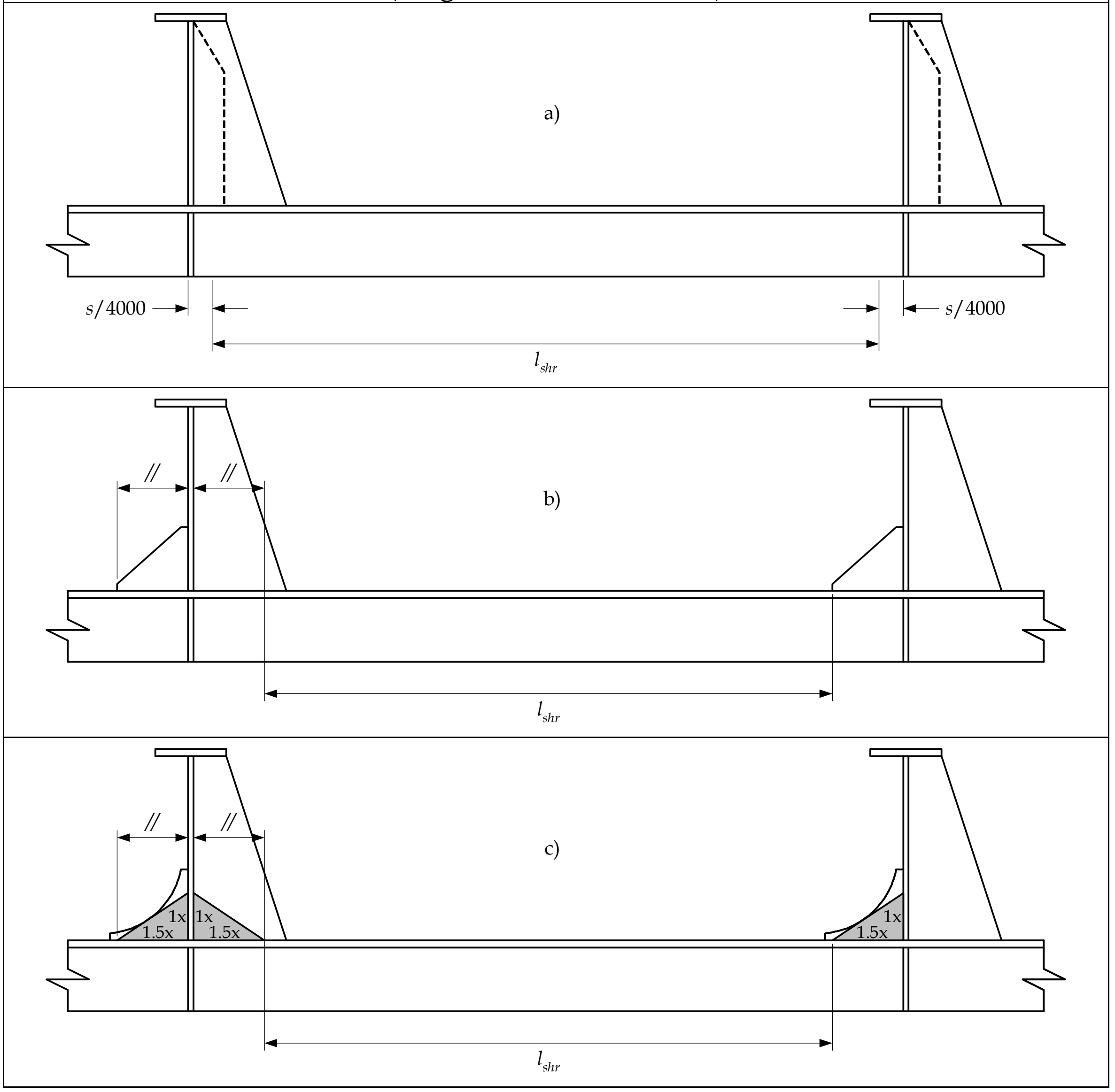
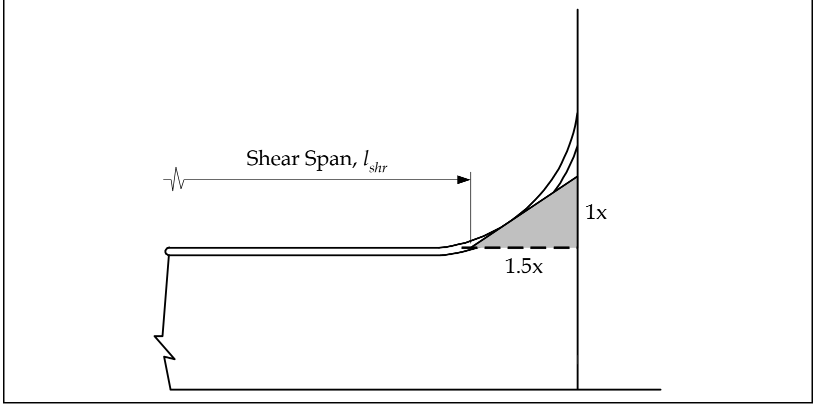


Figure 4.2.6
Effective Shear Span for Local Support Members with Continuous Face Plate along Bracket Edge



2.1.2.7 Where the face plate of the stiffener is continuous along the curved edge of the bracket, the effective shear span is to be taken as shown in *Figure 4.2.6*.

2.1.2.8 For curved and/or long brackets (high length/height ratio) the effective bracket length is to be taken as the maximum inscribed 1:1.5 bracket as shown in *Figure 4.2.4(c)* and *Figure 4.2.5(c)*.

2.1.3 Effect of hull form shape on span of local support members

2.1.3.1 The full length of the stiffener between primary support members, l, is to be measured along the flange for stiffeners with a flange, and along the free edge for flat bar stiffeners. For curved stiffeners the span is defined as the chord length between span points. The calculation of the effective span is to be in accordance with requirements given in *2.1.1*.

2.1.4 Effective bending span of primary support members

2.1.4.1 The effective bending span, l_{bdg}, of a primary support member may be taken as less than the full length of the member between supports provided that suitable end brackets are fitted.

2.1.4.2 For arrangements where the primary support member face plate is not carried continuously around the edge of the bracket, i.e. the bracket is welded to the primary support member, the span point at each end of the member, between which the effective bending span is measured, is to be taken at the point where the depth of end bracket measured from the face of the member is equal to one half the depth of the member, as shown in *Figure 4.2.7(b)*. The effective bracket used to define the span point is to be taken as given in *2.1.4.4*.

2.1.4.3 For brackets where the face plate of the primary support member is continuous along the face of the bracket, i.e. the bracket is integral part of the primary support member, the span point is to be taken at the position where the depth of the bracket is equal to one quarter the depth of the member, see *Figures 4.2.7(a)*, *(c)* and *(d)*. The effective bracket used to define the span point is to be taken as given in *2.1.4.4*.

2.1.4.4 The effective bracket is defined as the maximum size of triangular bracket with a length to height ratio of 1.5 that just fits inside the as fitted bracket, for curved brackets the tangent point is to be used to define the fit, see *Figure 4.2.7* for examples.

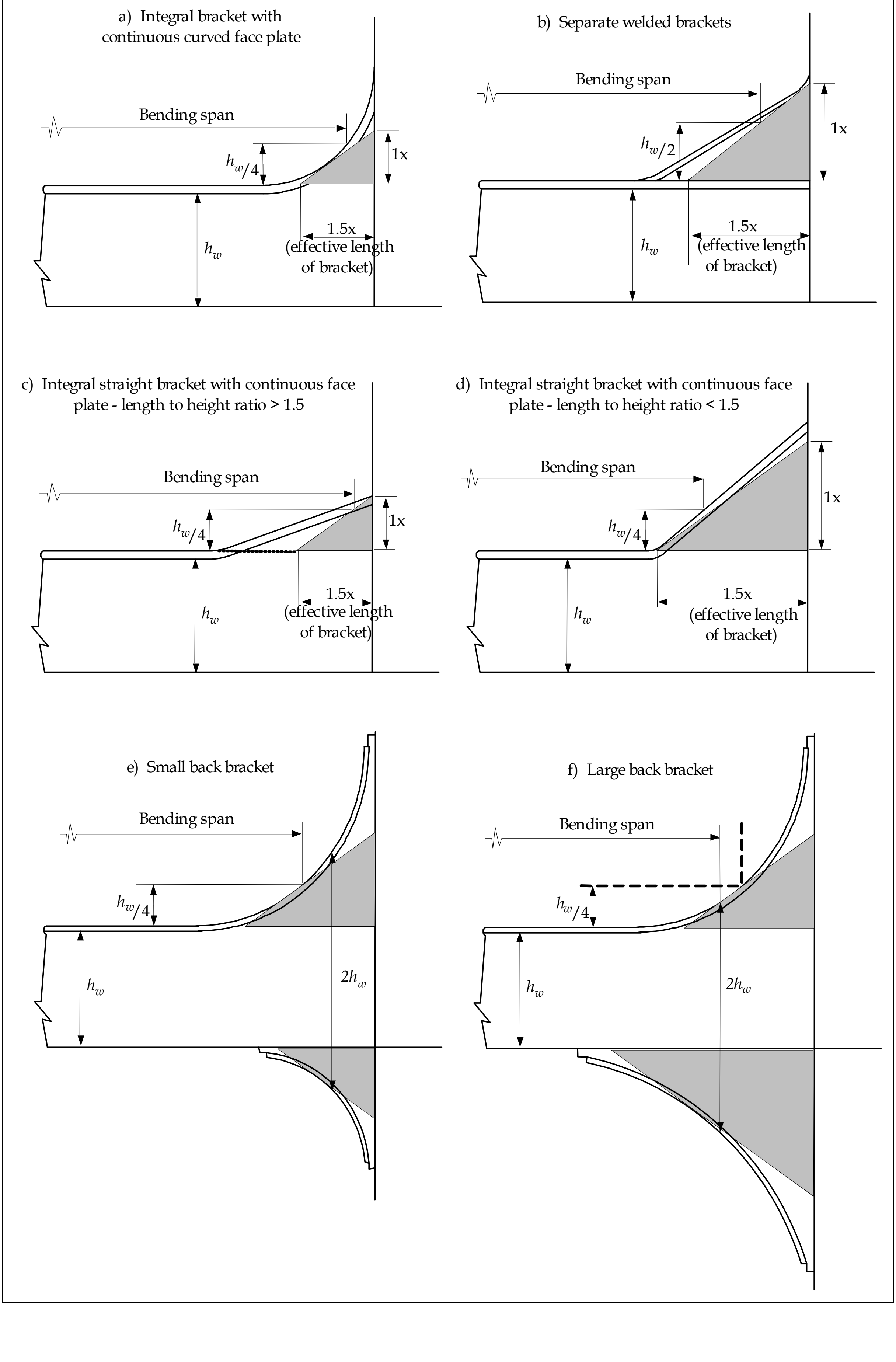
2.1.4.5 For straight brackets with a length to height ratio greater than 1.5, the span point is to be taken to the effective bracket; for steeper brackets the span point is to be taken to the as fitted bracket.

2.1.4.6 For curved brackets the span point is to be measured taken to the fitted bracket at span positions above the tangent point between fitted bracket and effective bracket. For span positions below the tangent point the span point is to be measured to the effective bracket.

2.1.4.7 For arrangements where the primary support member face plate is carried on to the bracket and backing brackets are fitted the span point need not be taken greater than to the position where the total depth reaches twice the depth of the primary support member. Arrangements with small and large backing brackets are shown in *Figure 4.2.7(e)* and *(f)*.

2.1.4.8 For arrangements where the height of the primary support member is maintained and the face plate width is increased towards the support the effective bending span may be taken to a position where the face plate breadth reaches twice the nominal breadth.

Figure 4.2.7
Effective Span of Primary Support Member for Bending Assessment

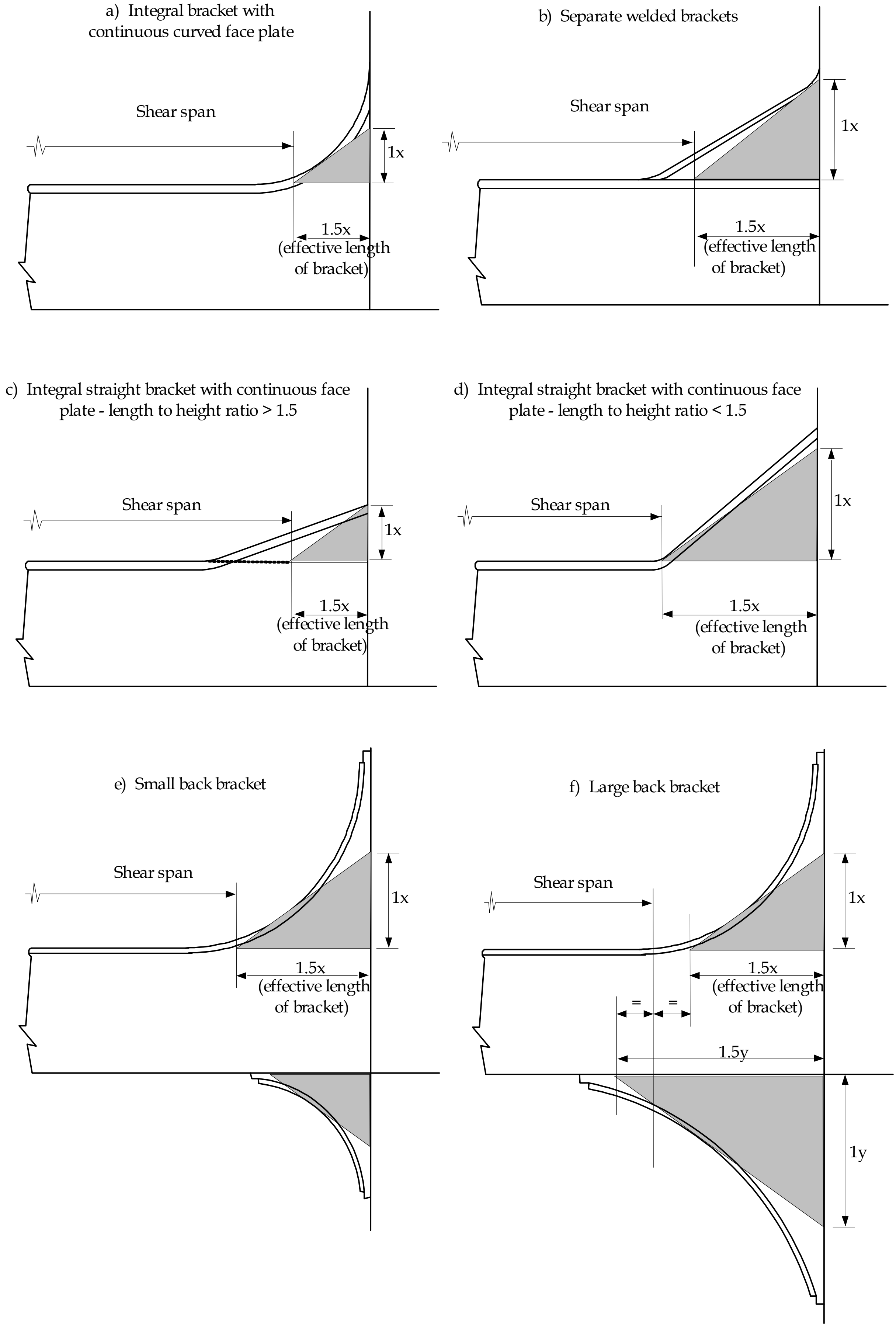


2.1.5 Effective shear span of primary support members

2.1.5.1 The span point at each end of the primary support member, between which the shear span is measured, is to be taken at the toe of the effective brackets supporting the member, where the toes of effective brackets are as shown in *Figure 4.2.8*. The effective bracket used to define the toe point is given in *2.1.4.4*.

2.1.5.2 For arrangements where the effective backing bracket is larger than the effective bracket in way of face plate, the shear span is to be taken as the mean distance between toes of the effective brackets as shown in *Figure 4.2.8 (f)*.

Figure 4.2.8
Effective Span of Primary Support Member for Shear Assessment



2.2 Definition of Spacing and Supported Breadth

2.2.1 Supported load breadth of local support members

2.2.1.1 The mean of the stiffener spacings on each side is to be used for the calculation of the effective plate flange of stiffeners and the load breadth supported by a stiffener, *s*, see *Figure 4.2.9*.

2.2.2 Spacing and supporting load breadth of primary support members

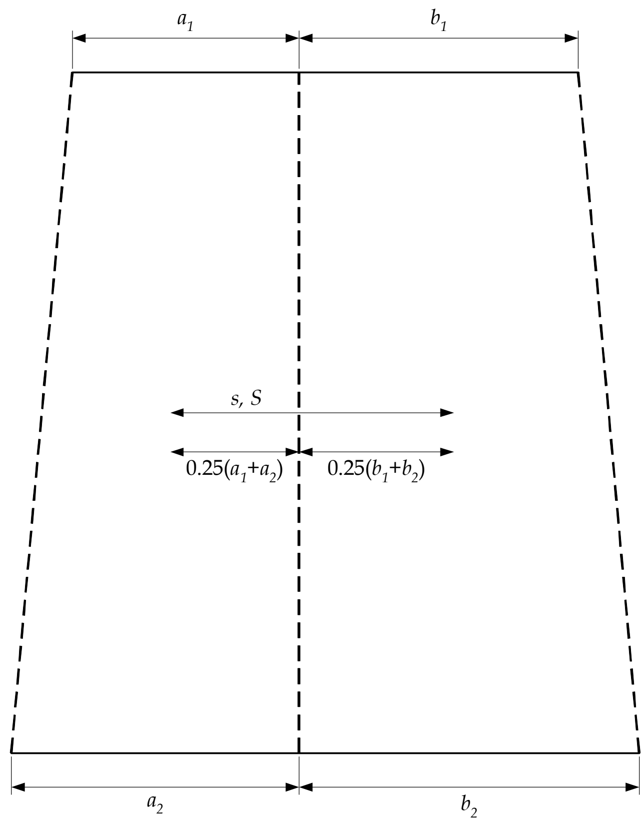
2.2.2.1 Primary support member spacing, *S*, for the calculation of the effective plate flange of primary support members is to be taken as the mean spacing between adjacent primary support members, as shown in *Figure 4.2.9*.

2.2.2.2 Unless specifically defined elsewhere in the Rules, the loading breadth supported by a girder is defined as half the sum of the primary support member spacing on each side, see *Figure 4.2.9*.

2.2.3 Effective spacing of curved plating

2.2.3.1 For curved plating the stiffener spacing or the primary support member spacing, *s* or S, is to be measured on the mean chord between members.

Figure 4.2.9
Supported Load Breadth and Breadth of Attached Plating for Local and Primary Support Members



Note

1. The mean breadth is to be taken as 0.25 $(a_1 + a_2 + b_1 + b_2)$, where a_1, a_2, b_1, b_2 are the spacings between local and primary support members at ends as appropriate.

2.3 Effective Breadth of Plating

2.3.1 Effective breadth of attached plate of local support members for strength evaluation

2.3.1.1 The effective breadth as defined in *2.3.1.2* is applicable to the scantling requirements of stiffeners as given in *Section 8*.

2.3.1.2 The effective breadth of the attached plate, b_{eff}, to be used for calculating the combined section modulus of the stiffener and attached plate is to be taken as the mean stiffener spacing, s, as given in *2.2.1*. However, where the attached plate net thickness, $t_{p\text{-}net}$, is less than 8mm, the effective breadth is not to be taken greater than 600mm.

2.3.2 Effective breadth of attached plate and flanges of primary support members for strength evaluation

2.3.2.1 The effective breadths as defined in *2.3.2.2* to *2.3.2.4* are applicable to the scantling requirements of primary support members as given in *Section 8*.

2.3.2.2 At the end of the span where no effective end bracket is fitted, the effective breadth of attached plate, b_{eff}, for calculating the section modulus and/or moment of inertia of a primary support member is to be taken as:

$$b_{eff} = 0.67\,S \sin\left[\frac{\pi}{6}\left(\frac{l_{bdg}\,(1-\frac{1}{\sqrt{3}})}{2\,S}\right)\right] \quad \text{m} \qquad \text{for } \left(\frac{l_{bdg}\,(1-\frac{1}{\sqrt{3}})}{2S}\right) \le 3$$

$$b_{eff} = 0.67S \quad \text{m} \qquad \text{for } \left(\frac{l_{bdg}\,(1-\frac{1}{\sqrt{3}})}{2S}\right) > 3$$

Where:

S mean spacing of primary support member as defined in *2.2.2* at position considered, in m

l_{bdg} effective bending span, as defined in *2.1.4*, in m

<u>Note</u> sin() is to be calculated in radians

2.3.2.3 At mid span, the effective breadth of attached plate, b_{eff}, for calculating the section modulus and/or moment of inertia of a primary support member is to be taken as:

$$b_{eff} = S \sin\left[\frac{\pi}{18}\left(\frac{l_{bdg}}{S\sqrt{3}}\right)\right] \quad \text{m} \qquad \text{for } \left(\frac{l_{bdg}}{S\sqrt{3}}\right) \le 9$$

$$b_{eff} = 1.0S \quad \text{m} \qquad \text{for } \left(\frac{l_{bdg}}{S\sqrt{3}}\right) > 9$$

Where:

S mean spacing of primary support member as defined in *2.2.2* at position considered, in m

l_{bdg} effective bending span, as defined in *2.1.4*, in m

<u>Note</u> sin() is to be calculated in radians

2.3.2.4 At the end of the span where an effective end bracket is fitted, the effective breadth of attached plate, b_{eff}, for calculating the section modulus of a primary support member is to be taken as the mean values of those given by *2.3.2.2* and *2.3.2.3*. A bracket is considered effective when the length as defined in *Figure 4.2.7* is equal or greater than $0.1l_{bdg}$.

2.3.2.5 The free flange of primary support members of single skin construction may generally be considered fully effective provided tripping bracket arrangements are fitted as required in *Section 10/2.3.3*. For curved face plates see *2.3.4*.

2.3.3 Effective breadth of attached plate of local support members for fatigue strength evaluation

2.3.3.1 The effective breadths as defined in *2.3.3.2* and *2.3.3.3* are applicable to the fatigue strength evaluation of local support members as given in *Section 9/3* and *Appendix C*.

2.3.3.2 At the ends of the span and in way of end brackets and supports, the effective breadth of attached plating, b_{eff}, to be used for calculating the combined section modulus of the stiffener and attached plate is to be taken as:

$$b_{eff} = 0.67\, s\, \sin\left[\frac{\pi}{6}\left(\frac{1000 l_{bdg}(1-\frac{1}{\sqrt{3}})}{2s}\right)\right] \quad \text{mm} \qquad \text{for } \left(\frac{1000 l_{bdg}\,(1-\frac{1}{\sqrt{3}})}{2s}\right) \le 3$$

$$b_{eff} = 0.67 s \quad \text{mm} \qquad \text{for } \left(\frac{1000 l_{bdg}\,(1-\frac{1}{\sqrt{3}})}{2s}\right) > 3$$

Where:

s stiffener spacing, in mm, as defined in *2.2.1*

l_{bdg} effective bending span, as defined in *2.1.1*, in m

<u>Note</u> sin() is to be calculated in radians

2.3.3.3 At mid span, the effective breadth of attached plate, b_{eff}, to be used for calculating the combined section modulus of the stiffener and attached plate is to be taken as:

$$b_{eff} = s\, \sin\left[\frac{\pi}{18}\left(\frac{1000 l_{bdg}}{s\sqrt{3}}\right)\right] \quad \text{mm} \qquad \text{for } \left(\frac{1000 l_{bdg}}{s\sqrt{3}}\right) \le 9$$

$$b_{eff} = 1.0\, s \quad \text{mm} \qquad \text{for } \left(\frac{1000 l_{bdg}}{s\sqrt{3}}\right) > 9$$

Where:

s stiffener spacing, in mm, as defined in *2.2.1*

l_{bdg} effective bending span, as defined in *2.1.1*, in m

<u>Note</u> sin() is to be calculated in radians

2.3.4 Effective area of curved face plates or attached plating of primary support members

2.3.4.1 The effective area as defined in *2.3.4.2* and *2.3.4.3* is applicable to primary support members as follows:

(a) deriving the effective net area of curved face plates and curved attached plating for calculating the section modulus of primary support members for the scantling requirements in *Section 8*

(b) deriving the effective net area of curved face plates, modelled by beam elements, for the strength assessment (FEM) in *Section 9/2* and *Appendix B*

2.3.4.2 The effective net area of curved face plates or attached plating of primary support members, $A_{eff\text{-}net50}$, is to be taken as:

$A_{eff\text{-}net50} = C_f\, t_{f\text{-}net50}\, b_f$ mm^2

Where:

C_f flange efficiency coefficient as shown in *Figure 4.2.10*

$= C_{f1} \dfrac{\sqrt{r_f\, t_{f-net50}}}{b_1}$ but not to be taken greater than 1.0

C_{f1} $= \dfrac{0.643\,(\sinh\beta\cosh\beta + \sin\beta\cos\beta)}{\sinh^2\beta + \sin^2\beta}$ for symmetrical and unsymmetrical face plates, see *Curve 1* in *Figure 4.2.10*

$= \dfrac{0.78\,(\sinh\beta + \sin\beta)(\cosh\beta - \cos\beta)}{\sinh^2\beta + \sin^2\beta}$ for attached plating of box girders with two webs, see *Curve 2* in *Figure 4.2.10*

$= \dfrac{1.56\,(\cosh\beta - \cos\beta)}{\sinh\beta + \sin\beta}$ for attached plating of box girders with multiple webs, see *Curve 3* in *Figure 4.2.10*

β $\dfrac{1.285\, b_1}{\sqrt{r_f\, t_{f-net50}}}$ rad

b_1 $= 0.5\,(b_f - t_{w\text{-}net50})$ for symmetrical face plates

$= b_f$ for unsymmetrical face plates

$= s_w - t_{w\text{-}net50}$ for attached plating of box girders

s_w spacing of supporting webs for box girders, in mm

$t_{f\text{-}net50}$ net flange thickness

$= t_{f\text{-}grs} - 0.5t_{corr}$ mm

for calculation of C_f and β for unsymmetrical face plates $t_{f\text{-}net50}$ is not to be taken greater than $t_{w\text{-}net50}$

$t_{f\text{-}grs}$ gross flange thickness, in mm

$t_{w\text{-}net50}$ net web plate thickness

$= t_{w\text{-}grs} - 0.5t_{corr}$ mm

$t_{w\text{-}grs}$ gross web thickness, in mm

t_{corr} corrosion addition, as given in *Section 6/3.2*

r_f radius of curved face plate or attached plating, in mm

b_f breadth of face plate or attached plating, in mm

2.3.4.3 The effective net area of curved face plates supported by radial brackets, or attached plating supported by cylindrical stiffeners, $A_{eff\text{-}net50}$, is given by:

$$A_{eff-net50} = \left(\frac{3r_f\ t_{f-net50} + C_f\ s_r^2}{3r_f\ t_{f-net50} + s_r^2} \right) t_{f-net50}\ b_f \quad \text{mm}^2$$

Where:

C_f as defined in *2.3.4.2*

$t_{f\text{-}net50}$ net flange thickness, as defined in *2.3.4.2*

s_r spacing of tripping brackets or web stiffeners or stiffeners normal to the web plating, in mm, see *Figure 4.2.11*

b_f breadth of face plate or attached plating, in mm, see *Figure 4.2.11*

r_f radius of curved face plate or attached plating, in mm, see *Figure 4.2.11*

Figure 4.2.10
Effective Width of Curved Face Plates for Alternative Structural Configurations

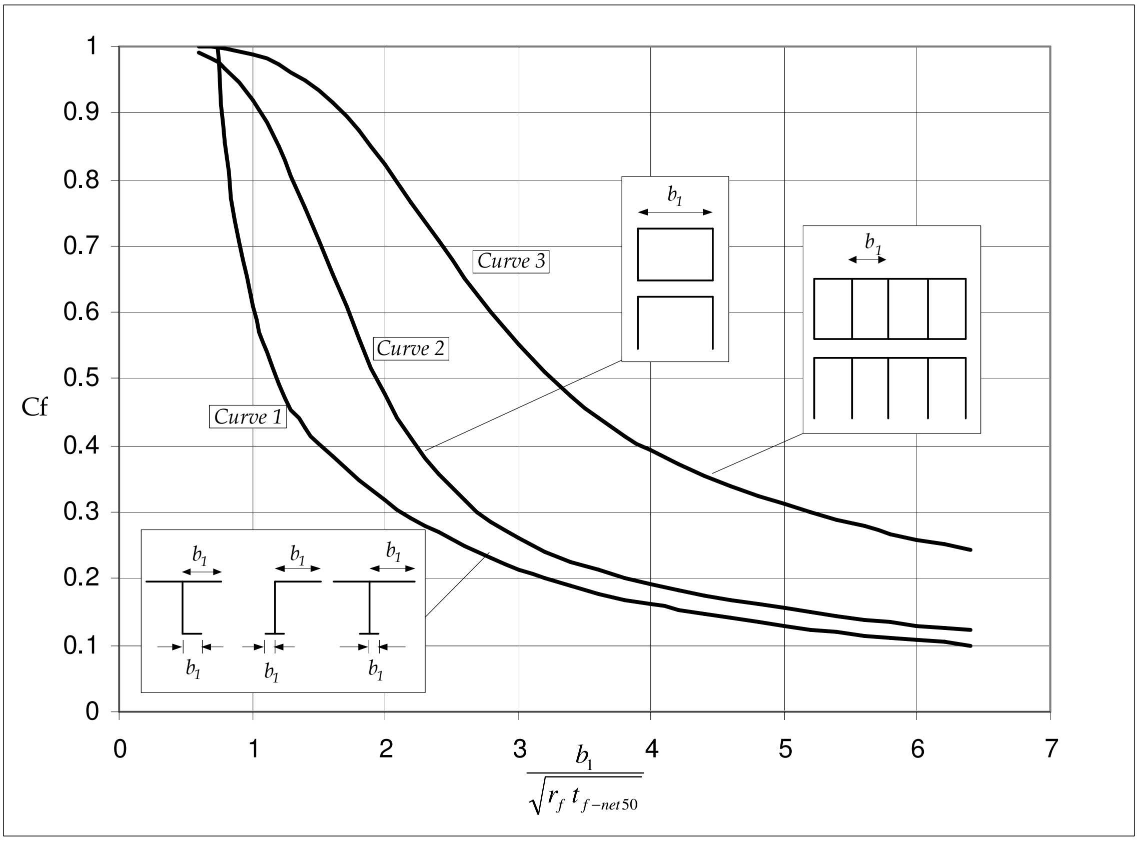
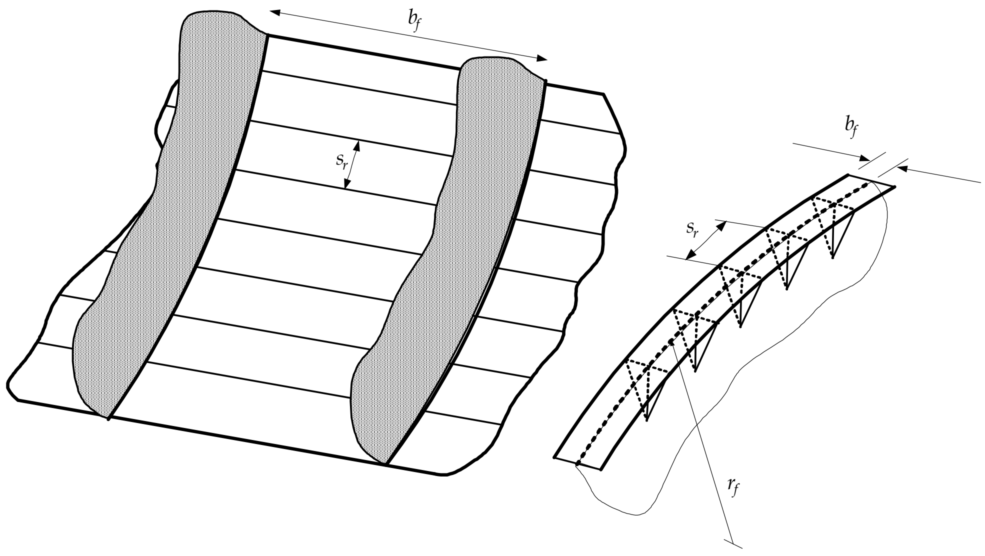


Figure 4.2.11
Curved Shell Panel and Face Plate



2.3.4.4 The effective area given in *2.3.4.2* and *2.3.4.3* is only applicable to faceplates and attached plating of primary support members. This is not to be applied for the area of web stiffeners parallel to the face plate.

2.4 Geometrical Properties of Local Support Members

2.4.1 Calculation of net section properties for local support members

2.4.1.1 The net section modulus, moment of inertia and shear area properties of local support members are to be calculated using the net thicknesses of the attached plate, web and flange.

2.4.1.2 The description of the net dimensions for typical profiles is given in *Figure 4.2.12*.

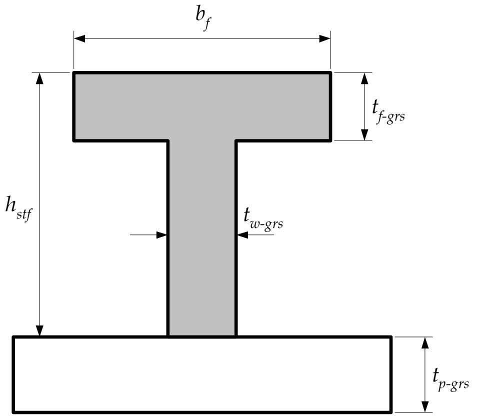
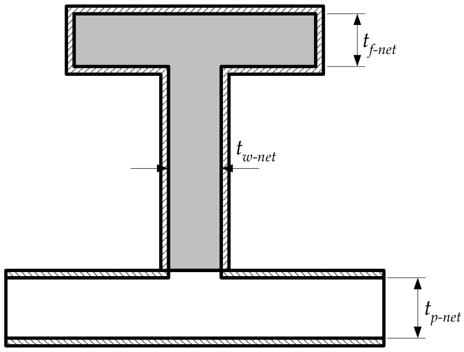
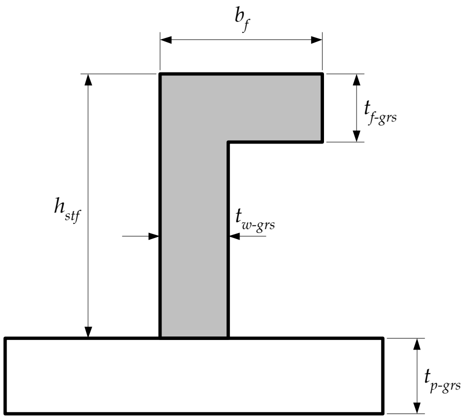
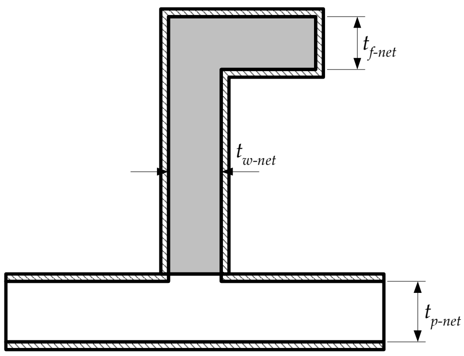
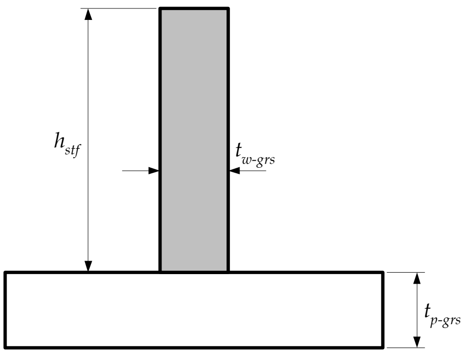
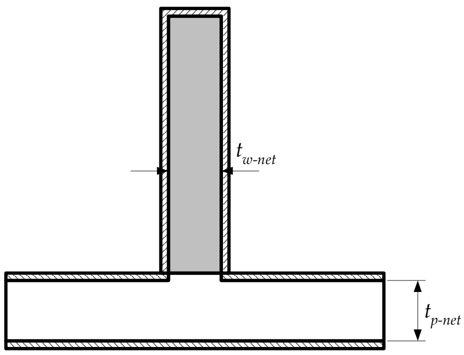
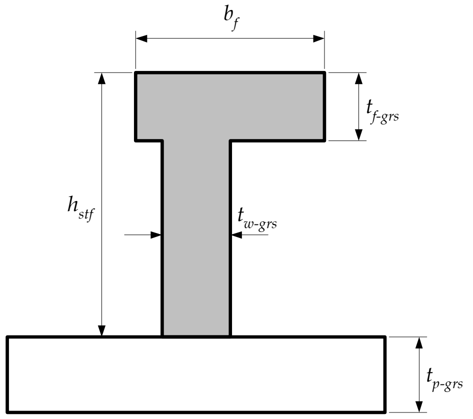
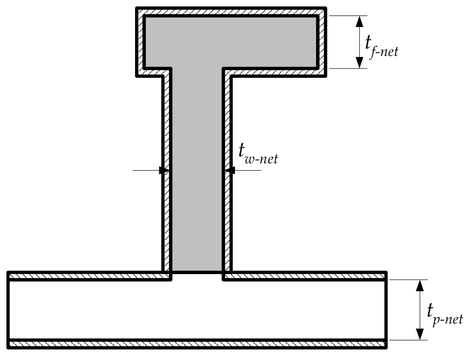
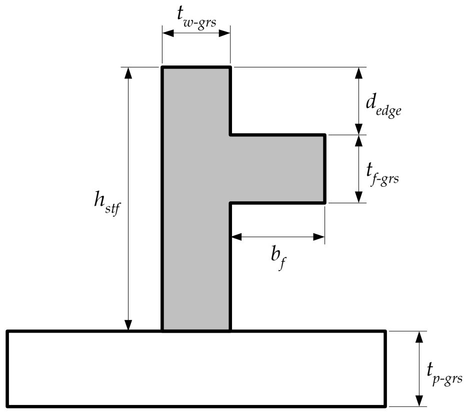
<table>
<tr><th colspan="2">**Figure 4.2.12**
Net Sectional Properties of Local Support Members</th></tr>
<tr><td rowspan="2">Profile</td><td>Reduction Methodology</td></tr>
<tr><td>Local Support Members</td></tr>
<tr><td>
T – Profile</td><td></td></tr>
<tr><td>
L – Profile</td><td></td></tr>
<tr><td>
Flat bar – Profile</td><td></td></tr>
</table>

Figure 4.2.12 (Continued)
Net Sectional Properties of Local Support Members

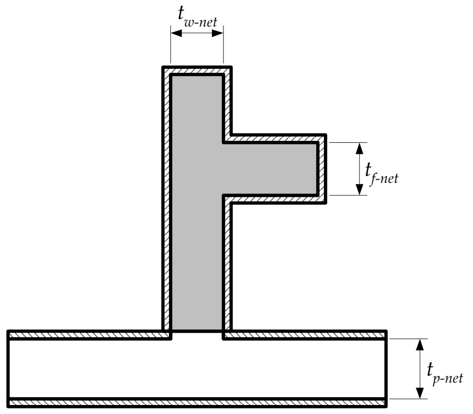


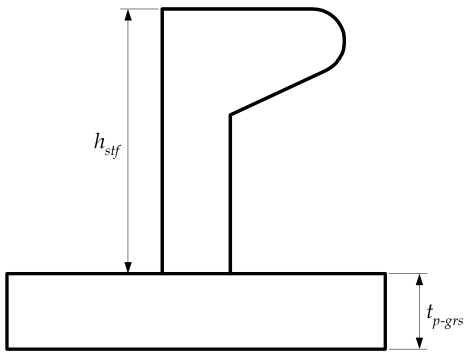
L2 – Profile



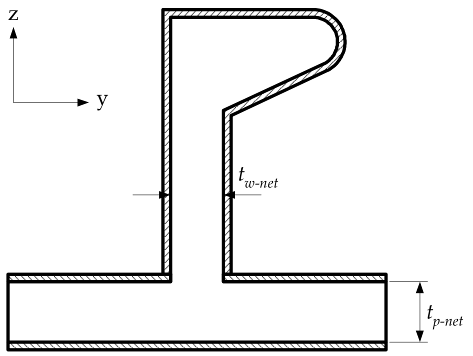


L3 – Profile





Bulb Profile and Similar Profiles



The net cross-sectional area, the moment of inertia about the y-axis and the associated neutral axis position of the profile is to be determined assuming the corrosion magnitude $0.5t_{corr}$ deducted from the surface of the profile cross-section

(RCN 2, effective from 1 July 2008))

2.4.1.3 (void) *(RCN 2, effective from 1 July 2008)*

2.4.1.4 (void) *(RCN 2, effective from 1 July 2008)*

2.4.1.5 (void) *(RCN 2, effective from 1 July 2008)*

Figure 4.2.13
(void) *(RCN 2, effective from 1 July 2008)*

Table 4.2.1
(void) *(RCN 2, effective from 1 July 2008)*

Table 4.2.2
(void) *(RCN 2, effective from 1 July 2008)*

2.4.2 Effective elastic sectional properties of local support members

2.4.2.1 The net elastic shear area, $A_{shr\text{-}el\text{-}net}$, of local support members is to be taken as:

$$A_{shr-el-net} = \frac{(h_{stf} + t_{p-net})t_{w-net} \sin \varphi_w}{100} \quad \text{cm}^2$$

Where:

h_{stf} stiffener height, including face plate, in mm. See also *2.4.1.2*

$t_{p\text{-}net}$ net thickness of attached plate, in mm

$t_{w\text{-}net}$ net web thickness, in mm

φ_w angle between the stiffener web and attached plating, see *Figure 4.2.14*, in degrees. φ_w is to be taken as 90 degrees if the angle is greater than or equal to 75 degrees

2.4.2.2 The effective shear depth of stiffeners, d_{shr}, is to be taken as:

$$d_{shr} = (h_{stf} + t_{p-net})\sin \varphi_w \quad \text{mm}$$

Where:

h_{stf} stiffener height, including face plate, in mm. See also *2.4.1.2*

$t_{p\text{-}net}$ net thickness of attached plate, in mm

φ_w angle between the stiffener web and attached plating, see *Figure 4.2.14*, in degrees. φ_w is to be taken as 90 degrees if the angle is greater than or equal to 75 degrees

2.4.2.3 The elastic net section modulus, $Z_{el-\varphi r\text{-net}}$ of local support members is to be taken as:

$$Z_{el-\varphi-net} = Z_{stf\text{-}net} \sin \varphi_w \quad \text{cm}^3$$

Where:

$Z_{stf\text{-}net}$ net section modulus of corresponding upright stiffener, i.e. when φ_w is equal to 90 degrees, in cm³. See also *2.4.1.2*

φ_w angle between the stiffener web and attached plating, see *Figure 4.2.14*, in degrees. φ_w is to be taken as 90 degrees if the angle is greater than or equal to 75 degrees

2.4.3 Effective plastic section modulus and shear area of stiffeners

2.4.3.1 The net plastic shear area, $A_{shr\text{-}pl\text{-}net}$, of local support members is to be taken as:

$$A_{shr-pl-net} = \frac{(h_{stf} + t_{p-net})t_{w-net} \sin \varphi_w}{100} \quad \text{cm}^2$$

Where:

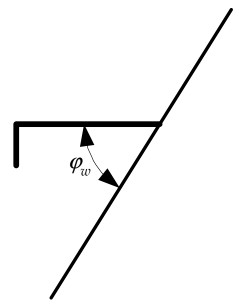
h_{stf} stiffener height, including face plate, in mm. See also *2.4.1.2*

$t_{p\text{-}net}$ net thickness of attached plate, in mm

$t_{w\text{-}net}$ net web thickness, in mm

φ_w angle between the stiffener web and the plate flange, see *Figure 4.2.14*, in degrees. φ_w is to be taken as 90 degrees if the angle is greater than or equal to 75 degrees

Figure 4.2.14
Angle between Stiffener Web and Plate Flange



2.4.3.2 The effective net plastic section modulus, $Z_{pl\text{-}net}$, of local support members is to be taken as:

$$Z_{pl-net} = \frac{f_w\, d_w{}^2\, t_{w-net} \sin\varphi_w}{2000} + \frac{(2\,\gamma - 1) A_{f-net} \left(h_{f-ctr} \sin\varphi_w - b_{f-ctr} \cos\varphi_w\right)}{1000} \quad \text{cm}^3$$

Where:

f_w web shear stress factor

= 0.75 for flanged profile cross-sections with n = 1 or 2

= 1.0 for flanged profile cross-sections with n = 0 and for flat bar stiffeners

n number of moment effective end supports of each member

= 0, 1 or 2

A moment effective end support may be considered where:

(a) the stiffener is continuous at the support

(b) the stiffener passes through the support plate while it is connected at it's termination point by a carling (or equivalent) to adjacent stiffeners

(c) the stiffener is attached to a abutting stiffener effective in bending (not a buckling stiffener) or bracket. The bracket is assumed to be bending effective when it is attached to another stiffener (not a buckling stiffener).

d_w depth of stiffener web, in mm:

= h_{stf} - $t_{f\text{-}net}$ for T, L (rolled and built up) and L2 profiles

= h_{stf} for flat bar and L3 profiles

to be taken as given in *Table 4.2.3* and *Table 4.2.4* for bulb profiles

h_{stf} stiffener height, in mm, see *Figure 4.2.12*

γ $= 0.25\left(1+\sqrt{3+12\,\beta}\right)$

β = 0.5 for all cases, except L profiles without a mid span tripping bracket

$$= \frac{10^6 t^2_{w-net} f_b l_f^2}{80 b_f^2 t_{f-net} h_{f-ctr}} + \frac{t_{w-net}}{2 b_f}$$

but not to be taken greater than 0.5 for L (rolled and built-up) profiles without a mid span tripping bracket

A_{f-net} net cross-sectional area of flange, in mm²:

= $b_f t_{f-net}$ in general

= 0 for flat bar stiffeners

b_f breadth of flange, in mm, see *Figure 4.2.12*. For bulb profiles, see *Table 4.2.3* and *Table 4.2.4*

b_{f-ctr} distance from mid thickness of stiffener web to the centre of the flange area:

$= 0.5(b_f - t_{w-grs})$ for rolled angle profiles

= 0 for T profiles

as given in *Table 4.2.3* and *Table 4.2.4* for bulb profiles

h_{f-ctr} height of stiffener measured to the mid thickness of the flange:

= h_{stf} – 0.5 t_{f-net} for profiles with flange of rectangular shape except for L3 profiles

= h_{stf} – d_{edge} – 0.5 t_{f-net} for L3 profiles

as given in *Table 4.2.3* and *4.2.4* for bulb profiles

d_{edge} distance from upper edge of web to the top of the flange, in mm. For L3 profiles, see *Figure 4.2.12*

f_b = 1.0 in general

= 0.8 for continuous flanges with end bracket(s). A continuous flange is defined as a flange that is not sniped and continuous through the primary support member

= 0.7 for non-continuous flanges with end bracket(s). A non-continuous flange is defined as a flange that is sniped at the primary support member or terminated at the support without aligned structure on the other side of the support

l_f length of stiffener flange between supporting webs, in m, but reduced by the arm length of end bracket(s) for stiffeners with end bracket(s) fitted

t_{f-net} net flange thickness, in mm

= 0 for flat bar stiffeners

as given in *Table 4.2.3* and *Table 4.2.4* for bulb profiles

t_{w-net} net web thickness, in mm

φ_w angle between the stiffener web and the plate flange, see *Figure 4.2.14*, in degrees. φ_w is to be taken as 90 degrees if the angle is greater than or equal to 75 degrees

Table 4.2.3
Characteristic Flange Data for HP Bulb Profiles (see *Figure 4.2.15*)

h_{stf} (mm)	d_w (mm)	$b_{f\text{-}grs}{}^*$ (mm)	$t_{f\text{-}grs}{}^*$ (mm)	$b_{f\text{-}ctr}$ (mm)	$h_{f\text{-}ctr}$ (mm)
200	171	40	14.4	10.9	188
220	188	44	16.2	12.1	206
240	205	49	17.7	13.3	225
260	221	53	19.5	14.5	244
280	238	57	21.3	15.8	263
300	255	62	22.8	16.9	281
320	271	65	25.0	18.1	300
340	288	70	26.4	19.3	318
370	313	77	28.8	21.1	346
400	338	83	31.5	22.9	374
430	363	90	33.9	24.7	402

Note

1. Characteristic flange data converted to net scantlings are given as:

$b_f \cong b_{f\text{-}grs}{}^* + 2\, t_{w\text{-}net}$

$t_{f\text{-}net} = t_{f\text{-}grs}{}^* - t_{corr}$

$t_{w\text{-}net} = t_{w\text{-}grs} - t_{corr}$

Table 4.2.4
Characteristic Flange Data for JIS Bulb Profiles (see *Figure 4.2.15*)

h_{stf} (mm)	d_w (mm)	$b_{f\text{-}grs}{}^*$ (mm)	$t_{f\text{-}grs}{}^*$ (mm)	$b_{f\text{-}ctr}$ (mm)	$h_{f\text{-}ctr}$ (mm)
180	156	34	11.9	9.0	170
200	172	39	13.7	10.4	188
230	198	45	15.2	11.7	217
250	215	49	17.1	12.9	235

Note

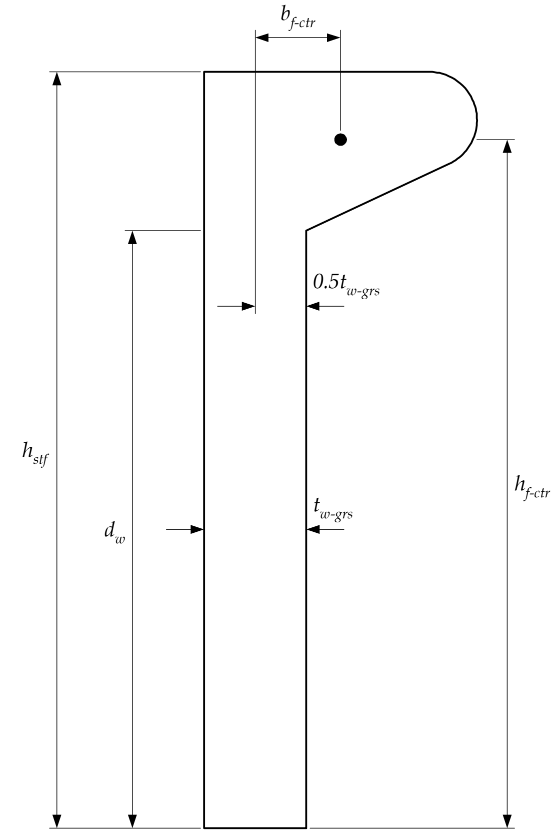
1. Characteristic flange data converted to net scantlings are given as:

$b_f \cong b_{f\text{-}grs}{}^* + 2\, t_{w\text{-}net}$

$t_{f\text{-}net} = t_{f\text{-}grs}{}^* - t_{corr}$

$t_{w\text{-}net} = t_{w\text{-}grs} - t_{corr}$

Figure 4.2.15
Characteristic Data for Bulb Profiles



2.5 Geometrical Properties of Primary Support Members

2.5.1 Effective shear area of primary support members

2.5.1.1 For calculation of the shear area of primary support members the web height, h_w, is to be taken as the moulded height of the primary support member.

2.5.1.2 For single and double skin primary support members, the effective net shear area, $A_{shr-net50}$, is to be taken as:

$$A_{shr-net50} = 0.01\, h_n\, t_{w-net50}\, \sin\varphi_w \quad \text{cm}^2$$

Where:

h_n — for a single skin primary support member, *see Figure* 4.2.16, the effective web height, in mm, is to be taken as the lesser of:

(a) h_w

(b) $h_{n3} + h_{n4}$

(c) $h_{n1} + h_{n2} + h_{n4}$

for a double skin primary support member, the same principle is to be adopted in determining the effective web height.

h_w — web height of primary support member, in mm

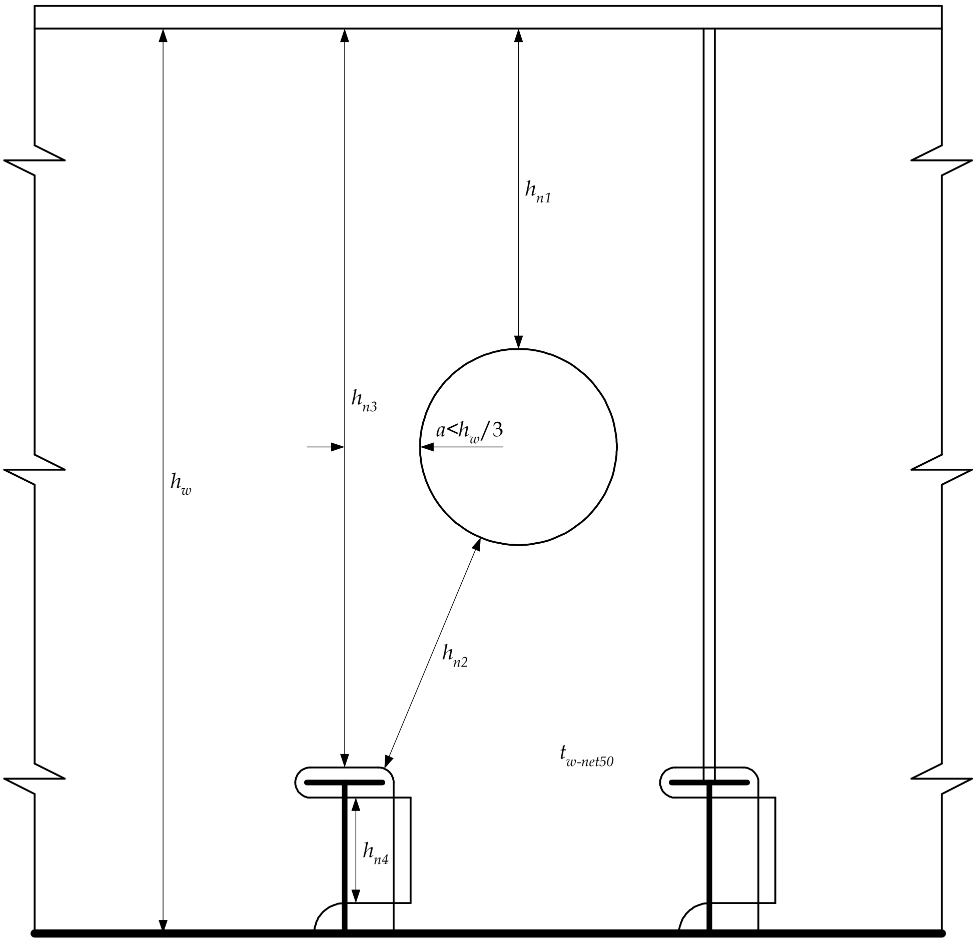
h_{n1}, h_{n2}, h_{n3}, h_{n4} — as shown in *Figure 4.2.16*

$t_{w-net50}$ — net web thickness
$= t_{w-grs} - 0.5\, t_{corr}$ mm

$t_{w\text{-}grs}$	gross web thickness, in mm
t_{corr}	corrosion addition, as given in *Section 6/3.2*, in mm
φ_w	angle between the web and attached plating, see *Figure 4.2.14*, in degrees. φ_w is to be taken as 90 degrees if the angle is greater than or equal to 75 degrees

(RCN 2, effective from 1 July 2008)

Figure 4.2.16
Effective Shear Area in way of Openings



Note
The figure shows effective web height for a single skin primary support member. The effective web height of a double skin primary support member follows the same principles.

2.5.1.3 Where an opening is located at a distance less than $h_w/3$ from the cross-section considered, h_n is to be taken as the smaller of the net height and the net distance through the opening. See *Figure 4.2.16.*

2.5.1.4 Where a girder flange of a single skin primary support member is not parallel to the axis of the attached plating, the effective net shear area, $A_{shr\text{-}net50}$, is to be taken as:

$$A_{shr\text{-}net50} = 0.01\, h_n\, t_{w\text{-}net50} + 1.3\, A_{f\text{-}net50} \sin 2\theta \sin\theta \quad \text{cm}^2$$

Where:

$A_{f\text{-}net50}$ net flange/face plate area

$= 0.01\, b_f\, t_{f\text{-}net50}$ cm^2

b_f breadth of flange or face plate, in mm

$t_{f\text{-}net50}$ net flange thickness

$= t_{f\text{-}grs} - 0.5t_{corr}$ mm

$t_{f\text{-}grs}$ gross flange thickness, in mm

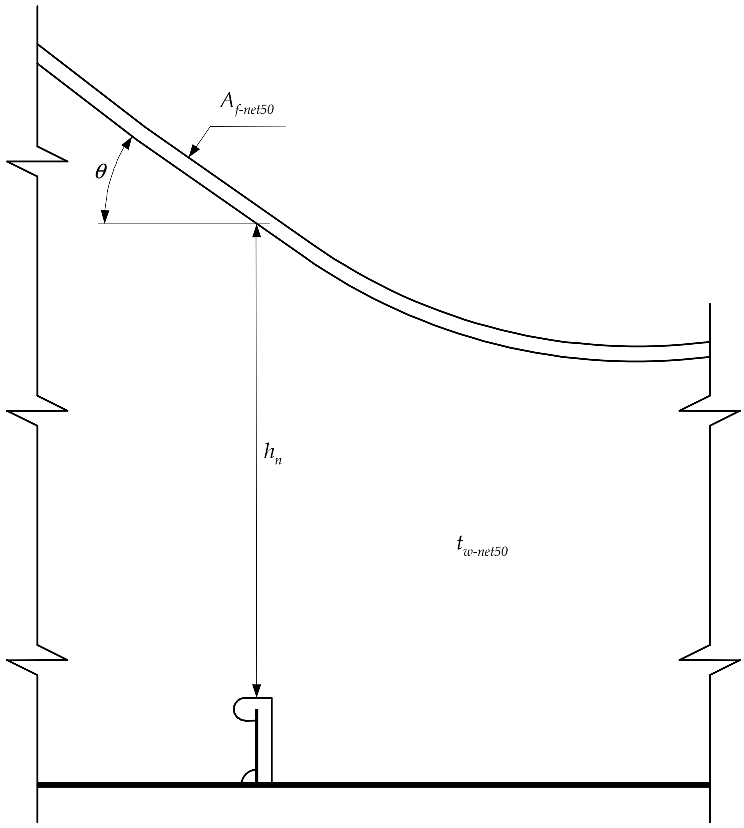
t_{corr} corrosion addition, as given in *Section 6/3.2*, in mm

θ angle of slope of continuous flange, see *Figure 4.2.17*

$t_{w\text{-}net50}$ net web thickness, as defined in *2.5.1.2*, in mm

h_n effective web height, as defined in *Figure 4.2.16,* in mm

Figure 4.2.17
Effective Shear Area in way of Brackets



2.5.2 Effective section modulus of primary support members

2.5.2.1 The net section modulus of primary support members is to be calculated using the net thicknesses of the attached plate, web and face plate (or top attached plate for double skin girders), where the net thicknesses are to be taken as:

$t_{w\text{-}net50} = t_{w\text{-}grs} - 0.5t_{corr}$ mm, for the net web thickness

$t_{p\text{-}net50} = t_{p\text{-}grs} - 0.5t_{corr}$ mm, for the net lower attached plate thickness

$t_{f\text{-}net50} = t_{f\text{-}grs} - 0.5t_{corr}$ mm, for the net upper attached plate or face plate

Where:

$t_{w\text{-}grs}$ gross web thickness, in mm

$t_{p\text{-}grs}$ gross thickness of lower attached plate, in mm

$t_{f\text{-}grs}$ gross thickness of upper attached plate or face plate, in mm

t_{corr} corrosion addition, as given in *Section 6/3.2*, in mm

Note

See *2.3.4* for curved face plates of primary support members

Where angle between the primary support member web and the plate flange is less than 75 degrees, the section modulus is to be directly calculated

(RCN 2, effective from 1 July 2008)

2.6 Geometrical Properties of the Hull Girder Cross-Section

2.6.1 Vertical hull girder section modulus

2.6.1.1 The effective vertical hull girder section modulus, Z_v, at any vertical distance, z, above the baseline is defined by:

$$Z_v = \frac{I_v}{|z - z_{NA}|} \quad \text{m}^3$$

where:

I_v vertical hull girder moment of inertia, of all longitudinally continuous members in cross section under consideration, after deduction of openings as given in *2.6.3*, in m^4

z distance from the structural member under consideration to the baseline, in m

z_{NA} distance from the baseline to the horizontal neutral axis of the hull girder cross-section, in m

2.6.1.2 For calculation of the vertical net hull girder section modulus for the strength assessment, $Z_{v\text{-}net50}$, required by *Section 8,* the vertical net hull girder moment of inertia and position of horizontal neutral axis is to be calculated based on gross thickness minus the corrosion addition $0.5t_{corr}$ of all effective structural members comprising the hull girder section, where t_{corr} is as defined in *Section 6/3.2*.

2.6.1.3 For calculation of vertical net hull girder section modulus for the fatigue assessment, $Z_{v\text{-}net75}$, required by *Section 9/3,* the vertical net hull girder moment of inertia and position of horizontal neutral axis is to be calculated based on gross thickness minus the corrosion addition $0.25t_{corr}$ of all effective structural members comprising the hull girder section, where t_{corr} is as defined in *Section 6/3.2.*

2.6.2 Horizontal hull girder section modulus

2.6.2.1 The effective horizontal hull girder section modulus, Z_h, at any transverse coordinate, y, is to be taken as:

$$Z_h = \frac{I_h}{|y - y_{NA}|} \quad \text{m}^3$$

where:

I_h horizontal hull girder moment of inertia, of all longitudinally continuous members in cross section under consideration, after deduction of openings as given in *2.6.3*, in m^4

y transverse coordinate, in m

y_{NA} distance from the centreline to the vertical neutral axis of the hull girder cross section, in m

2.6.2.2 For calculation of the horizontal net hull girder section modulus for the strength assessment, $Z_{h\text{-}net50}$, required by *Section 8,* the horizontal net hull girder moment of inertia and position of vertical neutral axis is to be calculated based on gross thickness minus the corrosion addition $0.5t_{corr}$ of all effective structural members comprising the hull girder section, where t_{corr} is as defined in *Section 6/3.2.*

2.6.2.3 For calculation of the horizontal net hull girder section modulus for fatigue assessment, $Z_{h\text{-}net75}$, as required in *Section 9/3,* the net horizontal hull girder moment of inertia and position of vertical neutral axis is to be calculated based on gross thickness minus the corrosion addition $0.25t_{corr}$ of all effective structural members comprising the hull girder section, where t_{corr} is as defined in *Section 6/3.2.*

2.6.3 Effective area for calculation of hull girder moment of inertia and section modulus

2.6.3.1 The effective hull girder sectional area includes all the longitudinally continuous structural members after deduction of openings. The structural members given in *2.6.3.2* are not to be included in the effective hull girder sectional area. The definition of openings to be deducted and deduction free openings are given in *2.6.3.4 – 2.6.3.9*. The definition of effective area in way of non-continuous bulkheads and decks is given in *2.6.3.10.*

2.6.3.2 The following structural members are not to be considered as effectively contributing to the hull girder sectional area as they do not provide sufficient structural continuity and are therefore to be excluded in the calculation:

(a) superstructures which do not form a strength deck
(b) deck houses
(c) vertically corrugated bulkheads
(d) bulwarks and gutter plates
(e) bilge keels
(f) sniped or non-continuous longitudinal stiffeners if the cross-section under consideration is closer than twice the height of the stiffener from the end of the stiffener.

2.6.3.3 The following definitions of opening are to be applied:

(a) large openings are openings exceeding 2.5m in length and/or 1.2m in breadth, where the length is measured along the global x-axis of the ship as defined in *Figure 4.1.1*
(b) small openings are openings that are not large openings i.e. manholes, lightening holes, etc.
(c) isolated openings are openings spaced not less than 1m apart in the ship's transverse/vertical direction

2.6.3.4 Large openings and small openings that are not isolated are to be deducted from the sectional area used in the section modulus calculation.

2.6.3.5 Isolated small openings in longitudinal stiffeners or girders are to be deducted if their depth exceeds 25% of the web depth.

2.6.3.6 When several openings are located in or adjacent to the same cross-section, the total equivalent breadth of the combined openings, Σb_{ded}, is to be deducted, see *2.6.3.7* to *2.6.3.8* and *Figure 4.2.18*.

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2.6.3.7 Isolated small openings need not be deducted provided that the sum of their breadths, or shadow area breadths, in one transverse section does not reduce the hull girder section modulus at deck or baseline by more than 3%. Alternatively isolated small openings need not to be deducted provided the total equivalent breadth of small openings, Σb_{sm}, is less than:

$$\Sigma b_{sm} = 0.06\left(B_{sect} - \Sigma b_{ded}\right) \quad \text{m}$$

Where:

Σb_{sm} total equivalent breadth of small openings, see *Figure 4.2.18*

$= b_{sm1} + b_{sm2} + b_{sm3}$ m

B_{sect} the breadth of the ship at the section being considered, in m

Σb_{ded} total equivalent breadth of combined openings specified in *2.6.3.7*, in m

The effect of the shadow area of deductible openings is to be taken into account.

2.6.3.8 When calculating the total equivalent breadth of small openings, Σb_{sm}, each opening is assumed to have a longitudinal shadow area, see *Figure 4.2.18*. This shadow area is obtained by drawing two tangent lines with an angle of 15 degrees to the longitudinal axis of the ship.

2.6.3.9 Full or partial compensation of openings may be provided by increasing the sectional area of the plating, longitudinal stiffeners or girders, or other suitable structure. The compensation area is to extend well beyond the forward and aft end of the opening. Any local edge reinforcement of the opening is not to be included in the effective area of the hull girder section modulus calculations. Compensation is not necessary for openings which are not required to be deducted in accordance with *2.6.3.7*.

2.6.3.10 When calculating the ineffective area in way of large openings and in way of non-continuous decks and longitudinal bulkheads, the effective area is to be taken as shown in *Figure 4.2.19.* The shadow area, which indicates the area that is not effective, is obtained by drawing two tangent lines with an angle of 15 degrees to the longitudinal axis of the ship.

Figure 4.2.18
Calculation of equivalent Breadth

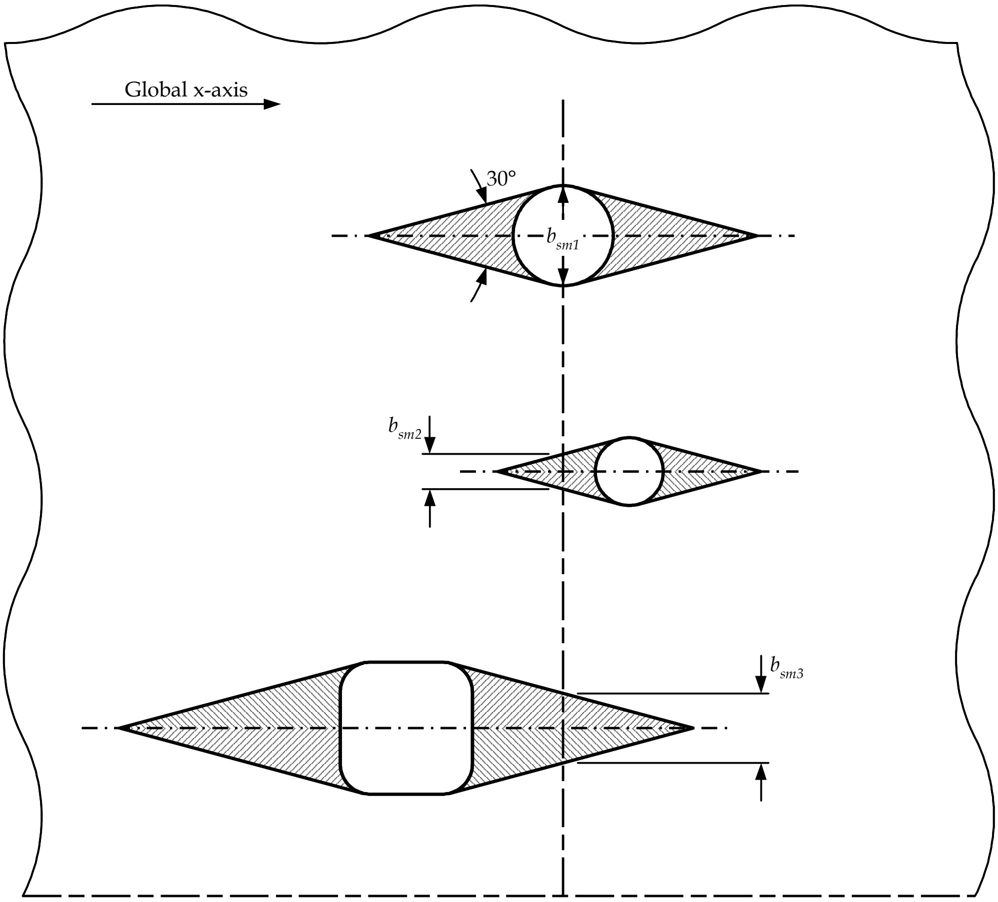
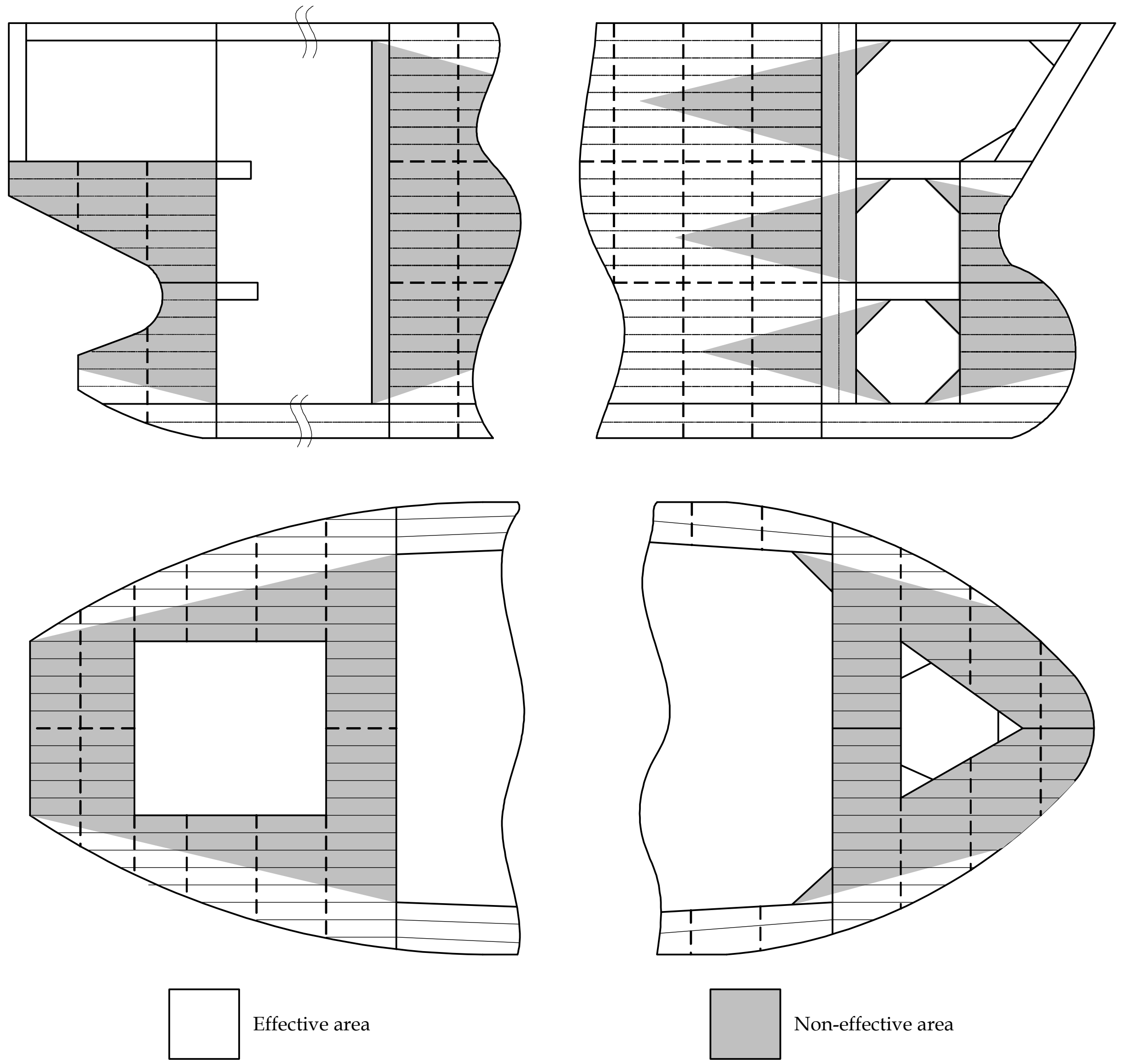


Figure 4.2.19
Effective Area in way of Non-Continuous Decks and Bulkheads



2.6.4 Effective vertical hull girder shear area

2.6.4.1 The effective net hull girder vertical shear area includes the net plating area of the side shell including the bilge, the inner hull including the hopper side and the outboard girder under and the longitudinal bulkheads including the double bottom girders in line.

2.6.4.2 For calculation of the net hull girder vertical shear area, the net plating area is to be calculated based on the net thickness, t_{net50}, given by the gross thickness minus the corrosion addition $0.5t_{corr}$ of all effective structural members given in *2.6.4.1*. Where t_{corr} is as defined in *Section 6/3.2*.

2.6.4.3 For longitudinal strength members forming the web of the hull girder which are inclined to the vertical, the area of the member to be included in the shear force calculation is to be based on the projected area onto the vertical plane. See *Figure 4.2.20*.

2.6.4.4 The calculation of the net effective shear area for vertical and horizontal corrugated bulkheads is to be based on the net effective equivalent thickness, $t_{cg\text{-}net50}$, given by:

$$t_{cg-net50} = \left[0.5\left(t_{w-grs} + t_{f-grs}\right) \frac{b_{cg}}{b_{w-cg} + b_{f-cg}} \right] - 0.5t_{corr} \quad \text{mm}$$

Where:

t_{w-grs} gross corrugation web thickness, in mm

t_{f-grs} gross corrugation flange thickness, in mm

b_{cg} projected length of one corrugation, in mm, as defined in *Figure 4.2.20*

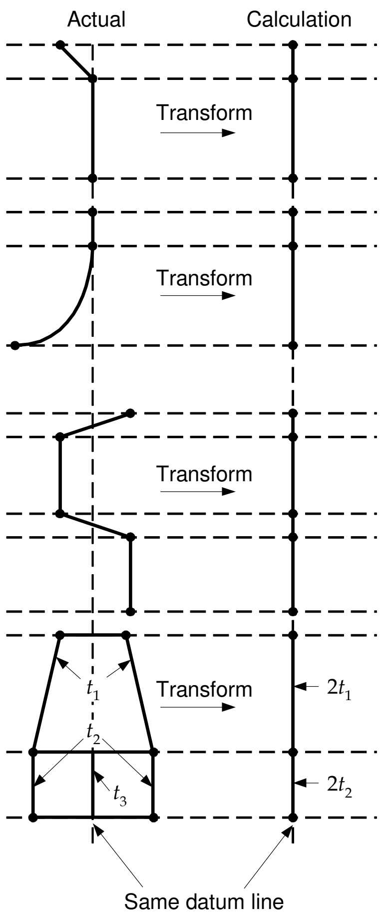
b_{w-cg} breadth of corrugation web, in mm, as defined in *Figure 4.2.20*

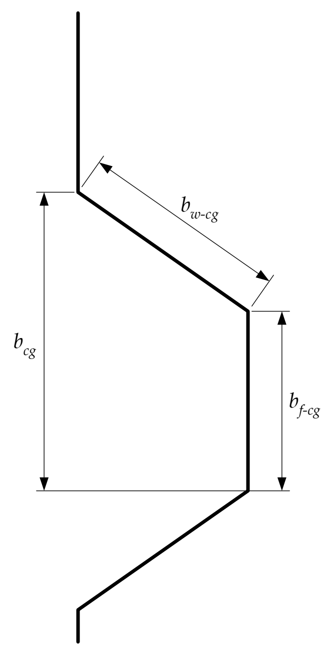
b_{f-cg} breadth of corrugation flange, in mm, as defined in *Figure 4.2.20*

t_{corr} corrosion addition, as defined in *Section 6/3.2*

2.6.4.5 The equivalent net corrugation thickness, $t_{cg-net50}$, is only applicable for the calculation of the effective area, $A_{eff-net50}$, and shear force distribution factor, f_i, as defined in *Section 8/1.3.2.2*.

Figure 4.2.20
Effective Shear Area





3 STRUCTURE DESIGN DETAILS

3.1 Standard Construction Details

3.1.1 Details to be submitted

3.1.1.1 A booklet of standard construction details is to be submitted for review. It is to include the following:

(a) the proportions of built-up members to demonstrate compliance with established standards for structural stability, see Section 10

(b) the design of structural details which reduce the harmful effects of stress concentrations, notches and material fatigue; such as:

- details of the ends, at the intersections of members and associated brackets
- shape and location of air, drainage, and/or lightening holes
- shape and reinforcement of slots or cut-outs for internals
- elimination or closing of weld scallops in way of butts, 'softening' of bracket toes, reduction of abrupt changes of section or structural discontinuities
- proportion and thickness of structural members to reduce fatigue response due to engine, propeller or wave induced cyclic stresses, particularly for higher strength steels.

3.2 Termination of Local Support Members

3.2.1 General

3.2.1.1 In general, structural members are to be effectively connected to adjacent structures to avoid hard spots, notches and stress concentrations.

3.2.1.2 Where a structural member is terminated, structural continuity is to be maintained by suitable back-up structure fitted in way of the end connection of frames, or the end connection is to be effectively extended with additional structure and integrated with an adjacent beam, stiffener, etc.

3.2.1.3 All types of stiffeners (longitudinals, beams, frames, bulkhead stiffeners) are to be connected at their ends. However, in special cases sniped ends may be permitted. Requirements for the various types of connections (bracketed, bracketless or sniped ends) are given in *3.2.3* to *3.2.5*.

3.2.2 Longitudinal members

3.2.2.1 All longitudinals are to be kept continuous within the $0.4L$ amidships cargo tank region. In special cases, in way of large openings, foundations and partial girders, the longitudinals may be terminated, but end connection and welding is to be specially considered.

3.2.2.2 Where continuity of strength of longitudinal members is provided by brackets, the correct alignment of the brackets on each side of the primary support member is to be ensured, and the scantlings of the brackets are to be such that the combined stiffener/bracket section modulus and effective cross-sectional area are not less than those of the member.

3.2.3 Bracketed connections

3.2.3.1 At bracketed end connections, continuity of strength is to be maintained at the stiffener connection to the bracket and at the connection of the bracket to the supporting member. The brackets are to have scantlings sufficient to compensate for the non-continuous stiffener flange or non-continuous stiffener.

3.2.3.2 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection, the section modulus is less than that required for the stiffener.

3.2.3.3 Minimum net bracket thickness, $t_{bkt-net}$, is to be taken as:

$$t_{bkt-net} = \left(2 + f_{bkt}\sqrt{Z_{rl-net}}\right)\left(\sqrt{\frac{\sigma_{yd-stf}}{\sigma_{yd-bkt}}}\right)$$ mm, but is not to be less than 6mm and need not be greater than 13.5mm

Where:

f_{bkt} 0.2 for brackets with flange or edge stiffener
0.3 for brackets without flange or edge stiffener

Z_{rl-net} net rule section modulus, for the stiffener, in cm^3. In the case of two stiffeners connected, it need not be taken as greater than that of the smallest connected stiffener

σ_{yd-stf} specified minimum yield stress of the material of the stiffener, in N/mm^2

σ_{yd-bkt} specified minimum yield stress of the material of the bracket, in N/mm^2

3.2.3.4 Brackets to provide fixity of end rotation are to be fitted at the ends of discontinuous local support members, except as otherwise permitted by *3.2.4*. The end brackets are to have arm lengths, l_{bkt}, not less than:

$$l_{bkt} = c_{bkt}\sqrt{\frac{Z_{rl-net}}{t_{bkt-net}}}$$ mm, but is not to be less than:

- 1.8 times the depth of the stiffener web for connections where the end of the stiffener web is supported and the bracket is welded in line with the stiffener web or with offset necessary to enable welding, see *Figure 4.3.1(c)*
- 2.0 times for other cases, see *Figure 4.3.1(a), (b) and (d)*

Where:

c_{bkt} 65 for brackets with flange or edge stiffener
70 for brackets without flange or edge stiffener

Z_{rl-net} net rule section modulus, for the stiffener, in cm^3. In the case of two stiffeners connected, it need not be taken as greater than that of the smallest connected stiffener

$t_{bkt-net}$ minimum net bracket thickness, as defined in 3.*2.3.3*

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3.2.3.4bis In case of different arm lengths the lengths of the arms, measured from the plating to the toe of the bracket, are to be such that the sum of them is greater than $2l_{bkt}$ and each arm not to be less than $0.8l_{bkt}$, where l_{bkt} is as defined in 3.2.3.4.

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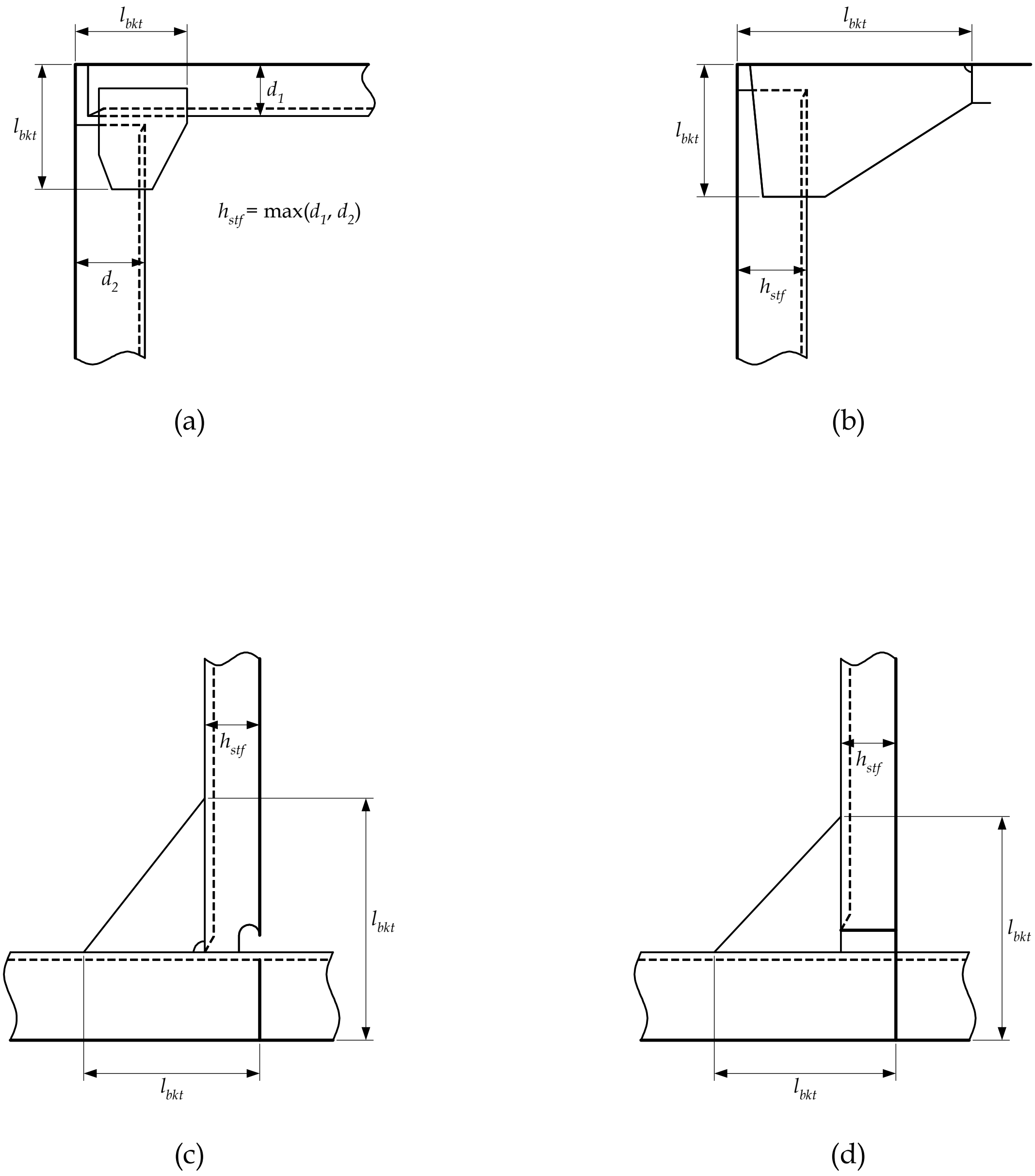
Figure 4.3.1
Bracket Arm Length



Note:

- For stiffeners of configuration (b) that are not lapped, the bracket arm length l_{bkt} is not to be less than the stiffener height h_{stf}.
- For stiffener arrangements similar to (c) and (d) where the smaller attached stiffener, labelled as h_{stf}, is connected to a primary support member or bulkhead, the height of the bracket is not to be less than the height of the attached stiffener, h_{stf}.

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3.2.3.5 The proportions and edge stiffening of brackets are to be in accordance with the requirements of *Section 10/2.4*. Where an edge stiffener is required, the depth of stiffener web, d_w, is not to be less than:

$$d_w = 45\left(1 + \frac{Z_{rl-net}}{2000}\right) \quad \text{mm, but is not to be less than 50mm}$$

Where:

$Z_{rl\text{-}net}$ net rule section modulus, for the stiffener, in cm^3. In the case of two stiffeners connected, it need not be taken as greater than that of the smallest connected stiffener

3.2.4 Bracketless connections

3.2.4.1 Local support members, for example longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are generally to be connected at their ends, in accordance with the requirements of *3.2.2* and *3.2.3*.

3.2.4.2 Where alternative connections are adopted, the proposed arrangements will be specially considered.

3.2.4.3 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

3.2.5 Sniped ends

3.2.5.1 Stiffeners with sniped ends may be used where dynamic loads are small and where the incidence of vibration is considered to be small, i.e. structure not in the stern area and structure not in the vicinity of engines or generators, provided the net thickness of plating supported by the stiffener, $t_{p\text{-}net}$, is not less than:

$$t_{p-net} = c_1\sqrt{\left(1000l - \frac{s}{2}\right)\frac{sPk}{10^6}}$$

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Where:

l stiffener span, in m

s stiffener spacing, in mm, as defined in *2.2*

P design pressure for the stiffener for the design load set being considered, in kN/m^2. The design load sets and method to derive the design pressure are to be taken in accordance with the following criteria, which define the acceptance criteria set to be used:

a) Table 8.2.5 in the cargo tank region

b) Section 8/3.9.2.2 in the area forward of the forward cargo tank, and in the aft end

c) Section 8/4.8.1.2 in the machinery space

d) Section 8/6.2.4.1 and 6.2.5.3 as applicable for the particular structure under consideration

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k higher strength steel factor, as defined in *Section 6/1.1.4*

c_1 coefficient for the design load set being considered, to be taken as:

=1.2 for acceptance criteria set AC1 and sloshing design load

=1.1 for acceptance criteria set AC2

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3.2.5.2 Bracket toes and sniped end members are, in general, to be kept within 25mm of the adjacent member. The maximum distance is not to exceed 40mm unless the bracket or member is supported by another member on the opposite side of the plating. Special attention is to be given to the end taper by using a sniped end of not more than 30 degrees. The depth of toe or sniped end is, generally, not to exceed the thickness of the bracket toe or sniped end member, but need not be less than 15mm.

3.2.5.3 The end attachments of non-load bearing members may be snipe ended. The sniped end is to be not more than 30 degrees and is generally to be kept within 50mm of the adjacent member unless it is supported by a member on the opposite side of the plating. The depth of the toe is generally not to exceed 15mm.

3.2.6 Air and drain holes and scallops

3.2.6.1 Air and drain holes and scallops are to be kept at least 200mm clear of the toes of end brackets, end connections and other areas of high stress concentration measured along the length of the stiffener toward the mid-span and 50mm measured along the length in the opposite direction. See Figure 4.3.2(b). Openings that have been fitted with closing plates, such as scallops, may be permitted in way of block fabrication butts. In areas where the shear stress is less than 60 percent of the allowable limit, alternative arrangements may be accepted. Openings are to be well-rounded. Figure 4.3.2(a) shows some examples of air and drain holes and scallops. In general, the ratio of a/b, as defined in Figure 4.3.2(a), is to be between 0.5 and 1.0. In fatigue sensitive areas further consideration may be required with respect to the details and arrangements of openings and scallops.

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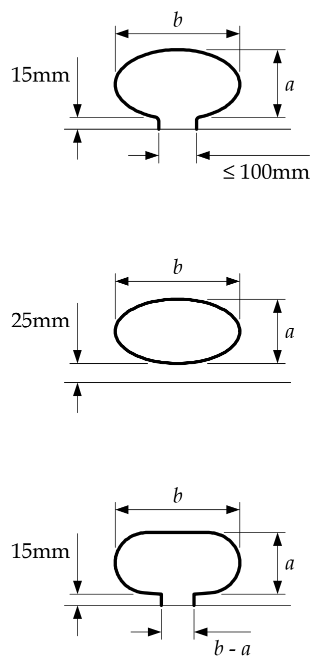
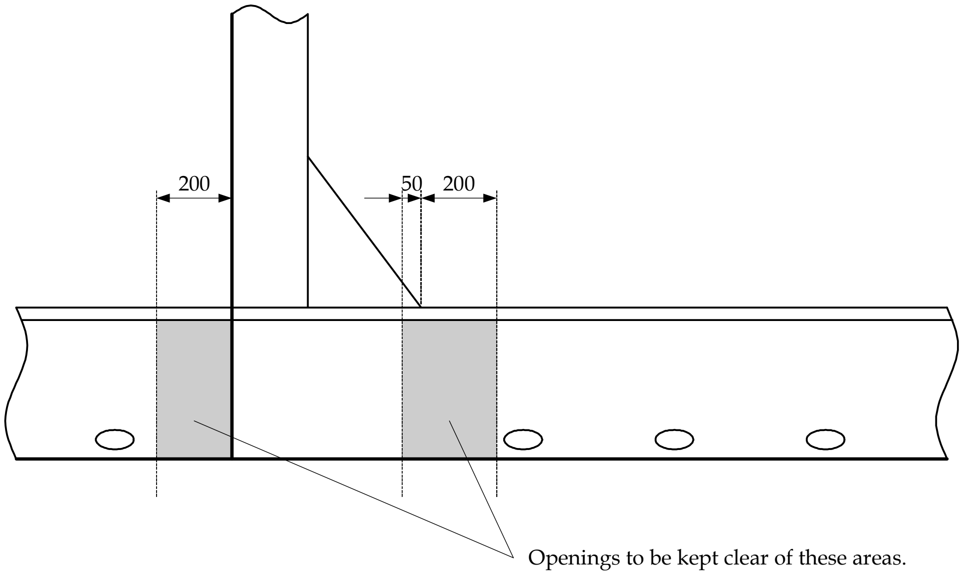
Figure 4.3.2(a)
Examples of Air and Drain Holes and Scallops



Note
The details shown in this figure are for guidance and illustration only.

Figure 4.3.2(b)
Location of Air and Drain Holes



3.2.7 Special requirements

3.2.7.1 Closely spaced scallops or drain holes, i.e. where the distance between scallops/drain holes is less than twice the width b as shown in *Figure 4.3.2(a)*, are not permitted in longitudinal strength members or within 20% of the stiffener span measured from the end of the stiffener. Widely spaced air or drain holes may be permitted provided that they are of elliptical shape or equivalent to minimise stress concentration and are, in general, cut clear of the weld connection.

3.3 Termination of Primary Support Members

3.3.1 General

3.3.1.1 Primary support members are to be arranged to ensure effective continuity of strength. Abrupt changes of depth or section are to be avoided. Primary support members in tanks are to form a continuous line of support and, wherever possible, a complete ring system.

3.3.1.2 The members are to have adequate lateral stability and web stiffening, and the structure is to be arranged to minimise hard spots and other sources of stress concentration. Openings are to have well-rounded corners and are to be located considering the stress distribution and buckling strength of the panel.

3.3.2 End connection

3.3.2.1 Primary support members are to be provided with adequate end fixity by brackets or equivalent structure. The design of end connections and their supporting structure is to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

3.3.2.2 The ends of brackets are generally to be soft-toed. The free edges of the brackets are to be stiffened. Scantlings and details are given in *3.3.3*.

3.3.2.3 Where primary support members are subject to concentrated loads additional strengthening may be required, particularly if these are out of line with the member web.

3.3.2.4 In general, ends of primary support members or connections between primary support members forming ring systems are to be provided with brackets. Bracketless connections may be applied provided that there is adequate support of the adjoining face plates.

3.3.3 Brackets

3.3.3.1 In general, the arm lengths of brackets connecting primary support members are not to be less than the web depth of the member, and need not be taken as greater than 1.5 times the web depth. The thickness of the bracket is, in general, not to be less than that of the girder web plate.

3.3.3.2 For a ring system where the end bracket is integral with the webs of the members and the face plate is carried continuously along the edges of the members and the bracket, the full area of the largest face plate is to be maintained close to the mid point of the bracket and gradually tapered to the smaller face plates. Butts in face plates are to be kept well clear of the bracket toes.

3.3.3.3 Where a wide face plate abuts a narrower one, the taper is generally not to be greater than 1 in 4. Where a thick face plate abuts against a thinner one and the difference in thickness is greater than 4mm, the taper of the thickness is not to be greater than 1 in 3.

3.3.3.4 Face plates of brackets (typical brackets similar to those indicated in *Figure 4.2.7b*) are to have a net cross-sectional area, A_{f-net}, which is not to be less than:

$$A_{f-net} = l_{bkt-edge} t_{bkt-net} \quad \text{cm}^2$$

Where:

$l_{bkt-edge}$ length of free edge of bracket, in m. For brackets that are curved the length of the free edge may be taken as the length of the tangent at the midpoint of the free edge. If $l_{bkt-edge}$ is greater than 1.5m, 40 percent of the face plate area is to be in a stiffener fitted parallel to the free edge and a maximum 0.15m from the edge

$t_{bkt-net}$ minimum net bracket thickness, in mm, as defined in *3.2.3.3*

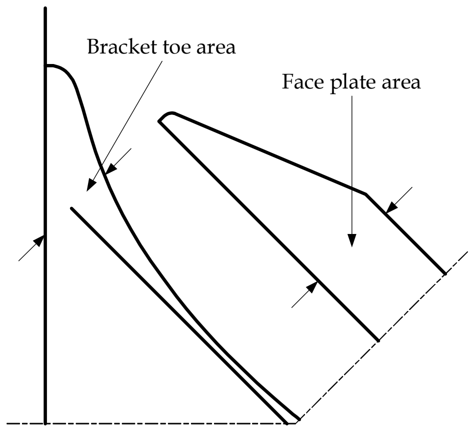
3.3.4 Bracket toes

3.3.4.1 The toes of brackets are not to land on unstiffened plating. Notch effects at the toes of brackets may be reduced by making the toe concave or otherwise tapering it off. In general, the toe height is not to be greater than the thickness of the bracket toe, but need not be less than 15mm. The end brackets of large primary support members are to be soft-toed. Where any end bracket has a face plate, it is to be sniped and tapered at an angle not greater than 30°.

3.3.4.2 Where primary support members are constructed of higher strength steel, particular attention is to be paid to the design of the end bracket toes in order to minimise stress concentrations. Sniped face plates, which are welded onto the edge of primary support member brackets, are to be carried well around the radiused bracket toe and are to incorporate a taper not greater than 1 in 3. Where sniped face plates are welded adjacent to the edge of primary support member brackets, adequate cross-sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area, measured perpendicular to the face plate

is to be not less than 60 percent of the full cross-sectional area of the face plate, see *Figure 4.3.3*.

Figure 4.3.3
Bracket Toe Construction



Note
The details shown in this figure are only used to illustrate items described in the text and are not intended to represent design guidance or recommendations.

3.4 Intersections of Continuous Local Support Members and Primary Support Members

3.4.1 General

3.4.1.1 Cut-outs for the passage of stiffeners through the web of primary support members, and the related collaring arrangements, are to be designed to minimize stress concentrations around the perimeter of the opening and on the attached web stiffeners.

3.4.1.2 Cut-outs in way of cross-tie ends and floors under bulkhead stools or in high stress areas are to be fitted with "full" collar plates, see *Figure 4.3.4*.

3.4.1.3 Lug type collar plates are to be fitted in cut-outs where required for compliance with the requirements of *3.4.3*, and in areas of significant stress concentrations, e.g., in way of primary support member toes. See *Figure 4.3.5* for typical lug arrangements.

3.4.1.4 When, in the following locations, the calculated direct stress, σ_w, in the primary support member web stiffener according to *3.4.3.5* exceeds 80% of the permissible values a soft heel is to be provided in way of the heel of primary support member web stiffeners:

(a) connection to shell envelope longitudinals below the scantling draught, T_{sc}

(b) connection to inner bottom longitudinals.

A soft heel is not required at the intersection with watertight bulkheads and primary support members, where a back bracket is fitted or where the primary support member web is welded to the stiffener face plate. The soft heel is to have a keyhole, similar to that shown in *Figure 4.3.6(c)*.

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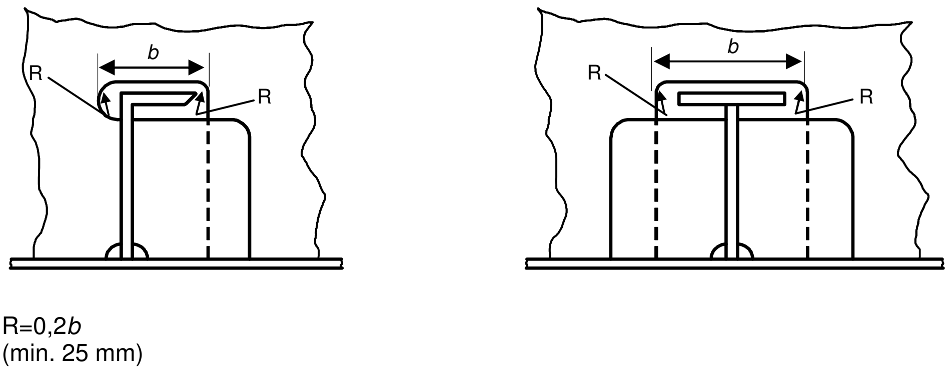
Figure 4.3.4
Collars for Cut-outs in Areas of High Stress



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3.4.2 Details of cut-outs

3.4.2.1 In general, cut-outs are to have rounded corners and the corner radii, *R*, are to be as large as practicable, with a minimum of 20 percent of the breadth, *b*, of the cut-out or 25mm, whichever is greater, but need not be greater than 50mm, see Figure 4.3.4. Consideration will be given to other shapes on the basis of maintaining equivalent strength and minimizing stress concentration.

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3.4.3 Connection between primary support members and intersecting stiffeners (local support members)

3.4.3.1 The cross-sectional areas of the connections are to be determined from the proportion of load transmitted through each component in association with its appropriate permissible stress.

3.4.3.2 The total load, *W*, transmitted through the connection to the primary support member is given by:

$$W = P s \left(S - \frac{s}{2000} \right) 10^{-3} \quad \text{kN}$$

Where:

P design pressure for the stiffener for the design load set being considered, in kN/m². The design load sets, method to derive the design pressure and applicable acceptance criteria set are to be taken in accordance with the following criteria, which define the Acceptance Criteria Set to be used:

Table 8.2.5 in the cargo tank region

Section 8/3.9.2.2 in the area forward of the forward cargo tank

Section 8/3.9.2.2 in the aft end

Section 8/4.8.1.2 in the machinery space

Section 8/6.2.4.1 if subjected to sloshing loads

Section 8/6.3.5.1 if subjected to bottom slamming loads

Section 8/6.4.5.1 if subjected to bow impact loads

S primary support member spacing, in m, as defined in *Section*

4/2.2

s stiffener spacing, in mm, as defined in *Section 4/2.2*

For stiffeners having different primary support member spacing, S, and/or different pressure, P, at each side of the primary support member, the average load for the two sides is to be applied, e.g. vertical stiffeners at transverse bulkhead.

3.4.3.3 The load, W_1, transmitted through the shear connection is to be taken as follows.

If the web stiffener is connected to the intersecting stiffener:

$$W_1 = W\left(\alpha_a + \frac{A_{1-net}}{4 f_c A_{w-net} + A_{1-net}}\right) \quad \text{kN}$$

If the web stiffener is not connected to the intersecting stiffener:

$$W_1 = W$$

Where:

W the total load, in kN, as defined in *3.4.3.2*

α_a panel aspect ratio, not to be taken greater than 0.25

$$= \frac{s}{1000S}$$

S primary support member spacing, in m

s stiffener spacing, in mm

A_{1-net} effective net shear area of the connection, to be taken as the sum of the components of the connection:

$$A_{1d-net} + A_{1c-net} \quad \text{cm}^2$$

in case of a slit type slot connections area, A_{1-net}, is given by:

$$A_{1-net} = 2 l_d t_{w-net} 10^{-2} \quad \text{cm}^2$$

in case of a typical double lug or collar plate connection area, A_{1-net}, is given by:

$$A_{1-net} = 2 f_1 l_c t_{c-net} 10^{-2} \quad \text{cm}^2$$

A_{1d-net} net shear connection area excluding lug or collar plate, as given by the following and *Figure 4.3.5*:

$$A_{1d-net} = l_d t_{w-net} 10^{-2} \quad \text{cm}^2$$

l_d length of direct connection between stiffener and primary support member web, in mm

t_{w-net} net web thickness of the primary support member, in mm

A_{1c-net} net shear connection area with lug or collar plate, given by the following and *Figure 4.3.5*:

$$A_{1c-net} = f_1 l_c t_{c-net} 10^{-2} \quad \text{cm}^2$$

l_c length of connection between lug or collar plate and primary support member, in mm

t_{c-net} net thickness of lug or collar plate, not to be taken greater than the net thickness of the adjacent primary support member web, in mm

f_1 shear stiffness coefficient:

= 1.0 for stiffeners of symmetrical cross section

= $140/w$ for stiffeners of asymmetrical cross section

but is not to be taken as greater than 1.0

w the width of the cut-out for an asymmetrical stiffener, measured from the cut-out side of the stiffener web, in mm, as indicated in *Figure 4.3.5*

A_{w-net} effective net cross-sectional area of the primary support member web stiffener in way of the connection including backing bracket where fitted, as shown in *Figure 4.3.6,* in cm^2. If the primary support member web stiffener incorporates a soft heel ending or soft heel and soft toe ending, A_{w-net}, is to be measured at the throat of the connection, as shown in *Figure 4.3.6*.

f_c the collar load factor defined as follows:

for intersecting stiffeners of symmetrical cross section:

= 1.85 for $A_{w-net} \leq 14$

= $1.85 - 0.0441(A_{w-net} - 14)$ for $14 < A_{w-net} \leq 31$

= $1.1 - 0.013(A_{w-net} - 31)$ for $31 < A_{w-net} \leq 58$

= 0.75 for $A_{w-net} > 58$

for intersecting stiffeners of asymmetrical cross section:

$$= 0.68 + 0.0172 \frac{l_s}{A_{w-net}}$$

where:

$l_s = l_c$ for a single lug or collar plate connection to the primary support member

= l_d for a single sided direct connection to the primary support member

= mean of the connection length on both sides, i.e., in the case of a lug or collar plus a direct connection, $l_s = 0.5(l_c + l_d)$

3.4.3.4 The load, W_2, transmitted through the primary support member web stiffener is to be taken as follows.

If the web stiffener is connected to the intersecting stiffener:

$$W_2 = W\left(1 - \alpha_a - \frac{A_{1-net}}{4 f_c A_{w-net} + A_{1-net}}\right) \quad \text{kN}$$

If the web stiffener is not connected to the intersecting stiffener:

$W_2 = 0$

Where:

W the total load, in kN, as defined in *3.4.3 2*

α_a panel aspect ratio

$$= \frac{s}{1000S}$$

S primary support member spacing, in m

s stiffener spacing, in mm

A_{1-net} effective net shear area of the connection, in cm², as defined in *3.4.3.3*

f_c collar load factor, as defined in *3.4.3.3*

A_{w-net} effective net cross-sectional area of the primary support member web stiffener , in cm², as defined in *3.4.3.3*

3.4.3.5 The values of A_{w-net}, A_{wc-net} and A_{1-net} are to be such that the calculated stresses satisfy the following criteria:

for the connection to the primary support member web stiffener away from the weld:

$$\sigma_w \le \sigma_{perm}$$

for the connection to the primary support member web stiffener in way of the weld:

$$\sigma_{wc} \le \sigma_{perm}$$

for the shear connection to the primary support member web:

$$\tau_w \le \tau_{perm}$$

Where:

σ_w direct stress in the primary support member web stiffener at the minimum bracket area away from the weld connection:

$$= \frac{10 W_2}{A_{w-net}} \quad \text{N/mm}^2$$

σ_{wc} direct stress in the primary support member web stiffener in way of the weld connection:

$$= \frac{10 W_2}{A_{wc-net}} \quad \text{N/mm}^2$$

τ_w shear stress in the shear connection to the primary support member

$$= \frac{10 W_1}{A_{1-net}} \quad \text{N/mm}^2$$

A_{w-net} effective net cross-sectional area of the primary support member web stiffener, in cm², as defined in *3.4.3.3*

A_{wc-net} effective net area of the web stiffener in way of the weld as shown in *Figure 4.3.6*, in cm²

A_{1-net} effective net shear area of the connection, in cm², as defined in *3.4.3.3*

W_1 load transmitted through the shear connection, in kN, as defined in *3.4.3.3*

W_2 load transmitted through the web stiffener, in kN, as defined in *3.4.3.4*

σ_{perm} permissible direct stress given in *Table 4.3.1* for the applicable acceptance criteria, see *3.4.3.2*, in N/mm²

τ_{perm} permissible shear stress given in *Table 4.3.1* for the applicable acceptance criteria, see *3.4.3.2*, in N/mm²

3.4.3.5 bis 1 When total load, W, is bottom slamming or bow impact loads the following criteria apply in lieu of 3.4.3.3-3.4.3.5.

$$0.9W \le \frac{\left(A_{1-net}\tau_{perm} + A_{w-net}\sigma_{perm}\right)}{10}\ \text{kN}$$

A_{1-net} effective net shear area in cm² of the connection, as defined in 3.4.3.3.

A_{w-net} effective net cross sectional area in cm² of the primary support member web stiffener in way of the connection including backing bracket where fitted, as defined in 3.4.3.3.

σ_{perm} permissible direct stress given in *Table 4.3.1* for AC-3, in N/mm²

τ_{perm} permissible shear stress given in *Table 4.3.1* for AC-3, in N/mm²

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3.4.3.6 Where a backing bracket is fitted in addition to the primary support member web stiffener, it is to be arranged on the opposite side to, and in alignment with the web stiffener. The arm length of the bracket is to be not less than the depth of the web stiffener and its net cross-sectional area through the throat of the bracket is to be included in the calculation of A_{w-net} as shown in *Figure 4.3.6*.

3.4.3.7 Lapped connections of primary support member web stiffeners or tripping brackets to local support members are not permitted in the cargo tank region, e.g., lapped connections between transverse and longitudinal local support members.

3.4.3.8 Fabricated stiffeners having their face plate welded to the side of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where such sections are connected to the primary support member web stiffener, a symmetrical arrangement of connection to the transverse members is to be incorporated. This may be implemented by fitting backing brackets on the opposite side of the transverse web or bulkhead. In way of the cargo tank region, the primary support member web stiffener and backing brackets are to be butt welded to the intersecting stiffener web.

3.4.3.9 Where the web stiffener of the primary support member is parallel to the web of the intersecting stiffener, but not connected to it, the offset primary support member web stiffener may be located as shown in *Figure 4.3.7*. The offset primary support member web stiffener is to be located in close proximity to the slot edge. See also *Figure 4.3.7*. The ends of the offset web stiffeners are to be suitably tapered and softened.

3.4.3.10 Alternative arrangements will be specially considered on the basis of their ability to transmit load with equivalent effectiveness. Details of calculations made and/or testing procedures and results are to be submitted.

3.4.3.11 The size of the fillet welds is to be calculated according to *Section 6/5* based on the weld factors given in *Table 4.3.2*. For the welding in way of the shear connection the size is not to be less than that required for the primary support member web plate for the location under consideration.

Table 4.3.1
Permissible Stresses for Connection between Stiffeners and Primary Support Members

Item	Direct Stress, σ_{perm}, in N/mm²			Shear Stress, τ_{perm}, in N/mm²		
	Acceptance Criteria Set See *3.4.3.2*			Acceptance Criteria Set See *3.4.3.2*		
	AC1	AC2	AC3	AC1	AC2	AC3
Primary support member web stiffener	$0.83\sigma_{yd}$ (3)	σ_{yd}	σ_{yd}	-	-	-
Primary support member web stiffener to intersecting stiffener in way of weld connection:						
double continuous fillet	$0.58\ \sigma_{yd}$ (3)	$0.70\ \sigma_{yd}$ (3)	σ_{yd}	-	-	-
partial penetration weld	$0.83\ \sigma_{yd}$ (2)(3)	σ_{yd} (2)	σ_{yd}	-	-	-
Primary support member stiffener to intersecting stiffener in way of lapped welding	$0.50\ \sigma_{yd}$	$0.60\ \sigma_{yd}$	σ_{yd}	-	-	-
Shear connection including lugs or collar plates:						
single sided connection	-	-	-	$0.71\ \tau_{yd}$	$0.85\ \tau_{yd}$	τ_{yd}
double sided connection	-	-	-	$0.83\ \tau_{yd}$	τ_{yd}	τ_{yd}

Where:

τ_{perm} permissible shear stress, in N/mm²

σ_{perm} permissible direct stress, in N/mm²

σ_{yd} minimum specified material yield stress, in N/mm²

τ_{yd} $\frac{\sigma_{yd}}{\sqrt{3}}$, in N/mm²

Note

1. The stress computation on plate type members is to be performed on the basis of net thicknesses, whereas gross values are to be used in weld strength assessments, see *3.4.3.11*.
2. The root face is not to be greater than one third of the gross thickness of the primary support member stiffener.
3. Allowable stresses may be increased by 5 percent where a soft heel is provided in way of the heel of the primary support member web stiffener.

Table 4.3.2
Weld Factors for Connection between Stiffeners and Primary Support Members

Item	Weld factor
Primary support member stiffener to intersecting stiffener	$0.6\ \sigma_{wc} / \sigma_{perm}$ not to be less than 0.38
Shear connection inclusive lug or collar plate	0.38
Shear connection inclusive lug or collar plate, where the web stiffener of the primary support member is not connected to the intersection stiffener	$0.6\ \tau_w / \tau_{perm}$ not to be less than 0.44

Where:

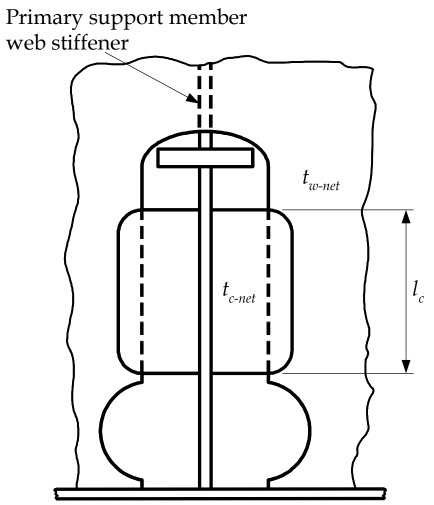
τ_w shear stress, as defined in *3.4.3.5*

σ_w as defined in *3.4.3.5*

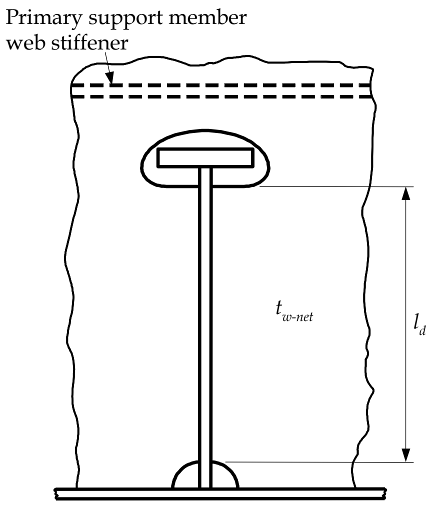
τ_{perm} permissible shear stress, in N/mm², see *Table 4.3.1*

σ_{perm} permissible direct stress, in N/mm² see *Table 4.3.1*

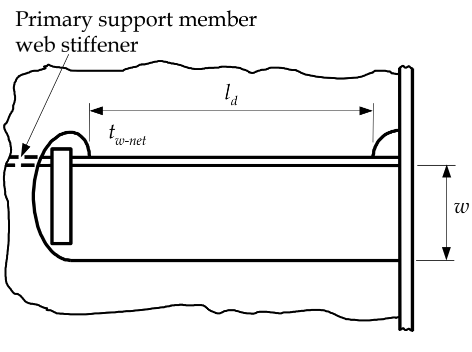
Figure 4.3.5
Symmetric and Asymmetric Cut outs



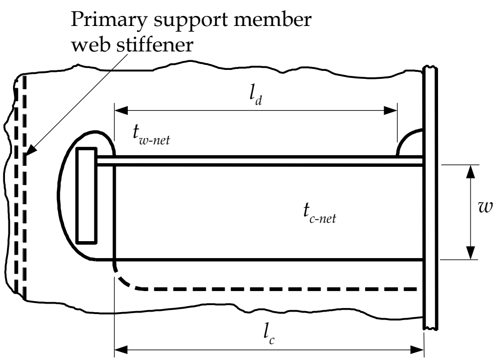
(a) double lug or collar plates



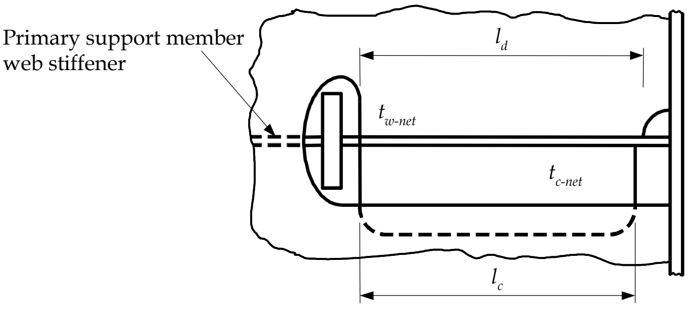
(b) slit type slot connection



(c) direct connection without lug or collar plate



(d) lug or collar plate and direct connection

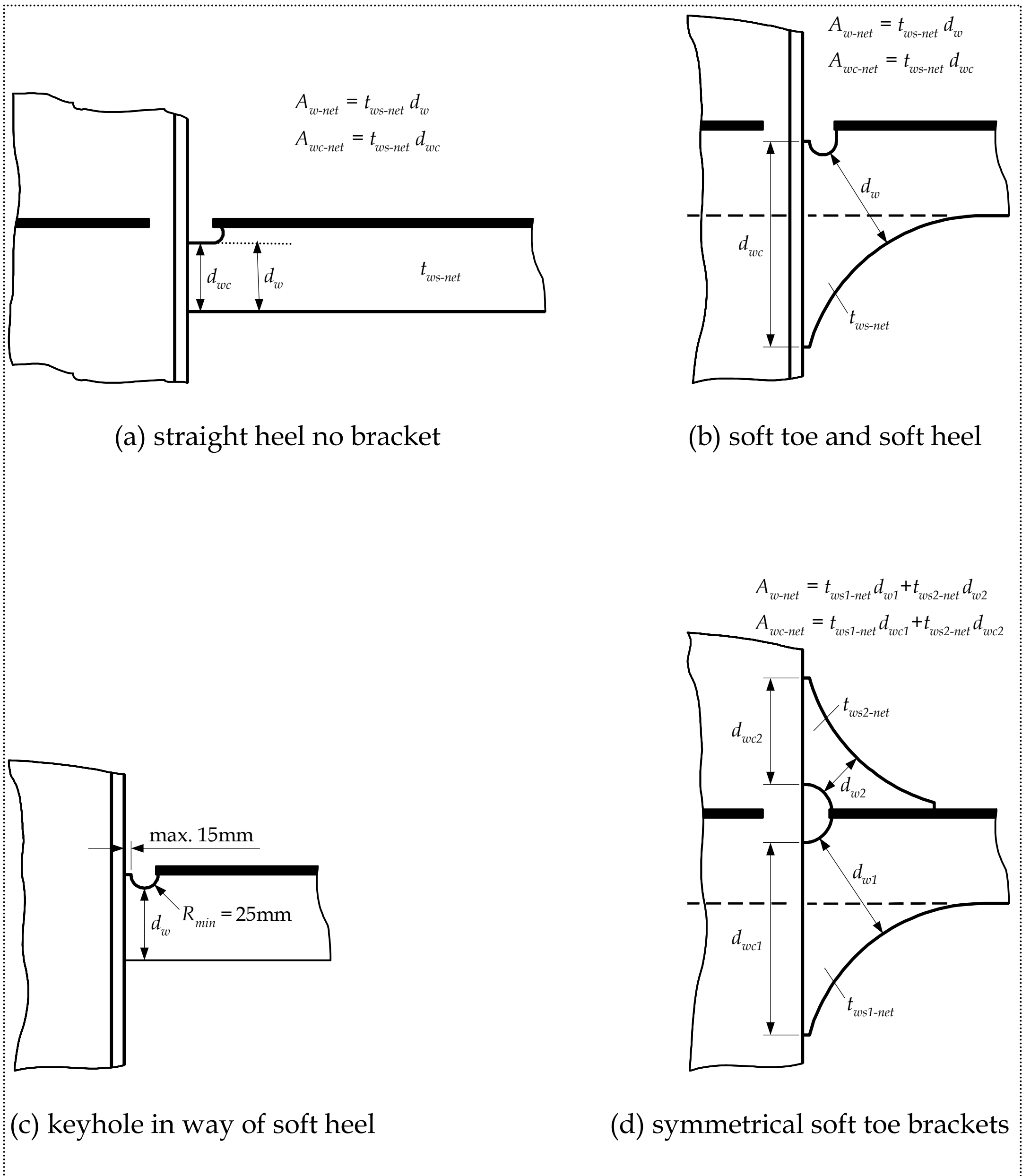


(e) lug or collar plate and direct connection

Note

The details shown in this figure are only used to illustrate symbols and definitions and are not intended to represent design guidance or recommendations.

Figure 4.3.6
Primary Support Member Web Stiffener Details



(a) straight heel no bracket

(b) soft toe and soft heel

(c) keyhole in way of soft heel

(d) symmetrical soft toe brackets

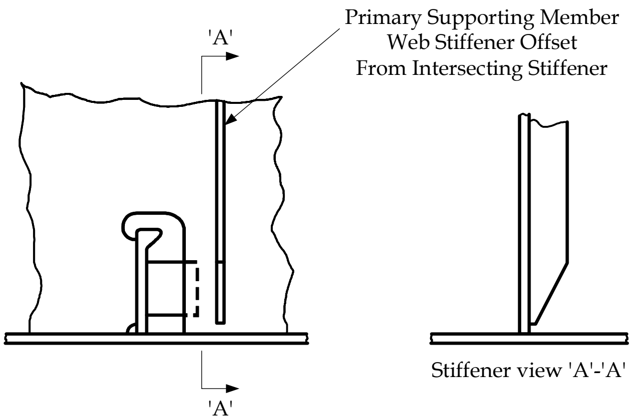
Where:

$t_{ws\text{-}net}$, $t_{ws1\text{-}net}$ and $t_{ws2\text{-}net}$	net thickness of the primary support member web stiffener/backing bracket, in mm
d_w, d_{w1} and d_{w2}	minimum depth of the primary support member web stiffener/backing bracket, in mm
d_{wc}, d_{wc1} and d_{wc2}	length of connection between the primary support member web stiffener/backing bracket and the local support stiffener, in mm

Note

Except where specific dimensions are noted for the details of the keyhole in way of the soft heel, see *3.4.1.4*, the details shown in this figure are only used to illustrate symbols and definitions and are not intended to represent design guidance or recommendations.

Figure 4.3.7
Offset Primary Support Member Web Stiffeners



3.5 Openings

3.5.1 General

3.5.1.1 Openings are to have well rounded corners.

3.5.1.2 Manholes, lightening holes and other similar openings are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are to be avoided in high stress areas unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory. Examples of high stress areas include:

(a) in vertical or horizontal diaphragm plates in narrow cofferdams/double plate bulkheads within one-sixth of their length from either end

(b) in floors or double bottom girders close to their span ends

(c) above the heads and below the heels of pillars.

Where larger openings than given by *3.5.2* or *3.5.3* are proposed, the arrangements and compensation required will be specially considered.

3.5.2 Manholes and lightening holes in single skin sections not requiring reinforcement

3.5.2.1 Openings cut in the web with depth of opening not exceeding 25 percent of the web depth and located so that the edges are not less than 40 percent of the web depth from the faceplate do not generally require reinforcement. The length of opening is not to be greater than the web depth or 60 percent of the local support member spacing, whichever is greater. The ends of the openings are to be equidistant from the corners of cut outs for local support members.

3.5.3 Manholes and lightening holes in double skin sections not requiring reinforcement

3.5.3.1 Where openings are cut in the web and are clear of high stress areas, reinforcement of these openings is not required provided that the depth of the opening does not exceed 50 percent of the web depth and is located so that the edges are well clear of cut outs for the passage of local support members.

3.5.4 Manholes and lightening holes requiring reinforcement

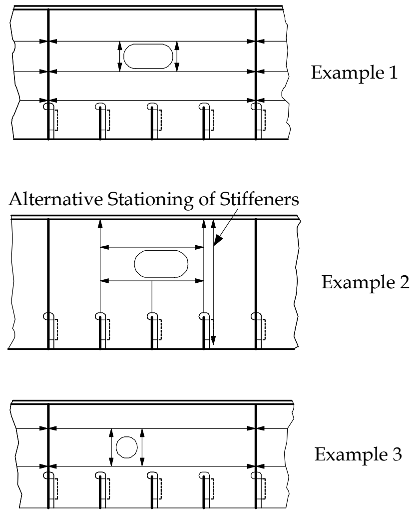
3.5.4.1 Manholes and lightening holes are to be stiffened as required by *3.5.4.2* and *3.5.4.3*. The stiffening requirements of *3.5.4.2* and *3.5.4.3* may be modified where

alternative arrangements are demonstrated as satisfactory with regards to stress and stability, in accordance with analysis methods described in *Section 9/2*.

3.5.4.2 The web plate is to be stiffened at openings when the mean shear stress, as determined by application of the requirements of *Section 8* or *Section 9/2*, is greater than 50N/mm² for acceptance criteria set AC1 or greater than 60N/mm² for acceptance criteria set AC2. The stiffening arrangement is to ensure buckling strength as required by *Section 10* under application of the loading as required in *Section 8* or *Section 9/2*.

3.5.4.3 On members contributing to longitudinal strength, stiffeners are to be fitted along the free edges of the openings parallel to the vertical and horizontal axis of the opening. Stiffeners may be omitted in one direction if the shortest axis is less than 400mm, and in both directions if length of both axes is less than 300mm. Edge reinforcement may be used as an alternative to stiffeners. See *Figure 4.3.8*.

Figure 4.3.8
Web Plate with Large Openings



3.6 Local Reinforcement

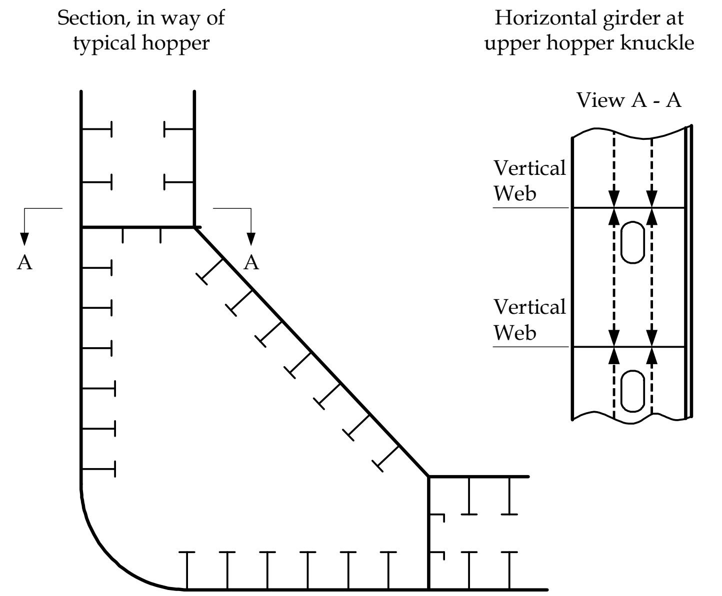
3.6.1 Reinforcement at knuckles

3.6.1.1 Whenever a knuckle in a main member (shell, longitudinal bulkhead etc.) is arranged, adequate stiffening is to be fitted at the knuckle to transmit the transverse load. This stiffening, in the form of webs, brackets or profiles, is to be connected to the transverse members to which they are to transfer the load (in shear). See *Figure 4.3.9*.

3.6.1.2 In general, for longitudinal shallow knuckles, closely spaced carlings are to be fitted across the knuckle, between longitudinal members above and below the knuckle. Carlings or other types of reinforcement need not be fitted in way of shallow knuckles that are not subject to high lateral loads and/or high in-plane loads across the knuckle, such as deck camber knuckles.

3.6.1.3 Generally, the distance between the knuckle and the support stiffening described in *3.6.1.1* is not to be greater than 50mm.

Figure 4.3.9
Example of Reinforcement at Knuckles



3.6.2 Reinforcement for openings and attachments associated with means of access for inspection purposes

3.6.2.1 Local reinforcement is to be provided taking into account proper location and strength of all attachments to the hull structure for access for inspection purposes.

3.7 Fatigue Strength

3.7.1 General

3.7.1.1 Structural details are to be designed for compliance with the requirements of fatigue strength as specified in *Section 9/3*.

SECTION 5

STRUCTURAL ARRANGEMENT

1 GENERAL

1.1 Introduction

1.1.1 Scope

1.1.1.1 This section covers the general structural arrangement requirements for the ship, which are based on or derived from National and International regulations, see *Sections 2/2.1.1* and *3/3.3*.

2 WATERTIGHT SUBDIVISION

2.1 Watertight Bulkhead Arrangement

2.1.1 General

2.1.1.1 All ships are to be provided with watertight bulkheads arranged to subdivide the hull into watertight compartments in accordance with the following requirements.

2.1.2 Minimum number and disposition of watertight bulkheads

2.1.2.1 The following watertight bulkheads are to be fitted on all ships:

(a) a collision bulkhead, see *2.2.1.1*

(b) an aft peak bulkhead

(c) a bulkhead at each end of the machinery space.

2.1.2.2 The bulkheads in the cargo tank region are to be spaced at uniform intervals so far as practicable.

2.1.2.3 The applicable number and disposition of bulkheads are to be arranged to suit the requirements for subdivision, floodability and damage stability, and are to be in accordance with the requirements of National regulations.

2.1.2.4 The number of openings in watertight bulkheads is to be kept to a minimum. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity. Additional requirements apply to collision bulkheads in *Section 8/3.6.2*.

2.2 Position of Collision Bulkhead

2.2.1 General

2.2.1.1 A collision bulkhead is to be fitted on all ships and is to extend to the freeboard deck. It is to be located between $0.05L_L$ or 10m, whichever is less, and $0.08L_L$ aft of the reference point, where the load line length, L_L, is as defined in *Section 4/1.1.2.1* and the reference point is as defined in *2.2.1.2*. Proposals for location of the collision bulkhead aft of $0.08L_L$ will be specially considered.

2.2.1.2 For ships without bulbous bows the reference point is to be taken where the forward end of L_L coincides with the forward side of the stem, on the waterline which L_L is measured. For ships with bulbous bows, it is to be measured from the forward end of L_L a distance x forward; where x is to be taken as the lesser of the following:

(a) half the distance, from the forward end of L_L and the extreme forward end of the bulb extension

(b) $0.015L_L$

(c) 3.0m.

2.2.1.3 In general, the collision bulkhead is to be in one plane, however, the bulkhead may have steps or recesses provided they are in compliance with the limits prescribed in *2.2.1.1* and *2.2.1.2*.

2.3 Position of Aft Peak Bulkhead

2.3.1 General

2.3.1.1 An aft peak bulkhead, enclosing the stern tube and rudder trunk in a watertight compartment, is to be provided. Where the shafting arrangements make enclosure of the stern tube in a watertight compartment impractical, alternative arrangements will be specially considered. The aft peak bulkhead location on ships powered and/or controlled by equipment that do not require the fitting of a stern tube and/or rudder trunk will also be subject to special consideration.

2.3.1.2 The aft peak bulkhead may terminate at the first deck above the summer load waterline, provided that this deck is made watertight to the stern or to a watertight transom floor.

3 DOUBLE HULL ARRANGEMENT

3.1 General

3.1.1 Protection of cargo tanks

3.1.1.1 Every tanker is to be provided with double bottom tanks and spaces, and double side tanks and spaces, in accordance with *3.2* and *3.3*. The double bottom and double side tanks and spaces, protect the cargo tanks or spaces, and are not to be used for the carriage of oil cargoes.

3.1.2 Capacity of ballast tanks

3.1.2.1 The capacity of the segregated ballast tanks shall be so determined that the ship may operate safely on ballast voyages without recourses to the use of cargo tanks for water ballast. The capacity of ballast shall be at least such that, in any ballast condition at any part of the voyage, including the conditions consisting of lightweight plus segregated ballast only, the ships draught and trim can meet the requirements in *3.1.2.2* to *3.1.2.4*.

3.1.2.2 The moulded draught amidships, T_{mid}, excluding any hogging or sagging correction, is not to be less than:

$$T_{mid} = 2.0 + 0.02L \quad \text{m}$$

Where:

L rule length, as defined in *Section 4/1.1.1.1*, in m

3.1.2.3 The draughts at the F.P. and A.P. are to correspond to those determined by the draught amidships, as given in *3.1.2.2*, and in association with a trim by the stern not greater than $0.015L$ (m).

3.1.2.4 The draught at the A.P. is not to be less than that required to obtain full immersion of the propeller(s).

3.1.3 Limitation of size and arrangement of cargo tanks

3.1.3.1 Cargo tanks are to be of a size and arrangement that hypothetical oil outflow from side and bottom damage, anywhere in the length of the ship, is limited.

3.2 Double Bottom

3.2.1 Double bottom depth

3.2.1.1 The minimum double bottom depth, d_{db}, is to be taken as the lesser of:

$$d_{db} = \frac{B}{15} \quad \text{m, but not less than 1.0m}$$

$$d_{db} = 2.0 \quad \text{m}$$

Where:

B moulded breadth, in m, as defined in *Section 4/1.1.3.1*

3.3 Double Side

3.3.1 Double side width

3.3.1.1 The minimum double side width, w_{ds}, is to be taken as the lesser of:

$$w_{ds} = 0.5 + \frac{DWT}{20000} \quad \text{m, but not less than 1.0m}$$

$$w_{ds} = 2.0 \quad \text{m}$$

Where:

DWT deadweight of the ship, in tonnes, as defined in *Section 4/1.1.14.1*

4 SEPARATION OF SPACES

4.1 Separation of Cargo Tanks

4.1.1 General

4.1.1.1 The cargo pump room, cargo tanks, slop tanks and cofferdams are to be positioned forward of machinery spaces. Main cargo control stations, control stations, accommodation and service spaces are to be positioned aft of cargo tanks, slop tanks, and spaces which isolate cargo or slop tanks from machinery spaces, but not necessarily aft of the oil fuel bunker tanks and ballast tanks.

4.2 Cofferdam Spaces

4.2.1 General

4.2.1.1 Cofferdam spaces are to be kept gas-tight. Where applicable, access requirements to permit internal inspections, are to be in accordance with *5.3*.

5 ACCESS ARRANGEMENTS

5.1 Access Into and Within Spaces in, and Forward of, the Cargo Tank Region

5.1.1 General

5.1.1.1 Access into and within spaces in, and forward of, the cargo tank region is to satisfy the *International Convention for the Safety of Life at Sea, 1974,* as amended, Chapter II-1, Part A-1, Regulation 3-6, as required by the Flag Administration, for details and arrangements of openings and attachments to the hull structure. This will be reviewed in conjunction with the structural requirements. In addition, the requirements of *5.1.1.2* to *5.1.1.5* are to be complied with.

5.1.1.2 Where a duct keel or pipe tunnel is fitted provision is to be made for at least two exits to the open deck arranged at a maximum distance from each other. The duct keel or pipe tunnel is not to pass into machinery spaces. The aft access may lead from the pump room to the duct keel. Where an aft access is provided from the pump room to the duct keel, the access opening from the pump room to the duct keel is to be provided with an oil-tight cover plate or a watertight door. Mechanical ventilation is to be provided and such spaces are to be sufficiently ventilated prior to entry. A notice board is to be fitted at each entrance to the pipe tunnel stating that before any attempt is made to enter, the ventilating fan must have been in operation for a sufficient period. In addition, the atmosphere in the tunnel is to be sampled by a gas monitor, and where an inert gas system is fitted in cargo tanks, an oxygen monitor is to be provided.

5.1.1.3 Where a watertight door is fitted in the pump room for access to the duct keel, the scantlings of the watertight door are to comply with the requirements of the individual Classification Society and the following additional requirements:

(a) the watertight door is to be capable of being manually closed from outside the main pump room entrance, in addition to bridge operation. A means of indicating whether the door is open or closed is to be provided locally and on the bridge.

(b) a notice is to be affixed at each operating position to the effect that the watertight door is to be kept closed during normal operations of the ship, except when access to the pipe tunnel is required.

5.1.1.4 At least one horizontal access opening of 600mm by 800mm clear opening is to be fitted in each horizontal girder in the vertical wing ballast space and weather deck to assist in rescue operations. Where an opening of 600mm by 800mm is not permitted due to structural arrangements, a 600mm by 600mm clear opening will be accepted.

5.1.1.5 Special consideration will be given to any proposals to fit permanent repair/maintenance access openings with oil-tight covers in cargo tank bulkheads. Attention is drawn to the relevant National regulations concerning load line and oil outflow aspects of such arrangements.

SECTION 6

MATERIALS AND WELDING

1 STEEL GRADES

1.1 Hull Structural Steel

1.1.1 Scope

1.1.1.1 Materials used during construction are to comply with the Rules for Materials of the individual Classification Society. Use of other materials and the corresponding scantlings will be specially considered.

1.1.2 Strength

1.1.2.1 Steel having a specified minimum yield stress of 235N/mm^2 is regarded as normal strength hull structural steel. Steel having a higher specified minimum yield stress is regarded as higher strength hull structural steel.

1.1.3 Material grades

1.1.3.1 Material grades of hull structural steels are referred to as follows:

(a) A, B, D and E denote normal strength steel grades

(b) AH, DH and EH denote higher strength steel grades.

1.1.4 Higher strength steel factor

1.1.4.1 For the determination of hull girder section modulus, where higher strength hull structural steel is used, a higher strength steel factor, k is given in *Table 6.1.1*.

Table 6.1.1
Values of k

Specified minimum yield stress, N/mm^2	k
235	1.00
265	0.93
315	0.78
340	0.74
355	0.72
390	0.68

Note
1. Intermediate values are to be calculated by linear interpolation.

1.1.5 Through thickness property

1.1.5.1 Where tee or cruciform connections employ partial or full penetration welds, and the plate material is subject to significant tensile strain in a direction perpendicular to the rolled surfaces, consideration is to be given to the use of special material with specified through thickness properties, in accordance with the Rules for Materials of the individual Classification Society. These steels are to be designated on the approved plan by the required steel strength grade followed by the letter Z (e.g. EH36 Z).

1.1.6 Steel castings and forgings

1.1.6.1 Steel castings or forgings that are used for stern frames, rudder frames, rudder stocks, propeller shaft brackets and other major structural items are to be in accordance with the Rules for Materials of the individual Classification Society.

1.2 Application of Steel Materials

1.2.1 Selection of material grades

1.2.1.1 Steel materials for particular locations are not to be of lower grades than those given in *Table 6.1.2* for the material class given in *Table 6.1.3*.

1.2.2 Applicable thickness

1.2.2.1 For application of *Table 6.1.2* and *Table 6.1.3*, the steel grade is to correspond to the as-built thickness.

1.2.3 Operation in areas with low air temperature

1.2.3.1 For ships intended to operate for long periods in areas with a lowest mean daily average temperature below –10 degrees C (i.e. regular service during winter to Arctic or Antarctic waters) the materials in exposed structures will be specially considered.

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Table 6.1.2
Material Grades

Thickness, t in mm	Material Class		
	I	II	III
$t \le 15$	A, AH	A, AH	A, AH
$15 < t \le 20$	A, AH	A, AH	B, AH
$20 < t \le 25$	A, AH	B, AH	D, DH
$25 < t \le 30$	A, AH	D, DH	D, DH
$30 < t \le 35$	B, AH	D, DH	E, EH
$35 < t \le 40$	B, AH	D, DH	E, EH
$40 < t \le 51$	D, DH	E, EH	E, EH

Table 6.1.3
Material Class or Grade of Structural Members

Structural member category	Material Class or Grade	
	Within 0.4L Amidships	Outside 0.4L
Secondary Longitudinal bulkhead strakes, other than those belonging to primary category Deck plating exposed to weather other than that belonging to primary or special category Side plating	Class I	Grade A(8)/AH
Primary Bottom plating including keel plate Strength deck plating, excluding that belonging to the special category (10) (11) Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings (11) Uppermost strake in longitudinal bulkheads (10) Vertical strake (hatch side girder) and upper sloped strake in top wing tank	Class II	Grade A(8) / AH
Special Sheer strake at strength deck (1)(2)(3)(10) (11) Stringer plate in strength deck (1)(2)(3)(10) (11) Deck strake at longitudinal bulkhead, excluding deck plating in way of inner hull longitudinal bulkhead (2)(4)(10) (11) Strength deck plating at outboard corners of cargo hatch openings (11) Bilge strake (2)(6) Continuous longitudinal hatch coamings (11)	Class III	Class II (Class I outside 0.6L amidships)
Other Categories Plating for stern frames, rudder horns and shaft brackets Longitudinal strength members of strength deck plating for ships with single strength deck (11) Strength members not referred to in above categories (9)	– Grade B / AH Grade A(8) / AH	Class II - Grade A(8) / AH

Note

1. Not to be less than E/EH within 0.4L amidships in vessels with length, L, exceeding 250m.
2. Single strakes required to be of material class III or E/EH are, within 0.4L amidships, to have breadths not less than 800 + 5L mm, but need not be greater than 1800mm.
3. A radius gunwale plate may be considered to meet the requirements for both the stringer plate and the sheer strake, provided it extends generally 600mm inboard and vertically.
4. For tankers having a breadth, B, exceeding 70m, the centreline strake and the strakes in way of the longitudinal bulkheads port and starboard, are to be class III.
5. (void)
6. To be not lower than D/DH within 0.6L amidships of vessels with length, L, exceeding 250m.
7. (void)
8. Grade B/AH to be used for plate thickness more than 40mm. For engine foundation heavy plates, Grade B/AH to be used for plate thickness more than 30mm. However, engine foundation heavy plates outside 0.6L amidships may be of Grade A/AH.
9. The material class used for reinforcement and the quality of material (i.e. whether normal or higher strength steel) used for welded attachments, such as spill protection bars and bilge keel, is to be similar to that of the hull envelope plating in way. Where attachments are made to round gunwale plates, special consideration will be given to the required grade of steel, taking account of the intended structural arrangements and attachment details.
10. The material class for deck plating, sheer strake and upper strake of longitudinal bulkhead within 0.4L amidships is also to be applied at structural breaks of the superstructure, irrespective of position.
11. To be not lower than B/AH within 0.4L amidships for ships with single strength deck.

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1.2.4 Guidance for repairs

1.2.4.1 Where materials are used in the construction, which are not in accordance with the Rules for Materials of the individual Classification Society, a set of plans showing the following information, for each material, is to be placed aboard the vessel in addition to those normally retained on the vessel:

(a) material specification and applicable thickness

(b) welding procedure

(c) location and extent of application.

1.3 Aluminium Alloys

1.3.1 General

1.3.1.1 The use of aluminium alloys in superstructures, deckhouses, hatch covers, helicopter platforms, or other local components will be specially considered. A specification of the proposed alloys and their proposed method of fabrication is to be submitted for approval.

1.3.1.2 Details of the proposed method of joining any aluminium and steel structures are to be submitted for approval.

1.3.1.3 Material requirements and scantlings are to comply with the Rules for Materials of the individual Classification Society.

1.3.2 Incendiary sparking on impact with steel

1.3.2.1 Aluminium may, under certain circumstances give rise to incendiary sparking on impact with oxidized steel. A particular risk is where an aluminium component is dragged or rubbed against the uncoated steel structure creating a thin smear of aluminium on the surface. Subsequent high energy impact by a rusted component on that smear could generate an incendiary spark capable of igniting any surrounding inflammable gas. The following requirements are therefore to be complied with:

(a) aluminium fittings in tanks used for the carriage of oil, and in cofferdams and pump rooms are to be avoided

(b) where fitted, aluminium fittings, units and supports, in tanks used for the carriage of oil, cofferdams and pump rooms are to satisfy the requirements of *2.1.2* for aluminium anodes

(c) the underside of heavy portable aluminium structures such as gangways, etc., is to be protected by means of a hard plastic or wood cover, or other approved means, in order to avoid the creation of smears. Such protection is to be permanently and securely attached to the structures.

2 CORROSION PROTECTION INCLUDING COATINGS

2.1 Hull Protection

2.1.1 General

2.1.1.1 All dedicated seawater ballast tanks are to have an efficient corrosion prevention system, as required by *SOLAS Reg. II-1/3-2*, see *Section 2/2.1.1*.

2.1.1.2 For ships contracted for construction on or after 8 December 2006, the date of IMO adoption of the amended SOLAS Regulation II-1/3-2, by which an IMO "Performance standard for protective coatings for ballast tanks and void spaces" will be made mandatory, the coatings of internal spaces subject to the amended SOLAS Regulation are to satisfy the requirements of the IMO performance standard. For ships contracted for construction on or after 1 July 2012, the IMO performance standard is to be applied as interpreted by IACS UI SC 223 and UI SC 227. In applying IACS UI SC 223, "Administration" is to be read to be the "Classification Society".

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2.1.1.3 Consistent with *IMO Resolution A.798(19)* and *IACS UI SC 122*, the selection of the coating system, including coating selection, specification, and inspection plan, are to be agreed between the shipbuilder, coating system supplier and the owner, in consultation with the Classification Society, prior to commencement of construction . The specification for the coating system for these spaces is to be documented and this documentation is to be verified by the Classification Society and is to be in full compliance with the coating performance standard.

2.1.1.4 The shipbuilder is to demonstrate that the selected coating system with associated surface preparation and application methods is compatible with the manufacturing processes and methods.

2.1.1.5 The shipbuilder is to demonstrate that the coating inspectors have proper qualification as required by the IMO standard.

2.1.1.6 The attending surveyor of the Classification Society will not verify the application of the coatings but will review the reports of the coating inspectors to verify that the specified shipyard coating procedures have been followed.

2.1.1.7 Where anodes are fitted in ballast tanks, ballast tank anode distribution drawings are to be submitted for approval. Such drawings are to include details of the connections to the hull, e.g. welding details.

2.1.2 Internal cathodic protection systems

2.1.2.1 When a cathodic protection system is to be fitted to steel structures in tanks used for liquid cargo with flash point below 60°C, a plan of the fitting arrangement is to be submitted for approval. The arrangements will be considered for safety against fire and explosion. This approval also applies to adjacent tanks.

2.1.2.2 Permanent anodes in tanks made of, or alloyed with magnesium are not acceptable, except in tanks solely intended for water ballast that are not adjacent to cargo tanks. Impressed current systems are not to be used in cargo tanks due to the development of chlorine and hydrogen that can result in an explosion. Aluminium anodes are accepted, however, in tanks with liquid cargo with flash point below 60°C and in

adjacent ballast tanks, aluminium anodes are to be located so a kinetic energy of not more than 275J is developed in the event of their loosening and becoming detached.

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2.1.2.3 Aluminium anodes are to be located in such a way that they are protected from falling objects. They are not to be located under tank hatches or Butterworth openings unless protected by adjacent structure.

2.1.2.4 All anodes are to be attached to the structure in such a way that they will remain securely fastened both initially and during service. The following methods are acceptable:

(a) steel core connected to the structure by continuous fillet welds of sufficient cross section

(b) attachment by properly secured through-bolts or other positive locking devices. Attachment by clamps fixed with setscrews is to be by approved means.

2.1.2.5 Anode steel cores bent and directly welded to the steel structure are to be of a material complying with the requirements for grade A of the Rules for Materials of the individual Classification Society.

2.1.2.6 Anodes are to be attached to stiffeners or aligned in way of stiffeners on plane bulkhead plating, but they are not to be attached to the shell. The two ends are not to be attached to separate members which are capable of relative movement.

2.1.2.7 Where cores or supports are welded to local support members or primary support members, they are to be kept clear of end supports, toes of brackets and similar stress raisers. Where they are welded to asymmetrical members, the welding is to be at least 25mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the face plate, but well clear of the free edges. Generally, anodes are not to be fitted to a face plate of higher strength steel.

2.1.2.8 Tanks in which anodes are installed, are to have sufficient holes for the circulation of air to prevent gas from collecting in pockets.

2.1.3 Paint containing aluminium

2.1.3.1 Paint containing aluminium is not to be used in positions where cargo vapours may accumulate unless it has been shown by appropriate tests that the paint to be used does not increase the incendiary sparking hazard. Tests need not be performed for coatings with less than 10 percent aluminium by weight.

3 CORROSION ADDITIONS

3.1 General

3.1.1 Introduction

3.1.1.1 The required net thickness of steel structures is to be increased by the corrosion addition as specified in this Sub-Section.

3.1.1.2 The corrosion additions given in this Sub-Section are applicable to carbon-manganese steels, see *1.1*. Application of corrosion additions for other materials, such as stainless steel, is to be in accordance with the requirements of the individual Classification Society.

3.1.1.3 The application of the corrosion additions in rule calculations is given in *3.3*.

3.2 Local Corrosion Additions

3.2.1 General

3.2.1.1 The local corrosion additions, t_{corr}, for structural members are to be taken as:

$$t_{corr} = t_{was} + 0.5 \quad \text{mm}$$

Where:

t_{was} total wastage allowance of the considered structural member, in mm, as given in *Section 12/1.4.2.2*

3.2.1.2 The local corrosion additions, t_{corr}, for typical structural elements in the cargo tank region are given in *Table 6.3.1* and *Figure 6.3.1*.

Table 6.3.1
Corrosion Addition, t_{corr}, for Typical Structural Elements Within the Cargo Tank Region

Category of contents			**Corrosion Addition t_{corr}, in mm**
Internal members and plate boundary between spaces with the same category of contents			
In and between ballast water tanks	Face plate of PSM	Within 3m below top of tank (1)	4.5
		Elsewhere	3.5
	Other members	Within 3m below top of tank (1)	4.0
		Elsewhere	3.0
	Stiffeners on boundaries to heated cargo tanks	Within 3m below top of tank (1)	4.5
		Elsewhere	3.5
In and between cargo oil tanks	Face plate of PSM	Within 3m below top of tank (1)	4.0
		Elsewhere	3.5
	Other members	Within 3m below top of tank (1)	4.0
		Elsewhere	2.5
Exposed to atmosphere on both sides	Support members on deck		2.5
In and between void spaces	Spaces not normally accessed, e.g. access only via bolted manhole openings, pipe tunnels, etc.		2.0
In and between dry spaces	Internals of deckhouses, machinery spaces, pump room, store rooms, steering gear space, etc.		1.5
Plate boundary between spaces having a different category			
Boundary between ballast tank and cargo oil tank	Unheated cargo tank	Within 3m below top of tank (1)	4.0
		Inner bottom plating	4.0
		Elsewhere	3.0
	Heated cargo tank	Within 3m below top of tank (1)	4.5
		Inner bottom plating	4.5
		Elsewhere	3.5
Boundary between ballast tank and atmosphere or sea	Weather deck plating		4.0
	Other members(2)	Within 3m below top of tank (1)	3.5
		Elsewhere	3.0
Boundary between ballast tank and void or dry space	Within 3m below top of tank(1)		3.0
	Elsewhere		2.5
Boundary between cargo tank and atmosphere	Weather deck plating		4.0
Boundary between cargo tank and void spaces	Within 3m below top of tank (1)		3.0
	Elsewhere		2.5
Boundary between cargo tank and dry spaces	Within 3m below top of tank (1)		3.0
	Elsewhere		2.0

Note
1. Only applicable to cargo and ballast tanks with weather deck as the tank top
2. 0.5mm to be added for side plating in the quay contact region defined in *Section 8/Figure 8.2.2*
3. Heated cargo oil tanks are defined as cargo tanks arranged with any form of heating capability

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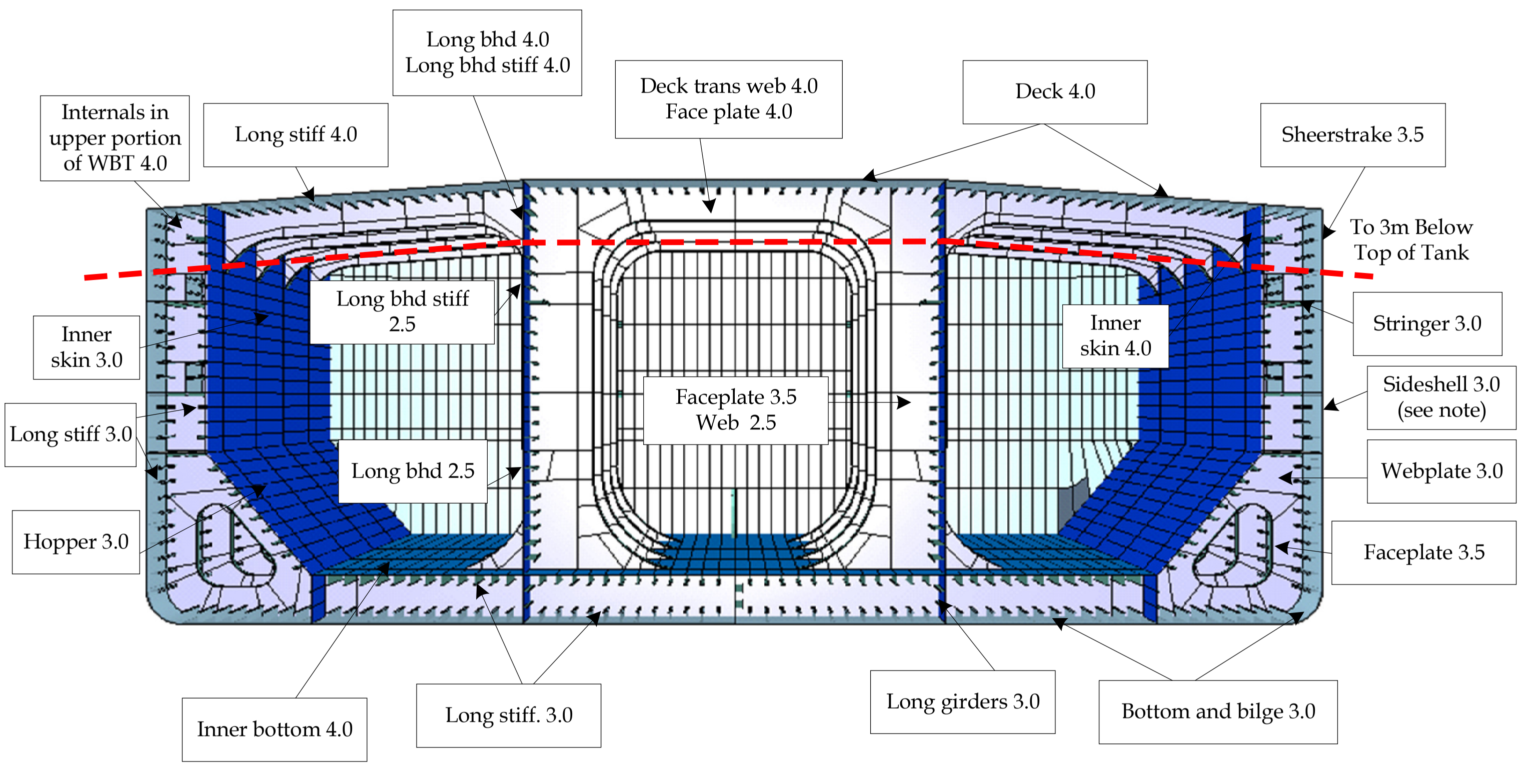
Figure 6.3.1
Corrosion Addition, t_{corr}, for Typical Structural Elements Within the Cargo Tank



Note
1. Corrosion additions are given for a standard configuration and without heated cargo
2. 0.5mm to be added for side plating in the quay contact region defined in *Section 8/Figure 8.2.2*
3. The distance 3m below top of tank is to be measure parallel to the deck

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3.3 Application of Corrosion Additions

3.3.1 General

3.3.1.1 The application of corrosion additions described in *3.3.2* to *3.3.7* is to be applied unless otherwise specified in the specific rule requirements.

3.3.1.2 Compliance with the Rules may be performed either by:

(a) comparison of the proposed gross scantling with the gross required, in which case the applicable corrosion addition is added to the net requirement of the Rules

(b) comparison of the proposed net scantling with the net required, in which case the applicable corrosion addition is deducted from the gross proposed.

Methods (a) and (b) are suitable for assessment of thickness. Method (b) is the most suitable for assessment of section properties, e.g. section modulus, area and moment of inertia.

3.3.1.3 The gross scantlings specified in *3.3.2* to *3.3.7* used to derive the net scantlings are to exclude any owner's extra thicknesses, see also *Section 2/4.3.4.3*.

3.3.2 Application for hull girder longitudinal strength calculations

3.3.2.1 The calculation of hull girder stresses for the assessment of longitudinal strength as given in *Section 8/1* is to be based on the net hull girder sectional properties calculated by deducting half the corrosion addition, i.e. $-0.5t_{corr}$, from the gross thickness of all structural elements comprising the hull girder cross-section.

3.3.2.2 The local buckling capacity of plates and stiffeners subject to hull girder stresses are to be calculated based on the net scantlings, as given in *Section 8/1.4.2.* The net scantling is calculated by deducting the full corrosion addition, i.e. $-1.0t_{corr}$, from the gross thickness.

3.3.3 Application for scantling assessment of plates and local support members

3.3.3.1 The required gross thickness for plates and local support members are calculated by adding the full corrosion addition, i.e. $+1.0t_{corr}$, to the net thickness required in accordance with the scantling requirements in *Sections 4/3.4* and *8/2* to *8/7*.

3.3.3.2 The net sectional properties of local support members are calculated by deducting the full corrosion addition, i.e. $-1.0t_{corr}$, from the web, flange and attached plate gross thicknesses as described in *Section 4/2.4.1* and are to comply with required section modulus, moment of inertia and shear area as given in *Sections 4/3.4* and *8/2* to *8/7*.

3.3.3.3 The calculation of hull girder stresses for the strength assessment of members under combined local and global loading is to be based on the net hull girder sectional properties calculated by deducting half the corrosion addition, i.e. $-0.5t_{corr}$, from the gross thickness of all structural elements comprising the hull girder cross-section.

3.3.3.4 The required minimum gross thickness of plates and local support members is calculated by adding the full corrosion addition, i.e. $+1.0t_{corr}$, to the minimum net thickness requirements given in *Section 8/2.1.5.*

3.3.4 Application of corrosion additions for scantling strength assessment of primary support members

3.3.4.1 The required gross thickness of primary support members is calculated by adding half the corrosion addition, i.e. $+0.5t_{corr}$, to the net thickness required in accordance with the strength requirements in *Section 8/2.6* and *8/3* to *8/7*.

3.3.4.2 The net sectional properties of primary support members are to be calculated by deducting half the corrosion addition, i.e. $-0.5t_{corr}$, from the web and flange gross thicknesses, and are to comply with the required section modulus, moment of inertia and area as given in *Section 8/2.6* and *8/3* to *8/7*.

3.3.4.3 The required minimum gross thickness of primary support members is calculated by adding the full corrosion addition, i.e. $+1.0t_{corr}$, to the minimum net thickness requirement given in *Section 8/2.1.6.1, 8/3.1.4.1, 8/4.1.5.1, 8/5.1.4.1, 8/6.3.7.5, 8/6.4.5.4* and *10/2.3*.

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3.3.5 Application of corrosion additions for hull girder ultimate strength analysis

3.3.5.1 The calculation of the hull girder ultimate capacity, M_u, as given in *Section 9/1*, is to be based on the net hull girder sectional properties calculated by deducting half the corrosion addition, i.e. $-0.5t_{corr}$, from the gross thickness of all structural elements comprising the hull girder cross-section.

3.3.5.2 The buckling capacity of the structural elements used to derive the hull girder ultimate capacity is to be calculated by deducting half the corrosion addition, i.e. $-0.5t_{corr}$, from the gross thicknesses of the plates and stiffener webs and flanges.

3.3.6 Application of corrosion additions for strength assessment by finite element analysis

3.3.6.1 For the cargo tank structural strength analysis, as given in *Section 9/2.2* and *Appendix B/2*, the finite element model is to be modelled with thicknesses calculated by deducting half the corrosion addition, i.e. $-0.5t_{corr}$, from the gross thickness of all structural elements.

3.3.6.2 The local buckling capacity of plates and stiffeners are to be calculated by deducting the full corrosion addition, i.e. $-1.0t_{corr}$, from the gross thickness.

3.3.6.3 The local fine mesh structural strength analysis models, as given in *Section 9/2.3* and *Appendix B/3,* are to be modelled with thicknesses calculated by deducting half the corrosion addition, i.e. $-0.5t_{corr}$, from the gross thickness. The specified fine mesh areas are to be modelled by deduction of the full corrosion addition, i.e. $-1.0t_{corr}$, from the gross thickness.

3.3.7 Application of corrosion additions for fatigue strength assessment

3.3.7.1 The calculation of hull girder stresses for the fatigue strength assessment, as given in *Section 9/3* and *Appendix C/1,* is to based on the net fatigue hull girder sectional properties, calculated by deducting a quarter of the corrosion addition, i.e. $-0.25t_{corr}$, from the gross thickness of all structural elements comprising the hull girder cross section.

3.3.7.2 The calculation of stresses in local support members from lateral load for the fatigue strength assessment, as given in *Section 9/3* and *Appendix C/1,* are to be based on deducting half the corrosion addition, i.e. $-0.5t_{corr}$, from the stiffener web, flange and attached plate.

3.3.7.3 For hot spot stress (FE based) approach, as given in *Section 9/3* and *Appendix C/2,* the FE model of the hopper knuckle is to be modelled with thickness calculated by deducting a quarter of the corrosion addition, i.e. $-0.25t_{corr}$, from the gross thicknesses. The very fine mesh areas are to be modelled by deduction of half the corrosion addition, i.e. $-0.5t_{corr}$, from the gross thickness.

3.3.7.4 As an alternative to *3.3.7.3,* the hopper fatigue FE model may be made in accordance with requirements for FE strength model, i.e. all areas at $-0.5t_{corr}$, as described in *3.3.6.1*. However the calculated stress range is then to be corrected by the factor f_{model} as described in *Appendix C/2.4.2.7*.

4 FABRICATION

4.1 General

4.1.1 Workmanship

4.1.1.1 All workmanship is to be of commercial marine quality and acceptable to the Surveyor. Welding is to be in accordance with the requirements of *Sub-Section 5.* Any defect is to be rectified to the satisfaction of the Surveyor before the material is covered with paint, cement or any other composition.

4.1.2 Fabrication standard

4.1.2.1 Structural fabrication is to be carried out, in accordance with '*IACS Recommendation 47, Shipbuilding and Repair Quality Standard for New Construction*' or a recognised fabrication standard which has been accepted by the Classification Society prior to the commencement of fabrication/construction.

4.1.2.2 The fabrication standard to be used during fabrication/construction is to be made available to the attending representative of the Classification Society, prior to the commencement of the fabrication/construction.

4.1.2.3 The fabrication standard is to include information, to establish the range and the tolerance limits, for the items specified as follows:

(a) Cutting edge
- the slope of the cut edge and the roughness of the cut edges

(b) Flanged longitudinals and brackets and built-up sections
- the breadth of flange and depth of web, angle between flange and web, and straightness in plane of flange or at the top of face plate

(c) Pillars
- the straightness between decks, and cylindrical structure diameter

(d) Brackets and small stiffeners
- the distortion at the free edge line of tripping brackets and small stiffeners

(e) Sub-assembly stiffeners
- details of snipe end of secondary face plates and stiffeners

(f) Plate assembly
- for flat and curved blocks the dimensions (length and breadth), distortion and squareness, and the deviation of interior members from the plate

(g) Cubic assembly
- in addition to the criteria for plate assembly, twisting deviation between upper and lower plates, for flat and curved cubic blocks

(h) Special assembly
- the distance between upper and lower gudgeons, distance between aft edge of propeller boss and aft peak bulkhead, twist of stern frame assembly, deviation of rudder from shaft centreline, twist of rudder plate, and flatness, breadth and length of top plate of main engine bed. Where boring out of the propeller boss and stern frame, skeg or solepiece is carried out at a late stage of construction, it is to be carried out after completing the major part of the welding of the aft part of the ship. Where block boring is used, the shaft

alignment is to be carried out using a method and sequence submitted to and recognized by the Classification Society. The fit-up and alignment of the rudder, pintles and axles, are to be carried out after completing the major part of the welding of the aft part of the ship. The contacts between the conical surfaces of pintles, rudder stocks and rudder axles are to be checked before the final mounting.

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(i) Butt joints in plating

- alignment of butt joint in plating

(j) Cruciform joints

- alignment measured on the median line and measured on the heel line of cruciform joints

(k) Alignment of interior members

- alignments of flange of T longitudinals, alignment of panel stiffeners, gaps in T joints and lap joints, and distance between scallop and cut outs for continuous stiffeners in assembly and in erection joints

(l) Keel and bottom sighting

- deflections for whole length of the ship, and for the distance between two adjacent bulkheads, cocking-up of fore body and of aft body, and rise of floor amidships

(m) Dimensions

- dimensions of length between perpendiculars, moulded breadth and depth at midship, and length between aft edge of propeller boss and main engine

(n) Fairness of plating between frames

- deflections between frames of shell, tank top, bulkhead, upper deck, superstructure deck, deck house deck and wall plating

(o) Fairness of plating in way of frames

- deflections of shell, tank top, bulkhead, strength deck plating and other structures measured in way of frames

4.2 Cold Forming

4.2.1 Special structural members

4.2.1.1 For highly stressed components of the hull girder where notch toughness is of particular concern (e.g. items required to be Class III in *Table 6.1.3*, such as radius gunwales and bilge strakes) the inside bending radius, in cold formed plating, is not to be less than 10 times the gross plate thickness for carbon-manganese steels (hull structural steels, see *1.1*). The allowable inside bending radius may be reduced below 10 times the gross plate thickness, providing the additional requirements stated in *4.2.3* are complied with.

4.2.2 Other members

4.2.2.1 For main structural members, e.g. corrugated bulkheads and hopper knuckles, the inside bending radius, in cold formed plating, is not to be less than 4.5 times the gross plate thickness for carbon-manganese steels (hull structural steels, see *1.1*). The allowable inside bending radius may be reduced below 4.5 times the gross plate thickness, providing the additional requirements stated in *4.2.3* are complied with.

4.2.3 Additional requirements

4.2.3.1 When steel is formed below 650°C with a radius of less than 10 or 4.5 times the gross plate thickness for special and other members, respectively, supporting data is to be provided. As a minimum, the following additional requirements are to be complied with:

(a) the steel is to be of grade D/DH or higher

(b) the material is impact tested in the strain-aged condition and satisfies the requirements stated herein. The deformation is to be equal to the maximum deformation to be applied during production, calculated by the formula $t_{grs}/(2r_{bdg}+t_{grs})$, where t_{grs} is the gross thickness of the plate material and r_{bdg} is the bending radius. One sample is to be plastically strained at the calculated deformation or 5%, whichever is greater and then artificially aged at 250°C for one hour then subject to Charpy V-notch testing. The average impact energy after strain ageing is to meet the impact requirements specified for the grade of steel used.

(c) 100% visual inspection of the deformed area is to be carried out. In addition, random checks by magnetic particle testing are to be carried out.

The bending radius is in no case to be less than twice the gross plate thickness.

4.3 Hot Forming

4.3.1 Temperature requirements

4.3.1.1 Steel is not to be formed between the upper and lower critical temperatures. If the forming temperature exceeds 650°C for as-rolled, controlled rolled, thermo-mechanical controlled rolled or normalised steels, or is not at least 28°C lower than the tempering temperature for quenched and tempered steels, mechanical tests are to be made to assure that these temperatures have not adversely affected both the tensile and impact properties of the steel. Where curve forming or fairing, by line or spot heating, is carried out in accordance with *4.3.2.1* these mechanical tests are not required.

4.3.1.2 Confirmation is required to demonstrate the mechanical properties after further heating meet the requirements specified by a procedure test using representative material, when considering further heating other than in *4.3.1.1* of thermo-mechanically controlled steels (TMCP plates) for forming and stress relieving.

4.3.2 Line or spot heating

4.3.2.1 Curve forming or fairing, by linear or spot heating, is to be carried out using approved procedures in order to ensure that the properties of the material are not adversely affected. Heating temperature, on the surface, is to be controlled so as not to exceed the maximum allowable limit applicable to the plate grade.

4.4 Welding

4.4.1 General

4.4.1.1 All welding is to be carried out by approved welders, in accordance with approved welding procedures, using approved welding consumables and is to comply with the Rules for Materials of the individual Classification Society.

4.4.2 Welding sequence

4.4.2.1 Consideration is to be given to the assembly sequence and the effect on the overall shrinkage of plate panels, assemblies, etc., resulting from the welding processes employed. Welding is to proceed systematically, with each welded joint being completed in the correct sequence, without undue interruption.

4.4.2.2 Where practicable, welding is to commence at the centre of a joint and proceed outwards, or at the centre of an assembly and progress outwards towards the perimeter so that each part has freedom to move in one or more directions.

4.4.2.3 Generally, the welding of stiffener members, including transverses, frames, girders, etc., to welded plate panels by automatic processes is to be carried out in such a way as to minimize angular distortion of the stiffener.

4.4.3 Arrangements at junctions of welds

4.4.3.1 Welds are to be made flush in way of the faying surface where stiffening members, attached by continuous fillet welds, cross the completely finished butt or seam welds. Similarly, butt welds in webs of stiffening members are to be completed and made flush with the stiffening member before the fillet weld is made. The ends of the flush portion are to run out smoothly without notches or sudden changes of section. Where these conditions cannot be complied with, a scallop is to be arranged in the web of the stiffening member. Scallops are to be of a size, and in a position, that a satisfactory return weld can be made.

4.4.4 Leak stoppers

4.4.4.1 Where structural members pass through the boundary of a tank, leakage into the adjacent space could be hazardous or undesirable, and full penetration welding is to be adopted for the members for at least 150mm on each side of the boundary. Alternatively, a small scallop of suitable shape may be cut in the member close to the boundary outside of the compartment, and carefully welded all around.

5 WELD DESIGN AND DIMENSIONS

5.1 General

5.1.1 Scope

5.1.1.1 In general, weld sizes are based on the Rule gross thickness values.

5.1.1.2 Requirements for welding sequence, qualification of welders, welding procedures and welding consumables are given in *4.4*.

5.1.2 Plans and specifications

5.1.2.1 Plans and/or specifications showing weld sizes and weld details are to be submitted for approval for each new construction project.

5.1.2.2 Where reductions in weld sizes are proposed the requirements given in *5.9* are to be applied and the following details are to be included in the welding specification:

(a) proposed weld gap size

(b) proposed welding consumable.

5.1.3 Tolerance requirements

5.1.3.1 The gaps between the faying surfaces of members being joined are to be kept to a minimum or in accordance with approved specification.

5.1.3.2 Where the gap between the members joined by fillet welds exceeds 2mm, the weld size is to be increased in accordance with *5.7.1.6*.

5.1.4 Special precautions

5.1.4.1 Welding is to be based on approved welding procedure specifications where small fillets are used to attach heavy plates or sections. Special precautions, such as the use of preheating, low-hydrogen electrodes or low-hydrogen welding processes, are accepted.

5.1.4.2 When heavy structural members are attached to relatively light plating, the weld size and sequence may require modification.

5.2 Butt Joints

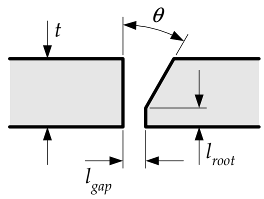
5.2.1 General

5.2.1.1 Joints in the plate components of stiffened panel structures are generally to be joined by butt welds. Typical types of butt welds with corresponding edge preparation are shown in *Figure 6.5.1*.

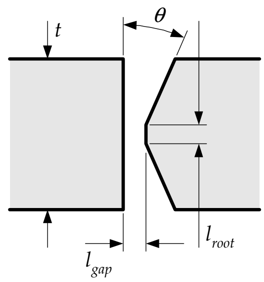
5.2.1.2 All types of butt joints are to be welded from both sides. Before welding is carried out on the second side, unsound weld metal is to be removed at the root by a suitable method. Butt welding from one side will only be permitted for specific applications with an approved welding procedure specification.

Figure 6.5.1
Typical Butt Welds

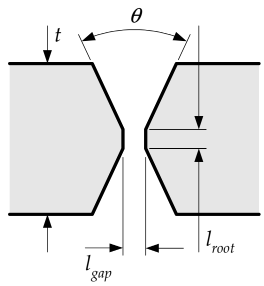
Single bevel butt



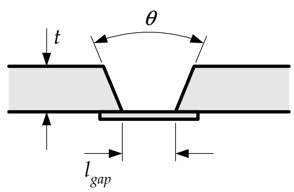
Double bevel butt



Double vee butt, uniform bevels



Single vee butt, one side welding with backing strip (temporary or permanent)



<u>Note</u>

1. The above figures are shown for guidance only. Actual details and dimensions are to be in accordance with a recognised fabrication standard. See *4.1.2.1*

5.2.2 Thickness difference in butt welds

5.2.2.1 Abrupt change of section is to be avoided where plates of different thicknesses are butt welded.

5.2.2.2 Where plates to be joined differ in thickness by more than 4mm, a suitable transition taper is to be provided. The transition may be formed by tapering the thicker member, or by specifying a weld joint design which provides the required transition.

5.2.2.3 For the transverse butts in longitudinal strength members, the transition taper length is to be not less than three times the offset.

5.2.2.4 Differences in thickness greater than 4mm and without transition taper may be accepted for specific applications.

5.3 Tee or Cross Joints

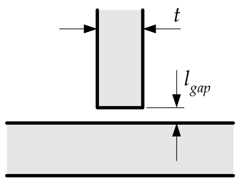
5.3.1 General

5.3.1.1 The connection of primary support members and stiffener web/end connections and joints formed by plating abutting on another plate panel is generally to be made by fillet welds sized in accordance with *5.7* and *Figure 6.5.2*. Examples of other typical tee or cross joint weld arrangements are shown in *Figure 6.5.3*.

5.3.1.2 Where the connection is highly stressed or otherwise considered critical, a partial or full penetration weld is to be achieved by bevelling the edge of the abutting plate. See *5.3.4* and *Figure 6.5.3*.

Figure 6.5.2
Typical Tee or Cross Joint Fillet Welds

Tee fillet

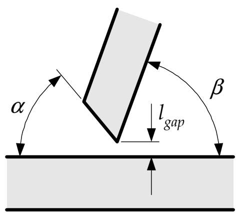


Note

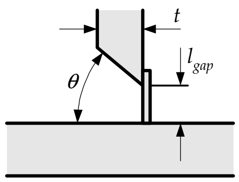
1. The above figure is shown for guidance only. Actual details and dimensions are to be in accordance with a recognised fabrication standard. See *4.1.2.1*.

Figure 6.5.3
Other Typical Tee and Cross Joint Welds

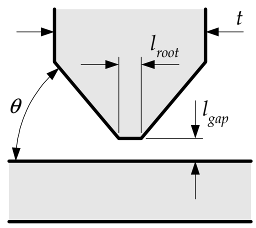
Small angle fillet



Single bevel tee with permanent backing



Double bevel tee symmetrical



Notes

1. The above figures are shown for guidance only. Actual details and dimensions are to be in accordance with a recognised fabrication standard. See *4.1.2.1*.

5.3.2 Continuous welding

5.3.2.1 Continuous welding is to be adopted in the following locations:

(a) all fillet welds where higher strength steel is used

(b) boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings

(c) boundaries of tanks and watertight compartments

(d) all structures in ballast and fresh water tanks and the ballast and fresh water tank bulkhead stiffeners

(e) all structures in the aft peak and the aft peak bulkhead stiffeners

(f) all structures in the fore peak tank/void

(g) all welding inside tanks intended for crude oil, petroleum products, chemicals, edible liquids or fresh water cargoes

(h) welding in way of all end connections, including end brackets, lugs, scallops, and at the orthogonal connections with other members

(i) all lap welds in the main hull

(j) primary support members and stiffener members to bottom shell in the $0.3L$ forward region

(k) flat bar longitudinals to plating

(l) the attachment of minor fittings to higher strength steel plating and other connections or attachments.

5.3.3 Intermittent welding

5.3.3.1 Where continuous welding is not required, intermittent welding may be applied.

5.3.3.2 Where beams, stiffeners, frames, etc, are intermittently welded and pass through slotted girders, shelves or stringers, there is to be a pair of matched intermittent welds on each side of every intersection. In addition, the beams, stiffeners and frames are to be efficiently attached to the girders, shelves and stringers.

5.3.4 Full or partial penetration corner or tee joints

5.3.4.1 Where high tensile stresses act through an intermediate plate (see *Figure 6.5.4*), increased fillet welds or penetration welds are to be used as required by *5.8*. Examples of such structures are:

(a) connection of hopper to inner hull

(b) longitudinal/transverse bulkhead primary support member end connections to the double bottom

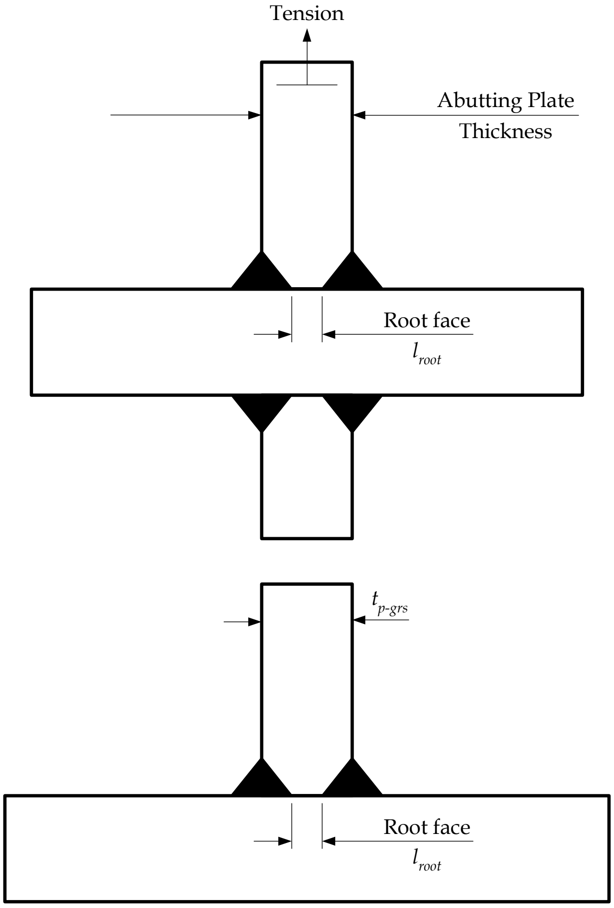
(c) connection of corrugated bulkhead lower stool side plates to shelf plate and inner bottom/hopper tank

(d) connections of gusset plates to corrugated bulkheads

(e) connection of double bottom floors, lower hopper tank webs and double bottom girders below corrugated bulkhead flanges and gusset plates for corrugated bulkheads configured without lower stools

(f) structural elements in double bottoms below bulkhead primary support members and stool plates.

Figure 6.5.4
Abutting Plate Panel



5.3.4.2 Full or partial penetration welds, with maximum root face, $l_{root} = t_{p\text{-}grs}/3$, where l_{root} is the weld root face length and $t_{p\text{-}grs}$ is the gross plate thickness, as shown in *Figure 6.5.4,* are to be used in the connection of hopper sloped plating to inner bottom.

5.3.4.3 Full penetration welds are to be used in the following connections:

(a) lower end of vertical corrugated bulkhead connections

(b) lower end of gusset plates fitted to corrugated bulkheads

(c) rudder horns and shaft brackets to shell structure

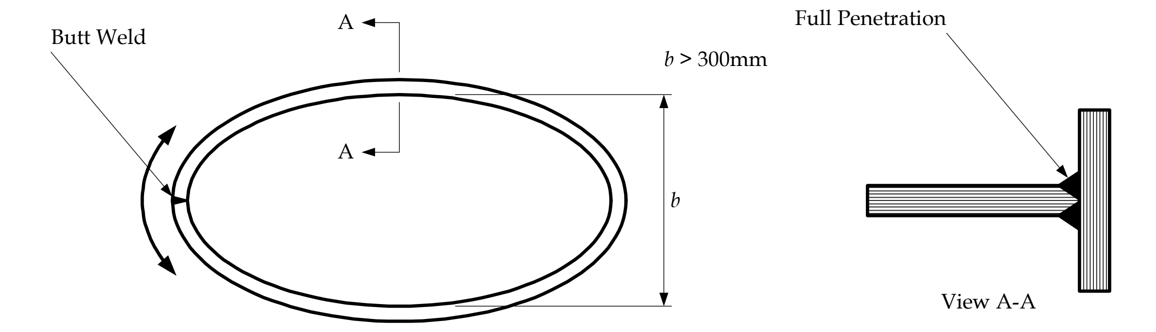
(d) rudder side plating to rudder stock connection areas

(e) edge reinforcements within 0.6*L* amidships to the strength deck, sheer strake, bottom and bilge plating, when the transverse dimensions of the opening exceeds 300mm, see *Figure 6.5.5*. Where collar plates are fitted in way of pipe penetrations, the collar plate is to be welded by a continuous fillet weld.

(f) abutting plate panels with gross plate thickness, $t_{p\text{-}grs}$, as shown in *Figure 6.5.4*, less than or equal to 12mm, forming outer shell boundaries below the scantling draught, T_{sc}, including, but not limited to; sea chests, rudder trunks, and portions of transoms. For gross plate thickness, $t_{p\text{-}grs}$, greater than 12mm, partial penetration welding with a maximum root face length $l_{root} = t_{p\text{-}grs}/3$ is acceptable.

(g) crane pedestals and associated bracketing and support structure, as required by *Section 11/3.1.4.14*.

Figure 6.5.5
Examples of Suitable Edge Reinforcements



5.4 Lapped Joints

5.4.1 General

5.4.1.1 Overlaps may be adopted for end connections where the connection is not subject to high tensile or compressive loading.

5.4.1.2 Where overlaps are adopted, the width of the overlap, w_{lap}, is not to be less than three times, but not greater than four times, the gross thickness of the thinner of the plates being joined. See *Figure 6.5.6*. Where the gross thickness of the thinner plate being joined has a thickness of 25mm or more the overlap will be subject to special consideration.

5.4.1.3 The overlaps for lugs and collars in way of cut-outs for the passage of stiffeners through webs and bulkhead plating are not to be less than three times the gross thickness of the lug but need not be greater than 50mm. The joints are to be positioned to allow adequate access for completion of sound welds.

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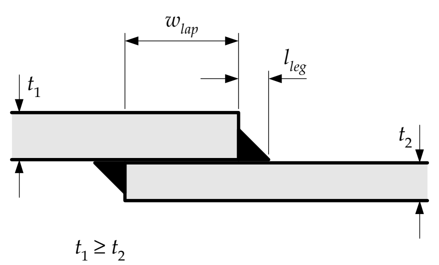
5.4.1.4 The faying surfaces of lap joints are to be in close contact and both edges of the overlap are to have continuous fillet welds.

Figure 6.5.6
Lapped Joints

Fillet weld in lap joint



5.4.2 Overlapped end connections

5.4.2.1 Lapped end connections, where accepted by the Rules, are to have continuous welds on each edge with leg length, l_{leg}, as shown in *Figure 6.5.6*, such that the sum of the two leg lengths is not less than 1.5 times the gross thickness of the thinner plate.

5.4.3 Overlapped seams

5.4.3.1 Overlapped seams are to have continuous welds on both edges, of the sizes required by *Table 6.5.1* for the boundaries of tank or watertight bulkheads. Seams for plates with a gross thickness of 12.5mm or less, which are clear of tanks, may have one edge with intermittent welds in accordance with *Table 6.5.1* for watertight bulkhead boundaries.

5.5 Slot Welds

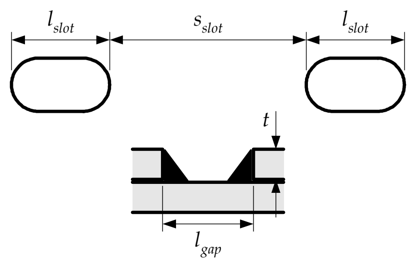
5.5.1 General

5.5.1.1 Slot welds may be specially approved for particular applications. Typical applications are indicated in *5.5.2* and *5.5.3,* and typical arrangements are shown in *Figure 6.5.7*.

5.5.1.2 Slots are to be well-rounded and have a minimum slot length, l_{slot}, of 75mm and width, w_{slot}, of twice the gross plate thickness. Where used in the body of doublers and similar locations, such welds are in general to be spaced a distance, s_{slot}, of $2l_{slot}$ to $3l_{slot}$ but not greater than 250mm.

Figure 6.5.7
Slot Welds

Slot welding



5.5.2 Closing plates

5.5.2.1 For the connection of plating to internal webs, where access for welding is not practicable, the closing plating may be attached by slot fillet welds to face plates fitted to the webs.

5.5.2.2 Slots are to be well rounded and have a minimum slot length, l_{slot}, of 90mm and a minimum width, w_{slot}, of twice the gross plate thickness. Slots cut in plating are to have smooth, clean and square edges and are in general to be spaced a distance, s_{slot}, not greater than 140mm. Slots are not to be filled with welding.

5.5.3 (void)

5.5.3.1 (void)

5.6 Stud Welds

5.6.1 General

5.6.1.1 Where permanent or temporary studs are to be attached by welding to main structural parts in areas subject to high stress, the proposed location of the studs is to be submitted for approval.

5.7 Determination of the Size of Welds

5.7.1 General

5.7.1.1 The following weld sizes are to be rounded to the nearest half millimetre.

5.7.1.2 The leg length, l_{leg}, as shown in *Figure 6.5.8*, of continuous, lapped or intermittent fillet welds, in association with the requirements of *5.7.2* to *5.7.5,* is not to be taken as less than:

(a) $l_{leg} = f_1 t_{p-grs}$

(b) $l_{leg} = f_{yd} f_{weld} f_2 t_{p-grs} + t_{gap}$

(c) l_{leg} as given in *Table 6.5.2*

Where:

f_1 = 0.30 for double continuous welding
= 0.38 for intermittent welding

t_{p-grs} the gross plate thickness, in mm. Is generally to be taken as that of the abutting member (member being attached). See *5.7.1.5*

f_{yd} correction factor taking into account the yield strength of the weld deposit:

$$= \left(\frac{1}{k}\right)^{0.5} \left(\frac{235}{\sigma_{weld}}\right)^{0.75}$$ but is not to be taken as less than 0.707

σ_{weld} minimum yield stress of the weld deposit, and is not to be less than:

305N/mm^2 for welding of normal strength steel

375N/mm^2 for welding of higher strength steels with yield strength of 265 to 355N/mm^2

400 N/mm^2 for welding of higher strength steel with yield strength of 390N/mm^2

See *5.9.4* for additional requirements that are to be applied where the weld size is determined based on a weld deposit yield strength that exceeds the specified minimum value

k higher strength steel factor, as defined in *1.1.4*. k is to be based on the material of the abutting member

f_{weld} weld factor depending on the type of structural member, see *5.7.2*, *5.7.3* and *5.7.5*

f_2 correction factor for the type of weld:

1.0 for double continuous fillet

$\frac{s_{ctr}}{l_{weld}}$ for intermittent or chain welding

l_{weld} the actual length of weld fillet, clear of crater, in mm

s_{ctr} the distance between successive weld fillets, from centre to centre, in mm

t_{gap} allowance for weld gap (lesser gaps may be permitted, see *5.9.2*):

$=2.0\text{mm}$ for $t_{p-grs} > 6.5\text{mm}$

$= 2\left(1.25 - \frac{1}{f_2}\right)\text{mm}$ for $t_{p-grs} \le 6.5\text{mm}$

5.7.1.3 The throat size is not to be less than $l_{leg}/\sqrt{2}$, where the leg length, l_{leg}, is as shown in *Figure 6.5.8*.

5.7.1.4 The leg size for matched fillet welds either side of an intersection with intermittent welding is not to be greater than $0.62t_{p-grs}$ or 6.5mm, whichever is the lesser.

5.7.1.5 Where the gross web thickness of the abutting longitudinal stiffener is greater than 15mm and exceeds the thickness of the table member (e.g. plating), the welding is to be double continuous and the leg length of the weld is to be not less than the greatest of the following:

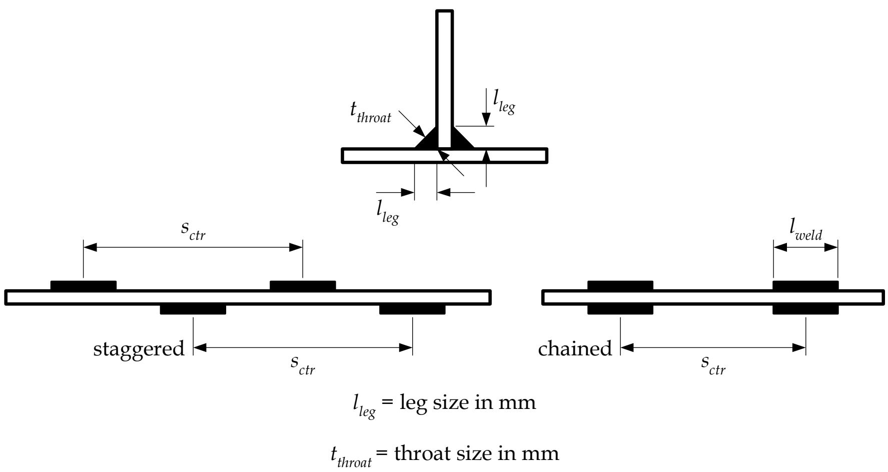
(a) 0.3 times the gross thickness of the table member. The table member thickness used need not be greater than 30mm

(b) 0.27 times the gross thickness of the abutting member plus 1.0mm. The leg size need not be greater than 8.0mm

(c) as given by *Table 6.5.2* for stiffeners to plating.

5.7.1.6 Where the gap between members being joined exceeds 2mm and is not greater than 5mm, the weld leg size is to be increased by the amount of the opening in excess of 2mm. Where the opening between members is greater than 5mm, corrective measures are to be taken, in accordance with an approved welding procedure specification.

Figure 6.5.8
Weld Definitions



5.7.2 Welding of fillet joints of main structural components

5.7.2.1 General weld factors for the connections of the structural components of the hull are given in *Table 6.5.1*.

5.7.2.2 Where components of the hull form a part of a double skin primary support member the requirements of *5.7.4* are also to be applied.

5.7.2.3 Where high tensile stresses act through an intermediate plate (see *Figure 6.5.4*), increased fillet welds or penetration welds are to be used as required by *5.8*.

5.7.3 Welding of primary support members

5.7.3.1 Weld factors for the connections of the web plating of primary support members are given in *Table 6.5.4*.

5.7.3.2 Where the minimum weld size is determined by the requirements of *5.7.1.2(b)* the weld connections to shell, decks or bulkheads are to take account of the material lost in the cut out where stiffeners pass through the member. In cases where the web plating and the width of the notch exceeds 15 percent of the stiffener spacing, the size of the weld leg length is to be multiplied by:

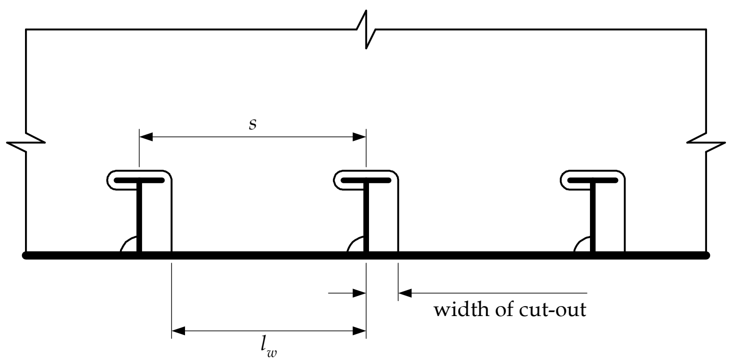
$$\frac{0.85s}{l_w}$$

Where:

s stiffener spacing, in mm

l_w length of web plating between notches, in mm, see *Figure 6.5.9*

Figure 6.5.9
Lost Material in Web Cut-outs for Stiffeners



5.7.4 Welding of end connections of primary support members

5.7.4.1 Welding of end connections of primary support members (i.e. transverse frames and girders) is to be such that the weld area, A_{weld}, is to be equivalent to the Rule gross cross-sectional area of the member. In terms of weld leg length, l_{leg}, this is to be taken as by:

$$l_{leg} = 1.41 f_{yd} \frac{h_w t_{p-grs}}{l_{dep}} \quad \text{mm}$$

Where:

h_w web height of primary support member, in mm, see *Figure 6.5.10*

t_{p-grs} rule gross thickness of the primary support member, in mm

l_{dep} total length of deposit of weld metal, in mm. Generally this can be taken as twice l_{weld} shown in *Figure 6.5.10* for a double continuous fillet weld

f_{yd} correction factor taking into account the yield strength of the weld deposit, as defined in *5.7.1.2*

In no case is the size of weld to be less than that calculated in accordance with *5.7.1.2*, using a minimum weld factor, f_{weld}, of 0.48 in tanks or 0.38 elsewhere.

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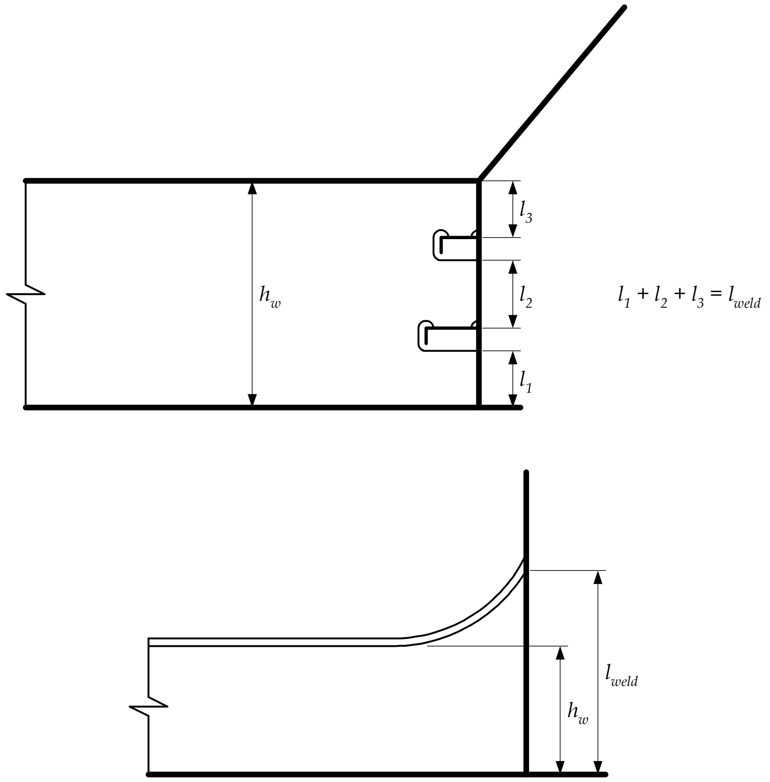
Figure 6.5.10
End Connection of Primary Support Members



Note

1. The length l_{weld} is the length of the welded connection. The total length of the weld deposit l_{dep} is, for double continuous fillet welds, twice the length of the welded connection l_{weld}

5.7.5 Welding at the ends of stiffeners

5.7.5.1 Welding of longitudinals to plating is to be double continuous at the ends of the longitudinals. In way of transverses the length of the double continuous weld is to be equal the depth of the longitudinal, or the depth of the end bracket, whichever is greater.

5.7.5.2 For deck longitudinals, a matched pair of welds is required at the intersection of longitudinals with transverses.

5.7.5.3 The welding of stiffener (i.e. longitudinals, beams and bulkhead stiffeners) end connections is to be not less than as required by *Table 6.5.5*. Where two requirements are given, the greater is to be complied with. The area of weld, A_{weld}, indicated in *Table 6.5.5*, is to be applied to each arm of the bracket or lapped connection.

5.7.5.4 Where a longitudinal strength member is cut at a primary support structure and the continuity of strength is provided by brackets, the weld area, A_{weld}, based on the effective throat times the length of the weld, is to be not less than the gross cross-sectional area of the member. If the longitudinal strength member is of high strength steel, the weld area, A_{weld}, is to be multiplied by f_{yd}, the correction factor taking into account the yield strength of the weld deposit as defined in *5.7.1.2*.

5.7.5.5 Where the stiffener member passes through, and is supported by the web of a primary support member, the weld connection is to be in accordance with the requirements of *Section 4/3.4.3.11*.

5.7.5.6 Where intermittent welding is permitted, unbracketed stiffeners of shell, watertight and oil-tight bulkheads, and house fronts are to have double continuous welds for one-tenth of their length at each end. Unbracketed stiffeners of non-tight structural bulkheads, deck house sides and aft ends are to have a pair of matched intermittent welds at each end.

5.8 Weld for Structures Subject to High Tensile Stresses

5.8.1 Minimum leg size

5.8.1.1 Where high tensile stresses act through an intermediate plate, see *Figure 6.5.11*, the minimum leg length, l_{leg}, of double continuous welds is to be taken as:

$$l_{leg} = 1.92\left(\frac{235}{\sigma_{weld}}\right)^{0.75}\left[0.2 + \left(\frac{\sigma}{270} - 0.25\right)\frac{l_{root}}{t_{p-grs}}\right]t_{p-grs} + 2.0 \quad \text{mm}$$

Where:

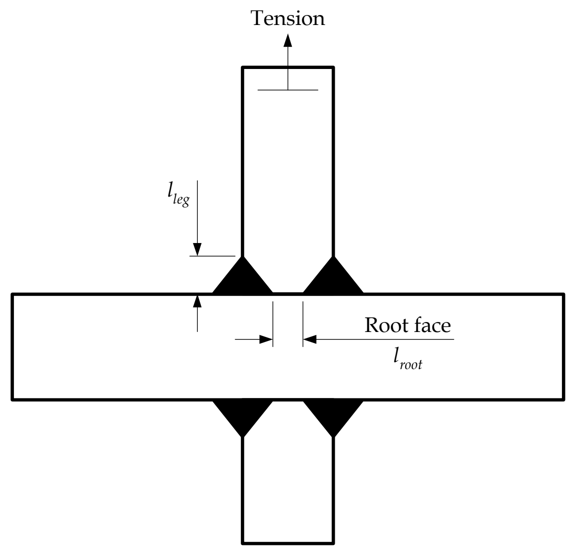
σ maximum tensile stress in plate being attached, in N/mm²

l_{root} root face length, in mm

t_{p-grs} gross thickness of plate being attached, in mm

σ_{weld} as defined in *5.7.1.2*, where σ_{weld} is limited to the maximum value permitted by the limits imposed on correction factor taking into account the yield strength of the weld deposit, f_{yd}, as defined in *5.7.1.2*

Figure 6.5.11
Welds Subject To High Tensile Stresses



5.9 Reduced Weld Size

5.9.1 General

5.9.1.1 Reduction in fillet weld sizes that are required by *5.7* may be specially approved in accordance with either *5.9.2*, *5.9.3* or *5.9.4*.

5.9.1.2 Where any of the methods for reduction of the weld size are adopted, the specific requirements giving justification for the reduction are to be indicated on the drawings. The drawings are to document the weld design and dimensioning requirements for the reduced weld leg length and the required weld leg length given by *5.7* without the permitted leg length reduction. Also, notes are to be added to the drawings to describe the difference in the two leg lengths and the requirements for their application.

5.9.2 Controlled gaps

5.9.2.1 Where quality control facilitates working to a gap between members of 1mm or less, a reduction in fillet weld leg size of 0.5mm is permitted.

5.9.3 Deep penetration welding

5.9.3.1 Where an approved automatic deep penetration procedure is used and quality control facilitates are working to a gap between members of 1mm or less, the weld factors given in *Tables 6.5.1, 6.5.2(c)* and *(d), 6.5.4* and *6.5.5* may be reduced by 15 percent. Reductions of up to 20 percent, but not more than the fillet weld leg size of 1.5mm, will be accepted provided that the Shipyard is able to consistently meet the following requirements:

(a) the welding is performed to a suitable process selection confirmed by welding procedure tests covering both minimum and maximum root gaps

(b) the penetration at the root is at least the same amount as the reduction into the members being attached

(c) demonstrate that an established quality control system is in place.

5.9.4 Controlled welding consumables

5.9.4.1 Where quality control systems are in place which ensure that the grade of welding consumable used is higher than the minimum required for the particular strength steel being welded, the welding consumables that are used may have a weld deposit material yield strength that is greater than the minimums specified in *5.7.1.2* and the size of the weld may be determined based on the yield strength of the higher grade welding consumable.

5.10 End Connections of Pillars and Cross Ties

5.10.1 Effective weld area

5.10.1.1 The end connections of pillars and cross ties are to have an effective fillet weld area (weld throat multiplied by weld length) not less than:

$$A_{weld} = f_3 \left(\frac{235}{\sigma_{weld}}\right)^{0.75} A_{grs} P \quad \text{cm}^2$$

Where:

A_{grs} gross cross-sectional area, for the pillar or cross tie, in m^2

P design pressure load, for the structure under consideration, in kN/m²

σ_{weld} minimum yield stress of the deposit, as given in *5.7.1.2*, where σ_{weld} is limited to the maximum value permitted by the limits imposed on f_{yd} in *5.7.1.2*

f_3 = 0.05 when pillar or cross tie is in compression only

= 0.14 when pillar or cross tie is in tension

5.11 Alternatives

5.11.1 General

5.11.1.1 The foregoing are considered minimum requirements for electric-arc welding in hull construction, but alternative methods, arrangements and details will be specially considered for approval.

5.11.1.2 The leg length limits given in *Table 6.5.2* are to be complied with in all cases.

Table 6.5.1
Weld Factors

Items	Weld Factor f_{weld}	Remarks
(1) General application		except as required by items 2-11
Watertight boundaries	0.43	
Non-tight plate boundaries	0.18	
Strength deck plating to shell	see *Table 6.5.3*	
Other decks to shell and bulkheads (except where forming tank boundaries)	0.30	generally continuous
Stiffeners to plating (clear of end connections)	0.13	in dry spaces
	0.18	in tanks
Stiffeners to plating for 0.1 span at ends	0.21	or extent of end bracket if greater
Panel stiffeners	0.13	
Overlapped welds generally	0.36	
Longitudinals, with gross web thickness greater than 15mm, to plating	see *5.7.1.5*	t_{p-grs} as defined in *5.7.1.5*
(2) Bottom construction in cargo tank region		(1)
Non-tight centre girder: to keel	0.30	
to inner bottom	0.28	no scallops
Non-tight boundaries of floors and girders	0.15	mid half span
	0.24	end quarters span
Floors and girder to inner bottom in way of:		
vertical primary supporting members	0.43	(1)
Connection between floors and girders	0.36	(1)
End connection of floors and girders	0.43	(1)
Docking brackets	0.30	

Table 6.5.1 (Continued)
Weld Factors

Items	Weld Factor f_{weld}	Remarks
(3) Side construction in cargo tank region		including bilge hopper tanks, (1)
Vertical webs to inner hull bulkhead		
in way of deck transverse/bracket	0.43	
in way of cross tie, as applicable	0.36	
Elsewhere	0.24	
Vertical webs to shell	0.24	
Vertical webs end connection	0.43	(1)
(4) Cargo tank bulkhead construction		including pump room and cofferdam, (1)
Longitudinal and transverse oil-tight bulkhead boundaries:		
to deck, inner bottom and bottom shell	0.51	
at sides	0.43	
Vertical corrugation		
at upper end	0.51	
at lower end	see *5.3.4*	
Non-tight bulkhead boundaries	0.24	
Primary support members	see *Table 6.5.4*	
Connection between primary support members	0.49	
(5) Structures in machinery space		
Centre girder to keel and inner bottom	0.36	
Floors to centre girder in way of:		
Engines	0.36	
thrust and boiler bearers	0.36	
Floors to main engine foundation girders	0.36	
Floors/girders to shell and inner bottom	0.24	
Main engine foundation girders to top plate and primary hull structure	Partial penetration	edge to be prepared with maximum root $0.33t_{p-grs}$ deep penetration
Foundation:		
auxiliary diesels (>350kw)	0.40	
boiler and other auxiliaries	0.35	
Brackets supporting engine foundation	0.21	
(6) Construction in 0.25*L* forward		
In way of flat of bottom:		
floors to shell and inner bottom	0.18	
girders to shell and inner bottom	0.28	
Bottom longitudinals to shell:		
flat of bottom forward	0.30	
Elsewhere	0.18	
side shell stringers to shell	0.24	
Fore peak construction:		
internal structures	0.18	
(7) Aft peak construction		
Internal structure:		
below water line	0.30	
above waterline	0.18	

Table 6.5.1 (Continued)
Weld Factors

Items	Weld Factor f_{weld}	Remarks
(8) Superstructures and deck houses		
Connection of external bulkhead to deck		
first and second tier erections	0.28	
Elsewhere	0.15	
Internal bulkheads	0.12	
(9) Closing Arrangements		
Hatch coaming to deck	0.43	
Cleats and fittings	0.60	minimum weld factor. Where t_{p-grs} > 11.5mm, l_{leg} need not exceed 0.62 t_{p-grs}. Penetration welding may be required depending on design
Hatch covers:		
oil-tight joints	0.46	
watertight joints:		
Outside	0.46	
Inside	0.18	
Hatch covers:		
at end of stiffener (unbracketed)	0.38	(2)
at end of stiffener (bracketed)	0.38	
Elsewhere	0.12	
(10) Deck Equipment		(3)
Masts, derrick posts, crane pedestals, etc., to deck	0.43	
Deck machinery seats to deck	0.20	
Mooring equipment seats	0.43	
(11) Miscellaneous fittings and equipment		
Rings for access hole type covers to ship	0.43	
Frames of shell and weathertight doors	0.43	
Stiffening of shell and weathertight doors	0.24	
Ventilators, air pipes, etc., coaming to deck	0.43	
Ventilators, etc., fittings	0.24	
Scuppers and discharge to deck	0.55	
Bulwark stays to deck	0.24	
Bulwark attachment to deck	0.43	
Guard rails, stanchions, etc., to deck	0.43	
Bilge keel ground bars to shell	see *Table 11.3.1*	
Bilge keels to ground bars	see *Table 11.3.1*	
Fabricated anchors	full penetration	

Note

1. The weld size is to be increased for areas with high tensile stress, see *5.8*.
2. Unbracketed stiffeners and webs of hatch covers are to be welded continuously to the plating and to the face plate for a length, at the ends, equal to the end depth of the member.
3. Weld factors are minimum values.

Table 6.5.2
Leg Size

Item	Minimum Leg Size(1), mm
(a) Gross plate thickness $t_{p\text{-}grs} \leq 6.5$mm (5)	
Hand or automatic welding	4.0
Automatic deep penetration welding	4.0
(b) Gross plate thickness $t_{p\text{-}grs} > 6.5$mm (5)	
Hand or automatic welding	4.5
Automatic deep penetration welding	4.0
(c) Welds within 3m below top of ballast and cargo tanks(2) (4)	6.5
(d) All welds in cargo tank region, except in (c) (4)	6.0

Note

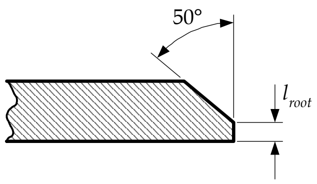
1. In all cases, the limiting value is to be taken as the greatest of the applicable values given above.
2. Only applicable to cargo and ballast tanks with weather deck as the tank top.
3. See *5.9* for provisions to reduce minimum leg size.
4. A reduction to 5.5mm leg size for the secondary structural elements such as carling, buckling stiffeners and tripping brackets may be applied without additional gap control.
5. For superstructure and deck houses, the minimum leg length may be taken as 3.5mm.

(RCN 2, effective from 1 July 2008)

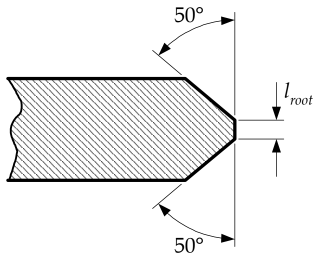
Table 6.5.3
Weld Connection of Strength Deck Plating to Sheer Strake

Stringer gross plate thickness, in mm	Weld type
$t_{p\text{-}grs} \le 15$	Double continuous fillet weld with a leg size of 0.60 $t_{p\text{-}grs}$ + 2.0mm
$15 < t_{p\text{-}grs} \le 20$	Single vee preparation to provide included angle of 50° with root face length $l_{root} < t_{p\text{-}grs}/3$ in conjunction with a continuous fillet weld with a weld factor of 0.35 or Double vee preparation to provide included angle of 50° with root face length $l_{root} < t_{p\text{-}grs}/3$
$t_{p\text{-}grs} > 20$	Double vee preparation to provide included angle of 50° with root face length $l_{root} < t_{p\text{-}grs}/3$, but not to be greater than 10mm

Where $t_{p\text{-}grs}$ = gross thickness of stringer plate, in mm



or



single vee preparation double vee preparation

Note

1. Welding procedure, including joint preparation, is to be specified and approved for individual builders.
2. Where structural members pass through the boundary of a tank a leak stopper is to be arranged in accordance with *4.4.4*.
3. Alternative connections will be specially considered.

Table 6.5.4
Connection of Primary Support Members

Primary Support Member gross face area, in cm²		Position [(1)]	Weld factor, f_{weld}			
			In tanks		In dry spaces	
Greater than	Not greater than		To face plate	To plating	To face plate	To plating
	30.0	At ends Remainder	0.20 0.12	0.26 0.20	0.20 0.12	0.20 0.15
30.0	65.0	At ends Remainder	0.20 0.12	0.38 0.26	0.20 0.12	0.20 0.15
65.0	95.0	At ends Remainder	0.42 0.30 [(2)]	0.59 [(3)] 0.42	0.20 0.15	0.30 0.20
95.0	130.0	At ends Remainder	0.42 0.30 [(2)]	0.59 [(3)] 0.42	0.30 0.20	0.42 0.30
130.0		At ends Remainder	0.59 [(3)] 0.42	0.59 [(3)] 0.42	0.42 0.30	0.59 [(3)] 0.42

Note

1. The weld factors 'at ends' are to be applied for 0.2 times the overall length of the member from each end, but at least beyond the toe of the member end brackets. On vertical webs, the increased welding may be omitted at the top, but is to extend at least 0.3 times overall length from the bottom.
2. Weld factor 0.38 to be used for cargo tanks.
3. Where the web plate thickness is increased locally to meet shear stress requirements, the weld size may be based on the gross web thickness clear of the increased area, but is to be not less than weld factor of 0.42 based on the increased gross thickness.
4. In regions of high stress, see *5.3.4*, *5.7.4* and *5.8*.

RCN 2 to July 2008 version (effective from 1 July 2010)

Table 6.5.5
Stiffener End Connection Welds

Connection	Weld area, A_{weld}, in cm²	Weld Factor, f_{weld} [(1)]
(1) Stiffener welded direct to plating	$0.25A_{stf\text{-}grs}$ or 6.5 cm² whichever is the greater	0.38
(2) Bracketless connection of stiffeners, stiffener lapped to bracket or bracket lapped to stiffener:		
(a) in dry space	$1.2\sqrt{Z_{grs}}$	0.26
(b) in tank	$1.4\sqrt{Z_{grs}}$	0.38
(c) main frame to tank side bracket in 0.15*L* forward	as (a) or (b)	0.38
(3) Bracket welded to face of stiffener and bracket connection to plating	–	0.38

Where:

$A_{stf\text{-}grs}$ gross cross sectional area of the stiffener, in cm²

A_{weld} weld area, in cm², and is calculated as total length of weld, in cm, times throat thickness, in cm (Where the gap exceeds 2mm the weld size is to be increased. See *5.7.1.6*)

Z_{grs} the gross section modulus required, in cm³, of the stiffener on which the scantlings of the bracket are based

Note

1. For minimum weld fillet sizes, see *Table 6.5.2*.

SECTION 7

LOADS

1 INTRODUCTION

1.1 General

1.1.1 Application

1.1.1.1 This section provides in detail the loads and load combinations for the scantling calculations. The loads cover load scenarios in harbour and at sea, see *Section 2/5.4*, dividing the loads into static load components, dynamic load components, sloshing loads and impact loads.

1.2 Definitions

1.2.1 Coordinate system

1.2.1.1 The applied coordinate system x, y, z is as defined in *Section 4/1.4.1.1*.

1.2.1.2 The direction of the incident waves are specified by the angle β between the x-axis and the propagating wave direction as shown in *Figure 7.1.1*. Examples given:

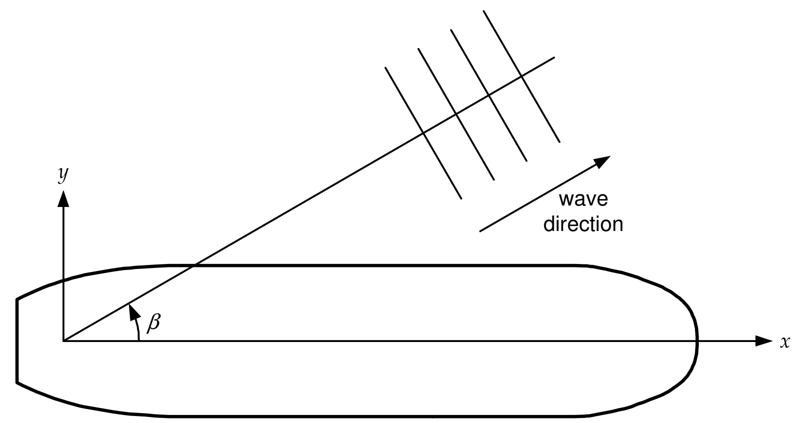
(a) head sea is waves propagating in the negative x-direction,

(b) beam sea is waves propagating in the positive or negative y-direction,

(c) oblique sea is waves propagating in a direction between head and beam sea (or following and beam sea), and

(d) following sea is waves propagating in positive x-direction.

Figure 7.1.1
Definition of Wave Heading



1.2.2 Sign conventions

1.2.2.1 Positive motions, as shown in *Figure 7.1.2,* are defined as:

(a) positive surge is translation along positive x-axis (forward)

(b) positive sway is translation along positive y-axis (towards port side of vessel)

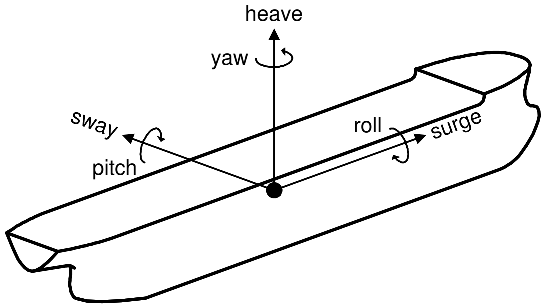
(c) positive heave is translation along positive z-axis (upwards)

(d) positive roll is starboard down and port side up

(e) positive pitch is bow down and stern up

(f) positive yaw is bow rotating towards portside of vessel and stern towards starboard side.

Figure 7.1.2
Definition of Positive Motions



Note
1. This figure shows the rotation axis and not the coordinate system.

1.2.2.2 Positive accelerations are defined as:

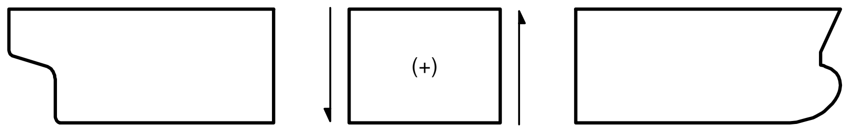
(a) positive longitudinal acceleration is acceleration along positive *x*-axis (forward)

(b) positive transverse acceleration is acceleration along positive *y*-axis (towards portside of vessel)

(c) positive vertical acceleration is acceleration along positive *z*-axis (upwards).

1.2.2.3 The sign convention of positive vertical hull girder shear force is shown in *Figure 7.1.3*.

Figure 7.1.3
Positive Vertical Shear Force



1.2.2.4 The sign conventions of positive hull girder bending moments are shown in *Figures 7.1.4* and *7.1.5,* and are defined as:

(a) positive vertical bending moment is a hogging moment and negative vertical bending moment is a sagging moment

(b) positive horizontal bending moment is tension on the starboard side and compression on the port side.

Figure 7.1.4
Positive Vertical Bending Moment

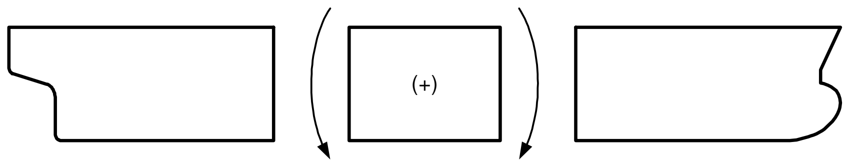
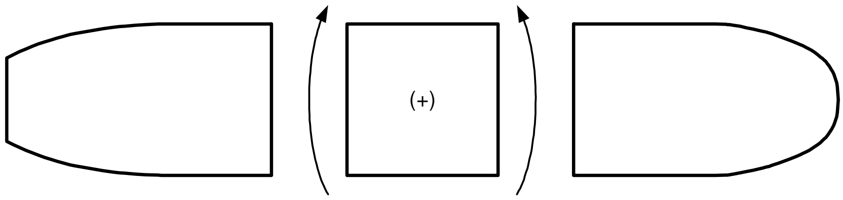


Figure 7.1.5
Positive Horizontal Bending Moment



2 STATIC LOAD COMPONENTS

2.1 Static Hull Girder Loads

2.1.1 Permissible hull girder still water bending moment

2.1.1.1 The designer is to provide the permissible hull girder hogging and sagging still water bending moment limits for seagoing, $M_{sw\text{-}perm\text{-}sea}$, and harbour/sheltered water operations, $M_{sw\text{-}perm\text{-}harb}$.

2.1.1.2 The permissible hull girder hogging and sagging still water bending moment limits are to be given at each transverse bulkhead in the cargo area, at the middle of cargo tanks, at the collision bulkhead, at the engine room forward bulkhead and at the midpoint between the fwd and aft engine room bulkhead.

2.1.1.3 The permissible hull girder hogging and sagging still water bending moment envelope is given by linear interpolation between values at the longitudinal positions given in *2.1.1.2.*

2.1.1.4 The permissible hull girder hogging and sagging still water bending moment envelopes are to be included in the loading manual as required in *Section 8/1.1.2*.

2.1.1.5 The permissible hull girder hogging and sagging still water bending moment envelopes for seagoing operations, $M_{sw\text{-}perm\text{-}sea}$, are to envelop the minimum hull girder hogging and sagging still water bending moments given in *2.1.2.1* and *2.1.2.2* and the most severe hogging and sagging hull girder still water bending moments calculated for any seagoing loading condition given in the loading manual. The requirements for the loading conditions are given in *Section 8/1.1.2*.

2.1.1.6 The permissible hull girder hogging and sagging still water bending moment envelopes for harbour/sheltered water operation, $M_{sw\text{-}perm\text{-}harb}$, are to envelop the minimum hull girder hogging and sagging still water bending moments given in *2.1.2.3* and the most severe hogging and sagging hull girder still water bending moments calculated for any harbour/sheltered water loading condition given in the loading manual and are not to be less than the permissible envelopes for seagoing operation, $M_{sw\text{-}perm\text{-}sea}$.

Guidance note:

It is recommended that, for initial design, the permissible hull girder hogging and sagging still water bending moment envelopes are at least 5% above the hull girder still water bending moment envelope from the loading conditions in the loading manual, to account for growth and design margins during the design and construction phase of the ship.

2.1.2 Minimum hull girder still water bending moment

2.1.2.1 The minimum hull girder hogging and sagging still water bending moment for seagoing operations, $M_{sw\text{-}min\text{-}sea\text{-}mid}$, at amidships is to be taken as:

for hogging:

$$M_{sw-min-sea-mid} = f_{sea}\left(Z_{v-\min}\,\sigma_{perm-sea}\,10^3 - M_{wv-hog}\right) \quad \text{kNm}$$

which is identical to

$$M_{sw-min-sea-mid} = 0.01\,C_{wv}\,L^2\,B\left(11.97 - 1.9C_b\right) \quad \text{kNm}$$

for sagging:

$$M_{sw-min-sea-mid} = f_{sea}\left(Z_{v-\min}\,\sigma_{perm-sea}\,10^3 + M_{wv-sag}\right) \quad \text{kNm}$$

which is identical to

$$M_{sw-min-sea-mid} = -0.05185\, C_{wv}\, L^2\, B(C_b + 0.7) \quad \text{kNm}$$

Where:

f_{sea} -0.85 for sagging
1.0 for hogging

Z_{v-min} rule minimum hull girder section modulus as given in *Section 8/1.2.2.2*, in m^3

$\sigma_{perm-sea}$ allowable seagoing hull girder bending stress at midships, as defined in *Section 8/1.2.3.2*, in N/mm^2

M_{wv-hog} envelope values of hogging vertical wave bending moment at midships as defined in *3.4.1.1*, in kNm

M_{wv-sag} envelope values of sagging vertical wave bending moment at midships as defined in *3.4.1.1*, in kNm

C_{wv} wave coefficient, as defined in *3.4.1.1*

L rule length, , in m, as defined in *Section 4/1.1.1.1*

B moulded breadth, in m, as defined in *Section 4/1.1.3.1*, in m

C_b block coefficient, as defined in *Section 4/1.1.9.1*

2.1.2.2 The minimum hull girder hogging and sagging still water bending moment for seagoing operations, $M_{sw-min-sea}$, at any longitudinal position is to be taken as:

$$M_{sw-min-sea} = f_{sw}\, M_{sw-min-sea-mid} \quad \text{kNm}$$

Where:

f_{sw} 1.0 within 0.4*L* amidships
0.15 at 0.1*L* from A.P. or F.P.
0 at A.P. and F.P.

intermediate f_{sw} values are to be obtained by linear interpolation, see *Figure 7.2.1*

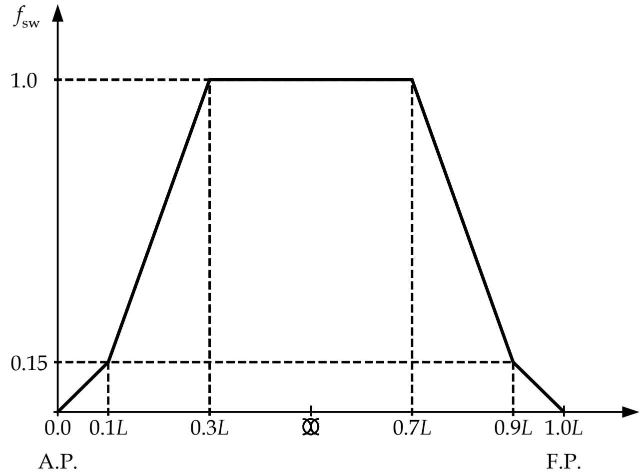
2.1.2.3 The minimum hull girder hogging and sagging still water bending moment for harbour/sheltered water operations, $M_{sw-min-harb}$, at any longitudinal position is to be taken as:

$$M_{sw-min-harb} = 1.25\, M_{sw-min-sea} \quad \text{kNm}$$

Where:

$M_{sw-min-sea}$ corresponding minimum hull girder hogging and sagging still water bending moment for seagoing operation at the section under consideration, see *2.1.2.1* and *2.1.2.2*

Figure 7.2.1
Still Water Bending Moment Distribution



2.1.3 Still water shear force

2.1.3.1 The designer is to provide the permissible hull girder positive and negative still water shear force limits for seagoing, $Q_{sw\text{-}perm\text{-}sea}$, and harbour/sheltered water operations, $Q_{sw\text{-}perm\text{-}harb}$.

2.1.3.2 The permissible hull girder positive and negative still water shear force limits are to be given at each transverse bulkhead in the cargo area, at the middle of cargo tanks, at the collision bulkhead and at the engine room forward bulkhead.

2.1.3.3 The permissible hull girder positive and negative still water shear force envelope is given by linear interpolation between values at the longitudinal positions given in *2.1.3.2.*

2.1.3.4 The permissible hull girder positive and negative still water shear force envelopes are to be included in the loading manual as required in *Section 8/1.1.2*.

2.1.3.5 The permissible hull girder positive and negative still water shear force envelopes for seagoing operation, $Q_{sw\text{-}perm\text{-}sea}$, are to envelope the minimum hull girder positive and negative still water shear forces given in *2.1.4.1, 2.1.4.2* and the most severe positive and negative hull girder still water shear forces for any seagoing loading condition given in the loading manual. The requirements for the loading conditions are given in *Section 8/1.1.2.*

2.1.3.6 The permissible hull girder positive and negative still water shear force envelopes for harbour operation, $Q_{sw\text{-}perm\text{-}harb}$, are to envelop the minimum hull girder positive and negative still water shear forces given in *2.1.4.3, 2.1.4.4* and the most severe positive and negative hull girder still water shear forces for any harbour/sheltered water loading condition given in the loading manual and are not to be less than the permissible envelopes for seagoing operation, $Q_{sw\text{-}perm\text{-}sea}$.

Guidance note:

It is recommended that, for initial design, the permissible hull girder still water shear force envelopes are at least 10% above the hull girder shear force envelope from the loading conditions in the loading manual, to account for growth and design margins during the design and construction phase of the ship.

2.1.4 Minimum hull girder still water shear force

2.1.4.1 For ships with two longitudinal bulkheads, the minimum hull girder positive and negative still water shear force for seagoing operation, $Q_{sw-min-sea}$, in way of transverse bulkheads between centre cargo tanks, is to be taken as:

$$Q_{sw-min-sea} = \pm \max \begin{cases} 0.225 \rho g B_{local} l_{tk} T_{sc} \\ 0.5 \rho g \left[0.98 (V_{CT} + 2V_{ST}) - 0.7 B_{local} l_{tk} T_{sc} \right] \end{cases} \quad \text{kN}$$

and taken as the maximum value of $Q_{sw-min-sea}$ calculated for cargo/ballast tanks forward and aft of the transverse bulkhead

Where:

ρ	density of cargo/sea water, not to be taken less than 1.025 tonnes/m^3
g	acceleration due to gravity, 9.81 m/s^2
B_{local}	local breadth at T_{sc} at the middle length of the tank under consideration, in m
l_{tk}	length of cargo tank under consideration, taken at the forward or aft side of the transverse bulkhead under consideration, in m
T_{sc}	scantling draught, in m, as defined in *Section 4/1.1.5.5*
V_{CT}	volume of centre cargo tank, taken for the cargo tank on the forward or aft side of the transverse bulkhead under consideration, in m^3
V_{ST}	volume of side cargo tank, taken for the cargo tank on the forward or aft side of the transverse bulkhead under consideration, in m^3

2.1.4.2 For ships with centreline longitudinal bulkhead, the minimum hull girder positive and negative still water shear force for seagoing operation, $Q_{sw-min-sea}$, in way of transverse bulkheads between cargo tanks is to be taken as:

$$Q_{sw-min-sea} = \pm 0.4 \rho g B_{local} l_{tk} T_{sc} \quad \text{kN}$$

and taken as the maximum value of $Q_{sw-min-sea}$ calculated for cargo/ballast tanks forward and aft of the transverse bulkhead

Where:

ρ	density of cargo/sea water, not to be taken less than 1.025 tonnes/m^3
g	acceleration due to gravity, 9.81 m/s^2
B_{local}	local breadth at T_{sc} at the middle length of the tank under consideration, in m
l_{tk}	length of cargo tank under consideration, taken at the forward or aft side of the transverse bulkhead under consideration, in m
T_{sc}	scantling draught, in m, as defined in *Section 4/1.1.5.5*

2.1.4.3 For ships with two longitudinal bulkheads, the minimum hull girder positive and negative still water shear force for harbour/sheltered water operation, $Q_{sw\text{-}min\text{-}harb}$, in way of transverse bulkheads between centre cargo tanks, is to be taken as:

$$Q_{sw-min-harb} = \pm \max\begin{cases} 0.275\rho g B_{local} l_{tk} T_{sc} \\ 0.5\rho g \left[0.98\left(V_{CT} + 2V_{ST}\right) - 0.6 B_{local} l_{tk} T_{sc}\right] \end{cases} \quad \text{kN}$$

and taken as the maximum value of $Q_{sw\text{-}min\text{-}harb}$ calculated for cargo/ballast tanks forward and aft of the transverse bulkhead

Where:

ρ	density of cargo/sea water, not to be taken less than 1.025 tonnes/m^3
g	acceleration due to gravity, 9.81 m/s^2
B_{local}	local breadth at T_{sc} at the middle length of the tank under consideration, in m
l_{tk}	length of cargo tank under consideration, taken at the forward or aft side of the transverse bulkhead under consideration, in m
T_{sc}	scantling draught, in m, as defined in *Section 4/1.1.5.5*
V_{CT}	volume of centre cargo tank, taken for the cargo tank on the forward or aft side of the transverse bulkhead under consideration, in m^3
V_{ST}	volume of side cargo tank, taken for the cargo tank on the forward or aft side of the transverse bulkhead under consideration, in m^3

2.1.4.4 For ships with centreline longitudinal bulkhead, the minimum hull girder positive and negative still water shear force for harbour/sheltered water operation, $Q_{sw\text{-}min\text{-}harb}$, in way of transverse bulkheads between cargo tanks, is to be taken as:

$$Q_{sw-min-harb} = \pm\, 0.45\rho g B_{local} l_{tk} T_{sc} \quad \text{kN}$$

and taken as the maximum value of $Q_{sw\text{-}min\text{-}harb}$ calculated for cargo/ballast tanks forward and aft of the transverse bulkhead

Where:

ρ	density of cargo/sea water, not to be taken less than 1.025 tonnes/m^3
g	acceleration due to gravity, 9.81 m/s^2
B_{local}	local breadth at T_{sc} at the middle length of the tank under consideration, in m
l_{tk}	length of cargo tank under consideration, taken at the forward or aft side of the transverse bulkhead under consideration, in m
T_{sc}	scantling draught, in m, as defined in *Section 4/1.1.5.5*

2.2 Local Static Loads

2.2.1 General

2.2.1.1 The following static loads are considered:

(a) static sea pressure

(b) static tank pressure

(c) tank overpressure

(d) static deck load

2.2.2 Static sea pressure

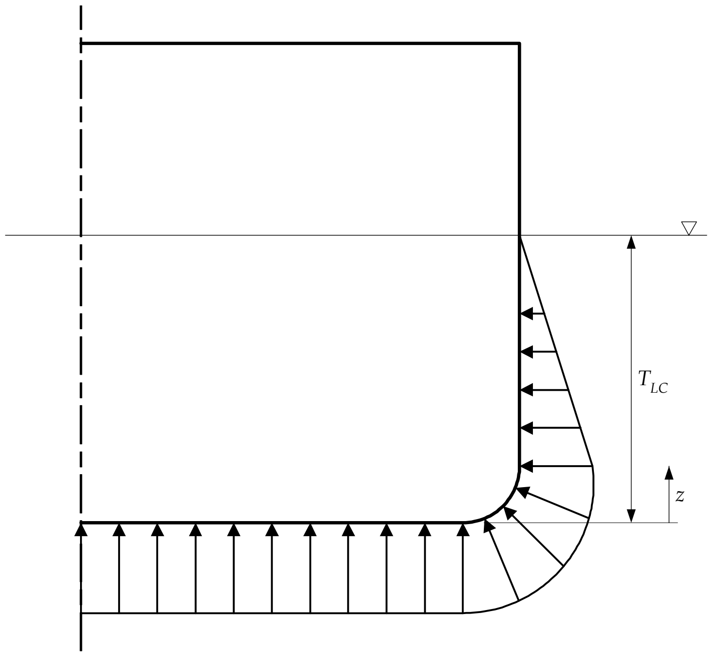
2.2.2.1 The static sea pressure, P_{hys}, is to be taken as:

$$P_{hys} = \rho_{sw} g (T_{LC} - z) \quad \text{kN/m}^2$$

Where:

z	vertical coordinate of load point, in m, and is not to be greater than T_{LC}, see *Figure 7.2.2*
ρ_{sw}	density of sea water, 1.025tonnes/m^3
T_{LC}	draught in the loading condition being considered, in m
g	acceleration due to gravity, 9.81m/s^2

Figure 7.2.2
Static Sea Pressure



2.2.3 Static tank pressure

2.2.3.1 The static tank pressure, P_{in-tk}, is to be taken as:

$$P_{in-tk} = \rho g z_{tk} \quad \text{kN/m}^2$$

Where:

z_{tk} vertical distance from highest point of tank, excluding small

	hatchways, to the load point, see *Figure 7.2.3,* in m
ρ	density of liquid in the tank, is not to be taken as less than 0.9 for liquid cargo for fatigue strength 1.025 otherwise see *Section 2/3.1.8*, in tonnes/m^3
g	acceleration due to gravity, 9.81m/s^2

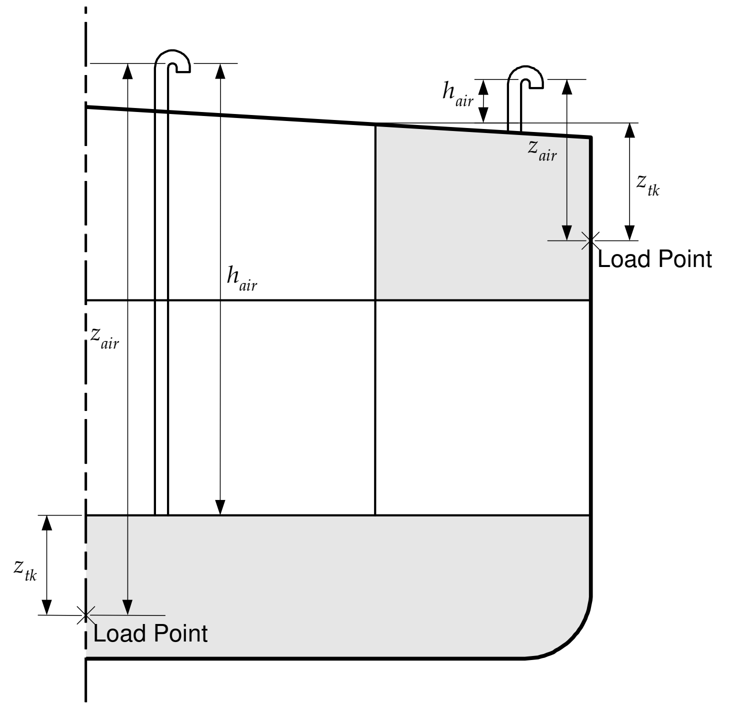
2.2.3.2 The static tank pressure, P_{in-air}, in the case of overfilling or filling during flow through ballast water exchange, is to be taken as:

$$P_{in-air} = \rho_{sw} g z_{air} \quad \text{kN/m}^2$$

Where:

z_{air}	vertical distance from top of air pipe or overflow pipe to the load point, whichever is the lesser, see *Figure 7.2.3*, in m $= z_{tk} + h_{air}$
ρ_{sw}	density of sea water, 1.025tonnes/m^3
g	acceleration due to gravity, 9.81m/s^2
h_{air}	height of air pipe or overflow pipe, in m, is not to be taken less than 0.76m above highest point of tank, excluding small hatchways. For tanks with tank top below the weather deck the height of air-pipe or overflow pipe is not to be taken less than 0.76m above deck at side unless a lesser height is approved by the flag Administration. See also *Figure 7.2.3*.

Figure 7.2.3
Pressure-Heads and Distances used for Calculation of Static Tank Pressure



2.2.3.3 The added overpressure due to sustained liquid flow through air pipe or overflow pipe in the case of overfilling or filling during flow through ballast water exchange, P_{drop}, is to be taken as 25 kN/m². Additional calculations may be required where piping arrangements may lead to a higher pressure drop, for example long pipes or arrangements such as bends and valves.

2.2.3.4 The pressure, $P_{in\text{-}flood}$, in compartments and tanks in a flooded or damaged condition is to be taken as:

$$P_{in-flood} = \rho_{sw} g z_{flood} \quad \text{kN/m}^2$$

Where:

z_{flood} vertical distance from the load point to the deepest equilibrium waterline in damaged condition obtained from applicable damage stability calculations or to freeboard deck if the damage waterline is not given, in m

ρ_{sw} density of sea water, 1.025tonnes/m³

g acceleration due to gravity, 9.81m/s²

2.2.3.5 The tank testing pressure, $P_{in\text{-}test}$, is to be taken as the greater of the following, see also the testing requirements in *Table 11.5.1*:

$$P_{in-test} = \rho_{sw} g z_{test} \quad \text{kN/m}^2$$

$$P_{in-test} = \rho_{sw} g z_{tk} + P_{valve} \quad \text{kN/m}^2$$

Where:

z_{test} vertical distance to the load point, is to be taken as the greater of the following, in m:

(a) top of overflow

(b) 2.4 m above top of tank

z_{tk} vertical distance from highest point of tank, excluding small hatchways, to the load point, see *Figure 7.2.3,* in m

ρ_{sw} density of sea water, 1.025tonnes/m³

g acceleration due to gravity, 9.81m/s²

P_{valve} setting of pressure relief valve, if fitted, is not to be taken less than 25kN/m²

2.2.4 Static deck pressure from distributed loading

2.2.4.1 The pressure on decks and inner bottom, P_{stat}, is to be taken as:

$$P_{stat} = P_{deck} \quad \text{kN/m}^2$$

Where:

P_{deck} uniformly distributed pressure on lower decks and decks within superstructures, including platform decks in the main engine room and for other spaces with heavy machinery components, in kN/m². P_{deck} is not to be taken less than 16kN/m². Design pressures for decks of deck houses are provided in *Section 11/1.4*.

2.2.5 Static deck loads from heavy units

2.2.5.1 The scantlings of structure in way of heavy units of cargo and equipment are to consider gravity forces acting where the mass is 20 tonnes or greater. The load acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, F_{stat}, is to be taken as:

$$F_{stat} = m_{un} g \quad \text{kN}$$

Where:

m_{un} mass of unit, in tonnes

g acceleration due to gravity, 9.81m/s²

3 DYNAMIC LOAD COMPONENTS

3.1 General

3.1.1 Basic components

3.1.1.1 Formulas for ship motions and accelerations are given in this sub-section.

3.1.1.2 Formulas for the envelope value of the basic dynamic load components are also given. The basic load components are:

(a) vertical wave bending moment and shear force

(b) horizontal wave bending moment

(c) dynamic wave pressure

(d) dynamic tank pressures.

3.1.2 Envelope load values

3.1.2.1 The envelope loads for scantling requirements and strength assessment are given at a 10^{-8} probability level, while the envelope loads for fatigue strength are given at a 10^{-4} probability level.

3.1.2.2 For scantling requirements and strength assessments, correction factors to account for non-linear effects and operational considerations in heavy weather are given.

3.1.2.3 For fatigue strength a factor adjusts the envelope load from a 10^{-8} probability level to a 10^{-4} probability level. A speed correction factor is applicable where appropriate.

3.1.2.4 The envelope value is the long term value, at a given probability level, taking into consideration the effect of all wave headings.

3.1.3 Metacentric height and roll radius of gyration

3.1.3.1 The metacentric height, GM, and roll radius of gyration, $r_{roll-gyr}$, associated with the rule loading conditions or specified draughts are specified in *Table 7.3.1*.

Table 7.3.1
GM and $r_{roll-gyr}$

	T_{LC}	GM	$r_{roll-gyr}$
Loaded at deep draught	between $0.9T_{sc}$ and T_{sc}	$0.12B$	$0.35B$
Loaded on reduced draught	$0.6T_{sc}$	$0.24B$	$0.40B$
In ballast	T_{bal}, T_{bal-n}	$0.33B$	$0.45B$

Where:

B moulded breadth, in m, as defined in *Section 4/1.1.3.1*

T_{LC} draught in the loading condition being considered, in m

T_{sc} scantling draught, in m, as defined in *Section 4/1.1.5.5*

T_{bal} minimum design ballast draught, in m, as defined in *Section 4/1.1.5.2*

T_{bal-n} normal ballast draught, in m, as defined in *Section 4/1.1.5.3*

3.1.3.2 For the optional loading conditions, GM is to be taken as the corrected metacentric height given in the loading manual. Where GM for optional loaded or gale/emergency ballast conditions is not specified, GM is to be taken as $0.12B$ for mean draught greater or equal to $0.9T_{sc}$, and $0.24B$ for mean draught equal or less than $0.6T_{sc}$. For optional loading conditions with a mean draught other than the

values defined, GM is to be obtained by linear interpolation based on values for $0.6T_{sc}$ and $0.9T_{sc}$.

3.1.3.3 $r_{roll\text{-}gyr}$ for optional loaded or gale/emergency ballast conditions is, unless provided based on the loading manual, to be taken as $0.35B$ for mean draught greater or equal to $0.9T_{sc}$, and $0.4B$ for mean draught equal or less than $0.6T_{sc}$. For optional loading conditions with a mean draught other than the values defined above, $r_{roll\text{-}gyr}$ may be obtained by linear interpolation based on values for $0.6T_{sc}$ and $0.9T_{sc}$.

3.1.3.4 For the loading conditions used for fatigue strength, GM is to be taken as the corrected metacentric height given in the loading manual. If not available, GM is to be taken as specified in *Table 7.3.1* for ballast condition and according to the procedure described in *3.1.3.2* for full load condition. $r_{roll\text{-}gyr}$ is, unless based on the loading condition, to be taken as specified in *Table 7.3.1* for ballast condition and according to the procedure described in 3.1.3.3 for full load condition.

3.2 Motions

3.2.1 General

3.2.1.1 The envelope values for ship motions are given at a 10^{-8} probability level.

3.2.2 Roll motion

3.2.2.1 The natural roll period, U_{roll}, is to be taken as:

$$U_{roll} = \frac{2.30 r_{roll-gyr}}{\sqrt{GM}} \quad \text{secs}$$

Where:

GM metacentric height, in m, as defined in *3.1.3*

$r_{roll\text{-}gyr}$ roll radius of gyration, in m, as defined in *3.1.3*

3.2.2.2 The roll angle, θ, is to be taken as:

$$\theta = \frac{50}{B+75}(1.25 - 0.025U_{roll})f_{bk} \quad \text{rads}$$

Where:

f_{bk} 1.2 for ships without bilge keels
1.0 for ships with bilge keels

B moulded breadth, in m, as defined in *Section 4/1.1.3.1*

U_{roll} roll period, in secs, as defined in *3.2.2.1*

3.2.3 Pitch motion

3.2.3.1 The characteristic pitch period, U_{pitch}, is to be taken as:

$$U_{pitch} = f_V \sqrt{0.6\frac{2\pi}{g}(1+f_T)L} \quad \text{s}$$

Where:

f_V $= 1.0 + \frac{V_0}{V}\left(\frac{L}{525} - 0.67\right)$

f_T = $\dfrac{T_{LC}}{T_{sc}}$

V_0 vessel speed, in knots, is to be taken as:

0 for scantling requirements and strength assessment

$0.75V$ for fatigue strength

V maximum service speed, in knots, as defined in *Section 4/1.1.8.1*

T_{sc} scantling draught, in m, as defined in *Section 4/1.1.5.5*

T_{LC} draught in the loading condition being considered, in m

L rule length, in m, as defined in *Section 4/1.1.1.1*

3.2.3.2 The pitch angle, φ, is to be taken as:

$$\varphi = 960\left(\frac{V_1}{C_b}\right)^{0.25}\frac{1}{L}\frac{\pi}{180} \quad \text{radians}$$

Where:

V_1 vessel speed, in knots. Is to be taken as V, but not to be taken as less than 10

V maximum service speed, in knots, as defined in *Section 4/1.1.8.1*

C_b block coefficient, as defined in *Section 4/1.1.9.1*

L rule length, in m, as defined in *Section 4/1.1.1.1*

3.3 Ship Accelerations

3.3.1 General

3.3.1.1 The envelope values for combined translatory accelerations due to motion in six degrees of freedom are given. The transverse and longitudinal components of acceleration include the component of gravity due to roll and pitch.

3.3.2 Common acceleration parameter

3.3.2.1 The common acceleration parameter, a_0, is to be taken as:

$$a_0 = (1.58 - 0.47C_b)\left(\frac{2.4}{\sqrt{L}} + \frac{34}{L} - \frac{600}{L^2}\right)$$

Where:

C_b block coefficient, as defined in *Section 4/1.1.9.1*

L rule length, in m, as defined in *Section 4/1.1.1.1*

3.3.3 Vertical acceleration

3.3.3.1 The envelope vertical acceleration, a_v, at any position, is to be taken as:

$$a_v = f_{prob}\sqrt{a_{heave}^2 + a_{pitch-z}^2 + a_{roll-z}^2} \quad \text{m/s}^2$$

Where:

a_{heave} vertical acceleration due to heave, is to be taken as:

$= f_V \, a_0 \, g$ m/s²

$a_{pitch\text{-}z}$ vertical acceleration due to pitch, is to be taken as:

$$= \left(0.3 + \frac{L}{325}\right)\varphi\left(\frac{2\pi}{U_{pitch}}\right)^2 |x - 0.45L| \quad \text{m/s}^2$$

$a_{roll\text{-}z}$ vertical acceleration due to roll, is to be taken as:

$$= 1.2\theta\left(\frac{2\pi}{U_{roll}}\right)^2 |y| \quad \text{m/s}^2$$

a_0 common acceleration parameter, as defined in *3.3.2.1*

g acceleration due to gravity, 9.81m/s²

φ pitch angle, in rads, as defined in *3.2.3.2*

U_{pitch} pitch period, in secs, as defined in *3.2.3.1*

L rule length, in m, as defined in *Section 4/1.1.1.1*

θ roll angle, in rads, as defined in *3.2.2.2*

U_{roll} roll period, in secs, as defined in *3.2.2.1*

x longitudinal coordinate, in m

y transverse coordinate, in m

f_{prob} as defined in *3.3.3.2* and *3.3.3.3* as appropriate

f_V as defined in *3.3.3.2* and *3.3.3.3* as appropriate

3.3.3.2 For scantling requirements and strength assessment:

f_{prob} is to be taken as 1.0

f_V is to be taken as 1.0

3.3.3.3 For fatigue strength:

f_{prob} is to be taken as 0.45

f_V $$= \left(\frac{C_{b-LC}}{C_b}\right)^2 \left(1.2 - \frac{L}{1000}\right)$$

Where:

$C_{b\text{-}LC}$ block coefficient for considered loading condition, as defined in *Section 4/1.1.9.2*

C_b block coefficient, as defined in *Section 4/1.1.9.1*

L rule length, in m, as defined in *Section 4/1.1.1.1*

3.3.4 Transverse acceleration

3.3.4.1 The envelope transverse acceleration, a_t, at any position, is to be taken as:

$$a_t = f_{prob}\sqrt{a_{sway}^2 + (g\, sin\theta + a_{roll-y})^2} \quad \text{m/s}^2$$

Where:

a_{sway} transverse acceleration due to sway and yaw, is to be taken as:

$= 0.3 g a_0$ m/s²

a_{roll-y} transverse acceleration due to roll, is to be taken as:

$$= \theta \left(\frac{2\pi}{U_{roll}} \right)^2 R_{roll} \quad \text{m/s}^2$$

θ roll angle, in rads, as defined in *3.2.2.2*

U_{roll} roll period, in secs, as defined in *3.2.2.1*

R_{roll} $= z - \left(\frac{D}{4} + \frac{T_{LC}}{2} \right)$ or $z - \left(\frac{D}{2} \right)$, whichever is the greater, in m

g acceleration due to gravity, 9.81m/s²

a_0 common acceleration parameter, as defined in *3.3.2.1*

T_{LC} draught in the loading condition being considered, in m

D moulded depth, as defined in *Section 4/1.1.4.1*

z vertical coordinate, in m

f_{prob} as defined in *3.3.4.2* or *3.3.4.3* as appropriate

3.3.4.2 For scantling requirements and strength assessment:

f_{prob} is to be taken as 1.0

3.3.4.3 For fatigue strength:

f_{prob} is to be taken as 0.5

3.3.5 Longitudinal acceleration

3.3.5.1 The envelope longitudinal acceleration, a_{lng}, at any position, is to be taken as:

$$a_{lng} = 0.7 f_{prob} \sqrt{a_{surge}^2 + \left(\frac{L}{325} \left(g \sin\varphi + a_{pitch-x} \right) \right)^2}$$

Where:

a_{surge} longitudinal acceleration due to surge, is to be taken as:
$= 0.2 g a_0$ m/s²

$a_{pitch-x}$ longitudinal acceleration due to pitch, is to be taken as:
$= f_V \varphi (2\pi / U_{pitch})^2 R_{pitch}$ m/s²

φ pitch angle, in rads, as defined in *3.2.3.2*

U_{pitch} pitch period, in secs, as defined in *3.2.3.1*

R_{pitch} pitch radius and is to be taken as the greater of
$z - \left(\frac{D}{4} + \frac{T_{LC}}{2} \right)$ or $z - \left(\frac{D}{2} \right)$, in m

g acceleration due to gravity, 9.81m/s²

a_0 common acceleration parameter, as defined in *3.3.2.1*

T_{LC} draught in the loading condition being considered, in m

D moulded depth, in m, as defined in *Section 4/1.1.4.1*

L rule length, in m, as defined in *Section 4/1.1.1.1*

z vertical coordinate, in m

f_{prob} as defined in *3.3.5.2* and *3.3.5.3* as appropriate

f_V as defined in *3.3.5.2* and *3.3.5.3* as appropriate

3.3.5.2 For scantling requirements and strength assessment:

f_{prob} is to be taken as 1.0

f_V is to be taken as 1.0

3.3.5.3 For fatigue strength:

f_{prob} is to be taken as 0.5

f_V is to be taken as 1.7

3.4 Dynamic Hull Girder Loads

3.4.1 Vertical wave bending moment

3.4.1.1 The envelope hogging and sagging vertical wave bending moments, $M_{wv\text{-}hog}$ and $M_{wv\text{-}sag}$, are to be taken as:

$$\begin{aligned} M_{wv-hog} &= f_{prob}\,0.19 f_{wv-v} C_{wv} L^2 B C_b \\ M_{wv-sag} &= -f_{prob}\,0.11 f_{wv-v} C_{wv} L^2 B (C_b + 0.7) \end{aligned} \quad \text{kNm}$$

Where:

$f_{wv\text{-}v}$ distribution factor for vertical wave bending moment along the vessel length, see *3.4.1.2* or *3.4.1.3* as appropriate

C_{wv} wave coefficient to be taken as:

$= 10.75 - \left(\dfrac{300 - L}{100}\right)^{\frac{3}{2}}$ for $150 \le L \le 300$

$= 10.75$ for $300 < L \le 350$

$= 10.75 - \left(\dfrac{L - 350}{150}\right)^{\frac{3}{2}}$ for $350 < L \le 500$

L rule length, in m, as defined in *Section 4/1.1.1.1*

B moulded breadth, in m, as defined in *Section 4/1.1.3.1*

C_b block coefficient, as defined in *Section 4/1.1.9.1*

3.4.1.2 For scantling requirements and strength assessment:

$f_{wv\text{-}v}$ distribution factor for vertical wave bending moment along the vessel length, is to be taken as:

0.0 at A.P.

1.0 for $0.4L$ to $0.65L$ from A.P.

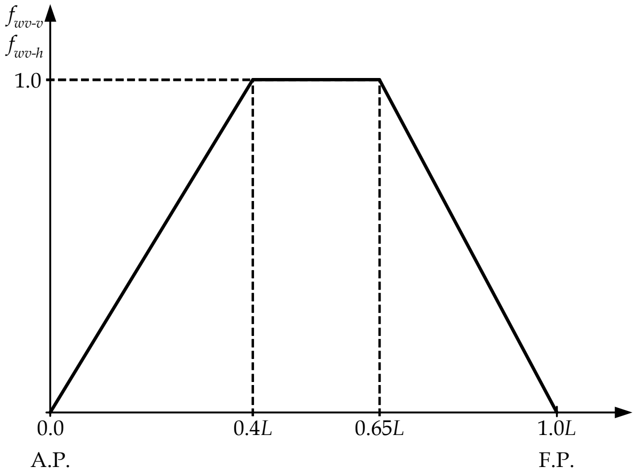
0.0 at F.P.

intermediate values to be obtained by linear interpolation, see *Figure 7.3.1*

f_{prob} is to be taken as 1.0

L rule length, in m, as defined in *Section 4/1.1.1.1*

Figure 7.3.1
Vertical and Horizontal Wave Bending Moment Distribution for Scantling Requirements and Strength Assessment



3.4.1.3 For fatigue strength:

f_{wv-v} distribution factor for vertical wave bending moment along the vessel length, is to be taken as:

0.0 at A.P.

0.1 at 0.1*L* from A.P.

1.0 for 0.4*L* to 0.65*L* from A.P.

0.1 at 0.9*L* from A.P.

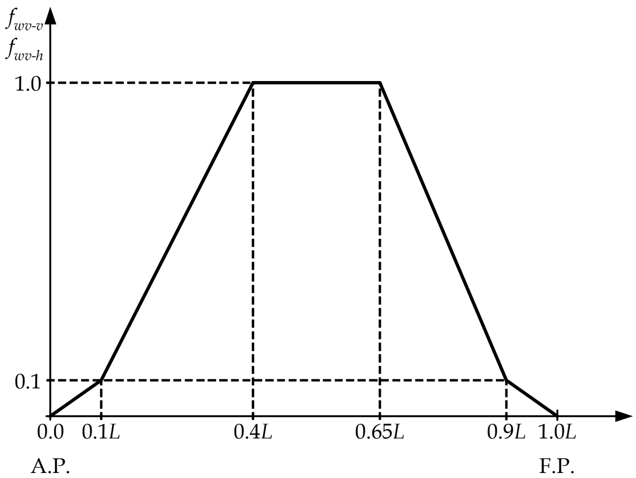
0.0 at F.P.

intermediate values to be obtained by linear interpolation, see *Figure 7.3.2*

f_{prob} is to be taken as 0.5

L rule length, in m, as defined in *Section 4/1.1.1.1*

Figure 7.3.2
Vertical and Horizontal Wave Bending Moment Distribution for Fatigue Strength



3.4.2 Horizontal wave bending moment

3.4.2.1 The envelope horizontal wave bending moment, M_{wv-h}, is to be taken as:

$$M_{wv-h} = f_{prob}(0.3 + \frac{L}{2000})f_{wv-h} C_{wv} L^2 T_{LC} C_b \quad \text{kNm}$$

Where:

f_{wv-h} distribution factor for wave horizontal bending moment along the vessel length, see *3.4.2.2* or *3.4.2.3* as appropriate

C_{wv} wave coefficient, as defined in *3.4.1.1*

L rule length, in m, as defined in *Section 4/1.1.1.1*

T_{LC} draught in the loading condition being considered, in m

C_b block coefficient, as defined in *Section 4/1.1.9.1*

3.4.2.2 For scantling requirements and strength assessment:

f_{wv-h} distribution factor for wave horizontal bending moment along the vessel length, is to be taken as:

0.0 at A.P.

1.0 for 0.4L to 0.65L from A.P.

0.0 at F.P.

intermediate values to be obtained by linear interpolation, see *Figure 7.3.1*

f_{prob} is to be taken as 1.0

L rule length, in m, as defined in *Section 4/1.1.1.1*

3.4.2.3 For fatigue strength:

f_{wv-h} distribution factor for wave horizontal bending moment along the vessel length, is to be taken as:

0.0 at A.P.

0.1 at 0.1L from A.P.

1.0 for 0.4L to 0.65L from A.P.

0.1 at 0.9L from A.P.

0.0 at F.P.

intermediate values to be obtained by linear interpolation, see *Figure 7.3.2*

f_{prob} is to be taken as 0.5

L rule length, in m, as defined in *Section 4/1.1.1.1*

3.4.3 Vertical wave shear force

3.4.3.1 The envelope positive and negative vertical wave shear forces, Q_{wv-pos} and Q_{wv-neg}, are to be taken as:

$$\begin{aligned} Q_{wv-pos} &= 0.3 f_{qwv-pos} C_{wv} LB(C_b + 0.7) \\ Q_{wv-neg} &= -0.3 f_{qwv-neg} C_{wv} LB(C_b + 0.7) \end{aligned} \quad \text{kN}$$

Where:

$f_{qwv\text{-}pos}$	distribution factor for positive vertical wave shear force along the vessel length and is to be taken as:	
	0.0	at A.P.
	$1.59\dfrac{C_b}{(C_b+0.7)}$	for 0.2L to 0.3L from A.P.
	0.7	for 0.4L to 0.6L from A.P.
	1.0	for 0.7L to 0.85L from A.P.
	0.0	at F.P.
$f_{qwv\text{-}neg}$	distribution factor for negative vertical wave shear force along the vessel length and is to be taken as:	
	0.0	at A.P.
	0.92	for 0.2L to 0.3L from A.P.
	0.7	for 0.4L to 0.6L from A.P.
	$1.73\dfrac{C_b}{(C_b+0.7)}$	for 0.7L to 0.85L from A.P.
	0.0	at F.P.
	intermediate values of $f_{qwv\text{-}pos}$ and $f_{qwv\text{-}neg}$ are to be obtained by linear interpolation, see *Figure 7.3.3* and *Figure 7.3.4* respectively.	
C_{wv}	wave coefficient, as defined in *3.4.1.1*	
L	rule length, in m, as defined in *Section 4/1.1.1.1*	
B	moulded breadth, in m, as defined in *Section 4/1.1.3.1*	
C_b	block coefficient, as defined in *Section 4/1.1.9.1*	

Figure 7.3.3
Positive Vertical Wave Shear Force Distribution

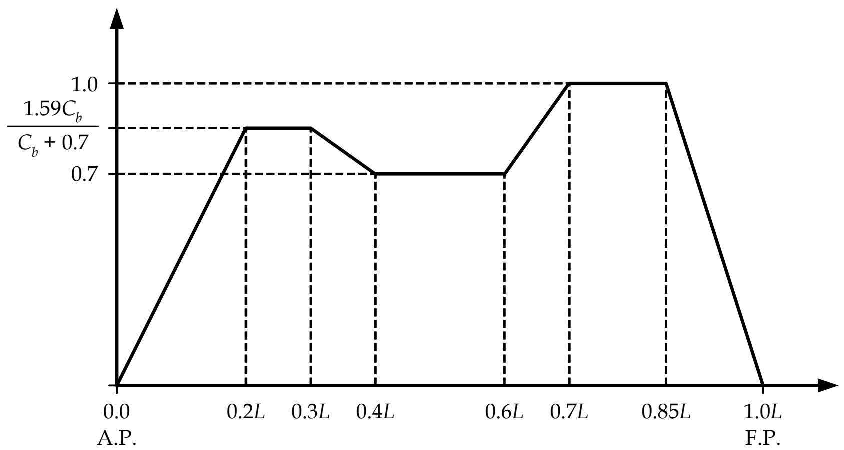
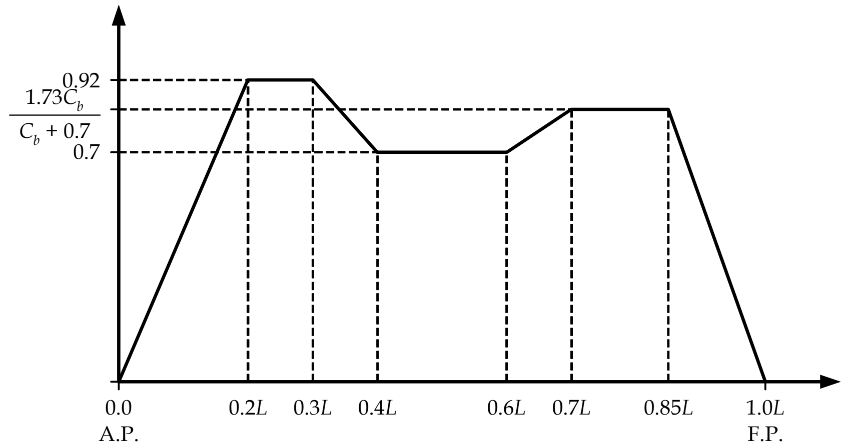


Figure 7.3.4
Negative Vertical Wave Shear Force Distribution



3.5 Dynamic Local Loads

3.5.1 General

3.5.1.1 This section provides the envelope values for dynamic wave pressure, dynamic tank pressure, green sea load and dynamic deck loads.

3.5.1.2 The envelope dynamic wave pressures are given in *3.5.2*

3.5.1.3 The envelope green sea load given in *3.5.3* only applies to scantling requirements and strength assessment. The green sea load for fatigue strength is to be taken as 0.

3.5.1.4 The envelope dynamic tank pressure is a combination of the inertial components due to vertical, transverse and longitudinal acceleration. The envelope dynamic tank pressure components are given in *3.5.4*.

3.5.1.5 The envelope dynamic deck loads are given in *3.5.5* and *3.5.6*.

3.5.2 Dynamic wave pressure

3.5.2.1 The envelope dynamic wave pressure, $P_{ex\text{-}dyn}$, is to be taken as the greater of the following:

$$P_1 = 2 f_{prob} f_{nl-P1}\left[\left(P_{11} + \frac{135B_{local}}{4(B+75)} - 1.2(T_{LC} - z)\right)f_1 + \frac{135B_{local}}{4(B+75)} f_2\right] \quad \text{kN/m}^2$$

$$P_2 = 26 f_{prob} f_{nl-P2}\left[\begin{aligned}&\left(\frac{B_{local}}{8}\theta + f_T C_b \frac{0.25B_{local} + 0.8C_{wv}}{14}\left(0.7 + \frac{2z}{T_{LC}}\right)\right)f_1 \\ &+\left(\frac{B_{local}}{8}\theta + f_T C_b \frac{0.25B_{local}}{14}\left(0.7 + \frac{2z}{T_{LC}}\right)\right)f_2\end{aligned}\right] \quad \text{kN/m}^2$$

Where:

B_{local} local breadth at the waterline, for considered draught, not to be taken less than 0.5B, in m

θ roll angle, in rads, as defined in *3.2.2.2*

P_{11} = $(3f_s + 0.8)C_{wv}$

C_{wv} wave coefficient, as defined in *3.4.1.1*

L rule length, in m, as defined in *Section 4/1.1.1.1*

B moulded breadth, in m, as defined in *Section 4/1.1.3.1*

T_{LC} draught in the loading condition being considered, in m

T_{sc} scantling draught, in m, as defined in *Section 4/1.1.5.5*

C_b block coefficient, as defined in *Section 4/1.1.9.1*

f_1 $= f_{lng} - \frac{f_{lng}}{f_V} f_2 + f_2$

f_2 $= 0.25 f_V \left(\frac{4|y|}{B_{local}} - 1 \right)$ for $|y| < 0.25 B_{local}$

$= f_V \left(\frac{4|y|}{B_{local}} - 1 \right)$ for $|y| \geq 0.25 B_{local}$

f_T $= \frac{T_{LC}}{T_{sc}}$

f_s $= C_b + \frac{1.33}{\sqrt{C_b}}$ at, and aft of A.P.

$= C_b$ between 0.2L and 0.7L from A.P.

$= C_b + \frac{1.33}{C_b}$ at, and forward of F.P.

intermediate values to be obtained by linear interpolation

f_{lng} = 1.0 at, and aft of A.P.

= 0.7 for 0.2L to 0.7L from A.P.

= 1.0 at, and forward of F.P.

intermediate values to be obtained by linear interpolation

y transverse coordinate, in m

z vertical coordinate, in m

$f_{nl\text{-}P1}$, $f_{nl\text{-}P2}$, f_{prob}, and f_V are given in *3.5.2.2* for scantling requirements and strength assessment application and in *3.5.2.3* for fatigue strength.

3.5.2.2 For scantling requirements and strength assessment, the envelope maximum dynamic wave pressure, $P_{ex\text{-}max}$, see *Figure 7.3.5,* and minimum dynamic wave pressure, $P_{ex\text{-}min}$, see *Figure 7.3.6*, are to be taken as:

$P_{ex\text{-}max}$ $= P_{ex\text{-}dyn}$ kN/m² below still waterline

$= P_{WL} - 10(z - T_{LC})$ kN/m² for $T_{LC} < z \leq T_{LC} + \frac{P_{WL}}{10}$

$= 0$ kN/m² for $z > T_{LC} + \frac{P_{WL}}{10}$

$P_{ex\text{-}min}$ $= - P_{ex\text{-}dyn}$ kN/m² below still waterline

$= 0$ kN/m² above still waterline

$P_{ex\text{-}min}$ is not to be taken as less than $-\rho_{sw} g (T_{LC} - z)$

Where:

$P_{ex\text{-}dyn}$ envelope dynamic wave pressure, in kN/m², as defined in *3.5.2.1* with:

f_{prob} = 1.0

$f_{nl\text{-}P1}$ = 0.9

$f_{nl\text{-}P2}$ = 0.65

f_V = 1.0

P_{WL} pressure at waterline, to be taken as $P_{ex\text{-}dyn}$ at still waterline, in kN/m²

T_{LC} draught in the loading condition being considered, in m

ρ_{sw} density of sea water, 1.025 tonnes/m³

z vertical coordinate, in m

Figure 7.3.5
Transverse Distribution of Maximum Dynamic Wave Pressure for Scantling Requirements and Strength Assessment

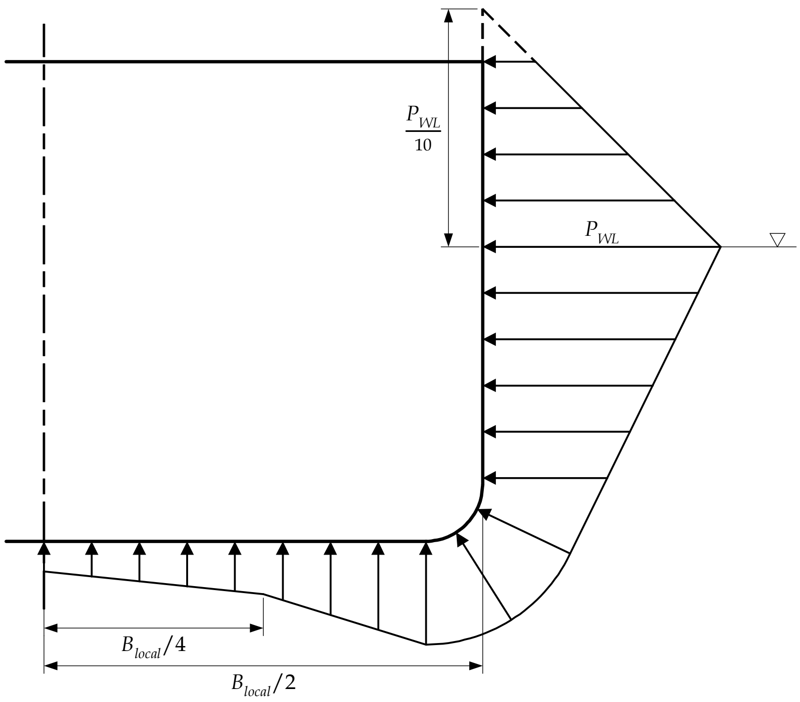
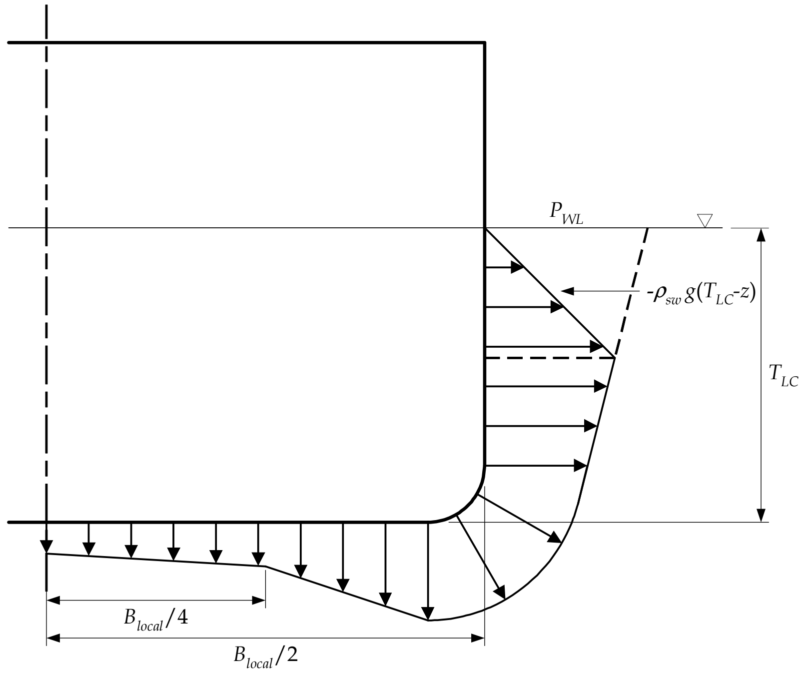


Figure 7.3.6
Transverse Distribution of Minimum Dynamic Wave Pressure for Scantling Requirements and Strength Assessment



3.5.2.3 The dynamic wave pressure pseudo-amplitude (half range), $P_{ex\text{-}amp}$, for fatigue strength, see *Figure 7.3.7,* is to be taken as:

$P_{ex\text{-}amp}$ = 0 kN/m^2		for $z \geq T_{LC} + h_{WL}$ or D, whichever is the lesser
	= 0.5 P_{WL} kN/m^2	at still waterline
	= $P_{ex\text{-}dyn}$ kN/m^2	for $z \leq T_{LC} - h_{WL}$ or 0, whichever is the greater

Intermediate values between the still waterline and $z = T_{LC} - h_{WL}$ to be obtained by linear interpolation

Where:

h_{WL} dynamic wave pressure head at the still waterline, is to be taken as:

$= P_{WL}/10$ m

P_{WL} pressure at waterline, and is to be taken as $P_{ex\text{-}max}$ at still waterline, in kN/m^2

$P_{ex\text{-}max}$ envelope maximum dynamic wave pressure is to be taken as the greater of P_1 and P_2, in kN/m^2

T_{LC} draught in the loading condition being considered, in m

D moulded depth, in m, as defined in *Section 4/1.1.4.1*

P_1 as defined in *3.5.2.* , in kN/m^2, with:

f_{prob} = 0.5

$f_{nl\text{-}P1}$ = 1.0

$$f_V = \begin{cases} 1.0 & \text{at, and aft of } 0.7L \\ 1.5 & \text{at, and forward of F.P.} \end{cases}$$

intermediate values of f_V to be obtained by linear interpolation

P_2 as defined in *3.5.2.1*, in kN/m², with:

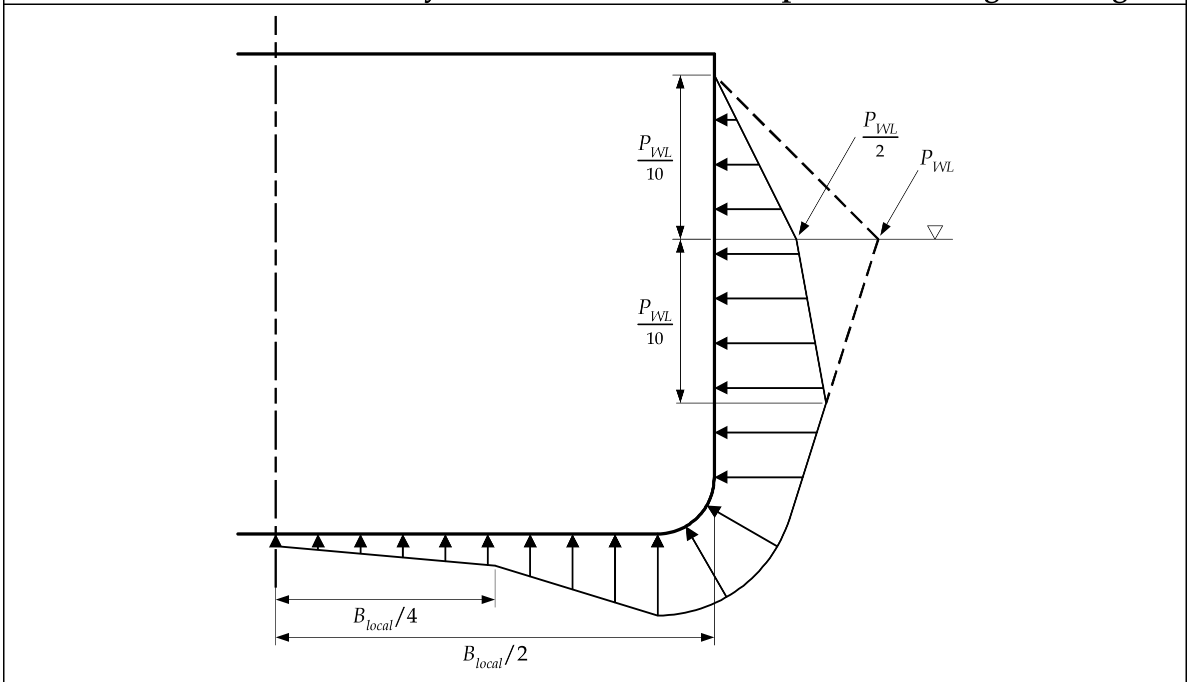
$f_{prob} = 0.5$

$f_{nl\text{-}P2} = 1.0$

$f_V = 1.0$

z vertical coordinate, in m

Figure 7.3.7
Transverse Distribution of Dynamic Wave Pressure Amplitude for Fatigue Strength



3.5.3 Green sea load

3.5.3.1 The envelope green sea load on the weather deck, P_{wdk}, is to be taken as the greater of the following:

$P_{wdk} = f_{1-dk}\left(f_{op} P_{1-WL} - 10 z_{dk-T}\right)$ kN/m²

$P_{wdk} = 0.8 f_{2-dk}\left(P_{2-WL} - 10 z_{dk-T}\right)$ kN/m²

$P_{wdk} = 34.3$ kN/m²

Where:

$f_{1-dk} = 0.8 + \dfrac{L}{750}$

$f_{2-dk} = 0.5 + \dfrac{|y|}{B_{wdk}}$

f_{op} = 1.0 at and forward of 0.2L from A.P.

= 0.8 at and aft of A.P.

intermediate values to be obtained by linear interpolation

$P_{1\text{-}WL}$	P_1 pressure at still waterline for considered draught, in kN/m², see *3.5.2.1*
$P_{2\text{-}WL}$	P_2 pressure at still waterline for considered draught, in kN/m², see *3.5.2.1*
$z_{dk\text{-}T}$	distance from the deck to the still waterline at the applicable draught for the loading condition being considered, in m
B_{wdk}	local breadth at the weather deck, in m
L	rule length, in m, as defined in *Section 4/1.1.1.1*
y	transverse coordinate of load point, in m

3.5.4 Dynamic tank pressure

3.5.4.1 The envelope dynamic tank pressure, $P_{in\text{-}v}$, due to vertical tank acceleration is to be taken as:

$P_{in-v} = \rho a_v (z_0 - z)$ kN/m² for strength assessment and scantling requirements

$P_{in-v} = \rho a_v |z_0 - z|$ kN/m² for fatigue strength

Where:

ρ	density of liquid in the tank, in tonnes/m³, and is not to be taken as less than: 0.9 for cargo tanks for fatigue strength 1.025 otherwise, see *Section 2/3.1.8*
a_v	envelope vertical acceleration, in m/s², as defined in *3.3.3.1,* and is to be taken at tank centre of gravity
z	vertical coordinate of load point, in m
z_0	vertical coordinate of reference point, see *6.3.7* for scantling requirements and strength assessment, and *3.5.4.5* for fatigue strength, in m

3.5.4.2 The envelope dynamic tank pressure, $P_{in\text{-}t}$, due to transverse acceleration is to be taken as:

$P_{in-t} = f_{ull-t} \rho a_t (y_0 - y)$ kN/m² for strength assessment and scantling requirements

$P_{in-t} = \rho a_t |y_0 - y|$ kN/m² for fatigue strength

Where:

ρ	density of liquid in the tank, in tonnes/m³, and is not to be taken as less than: 0.9 for cargo tanks for fatigue strength 1.025 otherwise, see *Section 2/3.1.8*

f_{ull-t} factor to account for ullage in cargo tanks, and is to be taken as:

0.67 for cargo tanks, including cargo tanks designed for filling with water ballast

1.0 for ballast and other tanks

a_t envelope transverse acceleration, in m/s^2, as defined in *3.3.4.1*, and is to be taken at tank centre of gravity

y transverse coordinate of load point, in m

y_0 transverse coordinate of reference point, see *6.3.7* for scantling requirements and strength assessment, and *3.5.4.5* for fatigue strength, in m

3.5.4.3 The envelope dynamic tank pressure, P_{in-lng}, due to longitudinal acceleration is to be taken as:

$P_{in-lng} = f_{ull-lng} \rho a_{lng} (x_0 - x)$ kN/m^2 for strength assessment and scantling requirements

$P_{in-lng} = \rho a_{lng} |x_0 - x|$ kN/m^2 for fatigue strength

Where:

ρ density of tank liquid, in tonnes/m^3, and is not to be taken as less than:

0.9 for cargo tanks for fatigue strength

1.025 otherwise, see *Section 2/3.1.8*

$f_{ull-lng}$ factor to account for ullage in cargo tanks, and is to be taken as:

0.62 for cargo tanks, including cargo tanks designed for filling with water ballast

1.0 for ballast and other tanks

a_{lng} envelope longitudinal acceleration, in m/s^2, as defined in *3.3.5.1,* and is to be taken at tank centre of gravity

x longitudinal coordinate of load point, in m

x_0 longitudinal coordinate of reference point, see *6.3.7* for scantling requirements and strength assessment, and *3.5.4.5* for fatigue strength, in m

3.5.4.4 For scantling requirements and strength assessment the simultaneous acting dynamic tank pressure, P_{in-dyn}, is to be taken as the summation of the components for the considered dynamic load case, see *6.3.7.*

3.5.4.5 For fatigue strength the dynamic tank pressure amplitude, P_{in-amp}, on a tank boundary with adjacent tank empty, is to be taken as:

$$P_{in-amp} = f_v P_{in-v} + f_{ull-t} f_t P_{in-t} + f_{ull-lng} f_{lng} P_{in-lng} \quad \text{kN/m}^2$$

Where:

P_{in-v} envelope dynamic tank pressure due to vertical acceleration, in kN/m^2, as defined in *3.5.4.1*

P_{in-t} envelope dynamic tank pressure due to transverse acceleration, in kN/m^2, as defined in *3.5.4.2*

$P_{in\text{-}lng}$ envelope dynamic tank pressure due to longitudinal acceleration, in kN/m², as defined in *3.5.4.3*

$f_{ull\text{-}t}$ factor to account for ullage in cargo tanks, not to be taken less than 0.0 nor greater than 1.0

$= \dfrac{|z_0 - z| + h_{roll}}{2h_{roll}}$ for cargo tanks

= 1.0 for ballast tanks

$f_{ull\text{-}lng}$ factor to account for ullage in cargo tanks, not to be taken less than 0.0 nor greater than 1.0

$= \dfrac{|z_0 - z| + h_{pitch}}{2h_{pitch}}$ for cargo tanks

= 1.0 for ballast tanks

h_{roll} roll height $= \dfrac{b_{fs} f_{prob} \theta}{2}$

h_{pitch} pitch height $= \dfrac{l_{fs} f_{prob} \varphi}{2}$

f_{prob} is to be taken as 0.5

θ roll angle, in rads, as defined in 3.2.2.2

φ pitch angle, in secs, as defined in *3.2.3.2*

b_{fs} tank breadth at the top of the tank, see *Figure 7.3.8*, in m

l_{fs} tank length at the top of the tank, in m

x_0 longitudinal coordinate of reference point, and is to be taken as the middle of tank length at the top of the tank, in m

y_0 transverse coordinate of reference point, and is to be taken as the middle of tank breadth at the top of the tank, see *Figure 7.3.8*, in m

z_0 vertical coordinate of reference point, and is to be taken as the highest point of the tank, excluding small hatchways, see *Figure 7.3.8*, in m

f_v pressure combination factor, as given in *Table 7.3.2*

f_t pressure combination factor, as given in *Table 7.3.2*

f_{lng} pressure combination factor, as given in *Table 7.3.2*

3.5.4.6 For fatigue strength the dynamic tank pressure amplitude, $P_{in\text{-}amp}$, on a longitudinal tank boundary with adjacent tank full, is to be taken as:

$$P_{in-amp} = f_v |P_{in-v-tk1} - P_{in-v-tk2}| + f_t |f_{ull-t-tk1} P_{in-t-tk1} + f_{ull-t-tk2} P_{in-t-tk2}| + f_{lng} |f_{ull-lng-tk1} P_{in-lng-tk1} - f_{ull-lng-tk2} P_{in-lng-tk2}| \quad \text{kN/m}^2$$

Where:

$P_{in\text{-}v\text{-}tk1}$ dynamic tank pressure due to vertical acceleration in tank 1, in kN/m²

$P_{in\text{-}v\text{-}tk2}$ dynamic tank pressure due to vertical acceleration in tank 2, in kN/m²

$P_{in-t-tk1}$ dynamic tank pressure due to transverse acceleration in tank 1, in kN/m²

$P_{in-t-tk2}$ dynamic tank pressure due to transverse acceleration in tank 2, in kN/m²

$P_{in-lng-tk1}$ dynamic tank pressure due to longitudinal acceleration in tank 1, in kN/m²

$P_{in-lng-tk2}$ dynamic tank pressure due to longitudinal acceleration in tank 2, in kN/m²

$f_{ull-t-tk1}$ factor to account for ullage for tank 1, as defined in *3.5.4.5*

$f_{ull-t-tk2}$ factor to account for ullage for tank 2, as defined in *3.5.4.5*

$f_{ull-lng-tk1}$ factor to account for ullage for tank 1, as defined in *3.5.4.5*

$f_{ull-lng-tk2}$ factor to account for ullage for tank 2, as defined in *3.5.4.5*

f_v pressure combination factor, as given in *Table 7.3.2*

f_t pressure combination factor, as given in *Table 7.3.2*

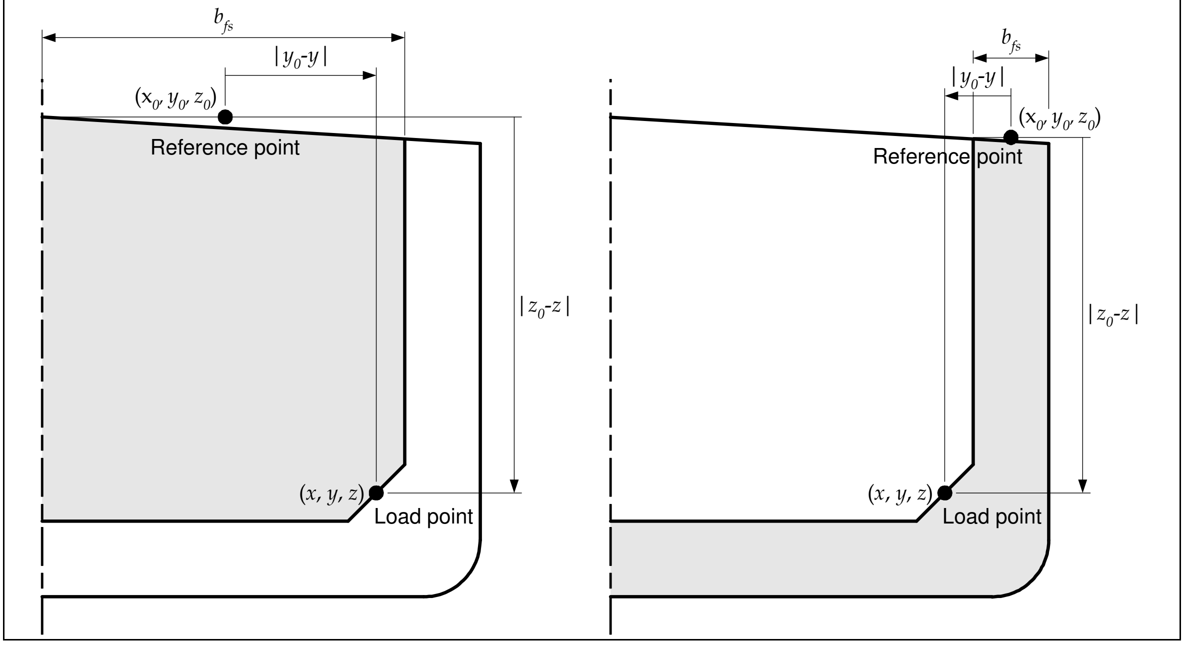
f_{lng} pressure combination factor, as given in *Table 7.3.2*

Tank 1 and 2 are adjacent tanks with common longitudinal boundary

Table 7.3.2
Pressure Combination Factors for Fatigue Assessment

	Cargo tanks	Ballast tanks
f_v	0.9	0.9
f_t	0.9	0.6
f_{lng}	0.4	0.4

Figure 7.3.8
Dynamic Tank Pressure Load and Reference Points for Fatigue Strength



3.5.4.7 For fatigue strength by hot spot stress (FE) approach, the dynamic tank pressure amplitudes due to vertical, transverse and longitudinal accelerations, illustrated in *Figure 7.3.9* are to be taken as:

$$P_{in-v} = \rho a_v (z_0 - z) \quad \text{in kN/m}^2$$

$$P_{in-t} = f_{ull-t} \rho a_t (y_0 - y) \quad \text{in kN/m}^2$$

$$P_{in-lng} = f_{ull-lng} \rho a_{lng} (x_0 - x) \quad \text{in kN/m}^2$$

Where:

ρ density of liquid in the tank, in tonnes/m^3, and is not to be taken as less than:

0.9 for cargo tanks

1.025 otherwise,

see *Section 2/3.1.8*

f_{ull-t} factor to account for ullage in cargo tanks, as defined in *3.5.4.5*

$f_{ull-lng}$ factor to account for ullage in cargo tanks, as defined in *3.5.4.5*

x longitudinal coordinate of load point, in m

y transverse coordinate of load point, in m

z vertical coordinate of load point, in m

x_0 longitudinal coordinate of reference point, and is to be taken as the middle of the tank length at the top of the tank, in m

y_0 transverse coordinate of reference point, and is to be taken as the middle of the tank breadth at the top of the tank, in m

z_0 vertical coordinate of reference point, and is to be taken as the highest point in the tank, in m

a_v envelope vertical acceleration, in m/s^2, as defined in *3.3.3.1*, at tank centre of gravity

a_t envelope transverse acceleration, in m/s^2, as defined in *3.3.4.1*, at tank centre of gravity

a_{lng} envelope longitudinal acceleration, in m/s^2, as defined in *3.3.5.1*, at tank centre of gravity

Figure 7.3.9 (a)
Dynamic Tank Pressure due to Vertical Acceleration for Fatigue Strength

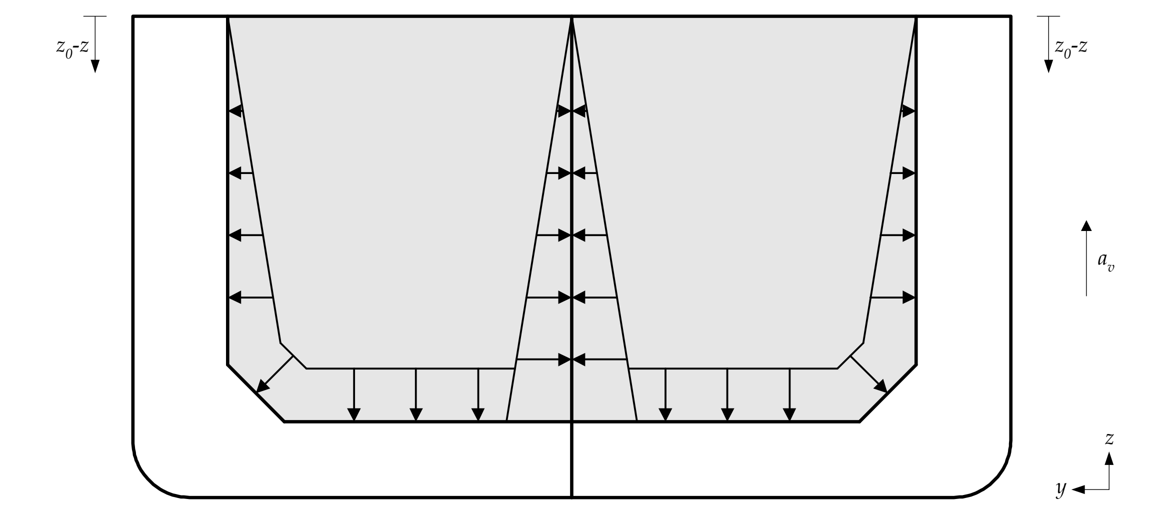


Figure 7.3.9 (b)
Dynamic Tank Pressure due to Transverse Acceleration for Fatigue Strength

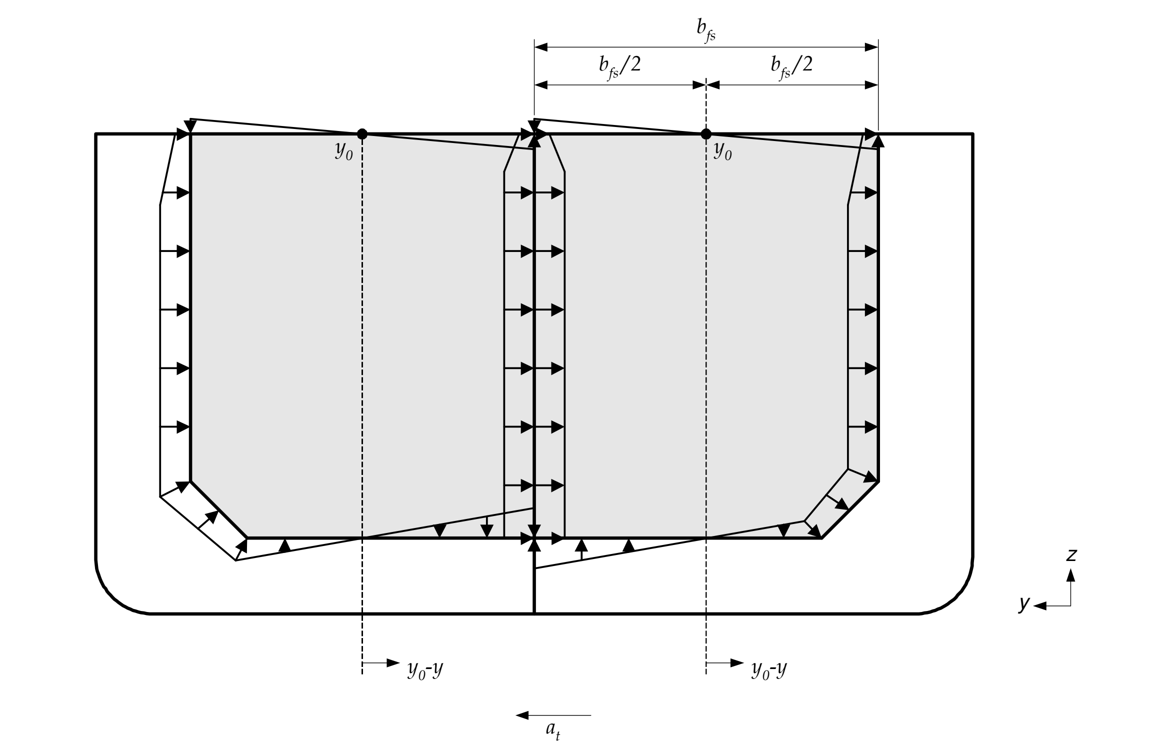
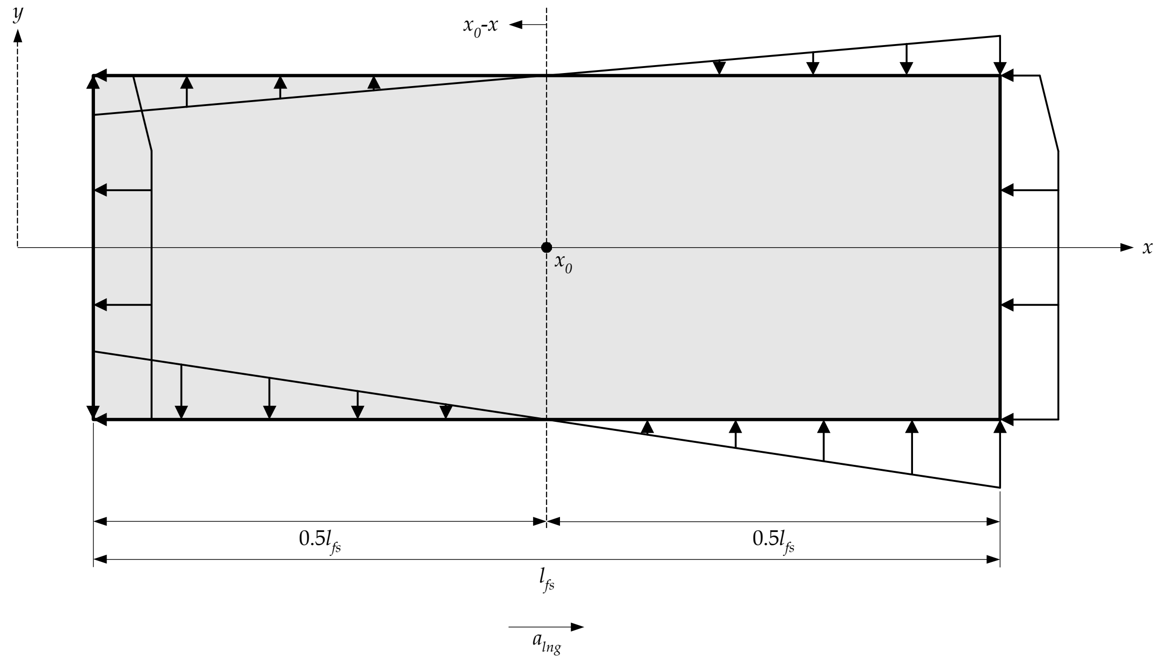


Figure 7.3.9 (c)
Dynamic Tank Pressure due to Longitudinal Acceleration for Fatigue Strength Illustrated for a Cargo Tank



3.5.5 Dynamic deck pressure from distributed loading

3.5.5.1 The envelope dynamic deck pressure, $P_{deck-dyn}$, on decks, inner bottom and hatch covers is to be taken as:

$$P_{deck-dyn} = P_{deck}\frac{a_v}{g} \quad \text{kN/m}^2$$

Where:

a_v envelope vertical acceleration, in m/s², as defined in *3.3.3.1*

P_{deck} uniformly distributed pressure on lower decks and decks within superstructure, in kN/m², as defined in *2.2.4.1*

g acceleration due to gravity, 9.81 m/s²

3.5.6 Dynamic loads from heavy units

3.5.6.1 The envelope dynamic deck loads, F_v, F_t, F_{lng} acting vertically, transversely and longitudinally on supporting structures and securing systems for heavy units of cargo, equipment or structural components are to be taken as:

$$F_v = m_{un} a_v \quad \text{kN}$$

$$F_t = m_{un} a_t \quad \text{kN}$$

$$F_{lng} = m_{un} a_{lng} \quad \text{kN}$$

Where:

m_{un} mass of unit, in tonnes

a_v envelope vertical acceleration, in m/s², as defined in *3.3.3.1*, at centre of gravity of considered unit

a_t envelope transverse acceleration, in m/s², as defined in *3.3.4.1*,

at centre of gravity of considered unit

a_{lng} envelope longitudinal acceleration, in m/s^2, as defined in *3.3.5.1,* at centre of gravity of considered unit

4 SLOSHING AND IMPACT LOADS

4.1 General

4.1.1 Load Components

4.1.1.1 Sloshing pressures in tanks, and bow impact and bottom slamming pressures are given in this sub-section.

4.2 Sloshing Pressure in Tanks

4.2.1 Application and limitations

4.2.1.1 The sloshing pressures given in *4.2.2* to *4.2.4* are pressures induced by free movement of the tank liquids as a result of ship motions.

4.2.1.2 The given pressures do not include the effect of impact pressures due to high velocity impacts with tank boundaries or internal structures. For tanks with a maximum effective sloshing breadth, b_{slh}, greater than 0.56B or a maximum effective sloshing length, l_{slh}, greater than 0.13L at any filling height from 0.05h_{max} to 0.95h_{max}, an additional impact assessment is to be carried out in accordance with the individual Classification Society procedures. The effective sloshing lengths and breadths, l_{slh} and b_{slh}, are calculated using the equations in *4.2.2.1* and *4.2.3.1* respectively.

4.2.2 Sloshing pressure due to longitudinal liquid motion

4.2.2.1 The sloshing pressure in way of transverse tight and wash bulkheads due to longitudinal liquid motion, $P_{slh-lng}$, for a particular filling height, is to be taken as:

$$P_{slh-lng} = \rho g l_{slh} f_{slh}\left[0.4 - \left(0.39 - \frac{1.7 l_{slh}}{L}\right)\frac{L}{350}\right] \quad \text{kN/m}^2$$

Where:

ρ density of liquid in the tank, in tonnes/m^3, and is not to be taken as less than 1.025

l_{slh} effective sloshing length, at considered filling height as given in *4.2.2.3* and *4.2.2.4* for transverse tight bulkheads and transverse wash bulkheads respectively, in m

f_{slh} $= 1 - 2\left(0.7 - \frac{h_{fill}}{h_{max}}\right)^2$

L rule length, in m, as defined in *Section 4/1.1.1.1*

h_{fill} filling height, measured from inner bottom, in m, see *Figure 7.4.1*

h_{max} maximum tank height excluding small hatchways, measured from inner bottom, in m, see *Figure 7.4.1*

g acceleration due to gravity, 9.81 m/s^2

4.2.2.2 The sloshing pressure due to longitudinal liquid motion, $P_{slh-lng}$, is to be taken as a constant value over the full tank depth and is to be taken as the greater of the sloshing pressures calculated for filling heights from 0.05h_{max} to 0.95h_{max}, in 0.05h_{max} increments.

4.2.2.3 For calculation of sloshing pressures in way of transverse tight bulkheads, the effective sloshing length, l_{slh}, is to be taken as:

$$l_{slh} = \frac{(1 + n_{wash-t}\alpha_{wash-t})(1 + f_{wf}\alpha_{wf})l_{tk-h}}{(1 + n_{wash-t})(1 + f_{wf})} \quad \text{m}$$

Where:

n_{wash-t} number of transverse wash bulkheads in the tank

α_{wash-t} transverse wash bulkhead coefficient,

$$= \frac{A_{opn\text{-}wash\text{-}t}}{A_{tk\text{-}t\text{-}h}}$$

see *Figure 7.4.1*

α_{wf} transverse web frame coefficient,

$$= \frac{A_{opn\text{-}wf\text{-}h}}{A_{tk\text{-}t\text{-}h}}$$

see *Figure 7.4.2*

for tanks with changing shape along the length and/or with web frames of different shape the transverse web frame coefficient, α_{wf}, may be taken as the weighted average of all web frame locations in the tank given as

$$= \frac{\sum_{i=1}^{n} \frac{A_{opn\text{-}wf\text{-}h-i}}{A_{tk\text{-}t\text{-}h-i}}}{n_{wf}}$$

$A_{opn\text{-}wash\text{-}t}$ total area of openings in the transverse section in way of the wash bulkhead below the considered filling height, in m^2

$A_{tk\text{-}t\text{-}h}$ total transverse cross sectional area of the tank below the considered filling height, in m^2

$A_{opn\text{-}wf\text{-}h}$ the total area of openings in the transverse section in way of the web frame below the considered filling height, in m^2

f_{wf} factor to account for number of transverse web frames and transverse wash bulkheads in the tank:

$= n_{wf}/(1 + n_{wash-t})$

n_{wf} number of transverse web frames, excluding wash bulkheads, in the tank

l_{tk-h} length of cargo tank, at considered filling height, in m

Figure 7.4.1
Transverse Wash Bulkhead Coefficient

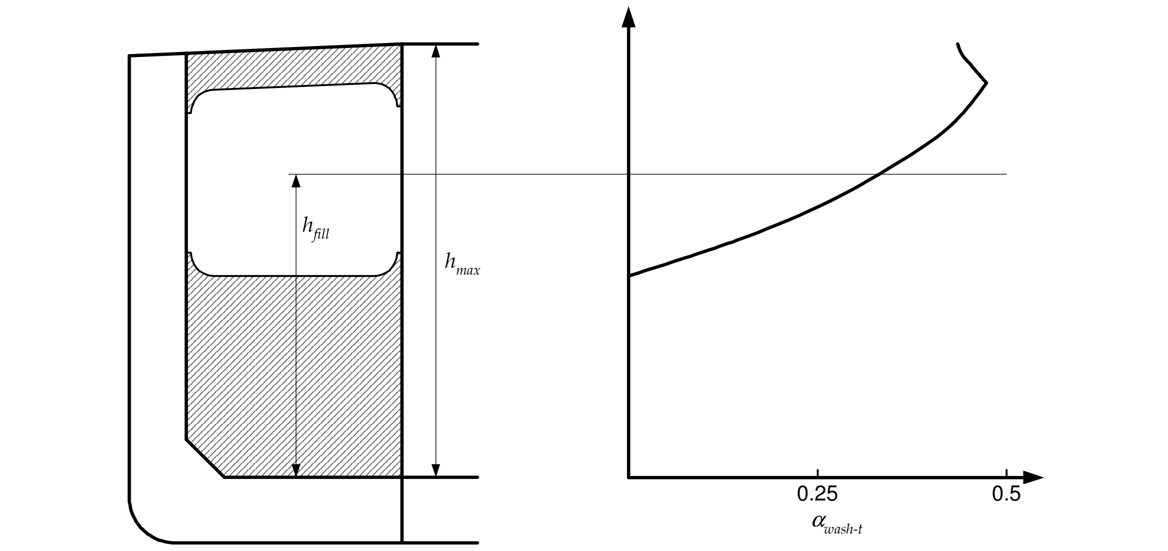
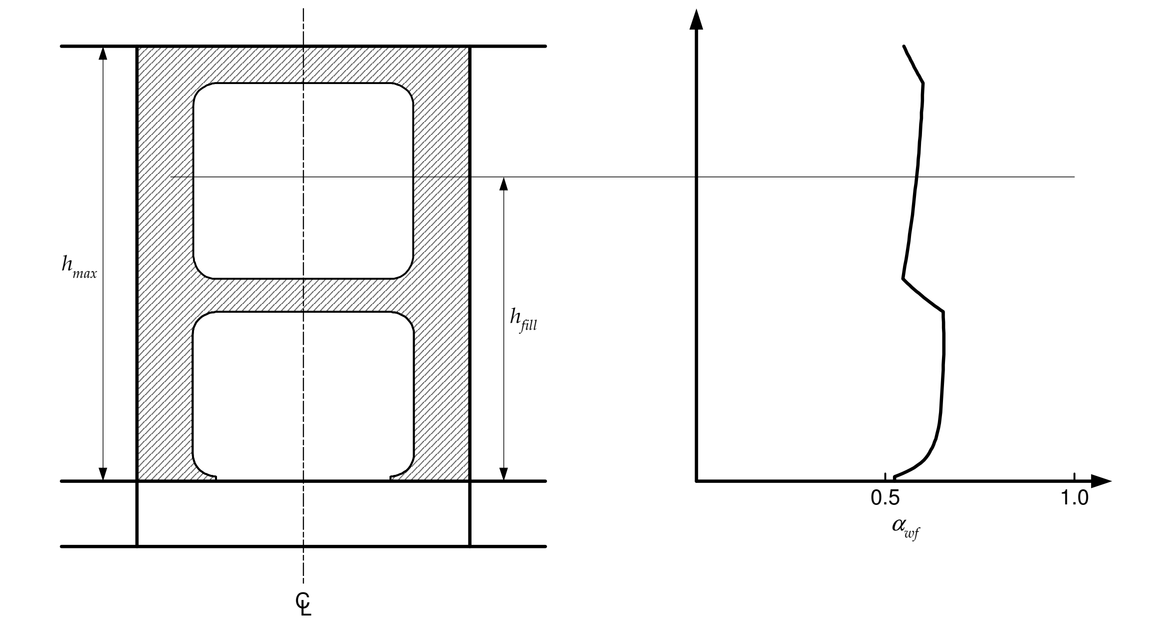


Figure 7.4.2
Transverse Web Frame Coefficient



4.2.2.4 For calculation of sloshing pressures in way of transverse wash bulkheads, the effective sloshing length, l_{slh}, is to be taken as:

$$l_{slh} = \frac{[1+(n_{wash-t}-1)\alpha_{wash-t}](1+f_{wf}\alpha_{wf})l_{tk-h}}{(1+n_{wash-t})(1+f_{wf})} \quad \text{m}$$

Where:

n_{wash-t} number of transverse wash bulkheads in the tank

α_{wash-t} transverse wash bulkhead coefficient,

$$= \frac{A_{opn-wash-t}}{A_{tk-t-h}}$$

see *Figure 7.4.1*

α_{wf} transverse web frame coefficient,

$$= \frac{A_{opn\text{-}wf\text{-}h}}{A_{tk\text{-}t\text{-}h}}$$

see *Figure 7.4.2*

for tanks with changing shape along the length and/or with web frames of different shape the transverse web frame coefficient, $\alpha_{wf,}$ may be taken as the weighted average of all web frame locations in the tank given as

$$= \frac{\sum_{i=1}^{n} \frac{A_{opn\text{-}wf\text{-}h-i}}{A_{tk\text{-}t\text{-}h-i}}}{n_{wf}}$$

$A_{opn\text{-}wash\text{-}t}$ the total area of openings in the transverse section in way of the wash bulkhead below the considered filling height, in m²

$A_{tk\text{-}t\text{-}h}$ total transverse cross sectional area of the tank below the considered filling height, in m²

$A_{opn\text{-}wf\text{-}h}$ the total area of openings in the transverse section in way of the web frame below the considered filling height, in m²

f_{wf} factor to account for number of transverse web frames and transverse wash bulkheads in the tank:

$=n_{wf}/(1 + n_{wash\text{-}t})$

n_{wf} number of transverse web frames, excluding wash bulkheads, in the tank

$l_{tk\text{-}h}$ length of cargo tank, at considered filling height, in m

4.2.2.5 For tanks with internal web frames the sloshing pressure acting on a web frame adjacent to a transverse tight or wash bulkhead, $P_{slh\text{-}wf}$, provided it is located within 0.25 l_{slh} from the bulkhead, is to be taken as:

$$P_{slh-wf} = P_{slh-lng}\left(1 - \frac{s_{wf}}{l_{slh}}\right)^2 \quad \text{kN/m}^2$$

Where:

$P_{slh\text{-}lng}$ sloshing pressure acting on bulkhead due to longitudinal liquid motion, as given in *4.2.2.1*

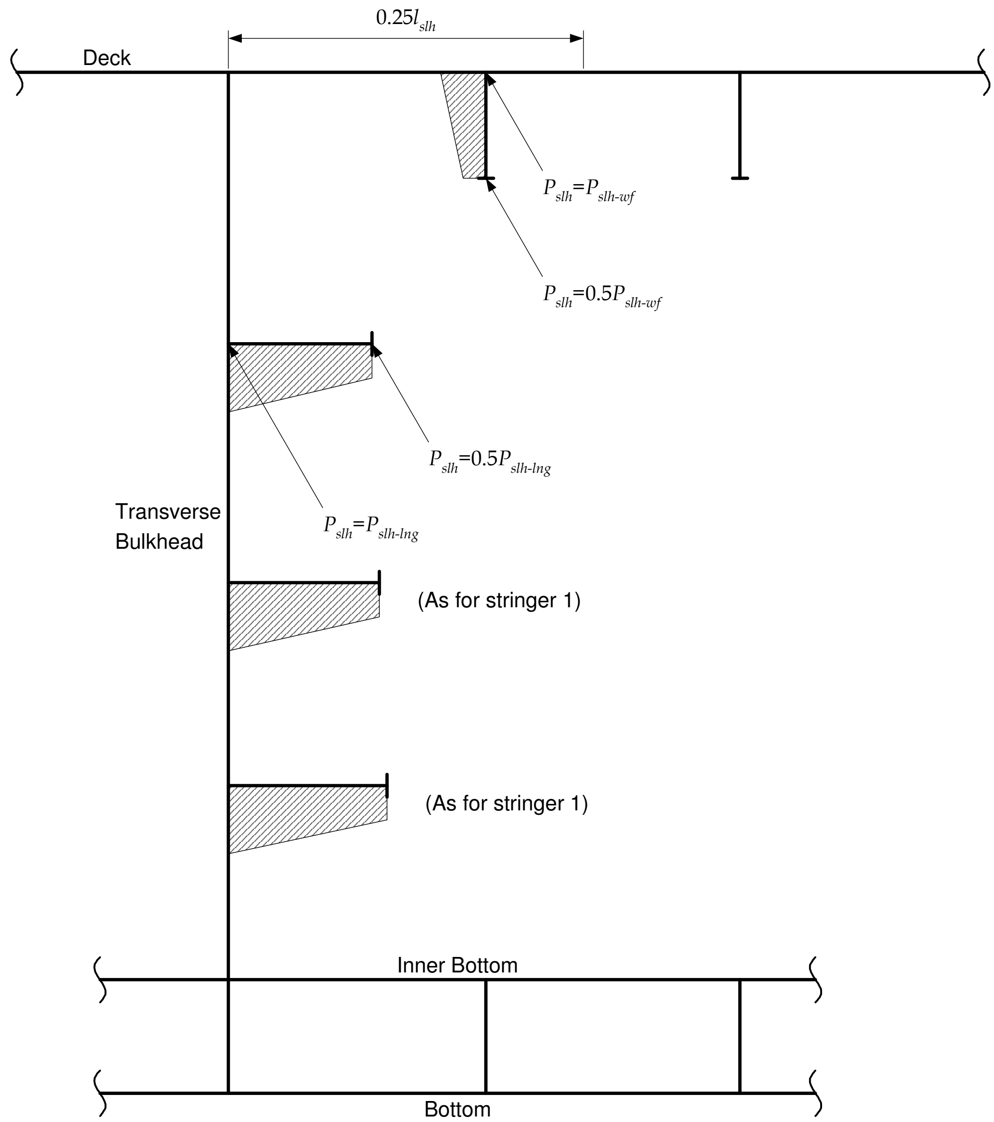
s_{wf} distance from bulkhead to web frame under consideration, in m

l_{slh} effective sloshing length, at considered filling height as defined in *4.2.2.3* and *4.2.2.4* for transverse tight and wash bulkheads respectively, in m

The distribution of pressure across the web frame is given in *Figure 7.4.3.*

4.2.2.6 For tanks with internal bulkhead stringers and/or web frames, the distribution of sloshing pressure, P_{slh}, across these members is shown in *Figure 7.4.3.*

Figure 7.4.3
Sloshing Pressure Distribution on Stringers and Web Frames



4.2.3 Sloshing pressure due to transverse liquid motion

4.2.3.1 The sloshing pressure in way of longitudinal tight and wash bulkheads due to transverse liquid motion, P_{slh-t}, for a particular filling height, is to be taken as:

$$P_{slh-t} = 7\rho g f_{slh}\left(\frac{b_{slh}}{B} - 0.3\right)GM^{0.75} \quad \text{kN/m}^2$$

Where:

ρ density of liquid in the tank, in tonnes/m^3, and is not to be taken as less than 1.025

b_{slh} effective sloshing breadth, see *4.2.3.3* and *4.2.3.4* for longitudinal tight bulkheads and longitudinal wash bulkheads respectively, not to be taken less than $0.3B$, in m.

GM metacentric height, is to be taken as $0.33B$ for calculation of sloshing pressures in ballast tanks and $0.24B$ for calculation of sloshing pressure in cargo tanks

f_{slh} $= 1 - 2\left(0.7 - \dfrac{h_{fill}}{h_{max}}\right)^2$

B moulded breadth, in m, as defined in *Section 4/1.1.3.1*

h_{fill} filling height, measured from inner bottom, in m, see *Figure 7.4.1*

h_{max} maximum tank height excluding small hatchways, measured from inner bottom, in m, see *Figure 7.4.1*

g acceleration due to gravity, 9.81m/s²

4.2.3.2 The sloshing pressure due to transverse liquid motion, P_{slh-t}, is to be taken as a constant value over the full tank depth and is to be taken as the greater of the sloshing pressures calculated for filling heights from $0.05h_{max}$ to $0.95h_{max}$, in $0.05h_{max}$ increments.

4.2.3.3 For calculation of sloshing pressures in way of longitudinal tight bulkheads the effective sloshing breadth, b_{slh}, is to be taken as:

$$b_{slh} = \frac{(1 + n_{wash-lng}\alpha_{wash-lng})(1 + f_{grd}\alpha_{grd})b_{tk-h}}{(1 + n_{wash-lng})(1 + f_{grd})} \quad \text{m}$$

Where:

$n_{wash-lng}$ number of longitudinal wash bulkheads in the tank

$\alpha_{wash-lng}$ longitudinal wash bulkhead coefficient

$= \dfrac{A_{opn-wash-lng}}{A_{tk-lng-h}}$

α_{grd} girder coefficient

$= \dfrac{A_{opn-grd-h}}{A_{tk-lng-h}}$

$A_{opn-wash-lng}$ total area of openings in the longitudinal section in way of the wash bulkhead below the considered filling height, in m²

$A_{tk-lng-h}$ total longitudinal cross sectional area of the tank below the considered filling height, in m²

$A_{opn-grd-h}$ total area of openings in the longitudinal section below the considered filling height, in m²

f_{grd} factor to account for longitudinal girders and longitudinal wash bulkheads in the tank:

$= n_{grd}/(1 + n_{wash-lng})$

n_{grd} number of longitudinal girders, excluding longitudinal wash bulkheads, in the tank

b_{tk-h} tank breadth at considered filling height, in m

4.2.3.4 For calculation of sloshing pressures in way of longitudinal wash bulkheads the effective sloshing breadth, b_{slh}, is to be taken as:

$$b_{slh} = \frac{[1 + (n_{wash-lng} - 1)\alpha_{wash-lng}](1 + f_{grd}\alpha_{grd})b_{tk-h}}{(1 + n_{wash-lng})(1 + f_{grd})} \quad \text{m}$$

Where:

$n_{wash-lng}$ number of longitudinal wash bulkheads in the tank

$\alpha_{wash-lng}$ longitudinal wash bulkhead coefficient

$$= \frac{A_{opn-wash-lng}}{A_{tk-lng-h}}$$

α_{grd} girder coefficient

$$= \frac{A_{opn-grd-h}}{A_{tk-lng-h}}$$

$A_{opn-wash-lng}$ total area of openings in the longitudinal section in way of the wash bulkhead below the considered filling height, in m²

$A_{tk-lng-h}$ total longitudinal cross sectional area of the tank below the considered filling height, in m²

$A_{opn-grd-h}$ total area of openings in the longitudinal section below the considered filling height, in m²

f_{grd} factor to account for longitudinal girders and longitudinal wash bulkheads in the tank:

$= n_{grd}/(1 + n_{wash-lng})$

n_{grd} number of longitudinal girders, excluding longitudinal wash bulkheads, in the tank

b_{tk-h} tank breadth at considered filling height, in m

4.2.3.5 For tanks with internal longitudinal girders or webframes, the sloshing pressure on the girder/webframe adjacent to a longitudinal wash bulkhead, $P_{slh-grd}$, provided it is located within $0.25b_{slh}$ from the bulkhead, is to be taken as:

$$P_{slh-grd} = P_{slh-t}\left(1 - \frac{s_{grd}}{b_{slh}}\right)^2 \quad \text{kN/m}^2$$

Where:

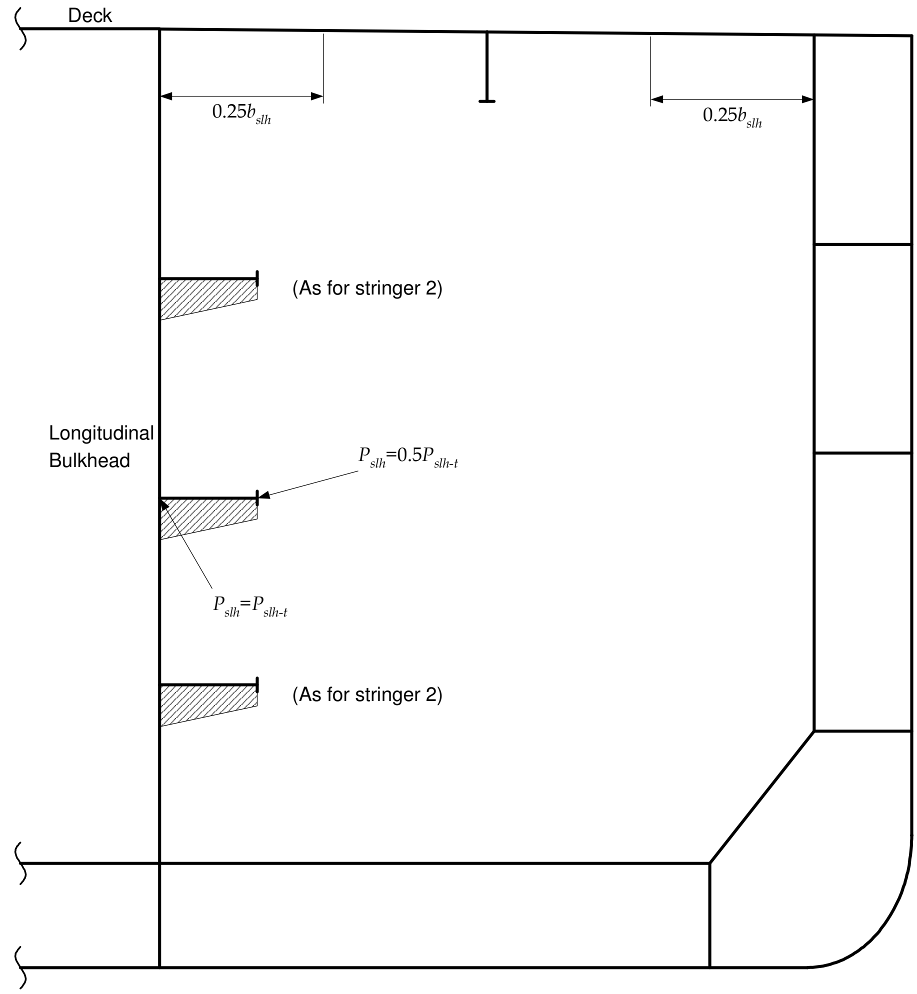
P_{slh-t} sloshing pressure acting on bulkhead due to transverse liquid motion, in kN/m², see *4.2.3.1*

s_{grd} distance from longitudinal bulkhead to longitudinal girder being considered, in m

b_{slh} effective sloshing breadth, see *4.2.3.3* and *4.2.3.4* for longitudinal tight bulkheads and longitudinal wash bulkheads respectively, in m

4.2.3.6 For tanks with internal longitudinal stringers and or girders/webframes, the distribution of sloshing pressure across these members is shown in *Figure 7.4.4*.

Figure 7.4.4
Pressure Distribution on Stringers and Longitudinal Girders



4.2.4 Minimum sloshing pressure

4.2.4.1 The minimum sloshing pressure, $P_{slh\text{-}min}$, in cargo and ballast tanks except tanks of cellular construction is to be taken as 20kN/m^2.

4.2.4.2 The minimum sloshing pressure, $P_{slh\text{-}min}$, in cellular construction ballast tanks is to be taken as 12kN/m^2.

4.3 Bottom Slamming Loads

4.3.1 Application and limitations

4.3.1.1 The slamming loads in this section apply to ships with $C_b \geq 0.7$ and bottom slamming draught $\geq 0.01L$ and $\leq 0.045L$.

4.3.2 Slamming pressure

4.3.2.1 The bottom slamming pressure, P_{slm}, is to be taken as the greater of:

$$P_{slm-mt} = f_{slm}\,130\,g\,c_{slm-mt}\,e^{c_1} \quad \text{kN/m}^2 \quad \text{for empty ballast tanks}$$

$$P_{slm-full} = f_{slm}\,130\,g\,c_{slm-full}\,e^{c_1} - c_{av}\,\rho g z_{ball} \quad \text{kN/m}^2 \quad \text{for full ballast tanks}$$

Where:

g	acceleration due to gravity, 9.81 m/s^2
f_{slm}	longitudinal slamming distribution factor, see *Figure 7.4.5*, is to be taken as: 0 at 0.5L 1 at $[0.175 - 0.5(C_{bl} - 0.7)]L$ from F.P. 1 at $[0.1 - 0.5(C_{bl} - 0.7)]L$ from F.P. 0.5 at, and forward of F.P. intermediate values to be obtained by linear interpolation.
C_{bl}	block coefficient, C_b, as defined in *Section 4/1.1.9.1*, but not to be taken less than 0.7 or greater than 0.8
$c_{slm\text{-}mt}$	slamming coefficient for empty ballast tanks $= 5.95 - 10.5\left(\frac{T_{FP-mt}}{L}\right)^{0.2}$
$c_{slm\text{-}full}$	slamming coefficient for full ballast tanks $= 5.95 - 10.5\left(\frac{T_{FP-full}}{L}\right)^{0.2}$
c_1	is to be taken as: 0 for $L \leq 180$m $= -0.0125(L-180)^{0.705}$ for $L > 180$m
$T_{FP\text{-}mt}$	design slamming ballast draught at F.P. with ballast tanks within the bottom slamming region empty as defined in *4.3.2.3,* in m
$T_{FP\text{-}full}$	design slamming ballast draught at F.P. with ballast tanks within the bottom slamming region full as defined in *4.3.2.4,* in m
c_{av}	dynamic load coefficient, to be taken as 1.25
L	rule length, in m, as defined in *Section 4/1.1.1.1*
z_{ball}	vertical distance from tank top to load point, in m

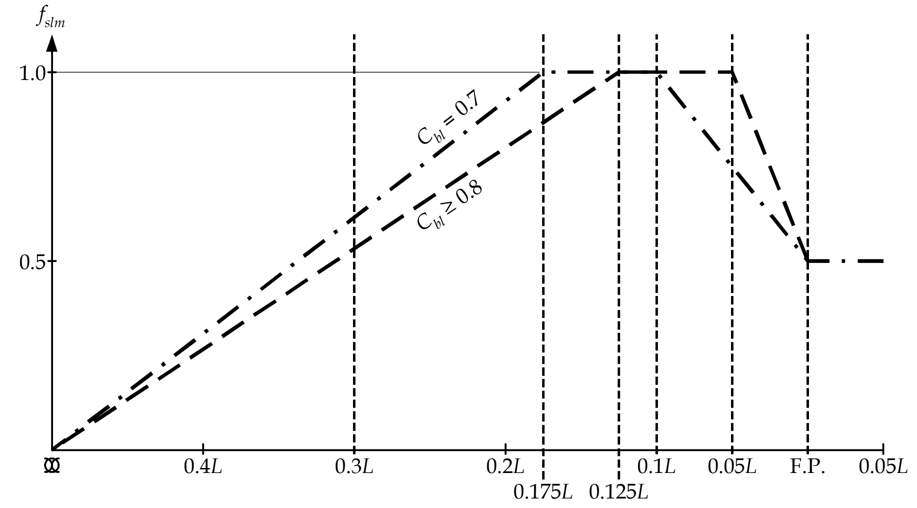
4.3.2.2 The designer is to provide the design slamming draughts $T_{FP\text{-}mt}$ and $T_{FP\text{-}full}$.

4.3.2.3 The design slamming draught at the F.P., $T_{FP\text{-}mt}$, is not to be greater than the minimum draught at the F.P. indicated in the loading manual for all seagoing conditions wherein the ballast tanks within the bottom slamming region are empty. This includes any loading conditions with tanks inside the bottom slamming region that use the "sequential" ballast water exchange method.

4.3.2.4 The design slamming draught at the F.P., $T_{FP\text{-}full}$, is not to be greater than the minimum draught at the F.P. indicated in the loading manual for any seagoing conditions wherein the ballast tanks within the bottom slamming region are full. This includes any loading condition with tanks inside the bottom slamming region that use the "flow-through" ballast water exchange method.

4.3.2.5 The loading guidance information is to clearly indicate the design slamming draughts and the ballast water exchange method used for each ballast tank, see *Section 8/1.1*.

Figure 7.4.5
Longitudinal Distribution of Slamming Pressure



4.4 Bow Impact Loads

4.4.1 Application and limitations

4.4.1.1 The bow impact pressure applies to the side structure in the area forward of 0.1L aft of F.P. and between the waterline at draught T_{bal} and the highest deck at side.

4.4.2 Bow impact pressure

4.4.2.1 The bow impact pressure, P_{im}, is to be taken as:

$$P_{im} = 1.025 f_{im} c_{im} V_{im}^2 \sin \gamma_{wl} \quad \text{kN/m}^2$$

Where:

f_{im} 0.55 at 0.1L aft of F.P.
0.9 at 0.0125L aft of F.P.
1.0 at and forward of F.P.
intermediate values to be obtained by linear interpolation

V_{im} impact speed, in m/s
$= 0.514 V_{fwd} \sin \alpha_{wl} + \sqrt{L}$

V_{fwd} forward speed, in knots
= 0.75V but is not to be taken as less than 10

V service speed, in knots, as defined in *Section 4/1.1.8.1*

α_{wl} local waterline angle at the position considered, but is not to be taken as less than 35 degrees, see *Figure 7.4.6*.

γ_{wl} local bow impact angle measured normal to the shell from the horizontal to the tangent line at the position considered but is not to be less than 50 degrees, see *Figure 7.4.6*.

c_{im}	1.0	for positions between draughts T_{bal} and T_{sc}
	$= \sqrt{1+\cos^2[90\frac{(h_{fb}-2h_o)}{h_{fb}}]}$	for positions above draught T_{sc}

h_{fb} vertical distance from the waterline at draught T_{sc} to the highest deck at side, see *Figure 7.4.6,* in m

h_o vertical distance from the waterline at draught T_{sc}, to the position considered, see *Figure 7.4.6*, in m

L rule length, in m, as defined in *Section 4/1.1.1.1*

T_{sc} scantling draught, in m, as defined in *Section 4/1.1.5.5*

T_{bal} minimum design ballast draught, in m, for the normal ballast condition as defined in *Section 4/1.1.5.2*

WL_j waterline at the position considered, see *Figure 7.4.6*

Guidance Note

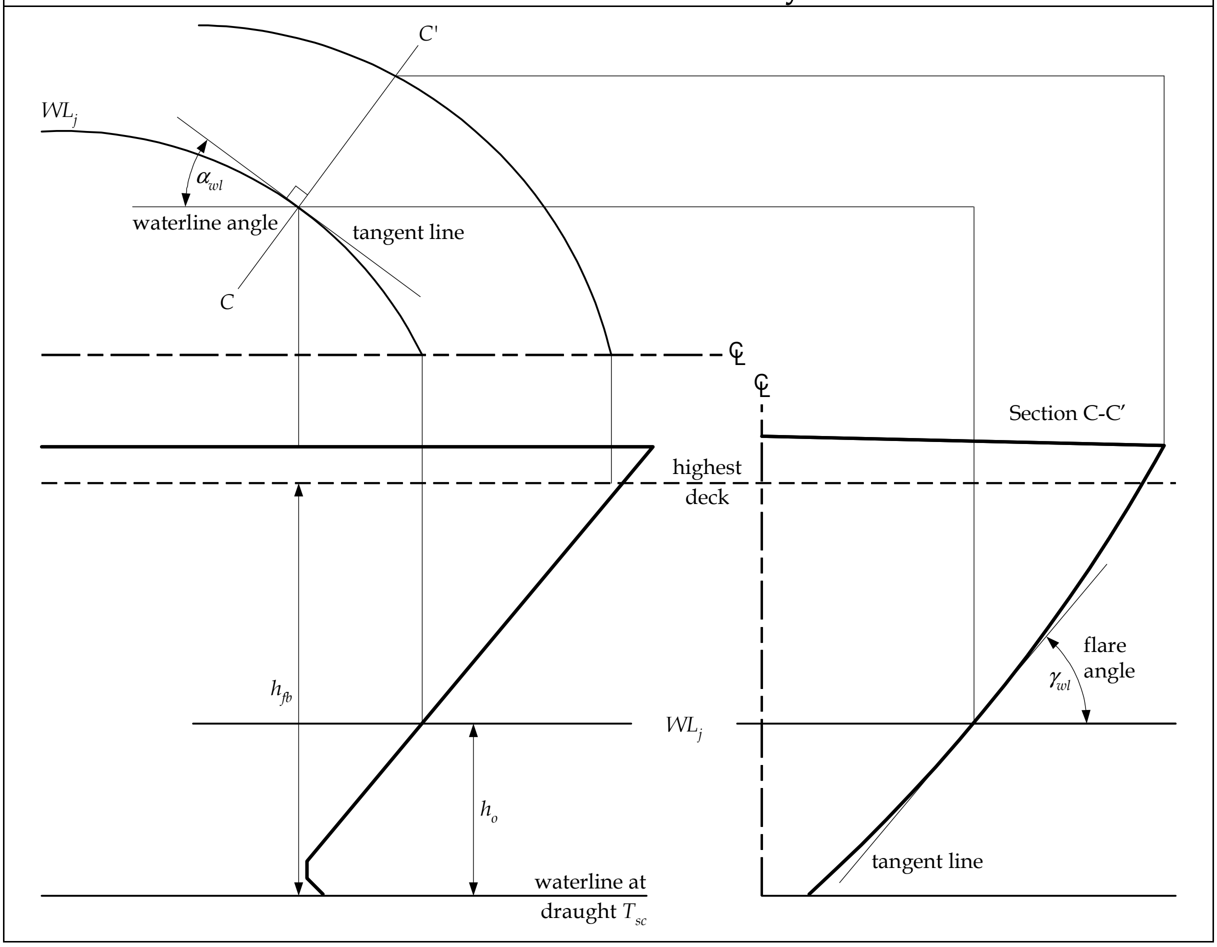
Where local bow impact angle measured normal to the shell, γ_{wl}, is not available, this angle may be taken as:

γ_{wl} $= \tan^{-1}\left(\frac{\tan\beta_{pl}}{\cos\alpha_{wl}}\right)$

Where

β_{pl} local body plan angle at the position considered from the horizontal to the tangent line, but is not to be less than 35 degrees

Figure 7.4.6
Definition of Bow Geometry



5 ACCIDENTAL LOADS

5.1 Flooded Condition

5.1.1 Local Pressure

5.1.1.1 The pressure in compartments and tanks in flooded condition or damaged condition is to be taken as $P_{in-flood}$, see *2.2.3.4.*

6 COMBINATION OF LOADS

6.1 General

6.1.1 Application

6.1.1.1 The design load combinations *S*, *S + D*, and *A* are to be used for scantling calculations for the scantling requirements and strength assessment (by FEM). design load combinations are defined in *Section 2/4.2.2* and the relevant loads and load combination are to be taken as given in *6.2*.

6.1.1.2 The dynamic loads, *D*, consist of several dynamic load cases. For each dynamic load case, the envelope load values as given in *Sub-Section 3* are multiplied with dynamic load combination factors to give simultaneously acting dynamic loads. The procedures for calculating the simultaneously acting dynamic loads are given in *6.3*. The dynamic load combination factors are given in *6.4* for strength assessment (by FEM) and in *6.5* for scantling requirements.

6.2 Design Load Combination

6.2.1 General

6.2.1.1 The design load combinations are given in *Table 7.6.1*.

Table 7.6.1
Design Load Combinations

Load components		S	S + D	A
$M_{v\text{-}total}$		$M_{sw\text{-}harb}$	$M_{sw\text{-}sea} + M_{wv}$	-
$M_{h\text{-}total}$		-	M_h	-
Q		$Q_{sw\text{-}harb}$	$Q_{sw\text{-}sea} + Q_{wv}$	-
P_{ex}	**Weather Deck**	-	$P_{wdk\text{-}dyn}$	-
	Hull envelope	P_{hys}	$P_{hys} + P_{wv\text{-}dyn}$	-
P_{in}	**Ballast tanks (BWE with sequential filling method)**	the greater of a) $P_{in\text{-}test}$ b) $P_{in\text{-}air} + P_{drop}$	$P_{in\text{-}tk} + P_{in\text{-}dyn}$	$P_{in\text{-}flood}$
	Ballast tanks (BWE with flow-through method)	the greater of a) $P_{in\text{-}test}$ b) $P_{in\text{-}air} + P_{drop}$	$P_{in\text{-}air} + P_{drop} + P_{in\text{-}dyn}$	$P_{in\text{-}flood}$
	Cargo tanks including cargo tanks designed for filling with water ballast	the greater of a) $P_{in\text{-}test}$ b) $P_{in\text{-}tk} + P_{valve}$	$P_{in\text{-}tk} + P_{valve} - 25 + P_{in\text{-}dyn}$	-
	Other tanks with liquid filling	the greater of a) $P_{in\text{-}test}$ b) $P_{in\text{-}air}$	$P_{in\text{-}tk} + P_{in\text{-}dyn}$	$P_{in\text{-}flood}$
	Watertight boundaries	-	-	$P_{in\text{-}flood}$
P_{dk}	**Internal decks for dry spaces**	P_{stat}	$P_{stat} + P_{dk\text{-}dyn}$	-
	Decks for heavy units	F_{stat}	$F_{stat} + F_{dk\text{-}dyn}$	-

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Table 7.6.1 (Continued)
Design Load Combinations

Note:

1. Separate load requirements may be specified in strength assessment (FEM) and scantling requirements.

Where:

$M_{v\text{-}total}$	design vertical bending moment, in kNm	
$M_{sw\text{-}perm\text{-}harb}$	permissible hull girder hogging and sagging still water bending moment envelopes for harbour/sheltered water operation, in kNm	see *2.1.1*
$M_{sw\text{-}perm\text{-}sea}$	permissible hull girder hogging and sagging still water bending moment envelopes for seagoing operation, in kNm	see *2.1.1*
M_{wv}	vertical wave bending moment for a considered dynamic load case, in kNm	see *6.3.2.1*
$M_{h\text{-}total}$	design horizontal bending moment, in kNm	
M_h	horizontal wave bending moment for a considered dynamic load case, in kNm	see *6.3.3.1*
Q	design vertical shear force, in kN	
$Q_{sw\text{-}perm\text{-}harb}$	permissible hull girder positive and negative still water shear force limits for harbour/sheltered water operation, in kN	see *2.1.3*
$Q_{sw\text{-}perm\text{-}sea}$	permissible hull girder positive and negative still water shear force limits for seagoing operation, in kN	see *2.1.3*
Q_{wv}	vertical wave shear force for a considered dynamic load case, in kN	see *6.3.4.1*
P_{ex}	design sea pressure, in kN/m²	
P_{hys}	static sea pressure at considered draught, in kN/m²	see *2.2.2.1*
$P_{wv\text{-}dyn}$	dynamic wave pressure for a considered dynamic load case, in kN/m²	see *6.3.5*
$P_{wdk\text{-}dyn}$	green sea load for a considered dynamic load case, in kN/m²	see *6.3.6*
P_{in}	design tank pressure, in kN/m²	
$P_{in\text{-}test}$	tank testing pressure, in kN/m²	see *2.2.3.5*
$P_{in\text{-}air}$	static tank pressure in the case of overfilling or filling during flow through ballast water exchange, in kN/m²	see *2.2.3.2*
P_{drop}	added overpressure due to liquid flow through air pipe or overflow pipe, in kN/m²	see *2.2.3.3*
P_{valve}	setting of pressure relief valve, in kN/m²	see *2.2.3.5*
$P_{in\text{-}tk}$	static tank pressure, in kN/m²	see *2.2.3.1*
$P_{in\text{-}dyn}$	dynamic tank pressure for a considered dynamic load case, in kN/m²	see *6.3.7*
$P_{in\text{-}flood}$	pressure in compartments and tanks in flooded or damaged condition, in kN/m²	see *2.2.3.4*
P_{stat}	static pressure on decks and inner bottom, in kN/m²	see *2.2.4.1*
P_{dk}	design deck pressure, in kN/m²	
$P_{dk\text{-}dyn}$	dynamic deck pressure on decks, inner bottom and hatch covers for a considered dynamic load case, in kN/m²	see *6.3.8.1*
F_{stat}	load acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, in kN	see *2.2.5.1*
$F_{dk\text{-}dyn}$	dynamic load acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, in kN	see *6.3.8.2*

6.3 Application of Dynamic Loads

6.3.1 Heading correction factor and dynamic load combination factors

6.3.1.1 The heading correction factor, f_β, is to be taken as:

f_β = 0.8 for beam sea dynamic load cases

= 1.0 for all other dynamic load cases

6.3.1.2 The dynamic load combination factors used for the calculations of the simultaneously acting dynamic loads, are to be taken as given in *Table 7.6.2* for strength assessment by FEM, see *6.4*. Dynamic load factors are to be taken as given in *Table 7.6.4* to *Table 7.6.9* for scantling assessment, see *6.5*.

6.3.2 Vertical wave bending moment for a considered dynamic load case

6.3.2.1 The simultaneously acting vertical wave bending moment, M_{wv}, is to be taken as:

$$M_{wv} = f_\beta f_{mv} M_{wv-hog} \quad \text{kNm} \qquad \text{for } f_{mv} \geq 0$$

$$M_{wv} = -f_\beta f_{mv} M_{wv-sag} \quad \text{kNm} \qquad \text{for } f_{mv} < 0$$

Where:

M_{wv-hog} hogging vertical wave bending moment, in kNm, as defined in *3.4.1.1*

M_{wv-sag} sagging vertical wave bending moment, in kNm, as defined in *3.4.1.1*

f_{mv} dynamic load combination factor for vertical wave bending moment for considered dynamic load case, see *6.3.1.2*

f_β heading correction factor, as defined in *6.3.1.1*

6.3.3 Horizontal wave bending moment for a considered dynamic load case

6.3.3.1 The simultaneously acting horizontal wave bending moment, M_h, is to be taken as:

$$M_h = f_\beta f_{mh} M_{wv-h} \quad \text{kNm}$$

Where:

M_{wv-h} horizontal wave bending moment, in kNm, as defined in *3.4.2*

f_{mh} dynamic load combination factor for horizontal wave bending moment for considered dynamic load case, see *6.3.1.2*

f_β heading correction factor, as defined in *6.3.1.1*

6.3.4 Vertical wave shear force for a considered dynamic load case

6.3.4.1 The simultaneously acting vertical wave shear force, Q_{wv}, is to be taken as:

$$Q_{wv} = f_\beta f_{qv} Q_{wv-pos} \quad \text{kN} \qquad \text{for } f_{qv} \geq 0$$

$$Q_{wv} = -f_\beta f_{qv} Q_{wv-neg} \quad \text{kN} \qquad \text{for } f_{qv} < 0$$

Where:

Q_{wv-pos} envelope positive vertical wave shear force, in kN, as defined in *3.4.3*

Q_{wv-neg} envelope negative vertical wave shear force, in kN, as defined in *3.4.3*

f_{qv} dynamic load combination factor for vertical wave shear force for considered dynamic load case, see *6.3.1.2*

f_β heading correction factor, as defined in *6.3.1.1*

6.3.5 Dynamic wave pressure distribution for a considered dynamic load case

6.3.5.1 The simultaneously acting dynamic wave pressure, $P_{wv\text{-}dyn}$, for the port and starboard side within the cargo tank region for a considered dynamic load case is to be taken as follows, but not to be less than $-\rho_{sw} g(T_{LC} - z)$ below still waterline or less than 0 above still waterline:

$$P_{wv-dyn} = P_{ctr} + \frac{|y|}{0.5B_{local}}\left(P_{bilge} - P_{ctr}\right)$$ between centreline and start of bilge

$$P_{wv-dyn} = P_{bilge} + \frac{z}{T_{LC}}\left(P_{WL} - P_{bilge}\right)$$ between end of bilge and still waterline

$$P_{wv-dyn} = P_{WL} - 10(z - T_{LC})$$ for side-shell above still waterline

intermediate values of $P_{wv\text{-}dyn}$ around the bilge are to be obtained by linear interpolation along the vertical distance

Where:

P_{ctr} dynamic wave pressure at bottom centreline, to be taken as:
$= f_{ctr} P_{ex-max}$ kN/m²

P_{bilge} dynamic wave pressure at z = 0 and $y = B_{local}/2$, to be taken as:
$= f_{bilge} P_{ex-max}$ kN/m²

P_{WL} dynamic wave pressure at waterline, to be taken as:
$= f_{WL} P_{ex-max}$ kN/m²

$P_{ex\text{-}max}$ envelope maximum dynamic wave pressure, in kN/m², as defined in *3.5.2.2*

f_{WL} dynamic load combination factor for dynamic wave pressure at still waterline for considered dynamic load case, see *6.3.1.2*

f_{bilge} dynamic load combination factor for dynamic wave pressure at bilge for considered dynamic load case, see *6.3.1.2*

f_{ctr} dynamic load combination factor for dynamic wave pressure at centreline for considered dynamic load case, see *6.3.1.2*

B_{local} local breadth at waterline for considered draught , in m

T_{LC} draught in the loading condition being considered, in m

y transverse coordinate, in m

z vertical coordinate, in m

ρ_{sw} density of sea water, 1.025tonnes/m³

g acceleration due to gravity, 9.81m/s²

6.3.5.2 The simultaneously acting dynamic wave pressure for the port and starboard side outside the cargo region, $P_{wv\text{-}dyn}$, for a considered dynamic load case is to be obtained by linear interpolation between P_{ctr} and P_{WL}, but not to be taken less than $-\rho_{sw} g(T_{LC} - z)$ below still waterline or less than 0 above still waterline.

$$P_{wv-dyn} = P_{ctr} + \frac{z}{T_{LC}}\left(P_{WL} - P_{ctr}\right)$$ between bottom centreline and still waterline

$$P_{wv-dyn} = P_{WL} - 10(z - T_{LC})$$ above still waterline

Where:

P_{ctr}	dynamic wave pressure at bottom centreline, and is to be taken as: $f_{ctr} P_{ex-\max}$ kN/m^2
P_{WL}	dynamic wave pressure at still waterline, and is to be taken as: $f_{WL} P_{ex-\max}$ kN/m^2
P_{ex-max}	envelope maximum dynamic wave pressure, in kN/m^2, as defined in *3.5.2.2*
f_{WL}	dynamic load combination factor for dynamic wave pressure at still waterline for considered dynamic load case, see *6.3.1.2*
f_{ctr}	dynamic load combination factor for dynamic wave pressure at centreline for considered dynamic load case, see *6.3.1.2*
T_{LC}	draught in the loading condition being considered, in m
z	vertical coordinate, in m
ρ_{sw}	density of sea water, 1.025tonnes/m^3
g	acceleration due to gravity, 9.81m/s^2

6.3.5.3 *Figure 7.6.1* to *Figure 7.6.3* illustrates simultaneously acting dynamic wave pressures.

Figure 7.6.1
Dynamic Wave Pressure for Head Sea Dynamic Load Cases

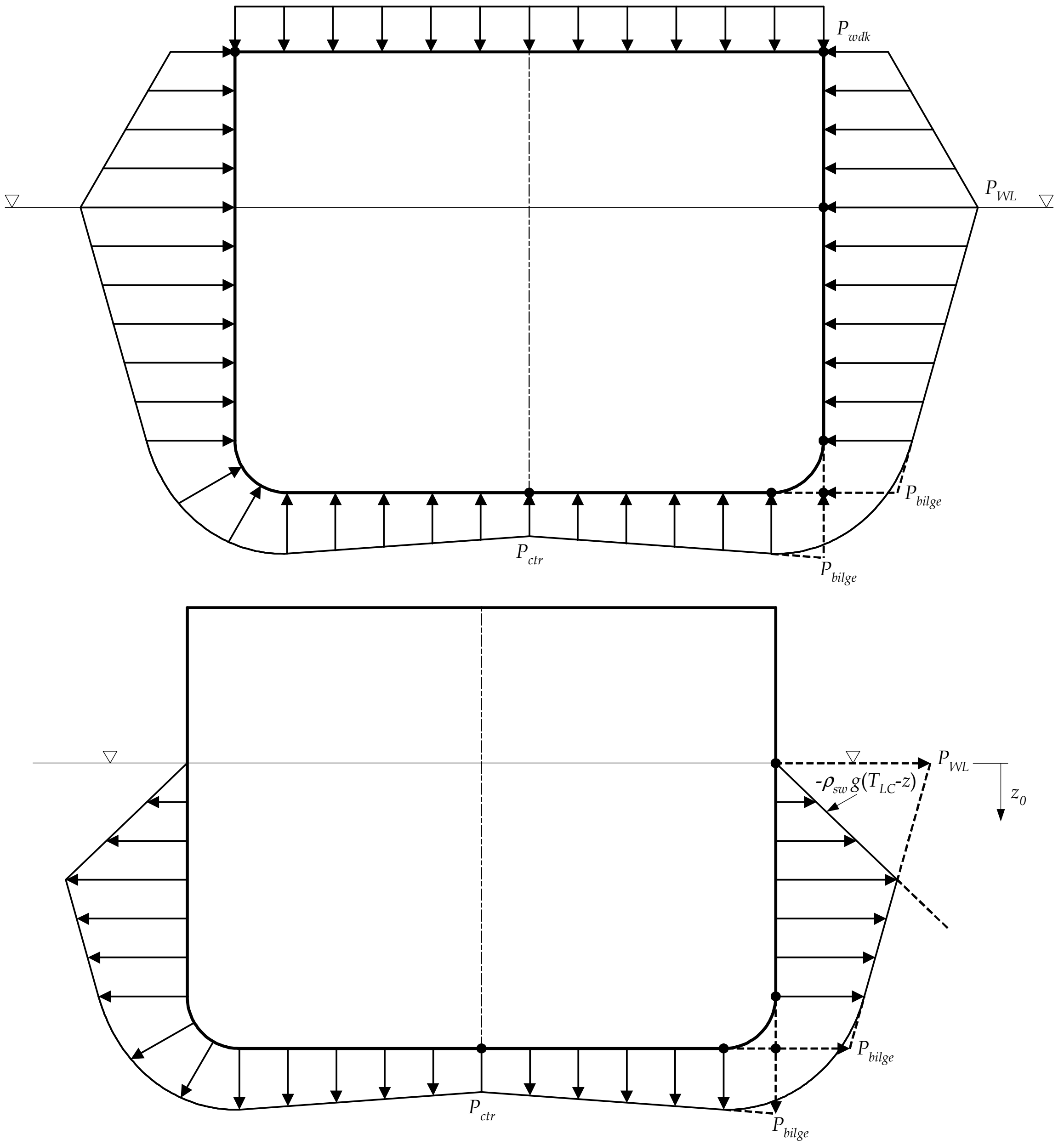


Figure 7.6.2
Dynamic Wave Pressure for Beam and Oblique Sea Dynamic Load Cases

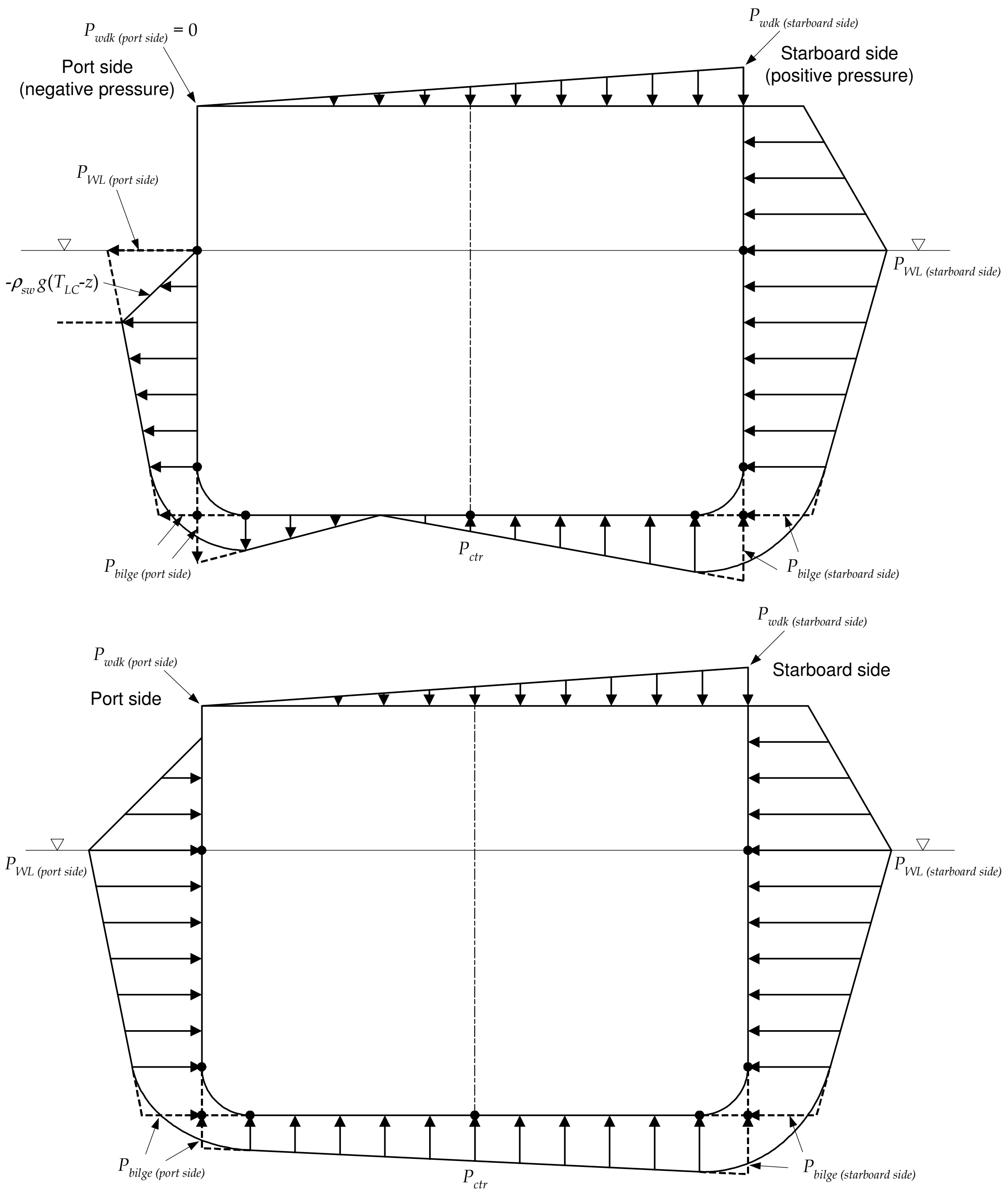
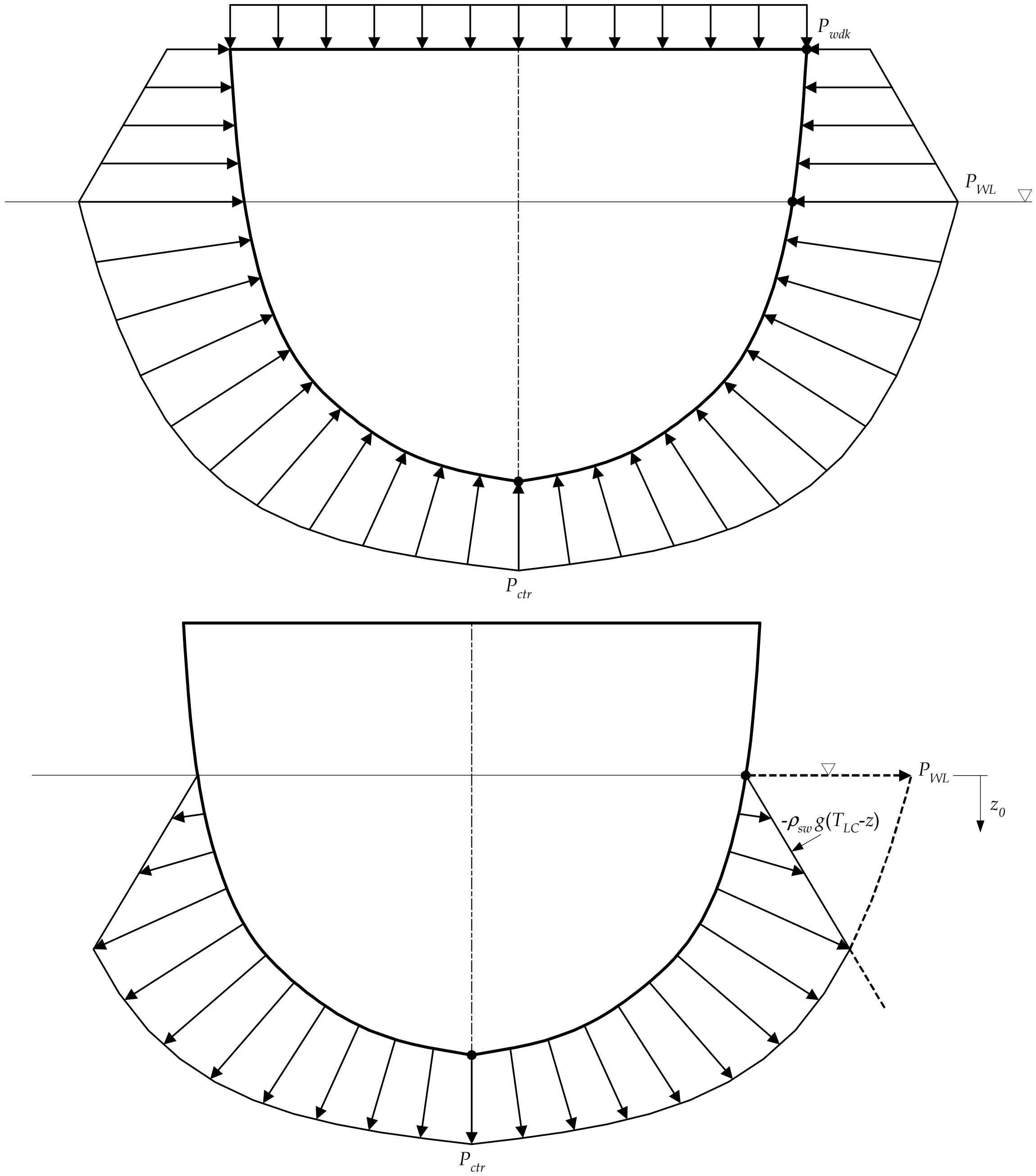


Figure 7.6.3
Pressure Distribution for Wave Crest and Wave Trough for Forward and Aft



6.3.6 Green sea load for a considered dynamic load case

6.3.6.1 The simultaneously acting green sea load on the weather deck, $P_{wdk-dyn}$, for strength assessment is obtained by linear interpolation between P_{wdk-pt} and $P_{wdk-stb}$:

The green sea load at the port side, P_{wdk-pt}, is to be taken as the greater of:

$$P_{wdk-pt} = f_{1-dk}\left(f_{WL} f_{op} P_{1-WL} - 10 z_{dk-T}\right) \quad \text{kN/m}^2$$

$$P_{wdk-pt} = 0.8\left(f_{WL} P_{2-WL} - 10 z_{dk-T}\right) \quad \text{kN/m}^2$$

P_{wdk-pt} is not to be taken as less than 34.3 kN/m² when f_{WL} = 1.0 and the ship's draught used in the design load case is greater or equal to $0.9T_{sc}$

The green sea load at the starboard side, $P_{wdk-stb}$, is to be taken as the greater of:

$$P_{wdk-stb} = f_{1-dk}\left(f_{WL} f_{op} P_{1-WL} - 10 z_{dk-T}\right) \quad \text{kN/m}^2$$

$$P_{wdk-stb} = 0.8\left(f_{WL} P_{2-WL} - 10 z_{dk-T}\right) \quad \text{kN/m}^2$$

$P_{wdk-stb}$ is not to be taken as less than 34.3 kN/m^2 when f_{WL} = 1.0 and the ship's draught used in the design load case is greater or equal to $0.9T_{sc}$

P_{wdk-pt} and $P_{wdk-stb}$ are not to be taken as less than 0.

Where:

f_{1-dk} $= 0.8 + \dfrac{L}{750}$

f_{op} = 1.0 at and forward of $0.2L$ from A.P.
= 0.8 at and aft of A.P.
intermediate values to be obtained by linear interpolation

P_{1-WL} P_1 pressure at still waterline for considered draught, in kN/m^2, see *3.5.2.1*

P_{2-WL} P_2 pressure at still waterline for considered draught, in kN/m^2, see *3.5.2.1*

f_{WL} dynamic load combination factor for dynamic wave pressure at still waterline for considered dynamic load case, see *6.3.1.2*

z_{dk-T} distance from the deck to the still waterline at the applicable draught for the loading condition being considered, in m

L rule length, in m, as defined in *Section 4/1.1.1.1*

6.3.6.2 The simultaneously acting green sea load on the weather deck, $P_{wdk-dyn}$, for scantling requirements is to be taken as the greater of:

$$P_{wdk-dyn} = f_{1-dk}\left(f_{WL} f_{op} P_{1-WL} - 10 z_{dk-T}\right) \quad \text{kN/m}^2$$

but is not to be taken as less than 34.3kN/m^2 when f_{WL} = 1.0 and the ship's draught used in the design load case is greater or equal to $0.9T_{sc}$

$$P_{wdk-dyn} = 0.8 f_{2-dk}\left(f_{WL} P_{2-WL} - 10 z_{dk-T}\right) \quad \text{kN/m}^2$$

but is not to be taken as less than 34.3kN/m^2 when f_{WL} = 1.0 and f_{2-dk} =1.0 and the ship's draught used in the design load case is greater or equal to $0.9T_{sc}$

$P_{wdk-dyn} = 0$

Where:

f_{1-dk} $= 0.8 + \dfrac{L}{750}$

f_{2-dk} $= 0.5 + \dfrac{|y|}{B_{wdk}}$

f_{op} = 1.0 at and forward of $0.2L$ from A.P.
= 0.8 at and aft of A.P.
intermediate values to be obtained by linear interpolation

P_{1-WL} P_1 pressure at still waterline for considered draught, in kN/m^2

$P_{2\text{-}WL}$	P_2 pressure at still waterline for considered draught, in kN/m²
f_{WL}	dynamic load combination factor for dynamic wave pressure at still waterline for considered dynamic load case, see *6.3.1.2*
y	transverse coordinate, in m
$z_{dk\text{-}T}$	distance from the deck at side to the still waterline at the applicable draught for the loading condition being considered, in m
B_{wdk}	local breadth at the weather deck, in m
L	rule length, in m, as defined in *Section 4/1.1.1.1*

6.3.7 Dynamic tank pressure for a considered dynamic load case

6.3.7.1 The simultaneously acting dynamic tank pressure, $P_{in\text{-}dyn}$, for tanks in the cargo region, is to be taken as:

$$P_{in-dyn} = f_\beta \left(f_v P_{in-v} + f_t P_{in-t} + f_{lng} P_{in-lng} \right) \quad \text{kN/m}^2$$

Where:

$P_{in\text{-}v}$ — envelope dynamic tank pressure due to vertical acceleration as defined in *3.5.4.1* with reference point z_0 taken as:

(a) top of tank

(b) top of air pipe/overflow for ballast tanks designed for BWE by flow-through method

see *Figure 7.6.4*, in kN/m²

$P_{in\text{-}t}$ — envelope dynamic tank pressure due to transverse acceleration as defined in *3.5.4.2* with reference point y_0 taken as:

(a) tank top towards port side for $f_t > 0$

(b) tank top towards starboard side for $f_t < 0$

see *Figure 7.6.5*, in kN/m²

$P_{in\text{-}lng}$ — envelope dynamic tank pressure due to longitudinal acceleration as defined in *3.5.4.3* with reference point x_0 taken as:

(a) forward bulkhead for $f_{lng} > 0$

(b) aft bulkhead of the tank for $f_{lng} < 0$

see *Figure 7.6.6*, in kN/m²

f_v — dynamic load combination factor for vertical acceleration for considered dynamic load case. f_v is to be taken as appropriate to the tank location, see *6.3.1.2*

f_t — dynamic load combination factor for transverse acceleration for considered dynamic load case, see *6.3.1.2*

f_{lng} — dynamic load combination factor for longitudinal acceleration for considered dynamic load case. f_{lng} is to be taken as most appropriate dependent on tank location, see *6.3.1.2*

f_β — heading correction factor, as defined in *6.3.1.1*

x_0 — longitudinal coordinate of reference point, in m

y_0 transverse coordinate of reference point, in m

z_0 vertical coordinate of reference point, in m

Note

1. For a non-parallel tank, y_0 should be selected from either forward or aft bulkhead corresponding to the reference point x_0. If the longitudinal load combination factor $f_{lng} = 0$, y_0 should be selected from the bulkhead with the greater breadth.
2. The vertical, transverse and longitudinal acceleration is to be taken at the centre of gravity of the tank under consideration.

6.3.7.2 The simultaneously acting dynamic tank pressure for tanks outside the cargo region, P_{in-dyn}, is to be taken as:

$$P_{in-dyn} = f_\beta \left(f_{v-mid} P_{in-v} + \left| f_t P_{in-t} \right| + \left| f_{lng} P_{in-lng} \right| \right) \quad \text{kN/m}^2$$

Where:

P_{in-v} envelope dynamic wave pressure due to vertical acceleration as given in *3.5.4.1* with reference point z_0 taken as:

(a) top of tank

(b) top of air pipe for ballast tanks design for BWE by flow through

see *Figure 7.6.5*, in kN/m^2

P_{in-t} envelope dynamic tank pressure due to transverse acceleration as given in *3.5.4.2* using $(y_0 - y)$ as extreme breadth of tank, in kN/m^2

P_{in-lng} envelope dynamic tank pressure due to longitudinal acceleration as given in *3.5.4.3* using $(x_0 - x)$ as extreme length of tank, in kN/m^2

f_{v-mid} dynamic load combination factor for vertical acceleration for considered dynamic load case, see *6.3.1.2*

f_t dynamic load combination factor for transverse acceleration for considered dynamic load case, see *6.3.1.2*

f_{lng} dynamic load combination factor for longitudinal acceleration for considered dynamic load case, see *6.3.1.2*

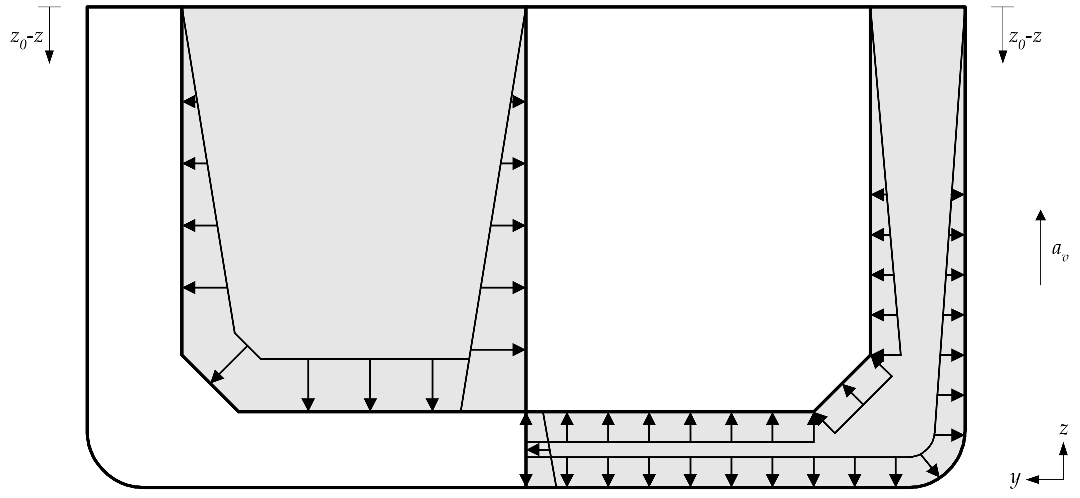
f_β heading correction factor, as defined in *6.3.1.1*

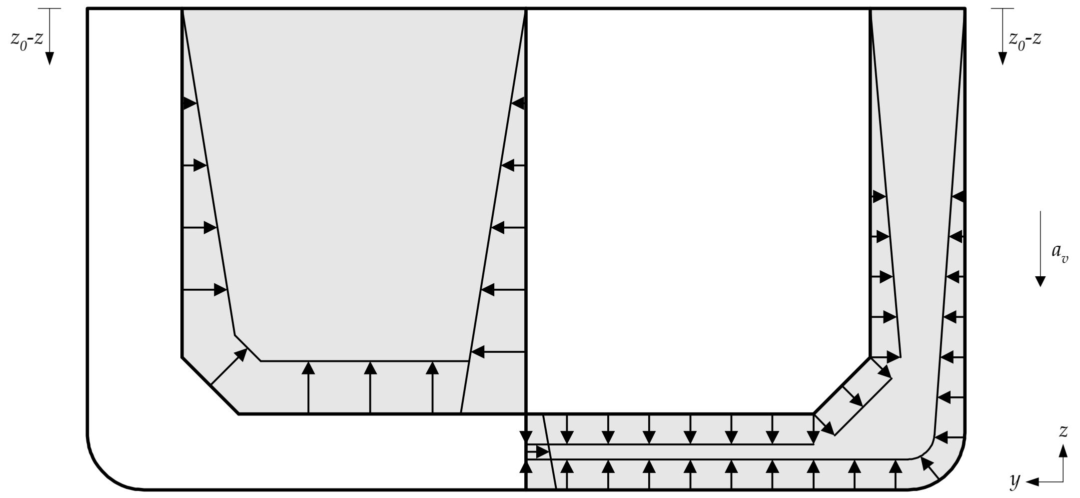
x_0 longitudinal coordinate of reference point, in m

y_0 transverse coordinate of reference point, in m

z_0 vertical coordinate of reference point, in m

Figure 7.6.4
Dynamic Tank Pressure in Cargo Tank (Left) and Ballast Tank (Right) due to Positive and Negative Vertical Tank Acceleration

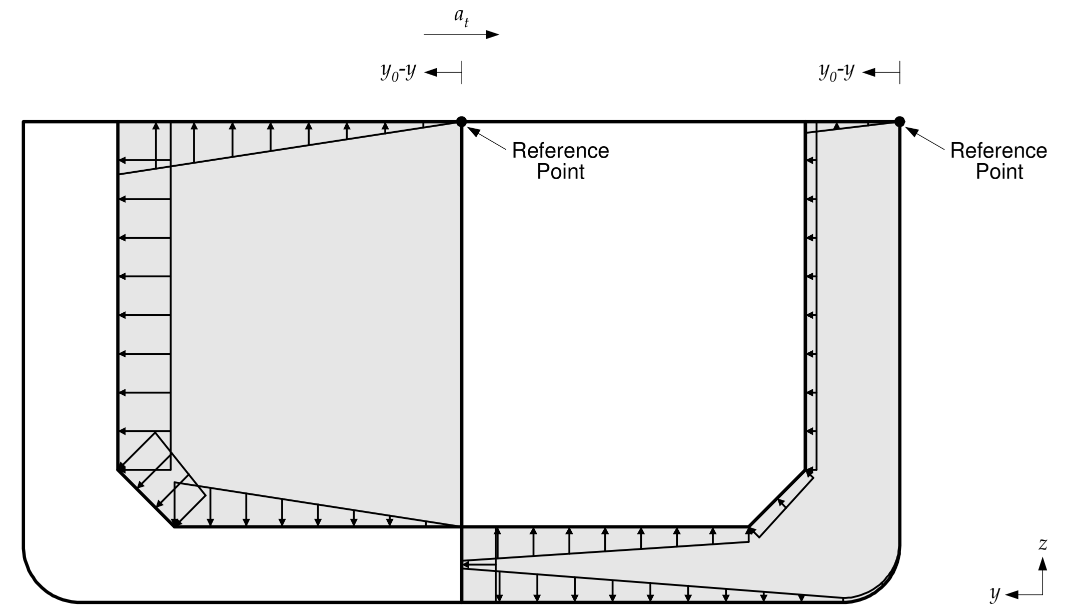




Note

For ballast tank which is designed for ballast water exchange by flow-through method, reference point z_0 is to be taken as top of air pipe/overflow of the tank.

Figure 7.6.5
Dynamic Tank Pressure in Cargo Tank (Left) and Ballast Tank (Right) due to Negative and Positive Transverse Tank Acceleration



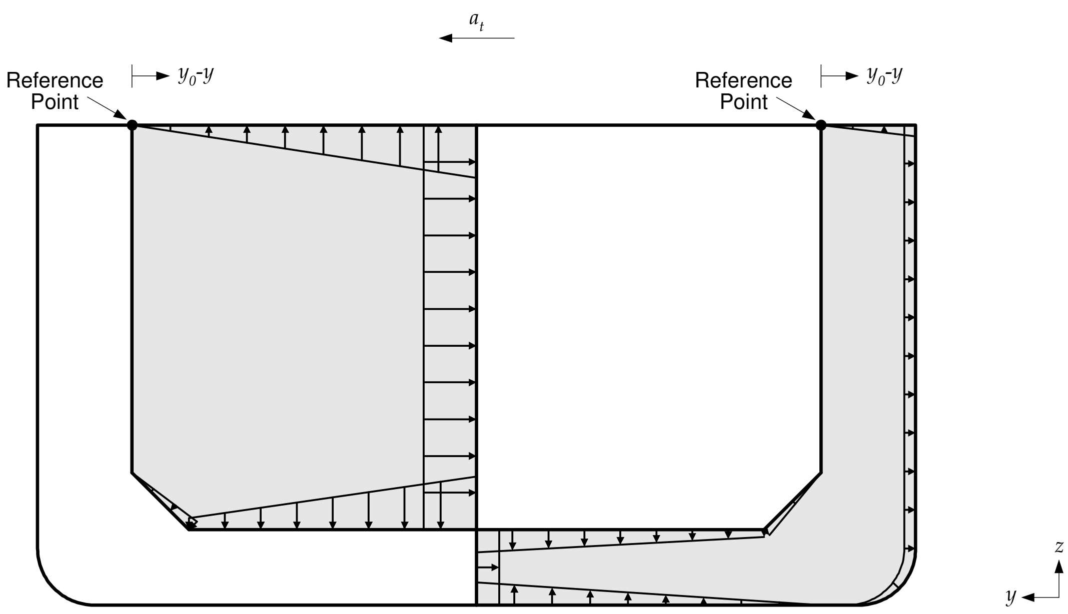
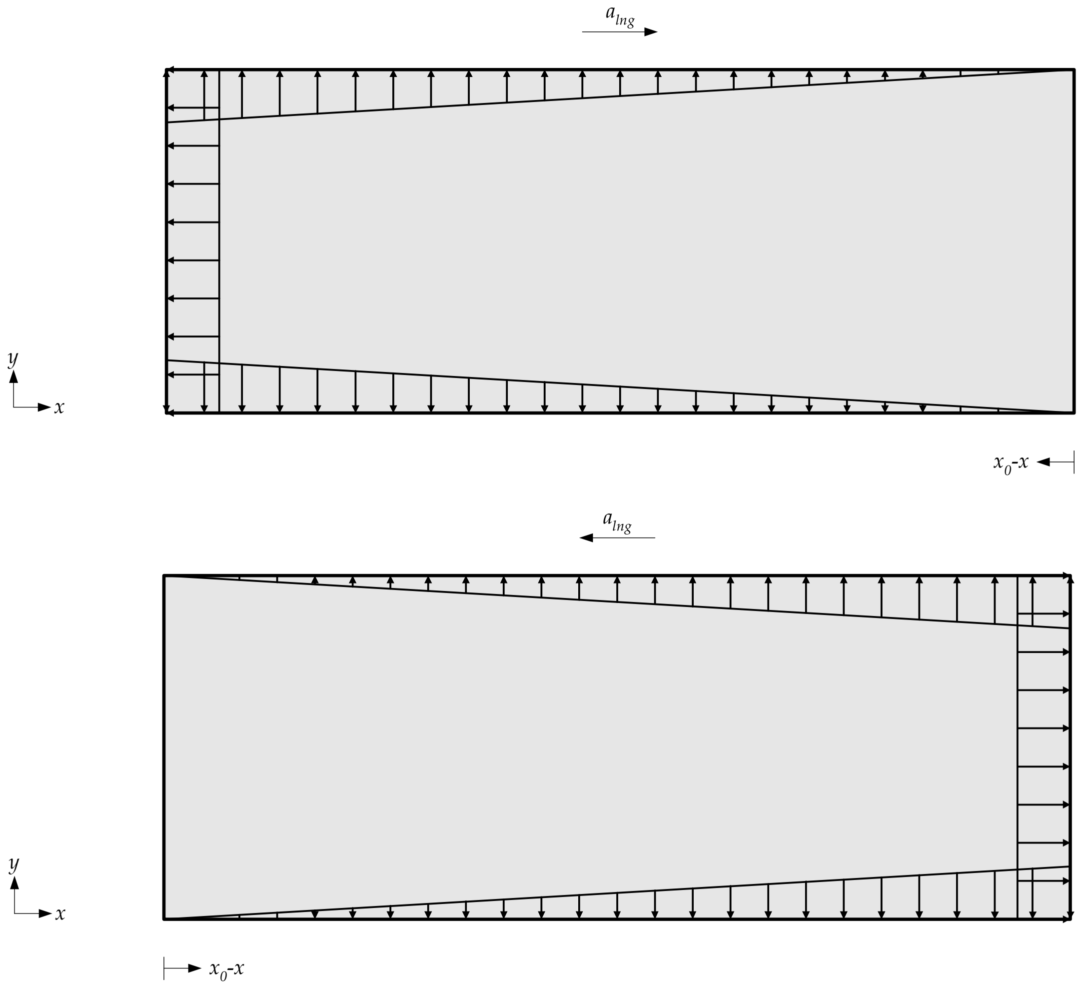


Figure 7.6.6
Dynamic Tank Pressure in Tanks due to Positive and Negative Longitudinal Acceleration



6.3.8 Dynamic deck loads for a considered dynamic load case

6.3.8.1 The simultaneously acting dynamic deck load for uniformly distributed load, $P_{dk\text{-}dyn}$, on the enclosed upper deck, where a forecastle or poop is fitted, and also on all lower decks, is to be taken as:

$$P_{dk-dyn} = f_\beta f_{v-mid} P_{deck-dyn} \quad \text{kN/m}^2$$

Where:

$P_{deck\text{-}dyn}$ envelope dynamic deck pressure on decks, inner bottom and hatch covers, in kN/m^2, as defined in *3.5.5.1*

$f_{v\text{-}mid}$ dynamic load combination factor for vertical acceleration for considered dynamic load case, see *6.3.1.2*

f_β heading correction factor, as defined in 6.3.1.1

6.3.8.2 The simultaneously acting dynamic vertical force for heavy units, $F_{dk\text{-}dyn}$, acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, is to be taken as:

$$F_{dk-dyn} = f_\beta f_{v-mid} F_v \quad \text{kN}$$

Where:

F_v envelope vertical dynamic load from heavy units, in kN, as defined in *3.5.6*

f_{v-mid} dynamic load combination factor for vertical acceleration for the considered dynamic load case, see *Table 7.6.2* and *Table 7.6.4* to *7.6.9*

f_β heading correction factor, as defined in *6.3.1.1*

6.4 Dynamic Load Cases and Dynamic Load Combination Factors for Strength Assessment

6.4.1 General

6.4.1.1 For strength assessment (FEM) the dynamic load cases given in *Table 7.6.2* are to be applied in accordance with the requirements of *Appendix B* for Design Load Combination *S + D*. The simultaneously acting dynamic load cases are to be derived using the dynamic load combination factors given in *Table 7.6.2*.

Table 7.6.2
Dynamic Load Cases for Strength Assessment (by FEM)

Wave direction			Head sea				Beam sea		Oblique sea	
Max response			M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Sagging)	Q_{wv} (Hogging)	a_v		M_{wv-h} (Hogging)	
Dynamic Load Case			**1**	**2**	**3**	**4**	**5a**	**5b**	**6a**	**6b**
Global loads	M_{wv}	f_{mv}	-1.0	1.0	-1.0	1.0	0.0	0.0	0.4	0.4
	Q_{wv}	f_{qv}	1.0	-1.0	1.0	-1.0	0.0	0.0	0.0	0.0
	M_{wv-h}	f_{mh}	0.0	0.0	0.0	0.0	0.0	0.0	1.0	-1.0
Accelerations	a_v	f_v	0.5	-0.5	0.3	-0.3	1.0	1.0	-0.1	-0.1
	a_t	f_t	0.0	0.0	0.0	0.0	-0.6	0.6	0.0	0.0
	a_{lng}	f_{lng}	-0.6	0.6	-0.6	0.6	-0.5	-0.5	0.5	0.5
Dynamic wave pressure for port side	P_{WL}	f_{WL}	-0.3	0.3	0.1	-0.1	1.0	0.4	0.6	0.0
	P_{bilge}	f_{bilge}	-0.3	0.3	0.1	-0.1	1.0	0.4	0.4	0.0
	P_{ctr}	f_{ctr}	-0.7	0.7	0.3	-0.3	0.9	0.9	0.5	0.5
Dynamic wave pressure for starboard side	P_{WL}	f_{WL}	-0.3	0.3	0.1	-0.1	0.4	1.0	0.0	0.6
	P_{bilge}	f_{bilge}	-0.3	0.3	0.1	-0.1	0.4	1.0	0.0	0.4
	P_{ctr}	f_{ctr}	-0.7	0.7	0.3	-0.3	0.9	0.9	0.5	0.5

Where:

Symbols are as defined in *3.3*, *6.3.5.1*, *Table 7.6.1* and below:

f_{v-mid} dynamic load combination factor associated with the vertical acceleration of a centre cargo and ballast tank

f_{v-pt} dynamic load combination factor associated with the vertical acceleration of a port cargo and side ballast tank

f_{v-stb} dynamic load combination factor associated with the vertical acceleration of a starboard cargo and side ballast tank

Note:

1. Load parameters and locations to be used for the calculations are to be taken as specified in *Appendix B/2.4.1*

6.5 Dynamic Load Cases and Dynamic Load Combination for Scantling Requirements

6.5.1 General

6.5.1.1 For the scantling requirements the dynamic load cases are to be applied in accordance with the design load sets given in *Table 8.2.7* through *Table 8.2.9* for the design load combination $S + D$. The simultaneously acting dynamic load cases are to be derived using the dynamic load combination factors given in *Table 7.6.4* to *Table 7.6.9*.

6.5.1.2 The Dynamic Load Combination Factor (DLCF) table to be used depends on the longitudinal position being considered and is specified in *Figure 7.6.7* and *Table 7.6.3*.

6.5.1.3 Each dynamic load case in the DLCF tables maximises one or more dynamic load components. The minimised dynamic load components are to be calculated by multiplying all the dynamic load combination factors for a dynamic load case by -1.0. The scantling requirements are to be evaluated for all maximised and minimised dynamic load cases.

6.5.1.4 Load parameters to be used for the calculations are to be taken as specified in *Table 8.2.8* and *Table 8.2.9*.

Figure 7.6.7
Illustration of Structural Regions

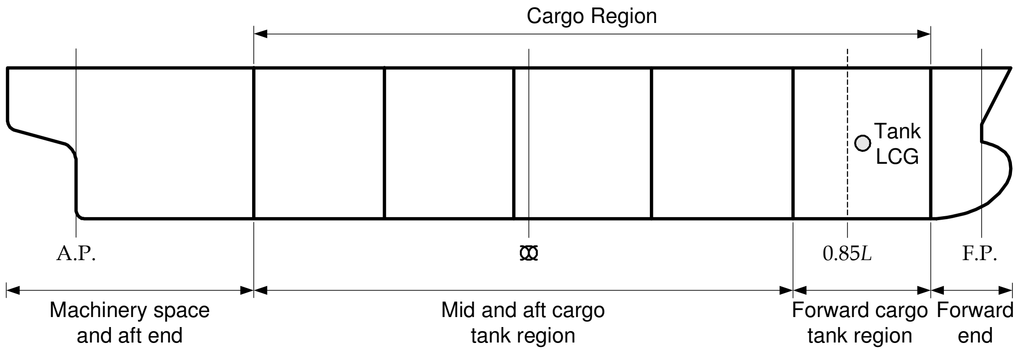


Table 7.6.3
Dynamic Load Combination Factor Tables used for Structural Region and Loading Condition

Structural region	Machinery Space and Aft End	Mid and aft cargo tank region	Forward cargo tank region	Forward end
Applicable for tanks and spaces	aft of aftmost cargo tank	where the tank LCG is aft of 0.85L	where the tank LCG is at or forward of 0.85L	forward of foremost bulkhead
Loaded DLCF	*Table 7.6.8*	*Table 7.6.4*	*Table 7.6.6*	*Table 7.6.8*
Ballast DLCF	*Table 7.6.9*	*Table 7.6.5*	*Table 7.6.7*	*Table 7.6.9*

Table 7.6.4
Dynamic Load Cases for Mid and Aft Cargo Tank Region for Loaded Condition

Wave direction			Head Sea			Oblique Sea		Beam Sea					
Max response			M_{wv}	a_v	a_{lng}	M_{wv-h}		a_t		P_{ctr}		P_{WL}	
Dynamic Load Case			**1**	**2**	**3**	**4a**	**4b**	**5a**	**5b**	**6a**	**6b**	**7a**	**7b**
Global loads	M_{wv}	f_{mv}	1.0	-1.0	0.5	-0.2	-0.2	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3
	M_{wv-h}	f_{mh}	0.0	0.0	0.0	1.0	-1.0	-0.1	0.1	0.0	0.0	0.0	0.0
Accelerations	a_{v-mid}	f_{v-mid}	-0.2	0.5	-0.4	-0.1	-0.1	0.5	0.5	1.0	1.0	1.0	1.0
	a_{v-pt}	f_{v-pt}	-0.2	0.5	-0.4	-0.1	-0.1	0.2	0.6	0.8	1.0	0.8	1.0
	a_{v-stb}	f_{v-stb}	-0.2	0.5	-0.4	-0.1	-0.1	0.6	0.2	1.0	0.8	1.0	0.8
	a_t	f_t	0.0	0.0	0.0	0.0	0.0	1.0	-1.0	0.5	-0.5	0.6	-0.6
	$a_{lng-mid}$	$f_{lng-mid}$	0.3	-0.6	1.0	-0.3	-0.3	-0.1	-0.1	-0.5	-0.5	-0.6	-0.6
	a_{lng-pt}	f_{lng-pt}	0.3	-0.6	1.0	-0.4	-0.2	-0.1	-0.1	-0.5	-0.5	-0.6	-0.6
	$a_{lng-stb}$	$f_{lng-stb}$	0.3	-0.6	1.0	-0.2	-0.4	-0.1	-0.1	-0.5	-0.5	-0.6	-0.6
	$a_{lng-ctr}$	$f_{lng-ctr}$	0.3	-0.6	1.0	-0.3	-0.3	-0.1	-0.1	-0.5	-0.5	-0.6	-0.6
Dynamic wave pressure for starboard side	P_{ctr}	f_{ctr}	0.7	-0.6	0.2	-0.3	-0.3	0.5	0.5	1.0	1.0	0.9	0.9
	P_{bilge}	f_{bilge}	0.3	-0.2	0.1	-0.4	-0.1	0.8	-0.3	0.9	0.4	1.0	0.4
	P_{WL}	f_{WL}	0.3	-0.3	0.1	-0.6	-0.1	0.5	-0.2	0.8	0.4	1.0	0.4
Dynamic wave pressure for port side	P_{ctr}	f_{ctr}	0.7	-0.6	0.2	-0.3	-0.3	0.5	0.5	1.0	1.0	0.9	0.9
	P_{bilge}	f_{bilge}	0.3	-0.2	0.1	-0.1	-0.4	-0.3	0.8	0.4	0.9	0.4	1.0
	P_{WL}	f_{WL}	0.3	-0.3	0.1	-0.1	-0.6	-0.2	0.5	0.4	0.8	0.4	1.0

Where: Symbols are as defined in *3.3*, *3.4.2*, *6.3.5.1* and *Table 7.6.1* and *Table 7.6.2* and below:

- a_{v-pt} vertical acceleration for port tank, in m/s²
- a_{v-stb} vertical acceleration for starboard tank, in m/s²
- $a_{lng-mid}$ longitudinal acceleration for centre tank, in m/s²
- a_{lng-pt} longitudinal acceleration for port tank, in m/s²
- $a_{lng-stb}$ longitudinal acceleration for starboard tank, in m/s²
- $a_{lng-ctr}$ longitudinal acceleration for centre double bottom ballast tank, in m/s²
- f_{lng-pt} dynamic load combination factor associated with the longitudinal acceleration of a port side cargo or ballast tank
- $f_{lng-stb}$ dynamic load combination factor associated with the longitudinal acceleration of a starboard side cargo or ballast tank
- $f_{lng-ctr}$ dynamic load combination factor associated with the longitudinal acceleration of a centre double bottom ballast tank
- $f_{lng-mid}$ dynamic load combination factor associated with the longitudinal acceleration of a centre tank

Table 7.6.5
Dynamic Load Cases for Mid and Aft Cargo Tank Region for Ballast Condition

Wave direction			Head Sea			Oblique Sea		Beam Sea					
Max response			M_{wv}	a_v	a_{lng}	M_{wv-h}		a_t		P_{ctr}		P_{WL}	
Dynamic Load Case			**1**	**2**	**3**	**4a**	**4b**	**5a**	**5b**	**6a**	**6b**	**7a**	**7b**
Global loads	M_{wv}	f_{mv}	1.0	-1.0	0.4	-0.4	-0.4	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2
	M_{wv-h}	f_{mh}	0.0	0.0	0.0	1.0	-1.0	0.1	-0.1	-0.1	0.1	-0.2	0.2
Accelerations	a_{v-mid}	f_{v-mid}	-0.1	0.4	-0.2	0.1	0.1	0.5	0.5	1.0	1.0	1.0	1.0
	a_{v-pt}	f_{v-pt}	-0.1	0.4	-0.2	0.1	0.1	0.1	0.8	0.7	1.0	0.6	1.0
	a_{v-stb}	f_{v-stb}	-0.1	0.4	-0.2	0.1	0.1	0.8	0.1	1.0	0.7	1.0	0.6
	a_t	f_t	0.0	0.0	0.0	0.0	0.0	1.0	-1.0	0.8	-0.8	0.6	-0.6
	$a_{lng-mid}$	$f_{lng-mid}$	0.2	-0.1	1.0	-0.6	-0.6	0.0	0.0	-0.2	-0.2	-0.1	-0.1
	a_{lng-pt}	f_{lng-pt}	0.2	-0.1	1.0	-0.6	-0.4	0.0	0.0	-0.2	-0.2	-0.1	-0.1
	$a_{lng-stb}$	$f_{lng-stb}$	0.2	-0.1	1.0	-0.4	-0.6	0.0	0.0	-0.2	-0.2	-0.1	-0.1
	$a_{lng-ctr}$	$f_{lng-ctr}$	0.2	-0.1	1.0	-0.4	-0.4	0.0	0.0	-0.2	-0.2	-0.1	-0.1
Dynamic wave pressure for starboard side	P_{ctr}	f_{ctr}	1.0	-0.8	0.3	-0.5	-0.5	0.3	0.3	0.8	0.8	0.4	0.4
	P_{bilge}	f_{bilge}	0.3	-0.2	0.1	-0.4	0.0	0.9	-0.4	0.9	0.3	0.9	0.2
	P_{WL}	f_{WL}	0.3	-0.2	0.1	-0.6	0.0	0.7	-0.4	0.9	0.2	1.0	0.2
Dynamic wave pressure for port side	P_{ctr}	f_{ctr}	1.0	-0.8	0.3	-0.5	-0.5	0.3	0.3	0.8	0.8	0.4	0.4
	P_{bilge}	f_{bilge}	0.3	-0.2	0.1	0.0	-0.4	-0.4	0.9	0.3	0.9	0.2	0.9
	P_{WL}	f_{WL}	0.3	-0.2	0.1	0.0	-0.6	-0.4	0.7	0.2	0.9	0.2	1.0

Where:

Symbols are as defined in *3.3*, *3.4.2*, *6.3.5.1* and *Table 7.6.1*, *Table 7.6.2* and *Table 7.6.4*

Table 7.6.6
Dynamic Load Cases for Forward Cargo Tank Region for Loaded Condition

Wave direction			Head Sea		Oblique Sea										Beam			
Max response			a_v	a_{lng}	a_{lng}		P_{ctr}		P_{bilge}		P_{WL}		a_v		a_t	
Dynamic Load Case			1	2	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b	8a	8b
Global loads	M_{wv}	f_{mv}	-0.7	0.9	0.3	0.3	-0.6	-0.6	-0.3	-0.3	-0.4	-0.4	-0.4	-0.4	-0.1	-0.1
	M_{wv-h}	f_{mh}	0.0	0.0	-0.2	0.2	0.2	-0.2	-0.1	0.1	0.2	-0.2	-0.1	0.1	-0.5	0.5
Accelerations	a_{v-mid}	f_{v-mid}	0.7	-0.6	-0.6	-0.6	0.7	0.7	0.9	0.9	0.7	0.7	1.0	1.0	0.4	0.4
	a_{v-pt}	f_{v-pt}	0.7	-0.6	-0.6	-0.6	0.7	0.7	0.9	1.0	0.7	0.7	0.9	1.0	0.3	0.6
	a_{v-stb}	f_{v-stb}	0.7	-0.6	-0.6	-0.6	0.7	0.7	1.0	0.9	0.7	0.7	1.0	0.9	0.6	0.3
	a_t	f_t	0.0	0.0	-0.4	0.4	0.1	-0.1	0.7	-0.7	0.5	-0.5	0.6	-0.6	1.0	-1.0
	$a_{lng-mid}$	$f_{lng-mid}$	-0.8	1.0	0.8	0.8	-1.0	-1.0	-0.5	-0.5	-1.0	-1.0	-0.5	-0.5	-0.1	-0.1
	a_{lng-pt}	f_{lng-pt}	-0.8	1.0	1.0	0.6	-1.0	-0.9	-0.5	-0.5	-1.0	-0.7	-0.5	-0.5	-0.1	-0.1
	$a_{lng-stb}$	$f_{lng-stb}$	-0.8	1.0	0.6	1.0	-0.9	-1.0	-0.5	-0.5	-0.7	-1.0	-0.5	-0.5	-0.1	-0.1
	$a_{lng-ctr}$	$f_{lng-ctr}$	-0.8	1.0	0.8	0.8	-1.0	-1.0	-0.5	-0.5	-1.0	-1.0	-0.5	-0.5	-0.1	-0.1
Dynamic wave pressure on starboard side	P_{ctr}	f_{ctr}	1.0	-0.9	-0.4	-0.4	1.0	1.0	0.8	0.8	0.5	0.5	0.8	0.8	0.4	0.4
	P_{bilge}	f_{bilge}	0.6	-0.7	-0.6	-0.2	0.9	0.6	1.0	0.5	0.7	0.3	1.0	0.5	0.8	-0.1
	P_{WL}	f_{WL}	0.3	-0.5	-0.9	-0.2	0.8	0.4	0.9	0.4	1.0	0.2	0.9	0.4	0.6	-0.2
Dynamic wave pressure on port side	P_{ctr}	f_{ctr}	1.0	-0.9	-0.4	-0.4	1.0	1.0	0.8	0.8	0.5	0.5	0.8	0.8	0.4	0.4
	P_{bilge}	f_{bilge}	0.6	-0.7	-0.2	-0.6	0.6	0.9	0.5	1.0	0.3	0.7	0.5	1.0	-0.1	0.8
	P_{WL}	f_{WL}	0.3	-0.5	-0.2	-0.9	0.4	0.8	0.4	0.9	0.2	1.0	0.4	0.9	-0.2	0.6

Where:

Symbols are as defined in *3.3*, *3.4.2*, *6.3.5.1* and *Table 7.6.1*, *Table 7.6.2* and *Table 7.6.4*

Table 7.6.7
Dynamic Load Cases for Forward Cargo Tank Region for Ballast Condition

Wave direction			Head Sea		Oblique Sea								Beam Sea			
Max response			a_v	a_{lng}	a_{lng}		P_{ctr}		P_{bilge}		P_{WL}		a_v		a_t	
Dynamic Load Case			1	2	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b	8a	8b
Global loads	M_{wv}	f_{mv}	-0.8	0.9	0.7	0.7	-1.0	-1.0	-0.2	-0.2	-0.3	-0.3	-0.1	-0.1	-0.1	-0.1
	M_{wv-h}	f_{mh}	0.0	0.0	-0.4	0.4	0.0	0.0	-0.5	0.5	0.3	-0.3	-0.4	0.4	-0.4	0.4
Accelerations	a_{v-mid}	f_{v-mid}	0.7	-0.6	-0.7	-0.7	0.4	0.4	0.6	0.6	0.9	0.9	1.0	1.0	0.4	0.4
	a_{v-pt}	f_{v-pt}	0.7	-0.6	-0.7	-0.7	0.4	0.4	0.3	0.8	0.7	0.7	0.5	1.0	0.0	0.7
	a_{v-stb}	f_{v-stb}	0.7	-0.6	-0.7	-0.7	0.4	0.4	0.8	0.3	0.7	0.7	1.0	0.5	0.7	0.0
	a_t	f_t	0.0	0.0	0.0	0.0	0.0	0.0	0.9	-0.9	0.2	-0.2	0.7	-0.7	1.0	-1.0
	$a_{lng-mid}$	$f_{lng-mid}$	-0.9	1.0	1.0	1.0	-0.6	-0.6	-0.3	-0.3	-0.9	-0.9	0.0	0.0	0.0	0.0
	a_{lng-pt}	f_{lng-pt}	-0.9	1.0	1.0	1.0	-0.6	-0.6	-0.5	0.2	-0.9	-0.6	0.0	0.0	0.0	0.0
	$a_{lng-stb}$	$f_{lng-stb}$	-0.9	1.0	1.0	1.0	-0.6	-0.6	0.2	-0.5	-0.6	-0.9	0.0	0.0	0.0	0.0
	$a_{lng-ctr}$	$f_{lng-ctr}$	-0.9	1.0	1.0	1.0	-0.6	-0.6	-0.3	-0.3	-0.9	-0.9	0.0	0.0	0.0	0.0
Dynamic wave pressure on starboard side	P_{ctr}	f_{ctr}	1.0	-0.7	-0.9	-0.9	1.0	1.0	0.6	0.6	0.6	0.6	0.4	0.4	0.2	0.2
	P_{bilge}	f_{bilge}	0.5	-0.4	-0.7	-0.3	0.6	0.6	1.0	-0.3	0.9	0.2	0.8	0.2	0.7	-0.3
	P_{WL}	f_{WL}	0.3	-0.2	-0.6	-0.1	0.4	0.4	0.9	-0.3	1.0	0.1	0.8	0.2	0.7	-0.4
Dynamic wave pressure on port side	P_{ctr}	f_{ctr}	1.0	-0.7	-0.9	-0.9	1.0	1.0	0.6	0.6	0.6	0.6	0.4	0.4	0.2	0.2
	P_{bilge}	f_{bilge}	0.5	-0.4	-0.3	-0.7	0.6	0.6	-0.3	1.0	0.2	0.9	0.2	0.8	-0.3	0.7
	P_{WL}	f_{WL}	0.3	-0.2	-0.1	-0.6	0.4	0.4	-0.3	0.9	0.1	1.0	0.2	0.8	-0.4	0.7

Where:

Symbols are as defined in 3.3, 3.4.2, 6.3.5.1 and *Table 7.6.1*, *Table 7.6.2* and *Table 7.6.4*

Table 7.6.8
Dynamic Load Cases for Spaces Outside the Cargo Tank Region for Loaded Condition

Ship location			Machinery Space and Aft End							Forward End			
Wave direction			Following Sea	Oblique Sea		Beam Sea				Beam Sea			
Max response			P_{ctr}	P_{WL}		a_v		a_t		a_v		a_t	
Dynamic Load Case			**1**	**2a**	**2b**	**3a**	**3b**	**4a**	**4b**	**5a**	**5b**	**6a**	**6b**
Global Load	M_{wv}	f_{mv}	-1.0	-0.7	-0.7	-0.4	-0.4	-0.1	-0.1	-	-	-	-
Accelerations	a_{v-mid}	f_{v-mid}	0.6	0.9	0.9	1.0	1.0	0.3	0.3	1.0	1.0	0.3	0.3
	a_{v-pt}	f_{v-pt}	0.6	-	0.9	-	1.0	-	0.4	-	1.0	-	0.3
	a_{v-stb}	f_{v-stb}	0.6	0.9	-	1.0	-	0.4	-	1.0	-	0.3	-
	a_t	f_t	0.0	0.2	-0.2	0.5	-0.5	1.0	-1.0	0.7	-0.7	1.0	-1.0
	a_{lng}	f_{lng}	0.8	0.7	0.7	0.6	0.6	-0.1	-0.1	-0.7	-0.7	-0.1	-0.1
Dynamic wave pressure on starboard side	P_{ctr}	f_{ctr}	1.0	0.8	0.8	0.7	0.7	0.2	0.2	1.0	1.0	0.2	0.2
	P_{WL}	f_{WL}	0.5	1.0	0.2	0.8	0.3	0.5	-0.3	1.0	0.8	0.2	0.0
Dynamic wave pressure on port side	P_{ctr}	f_{ctr}	1.0	0.8	0.8	0.7	0.7	0.2	0.2	1.0	1.0	0.2	0.2
	P_{WL}	f_{WL}	0.5	0.2	1.0	0.3	0.8	-0.3	0.5	0.8	1.0	0.0	0.2

Where:

Symbols are as defined in *3.3*, *6.3.5.1* and *Table 7.6.1*, *Table 7.6.2* and *Table 7.6.4*

Table 7.6.9
Dynamic Load Cases for Spaces Outside the Cargo Tank Region for Ballast Condition

Ship location			Machinery Space and Aft End							Forward End			
Wave direction			**Following Sea**	**Oblique Sea**		**Beam Sea**				**Beam Sea**			
Max response			P_{ctr}	P_{WL}		a_v		a_t		a_v		a_t	
Dynamic Load Case			**1**	**2a**	**2b**	**3a**	**3b**	**4a**	**4b**	**5a**	**5b**	**6a**	**6b**
Global Load	M_{wv}	f_{mv}	-1.0	-0.3	-0.3	0.2	0.2	0.1	0.1	-	-	-	-
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	0.6	0.9	0.9	1.0	1.0	0.3	0.3	1.0	1.0	0.3	0.3
	$a_{v\text{--}pt}$	$f_{v\text{-}pt}$	0.6	-	0.9	-	1.0	-	0.5	-	1.0	-	0.5
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	0.6	0.9	-	1.0	-	0.5	-	1.0	-	0.5	-
	a_t	f_t	0.0	0.1	-0.1	0.6	-0.6	1.0	-1.0	0.7	-0.7	1.0	-1.0
	a_{lng}	f_{lng}	0.7	0.8	0.8	0.2	0.2	0.0	0.0	-0.3	-0.3	0.0	0.0
Dynamic wave pressure on starboard side	P_{ctr}	f_{ctr}	1.0	0.7	0.7	0.5	0.5	0.1	0.1	0.6	0.6	0.1	0.1
	P_{WL}	f_{WL}	0.8	1.0	0.3	0.6	0.1	0.4	-0.3	0.7	0.3	0.3	-0.1
Dynamic wave pressure on port side	P_{ctr}	f_{ctr}	1.0	0.7	0.7	0.5	0.5	0.1	0.1	0.6	0.6	0.1	0.1
	P_{WL}	f_{WL}	0.8	0.3	1.0	0.1	0.6	-0.3	0.4	0.3	0.7	-0.1	0.3

Where:

Symbols are as defined in *3.3*, *6.3.5.1* and *Table 7.6.1*, *Table 7.6.2* and *Table 7.6.4*

Common Structural Rules for Double Hull Oil Tankers

Sections 8 to 12

July 2013

Lloyd's Register

SECTION 8

SCANTLING REQUIREMENTS

1 LONGITUDINAL STRENGTH

1.1 Loading Guidance

1.1.1 General

1.1.1.1 All ships are to be provided with loading guidance information containing sufficient information to enable the master of the ship to maintain the ship within the stipulated operational limitations. The loading guidance information is to include an approved Loading Manual and Loading Computer System complying with the requirements given in *1.1.2* and *1.1.3* respectively.

1.1.1.2 The loading guidance information is to be based on the final data of the ship.

1.1.1.3 Modifications resulting in changes to the main data of the ship (lightship weight, buoyancy distribution, tank volumes or usage, etc), require the Loading Manual to be updated and re-approved, and subsequently the Loading Computer System to be updated and re-approved. However, new loading guidance need not be re-submitted provided that the resulting draughts, still water bending moments and shear forces do not differ from the originally approved data by more than 2%.

1.1.1.4 The loading guidance is to be prepared in a language understood by the users. If this language is not English, a translation into English shall be included. When applicable a document translating the language of the input and output data for the Loading Computer System into English is to be provided.

1.1.1.5 The loading guidance information is to include the following statement, to ensure the crew are aware of the operational limitations for minimum draught forward:

The scantlings are approved for a minimum draught forward, at F.P. In sea conditions where slamming is likely to occur, the forward draught is not to be less than the following:

(a) *…m with double bottom ballast tanks No(s)... filled*, or

(b) *…m with double bottom ballast tanks No(s)… empty*

1.1.2 Loading Manual

1.1.2.1 The Loading Manual is a document that:

(a) describes the loading conditions on which the design and approval of the ship has been based for seagoing- and harbour/sheltered water operation

(b) describes the results of the calculations of still water bending moments, shear forces and where applicable, limitations due to torsional and lateral loads

(c) describes relevant operational limitations as given in *1.1.2.7.*

1.1.2.2 The following loading conditions and design loading and ballast conditions upon which the approval of the hull scantlings is based are, as a minimum, to be included in the Loading Manual:

(a) Seagoing conditions including both departure and arrival conditions

- homogeneous loading conditions including a condition at the scantling draft (homogeneous loading conditions shall not include filling of dry and clean ballast tanks at departure condition)

RCN 1 to July 2010 version (effective from 1 July 2012)

- a normal ballast condition where:
    - the ballast tanks may be full, partially full or empty. Where partially full options are exercised, the conditions in *1.1.2.5* are to be complied with

- all cargo tanks are to be empty including cargo tanks suitable for the carriage of water ballast at sea
- the propeller is to be fully immersed, and
- the trim is to be by the stern and is not to exceed 0.015L, where L is as defined in Section 4/1.1.1

- a heavy ballast condition where:
  - the draught at the forward perpendicular is not to be less than that for the normal ballast condition
  - ballast tanks in the cargo tank region or aft of the cargo tank region may be full, partially full or empty. Where the partially full options are exercised, the conditions in 1.1.2.5 are to be complied with
  - the fore peak water ballast tank is to be full. If upper and lower fore peak water ballast tanks are fitted, the lower is required to be full. The upper fore peak tank may be full, partially full or empty.
  - If upper and lower fore peak tanks are fitted and only one of them is designated as water ballast tank, the other may be empty.

  RCN 2 to July 2008 version (effective from 1 July 2010)
  - all cargo tanks are to be empty including cargo tanks suitable for the carriage of water ballast at sea
  - the propeller is to be fully immersed
  - the trim is to be by the stern and is not to exceed 0.015L, where L, is as defined in *Section 4/1.1.1*
- any specified non-uniform distribution of loading
- conditions with high density cargo including the maximum design cargo density, when applicable
- mid-voyage conditions relating to tank cleaning or other operations where these differ significantly from the ballast conditions
- conditions covering ballast water exchange procedures with the calculations of the intermediate conditions just before and just after ballasting and/or deballasting any ballast tank

Harbour/sheltered water conditions

- conditions representing typical complete loading and unloading operations
- docking condition afloat
- propeller inspection afloat condition, in which the propeller shaft centre line is at least $D_{prop}/4$ above the waterline in way of the propeller, where D_{prop} is the propeller diameter

(b) Additional design conditions

- a design ballast condition in which all segregated ballast tanks in the cargo tank region are full and all other tanks are empty including fuel oil and fresh water tanks.

Guidance Note
The design condition specified in (c) is for assessment of hull strength and is not intended for ship operation. This condition will also be covered by the *IMO 73/78 SBT* condition provided the corresponding condition in the Loading Manual only includes ballast in segregated ballast tanks in the cargo tank region.

(RCN 1, effective from 1 April 2007) (RCN 2, effective from 1 July 2008)

1.1.2.3 The calculation for the departure conditions are to be based on full tanks according to the applicable stability regulations for filling of tanks; note bunker tanks are not

to be taken less than 95% full and other consumables are to be taken at 100%

capacity. Arrival conditions are to be based on 10% of the maximum capacity of bunker, fresh water and stores.

1.1.2.4 Where the amount and disposition consumables at any intermediate stage of the voyage are considered more severe than of those described in *1.1.2.3*, calculations for such intermediate conditions are also to be submitted for approval.

1.1.2.5 Ballast loading conditions involving partially filled peak and/or other ballast tanks in any departure, arrival or intermediate condition are not permitted to be used as design loading conditions unless, for all filling levels between empty and full, the resulting stress levels are within the stress and buckling acceptance criteria. For design purposes this criteria will be satisfied if the stress levels are within the stress and buckling acceptance criteria for loading conditions with the appropriate tanks full, empty and partially filled at intended level in any departure, arrival or intermediate condition. The corresponding full, empty and partially filled tank conditions are to be considered as design conditions for calculation of the still water bending moment and shear force, but these do not need to comply with propeller immersion and trim requirements as specified in *1.1.2.2(a)*. Where multiple ballast tanks are intended to be partially filled, all combinations of full, empty or partially filled at intended levels for those tanks are to be investigated. These requirements are not applicable to ballast water exchange using the sequential method.

(RCN 2, effective from 1 July 2008)

1.1.2.6 In cargo loading conditions, the requirements for partially filled ballast tanks as specified in 1.1.2.5 are applicable to the peak ballast tanks only.

(RCN 2, effective from 1 July 2008)

1.1.2.7 The Loading Manual is to include the design basis and operational limitations upon which the approval of the hull scantlings are based. The information listed in *Table 8.1.1* is to be included in the Loading Manual.

1.1.2.8 The approval of the hull scantlings is based on the rule defined loading patterns and the loading conditions given in the Loading Manual.

Table 8.1.1
Design Parameters

Parameter
Permissible limits of still water bending moments (seagoing operation and harbour/sheltered water operation)
Permissible limits of still water shear forces (seagoing operation and harbour/sheltered water operation)
Scantling draught, T_{sc}
Design minimum ballast draught at midships, T_{bal}
Design slamming draught forward with forward double bottom ballast tanks filled, $T_{FP-full}$
Design slamming draught forward with forward double bottom ballast tanks empty, T_{FP-mt}
Maximum allowable cargo density
Maximum cargo density in any loading condition in Loading Manual
Description of the ballast exchange operations including any limitations
Design speed

1.1.2.9 The following additional loading conditions are to be included in the Loading Manual if the ship is specifically approved and intended to be operated in such conditions:

(a) sea-going ballast conditions including water ballast carried in one or more cargo tanks which are intended for use in emergency situations as allowed by MARPOL Regulation 13. (Ship approved for loading pattern A8 of *Table B.2.3* or B7 of *Table B.2.4*)

(b) seagoing loading conditions where the net static upward load on the double bottom exceeds that given with the combination of an empty cargo tank and a mean ship's draught of $0.9T_{sc}$

(c) seagoing loading conditions with cargo tanks less than 25% full with the combination of mean ship's draught greater than $0.9T_{sc}$

(d) seagoing loading conditions where the net static downward load on the double bottom exceeds that given with the combination of a full cargo tank at a cargo density of 1.025 tonnes/m^3 and a mean ship's draught of $0.6T_{sc}$

(e) for ships arranged with cross ties in the centre cargo tank , seagoing loading conditions showing a non-symmetric loading pattern where the difference in filling level between corresponding port and starboard wing cargo tanks exceeds 25% of the filling height in the wing cargo tank (Ship approved for loading pattern A7 of *Table B.2.3*)

1.1.2.10 This sub-section is not intended to prevent any other loading conditions to be included in the Loading Manual, nor is it intended to replace in any way the required Loading Manual/Instrument.

1.1.2.11 A tanker may in actual operation be loaded differently from the design loading conditions specified in the Loading Manual, provided limitations for longitudinal and local strength as defined in the Loading Manual and Loading Instrument onboard and applicable stability requirements are not exceeded.

1.1.3 Loading computer system

1.1.3.1 The loading computer system, is to be a system, which unless stated otherwise is digital and that can easily and quickly ascertain whether operational limitations are exceeded for any loading condition.

1.1.3.2 The loading computer system is to be approved based on the Rules of the individual Classification Society.

1.1.3.3 The loading computer system is to be capable of producing any specific loading condition and verify that these comply with all the operational limitations given in *1.1.2.2*, and provide plots including input and output.

1.1.3.4 If any of the operational limitations are not checked, the user is to be properly informed when using the system, and by the plots provided, so that each such item is verified by other means. The loading computer system is as a minimum to verify that the following are satisfied:

(a) draught limitations

(b) still water bending moments and shear forces are reported at the specified locations/read-out points.

1.1.3.5 The final test conditions for the loading computer are to be based on conditions given in the final Loading Manual. The test conditions are subject to approval and the shear forces and bending moments calculated by the loading computer system, at each read out point, are to be within $0.02Q_{sw\text{-}perm}$ or $0.02M_{sw\text{-}perm}$ of the results given

in the loading manual, where $Q_{sw\text{-}perm}$ and $M_{sw\text{-}perm}$ are the assigned permissible shear force and bending moment at each read out point respectively.

1.1.3.6 Before a loading computer system is accepted, all relevant aspects of the computer, including but not limited to the following, are to be demonstrated to the Surveyor:

(a) verification that the final data of the ship has been used

(b) verification that the relevant limits for all read-out points are correct

(c) that the operation of the system after installation onboard, is in accordance with the approved test conditions

(d) that the approved test conditions are available onboard

(e) that an operational manual is available onboard.

1.2 Hull Girder Bending Strength

1.2.1 General

1.2.1.1 The net vertical hull girder section modulus, $Z_{v\text{-}net50}$, is to be equal to or greater than the requirements given by *1.2.2.2* and *1.2.3.2*. The net vertical hull girder moment of inertia, $I_{v\text{-}net50}$, as defined in *Section 4/2.6.1.1* is to be equal to or greater than the requirement given by *1.2.2.1*.

1.2.1.2 Scantlings of all continuous longitudinal members of the hull girder based on moment of inertia and section modulus requirement in *1.2.2.1* and *1.2.2.2* are to be maintained within 0.4L midships.

1.2.1.3 The hull girder section modulus requirements in *1.2.3* apply along the full length of the hull girder, from A.P. to F.P.

1.2.1.4 Structural members included in the hull girder section modulus are to satisfy the buckling criteria given in *1.4*.

1.2.2 Minimum requirements

1.2.2.1 At the midship cross section the net vertical hull girder moment of inertia about the horizontal neutral axis, $I_{v\text{-}net50}$, is not to be less than the rule minimum vertical hull girder moment of inertia, $I_{v\text{-}min}$, defined as:

$$I_{v-min} = 2.7 C_{wv} L^3 B (C_b + 0.7) \cdot 10^{-8} \quad \text{m}^4$$

Where:

C_{wv} wave coefficient as defined in *Table 8.1.2*

L rule length, in m, as defined in *Section 4/1.1.1.1*

B moulded breadth, in m, as defined in *Section 4/1.1.3.1*

C_b block coefficient, as defined in *Section 4/1.1.9.1* but is not to be taken as less than 0.70

Table 8.1.2
Wave Coefficient C_{wv}

rule length	C_{wv}
$150 \le L \le 300$	$10.75 - [(300 - L) / 100]^{3/2}$
$300 < L < 350$	10.75
$350 \le L \le 500$	$10.75 - [(L - 350) / 150]^{3/2}$

1.2.2.2 At the midship cross section the net vertical hull girder section modulus, Z_{v-min}, at the deck and keel is not to be less than the rule minimum hull girder section modulus, Z_{v-min}, defined as:

$$Z_{v-min} = 0.9kC_{wv}L^2B(C_b + 0.7) \cdot 10^{-6} \quad \text{m}^3$$

Where:

k	higher strength steel factor, as defined in *Section 6/1.1.4*
C_{wv}	wave coefficient as defined in *Table 8.1.2*
L	rule length, in m, as defined in *Section 4/1.1.1.1*
B	moulded breadth, in m, as defined in *Section 4/1.1.3.1*
C_b	block coefficient, as defined in *Section 4/1.1.9.1* but is not to be taken as less than 0.70 *RCN 1 to July 2010 version (effective from 1 July 2012)*

1.2.2.3 The net hull girder section modulus at keel, $Z_{v-net50-kl}$, is to be calculated in accordance with *Section 4/2.6.1.2* and taking z at the keel.

1.2.2.4 The net hull girder section modulus at deck, $Z_{v-net50-dk}$, is to be calculated in accordance with *Section 4/2.6.1.2* and taking z at the effective deck height, see *1.2.2.5*.

1.2.2.5 The effective deck height from the horizontal neutral axis for the hull girder section modulus, z_{dk-eff}, is to be taken as:

$$z_{dk-eff} = z_{dk-side} - z_{NA-net50} \quad \text{m}$$

When no effective longitudinal strength members are positioned above a line extending from moulded deck line at side to a position $(z_{dk-side} - z_{NA-net50})/0.9$ from the neutral axis at the centreline

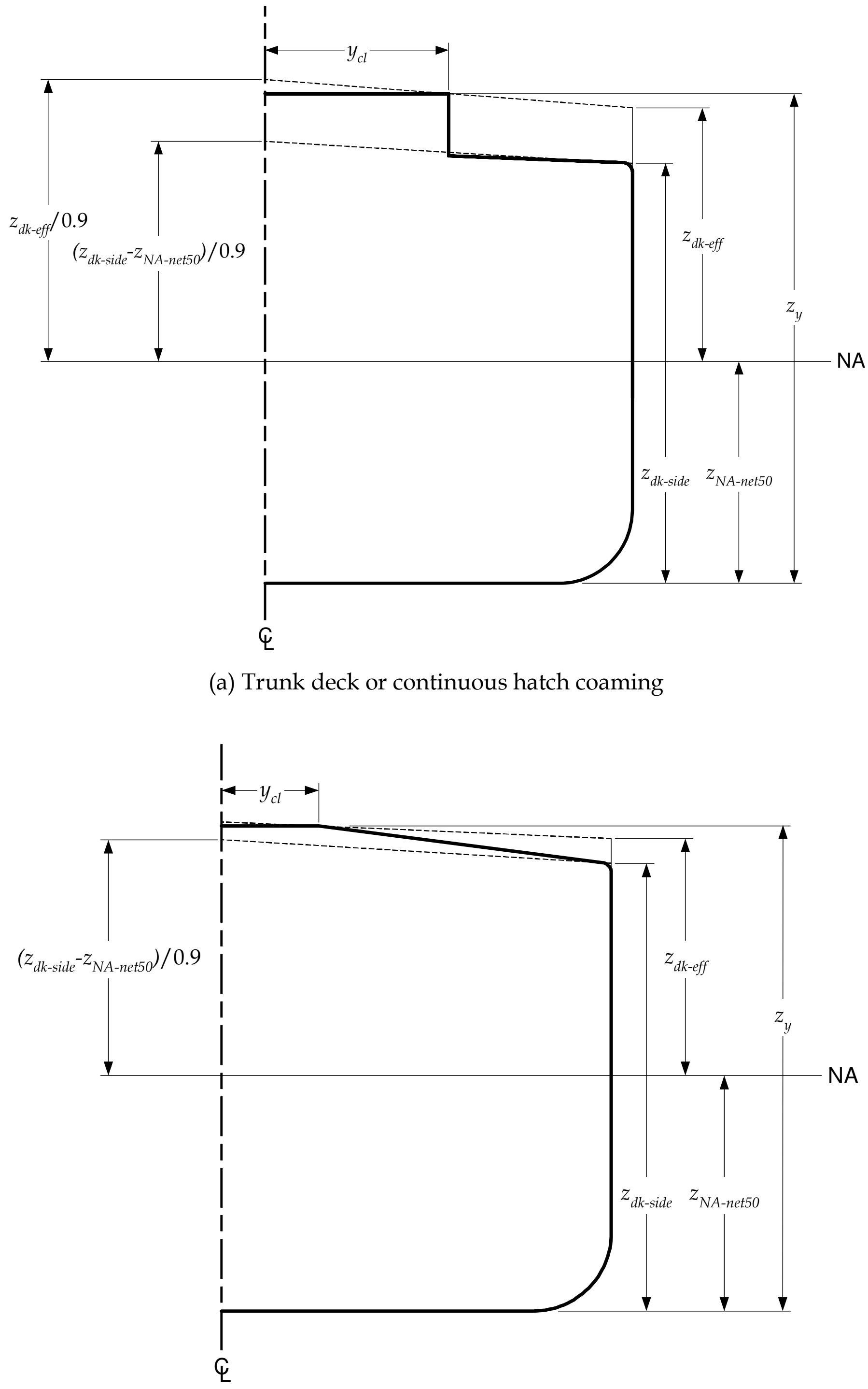
$$z_{dk-eff} = (z_y - z_{NA-net50})\left(0.9 + 0.2\frac{y_{cl}}{B}\right) \quad \text{m}$$

When any effective longitudinal strength members are positioned above a line extending from moulded deck line at side to a position $(z_{dk-side} - z_{NA-net50})/0.9$ from the neutral axis at the centreline

Where:

z_y	distance from the baseline to top of the continuous strength member at a distance y from the centreline, in m, giving the largest value of z_{dk-eff}, see *Figure 8.1.1*
$z_{NA-net50}$	distance from baseline to horizontal neutral axis, in m, see *Figure 8.1.1*
y_{cl}	distance from the top of the continuous strength member to the centreline of the ship, in m, giving the largest value of z_{dk-eff}, see *Figure 8.1.1*
B	moulded breadth, in m, as defined in *Section 4/1.1.3.1*
$z_{dk-side}$	distance from the baseline to the moulded deck line at side, in m, see *Figure 8.1.1*

Figure 8.1.1
Position for Calculation of Section Modulus Deck



(a) Trunk deck or continuous hatch coaming

(b) Ship with large camber

1.2.3 Hull girder requirement on total design bending moment

1.2.3.1 The net vertical hull girder section modulus requirement as defined in *1.2.3.2* is to be assessed for both hogging and sagging conditions.

1.2.3.2 The net hull girder section modulus about the horizontal neutral axis, $Z_{v\text{-}net50}$, is not to be less than the rule required hull girder section modulus, $Z_{v\text{-}req}$, based on the

permissible still-water bending moment and design wave bending moment defined as:

$$Z_{v-req} = \frac{\left|M_{sw-perm} + M_{wv-v}\right|}{\sigma_{perm}} 10^{-3} \quad \text{m}^3$$

Where:

$M_{sw-perm}$ permissible hull girder hogging or sagging still water bending moment as given in *Table 8.1.3*, in kNm

M_{wv-v} hogging or sagging vertical wave bending moment, in kNm as given in *Table 8.1.3*

σ_{perm} permissible hull girder bending stress as given in *Table 8.1.3*, in N/mm^2

Table 8.1.3
Loads and Corresponding Acceptance Criteria for Hull Girder Bending Assessment

Design load combination	**Still water bending moment, $M_{sw-perm}$**	**Wave bending moment, M_{wv-v}**	**Permissible hull girder bending stress, σ_{perm} (1)**	
(S)	$M_{sw-perm-harb}$	0	$143/k$	within $0.4L$ amidships
			$105/k$	at and forward of $0.9L$ from A.P. and at and aft of $0.1L$ from A.P.
(S + D)	$M_{sw-perm-sea}$	M_{wv-v}	$190/k$	within $0.4L$ amidships
			$140/k$	at and forward of $0.9L$ from A.P. and at and aft of $0.1L$ from A.P

Where:

$M_{sw-perm-harb}$ permissible hull girder hogging and sagging still water bending moment for harbour/sheltered water operation, in kNm, as defined in *Section 7/2.1.1*

$M_{sw-perm-sea}$ permissible hull girder hogging and sagging still water bending moment for seagoing operation, in kNm, as defined in *Section 7/2.1.1*

M_{wv-v} hogging and sagging vertical wave bending moments, in kNm, as defined in *Section 7/3.4.1*

M_{wv-v} is to be taken as:

M_{wv-hog} for assessment with respect to hogging vertical wave bending moment

M_{wv-sag} for assessment with respect to sagging vertical wave bending moment

k higher strength steel factor, as defined in *Section 6/1.1.4*

Note

1. σ_{perm} is to be linearly interpolated between values given.

1.3 Hull Girder Shear Strength

1.3.1 General

1.3.1.1 The hull girder shear strength requirements apply along the full length of the hull girder, from A.P to F.P.

1.3.2 Assessment of hull girder shear strength

1.3.2.1 The net hull girder shear strength capacity, $Q_{v-net50}$, as defined in *1.3.2.2* is not to be less than the required vertical shear force, Q_{v-req}, as indicated in the following:

$$Q_{v-req} = Q_{sw-perm} + Q_{wv} \quad \text{kN}$$

Where:

$Q_{sw-perm}$ permissible hull girder positive or negative still water shear force as given in *Section 7/2.1.3,* in kN

Q_{wv} vertical wave positive or negative shear force as defined in *Section 7/3.4.3,* in kN

1.3.2.2 The permissible positive and negative still water shear forces for seagoing and harbour/sheltered water operations, $Q_{sw-perm-sea}$ and $Q_{sw-perm-harb}$ are to satisfy:

$$Q_{sw-perm} \leq Q_{v-net50} - Q_{wv-pos} \quad \text{kN}$$

for maximum permissible positive shear force

$$Q_{sw-perm} \geq -Q_{v-net50} - Q_{wv-neg} \quad \text{kN}$$

for minimum permissible negative shear force

Where:

$Q_{sw-perm}$ permissible hull girder still water shear force as given in *Table 8.1.4,* in kN

$Q_{v-net50}$ net hull girder vertical shear strength to be taken as the minimum for all plate elements that contribute to the hull girder shear capacity

$$= \frac{\tau_{ij-perm} t_{ij-net50}}{1000 q_v} \quad \text{kN}$$

$\tau_{ij-perm}$ permissible hull girder shear stress, τ_{perm}, as given in *Table 8.1.4*, in N/mm^2 , for plate *ij*

Q_{wv-pos} positive vertical wave shear force, in kN, as defined in *Table 8.1.4*

Q_{wv-neg} negative vertical wave shear force, in kN, as defined in *Table 8.1.4*

$t_{ij-net50}$ equivalent net thickness, t_{net50}, for plate ij, in mm. For longitudinal bulkheads between cargo tanks, t_{net50} is to be taken as $t_{sfc-net50}$ and t_{str-k} as appropriate, see *1.3.3.1* and *1.3.4.1*

t_{net50} net thickness of plate, in mm

$$= t_{grs} - 0.5 t_{corr}$$

t_{grs} gross plate thickness, in mm. The gross plate thickness for corrugated bulkheads is to be taken as the minimum of t_{w-grs} and t_{f-grs}, in mm

t_{w-grs} gross thickness of the corrugation web, in mm

$t_{f\text{-}grs}$	gross thickness of the corrugation flange, in mm
t_{corr}	corrosion addition, in mm, as defined in *Section 6/3.2*
q_v	unit shear flow per mm for the plate being considered and based on the net scantlings. Where direct calculation of the unit shear flow is not available, the unit shear flow may be taken equal to:

$$= f_i \left(\frac{q_{1-net50}}{I_{v-net50}} \right) \cdot 10^{-9} \qquad mm^{-1}$$

f_i	shear force distribution factor for the main longitudinal hull girder shear carrying members being considered. For standard structural configurations f_i is as defined in *Figure 8.1.2*
$q_{1\text{-}net50}$	first moment of area, in cm^3 ,about the horizontal neutral axis of the effective longitudinal members between the vertical level at which the shear stress is being determined and the vertical extremity, taken at the section being considered. The first moment of area is to be based on the net thickness, t_{net50} *RCN 1 to July 2010 version (effective from 1 July 2012)*
$I_{v\text{-}net50}$	net vertical hull girder section moment of inertia, in m^4, as defined in *Section 4/2.6.1.1*

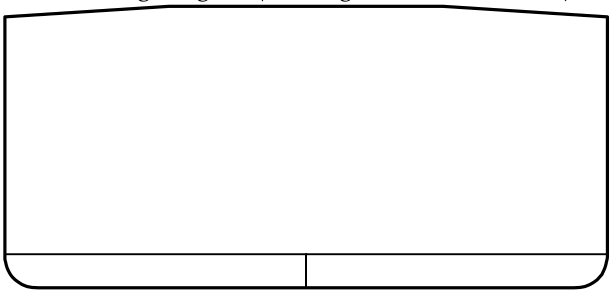
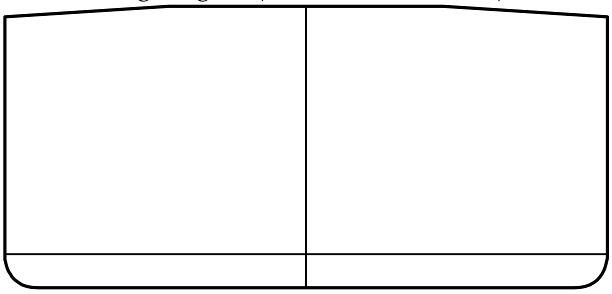
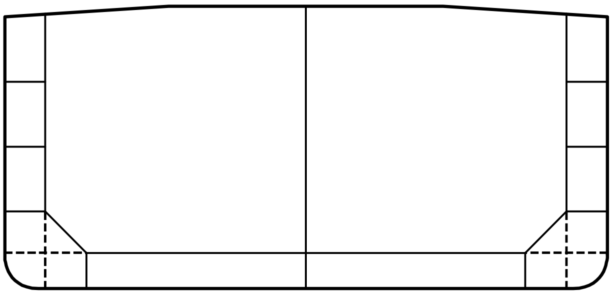
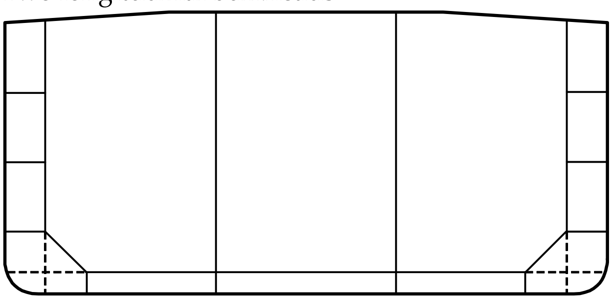
Table 8.1.4
Loads and Corresponding Acceptance Criteria for Hull Girder Shear Assessment

Design load combination	Still water shear force, $Q_{sw\text{-}perm}$	Vertical wave shear force, Q_{wv}	Permissible shear stress, τ_{perm}
Harbour/sheltered water operations (S)	$Q_{sw\text{-}perm\text{-}harb}$	0	105/k for plate ij
Seagoing operations (S + D)	$Q_{sw\text{-}perm\text{-}sea}$	Q_{wv}	120/k for plate ij

Where:

$Q_{sw\text{-}perm\text{-}harb}$	permissible positive or negative hull girder still water shear force for harbour operation, in kN, as defined in *Section 7/2.1.3*
$Q_{sw\text{-}perm\text{-}sea}$	permissible positive or negative hull girder still water shear force for seagoing operation, in kN, as defined in *Section 7/2.1.3*
Q_{wv}	positive or negative vertical wave shear, in kN, as defined in *Section 7/3.4.3*. Q_{vw} is to be taken as: $Q_{wv\text{-}pos}$ for assessment with respect to maximum positive permissible still water shear force $Q_{wv\text{-}neg}$ for assessment with respect to minimum negative permissible still water shear force
plate ij	for each plate j, index i denotes the structural member of which the plate forms a component
k	higher strength steel factor, as defined in *Section 6/1.1.4*

Figure 8.1.2
Shear Force Distribution Factors

Hull configuration	f_i **factors**
Outside cargo region (no longitudinal bulkhead) 	Side shell $f_1 = 0.5$
Outside cargo region (centreline bulkhead) 	Side shell $f_1 = 0.231 + 0.076 \frac{A_{1-net50}}{A_{3-net50}}$ Longitudinal bulkhead $f_3 = 0.538 - 0.152 \frac{A_{1-net50}}{A_{3-net50}}$
One centreline bulkhead 	Side shell $f_1 = 0.055 + 0.097 \frac{A_{1-net50}}{A_{2-net50}} + 0.020 \frac{A_{2-net50}}{A_{3-net50}}$ Inner hull $f_2 = 0.193 - 0.059 \frac{A_{1-net50}}{A_{2-net50}} + 0.058 \frac{A_{2-net50}}{A_{3-net50}}$ Longitudinal bulkhead $f_3 = 0.504 - 0.076 \frac{A_{1-net50}}{A_{2-net50}} - 0.156 \frac{A_{2-net50}}{A_{3-net50}}$
Two longitudinal bulkheads 	Side shell $f_1 = 0.028 + 0.087 \frac{A_{1-net50}}{A_{2-net50}} + 0.023 \frac{A_{2-net50}}{A_{3-net50}}$ Inner hull $f_2 = 0.119 - 0.038 \frac{A_{1-net50}}{A_{2-net50}} + 0.072 \frac{A_{2-net50}}{A_{3-net50}}$ Longitudinal bulkhead $f_3 = 0.353 - 0.049 \frac{A_{1-net50}}{A_{2-net50}} - 0.095 \frac{A_{2-net50}}{A_{3-net50}}$

Where:

i index for the structural member under consideration:
- 1, for the side shell
- 2, for the inner hull
- 3, for the longitudinal bulkhead

$A_{i-net50}$ net area as defined in *Section 4/2.6.4* and based on deduction of $0.5t_{corr}$, of the structural member, *i*, at one side of the section under consideration. The area $A_{3-net50}$ for the centreline bulkhead is not to be reduced for symmetry around the centreline.

1.3.3 Shear force correction for longitudinal bulkheads between cargo tanks

1.3.3.1 For longitudinal bulkheads between cargo tanks the effective net plating thickness of the plating above the inner bottom, $t_{sfc\text{-}net50}$ for plate *ij*, used for calculation of hull girder shear strength, $Q_{v\text{-}net50}$, is to be corrected for local shear distribution and is given by:

$$t_{sfc-net50} = t_{grs} - 0.5t_{corr} - t_{\Delta} \quad \text{mm}$$

Where:

t_{grs} gross plate thickness, in mm

t_{corr} corrosion addition, in mm, as defined in *Section 6/3.2*

t_{Δ} thickness deduction for plate *ij*, in mm, as defined in *1.3.3.2*

1.3.3.2 The vertical distribution of thickness reduction for shear force correction is assumed to be triangular as indicated in *Figure 8.1.3.* The thickness deduction, t_{Δ}, to account for shear force correction is to be taken as:

$$t_{\Delta} = \frac{\delta Q_3}{h_{blk}\tau_{ij-perm}}\left(1 - \frac{x_{blk}}{0.5l_{tk}}\right)\left(2 - \frac{2(z_p - h_{db})}{h_{blk}}\right) \quad \text{mm}$$

Where:

δQ_3 shear force correction for longitudinal bulkhead as defined in *1.3.3.3* and *1.3.3.5* for ships with one or two longitudinal bulkheads respectively, in kN.

l_{tk} length of cargo tank, in m

h_{blk} height of longitudinal bulkhead, in m, defined as the distance from inner bottom to the deck at the top of the bulkhead, as shown in *Figure 8.1.3*

x_{blk} the minimum longitudinal distance from section considered to the nearest cargo tank transverse bulkhead, in m. To be taken positive and not greater than $0.5l_{tk}$

z_p the vertical distance from the lower edge of plate *ij* to the base line, in m. Not to be taken as less than h_{db}

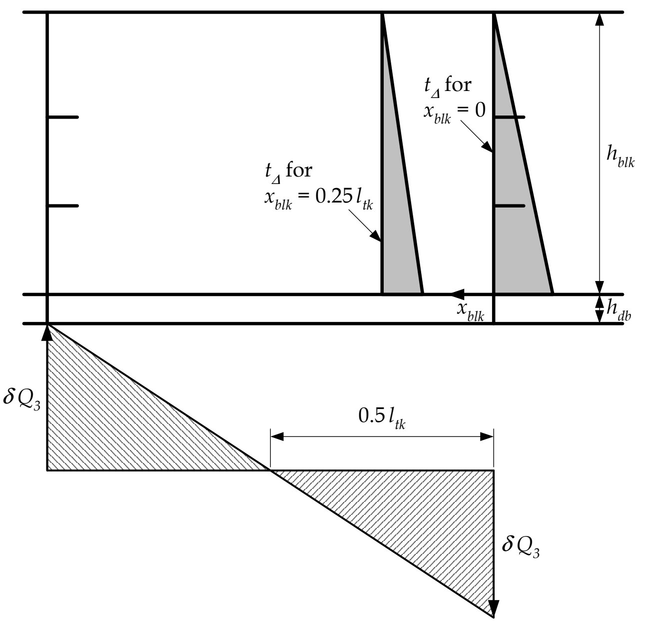
h_{db} height of double bottom, in m, as shown in *Figure 8.1.3*

$\tau_{ij-perm}$ permissible hull girder shear stress, τ_{perm}, in N/mm^2 for plate *ij*

$= 120/k_{ij}$

k_{ij} higher strength steel factor, *k*, for plate *ij* as defined in *Section 6/1.1.4*

Figure 8.1.3
Shear Force Correction for Longitudinal Bulkheads



1.3.3.3 For ships with a centreline bulkhead between the cargo tanks, the shear force correction in way of transverse bulkhead, δQ_3, is to be taken as:

$$\delta Q_3 = 0.5 K_3 F_{db} \quad \text{kN}$$

Where:

K_3 correction factor, as defined in *1.3.3.4*

F_{db} maximum resulting force on the double bottom in a tank, in kN, as defined in *1.3.3.7*

1.3.3.4 For ships with a centreline bulkhead between the cargo tanks, the correction factor, K_3, in way of transverse bulkheads is to be taken as:

$$K_3 = \left[0.40\left(1 - \frac{1}{1+n}\right) - f_3\right]$$

Where:

n number of floors between transverse bulkheads

f_3 shear force distribution factor, see *Figure 8.1.2*

1.3.3.5 For ships with two longitudinal bulkheads between the cargo tanks, the shear force correction, δQ_3, is to be taken as:

$$\delta Q_3 = 0.5 K_3 F_{db} \quad \text{kN}$$

Where:

K_3 correction factor, as defined in *1.3.3.6*

F_{db} maximum resulting force on the double bottom in a tank, in kN, as defined in *1.3.3.7*

1.3.3.6 For ships with two longitudinal bulkheads between the cargo tanks, the correction factor, K_3, in way of transverse bulkhead is to be taken as:

$$K_3 = \left[0.5\left(1 - \frac{1}{1+n}\right)\left(\frac{1}{r+1}\right) - f_3 \right]$$

Where:

n number of floors between transverse bulkheads

r ratio of the part load carried by the wash bulkheads and floors from longitudinal bulkhead to the double side and is given by:

$$r = \frac{1}{\left[\frac{A_{3-net50}}{A_{1-net50} + A_{2-net50}} + \frac{2\times 10^4 b_{80}(n_s + 1)A_{3-net50}}{l_{tk}(n_s A_{T-net50} + R)} \right]}$$

Note: for preliminary calculations, r may be taken as 0.5

l_{tk} length of cargo tank, between transverse bulkheads in the side cargo tank, in m

b_{80} 80% of the distance from longitudinal bulkhead to the inner hull longitudinal bulkhead, in m, at tank mid length

$A_{T-net50}$ net shear area of the transverse wash bulkhead, including the double bottom floor directly below, in the side cargo tank, in cm^2, taken as the smallest area in a vertical section. $A_{T-net50}$ is to be calculated with net thickness given by t_{grs} - $0.5t_{corr}$

$A_{1-net50}$ net area, as shown in *Figure 8.1.2,* in m^2

$A_{2-net50}$ net area, as shown in *Figure 8.1.2,* in m^2

$A_{3-net50}$ net area, as shown in *Figure 8.1.2,* in m^2

f_3 shear force distribution factor, as shown in *Figure 8.1.2*

n_S number of wash bulkheads in the side cargo tank

R total efficiency of the transverse primary support members in the side tank

$$R = \left(\frac{n - n_s}{2} - 1\right)\frac{A_{Q-net50}}{\gamma} \quad \text{cm}^2$$

$$\gamma = 1 + \frac{300 b_{80}{}^2 A_{Q-net50}}{I_{psm-net50}}$$

$A_{Q-net50}$ net shear area, in cm^2, of a transverse primary support member in the wing cargo tank, taken as the sum of the net shear areas of floor, cross ties and deck transverse webs. $A_{Q-net50}$ is to be calculated using the net thickness given by t_{grs} - $0.5t_{corr.}$ The net shear area is to be calculated at the mid span of the members.

$I_{psm-net50}$ net moment of inertia for primary support members, in cm^4, of a transverse primary support member in the wing cargo tank, taken as the sum of the moments of inertia of transverses and cross ties. It is to be calculated using the net thickness given by t_{grs} - $0.5t_{corr.}$ The net moment of inertia is to be calculated at the mid span of the member including an attached plate width equal to the primary support member spacing

t_{grs} gross plate thickness, in mm

t_{corr} corrosion addition, in mm, as defined in *Section 6/3.2*

1.3.3.7 The maximum resulting force on the double bottom in a tank, F_{db}, is to be taken as:

$$F_{db} = g\left|W_{CT} + W_{CWBT} - \rho_{sw} b_2 l_{tk} T_{mean}\right| \quad \text{kN}$$

Where:

W_{CT} weight of cargo, in tonnes, as defined in *Table 8.1.5*

W_{CWBT} weight of ballast, in tonnes, as defined in *Table 8.1.5*

b_2 breadth, in m, as defined in *Table 8.1.5*

l_{tk} length of cargo tank, between watertight transverse bulkheads in the wing cargo tank, in m

T_{mean} draught at the mid length of the tank for the loading condition considered, in m.

g acceleration due to gravity, 9.81 m/s²

ρ_{sw} density of sea water, 1.025 tonnes/m³

Table 8.1.5
Design Conditions for Double Bottoms

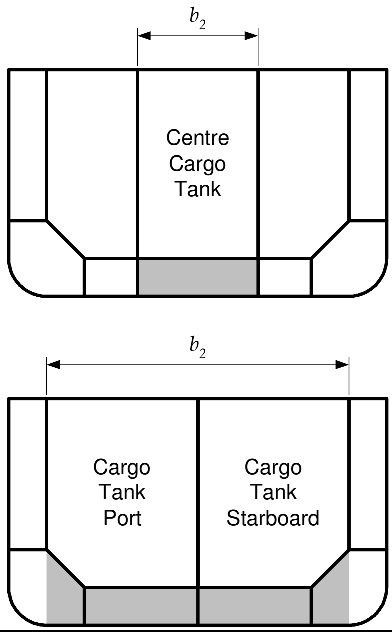
Structural Configuration	W_{CT}	W_{CWBT}	b_2
Ships with one longitudinal bulkhead	weight of cargo in cargo tanks, in tonnes, using a minimum specific gravity of 1.025 tonnes/m³	weight of ballast between port and starboard inner sides, in tonnes	maximum breadth between port and starboard inner sides at mid length of tank, in m, as shown in *Figure 8.1.4*
Ships with two longitudinal bulkheads	weight of cargo in the centre tank, in tonnes, using a minimum specific gravity of 1.025 tonnes/m³	weight of ballast below the centre cargo tank, in tonnes	maximum breadth of the centre cargo tank at mid length of tank, in m, as shown in *Figure 8.1.4*

1.3.3.8 The maximum resulting force on the double bottom in a tank, F_{db}, is in no case to be less than that given by the rule minimum conditions given in *Table 8.1.6*.

Table 8.1.6
Rule Minimum Conditions for Double Bottoms

Structural Configuration	Positive/negative force, F_{db}	Minimum condition
Ships with one longitudinal bulkhead	Max positive net vertical force, F_{db}+	$0.9T_{sc}$ and empty cargo and ballast tanks
	Max negative net vertical force, F_{db}-	$0.6T_{sc}$ and full cargo tanks and empty ballast tanks
Ships with two longitudinal bulkheads	Max positive net vertical force, F_{db}+	$0.9T_{sc}$ and empty cargo and ballast tanks
	Max negative net vertical force, F_{db}-	$0.6T_{sc}$ and full centre cargo tank and empty ballast tanks

Figure 8.1.4
Tank Breadth to be Included for Different Tanker Types



1.3.4 Shear force correction due to loads from transverse bulkhead stringers

1.3.4.1 In way of transverse bulkhead stringer connections, within areas as specified in *Figure 8.1.6*, the equivalent net thickness of plate used for calculation of the hull girder shear strength, t_{str-k}, where the index k refers to the identification number of the stringer, is not to be taken greater than:

$$t_{str-k} = t_{sfc-net50}\left(1 - \frac{\tau_{str}}{\tau_{ij-perm}}\right) \quad \text{mm}$$

Where:

$t_{sfc-net50}$ effective net plating thickness, in mm, as defined in *1.3.3.1* and calculated at the transverse bulkhead for the height corresponding to the level of the stringer

$\tau_{ij-perm}$ permissible hull girder shear stress, τ_{perm}, for plate ij

$= 120/k_{ij}$ N/mm^2

k_{ij} higher strength steel factor, k, for plate ij as defined in *Section 6/1.1.4*

τ_{str} $= \dfrac{Q_{str\text{-}k}}{l_{str} t_{sfc-net50}}$ N/mm²

l_{str} connection length of stringer, in m, see *Figure 8.1.5*

$Q_{str\text{-}k}$ shear force on the longitudinal bulkhead from the stringer in loaded condition with tanks abreast full

$$= 0.8 F_{str\text{-}k}\left(1 - \frac{z_{str} - h_{db}}{h_{blk}}\right) \quad \text{kN}$$

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$F_{str\text{-}k}$ total stringer supporting force, in kN, as defined in *1.3.4.2*

h_{db} the double bottom height, in m, as shown in *Figure 8.1.6*

h_{blk} height of bulkhead, in m, defined as the distance from inner bottom to the deck at the top of the bulkhead, as shown in *Figure 8.1.6*

z_{str} the vertical distance from baseline to the considered stringer, in m.

1.3.4.2 The total stringer supporting force, $F_{str\text{-}k}$, in way of a longitudinal bulkhead is to be taken as:

$$F_{str-k} = \frac{P_{str} b_{str} (h_k + h_{k-1})}{2} \quad \text{kN}$$

Where:

P_{str} pressure on stringer, in kN/m², to be taken as: $10h_{tt}$

h_{tt} the height from the top of the tank to the midpoint of the load area between $h_k/2$ below the stringer and $h_{k-1}/2$ above the stringer, in m

h_k the vertical distance from the considered stringer to the stringer below. For the lowermost stringer, it is to be taken as 80 % of the average vertical distance to the inner bottom, in m

h_{k-1} the vertical distance from the considered stringer to the stringer above. For the uppermost stringer, it is to be taken as 80 % of the average vertical distance to the upper deck, in m

b_{str} load breadth acting on the stringer, in m, see *Figure 8.1.7* and *8.1.8*

Figure 8.1.5
Effective Connection Length of Stringer

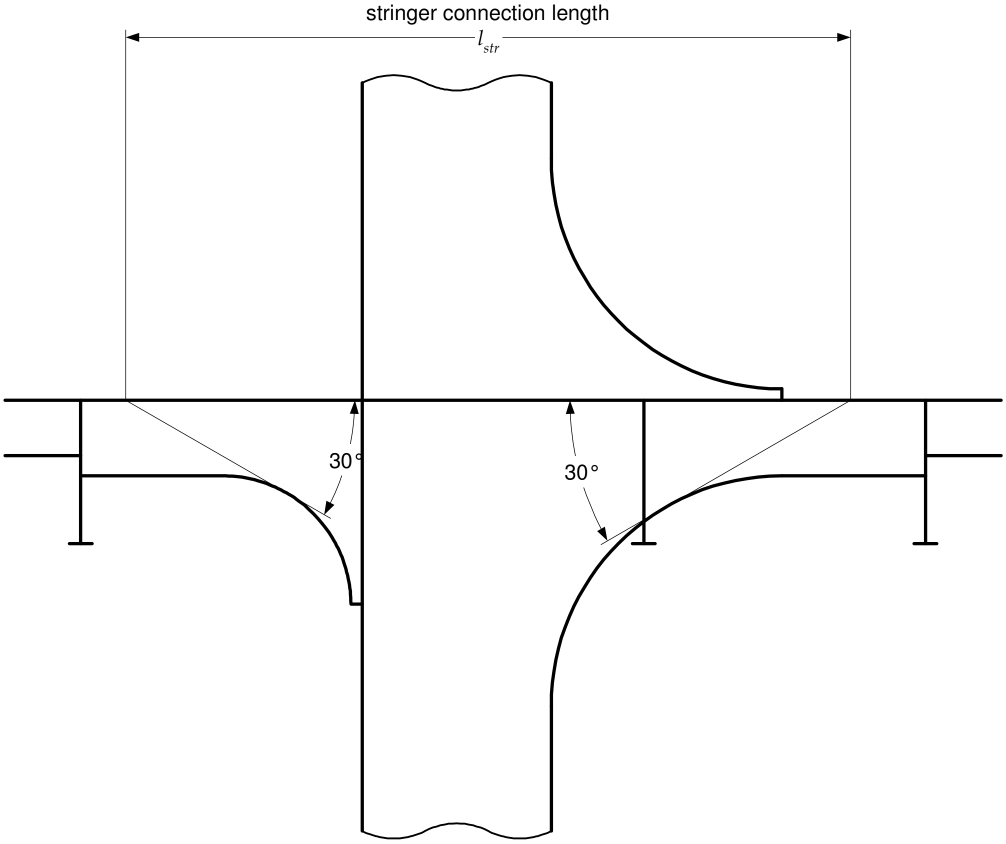


Figure 8.1.6
Region for Stringer Correction, t_{ij}, for a Tanker with Three Stringers

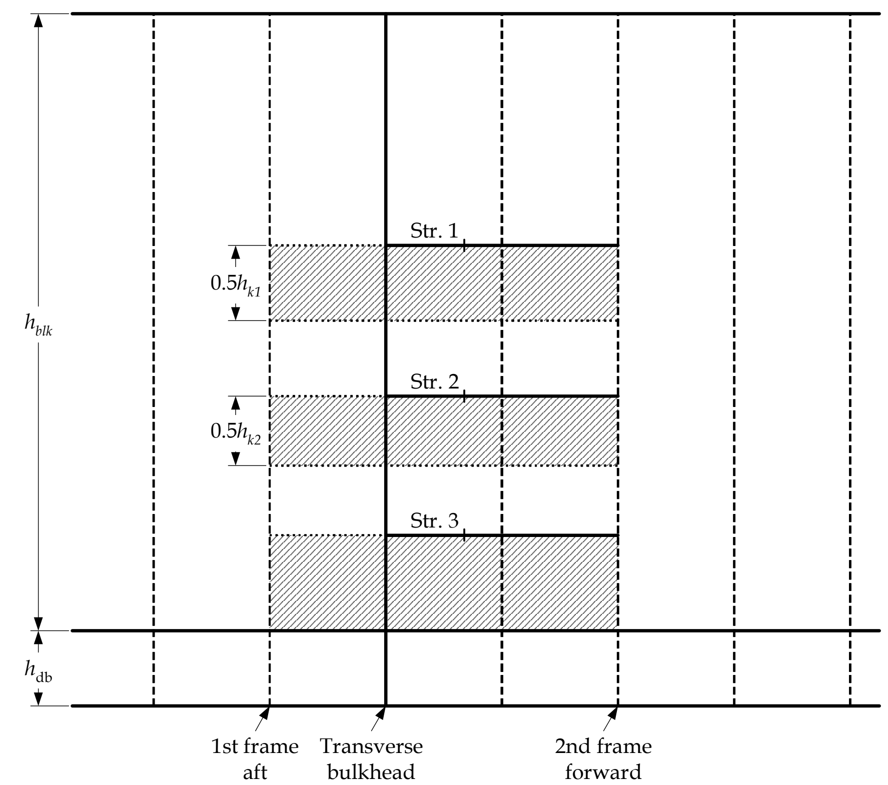
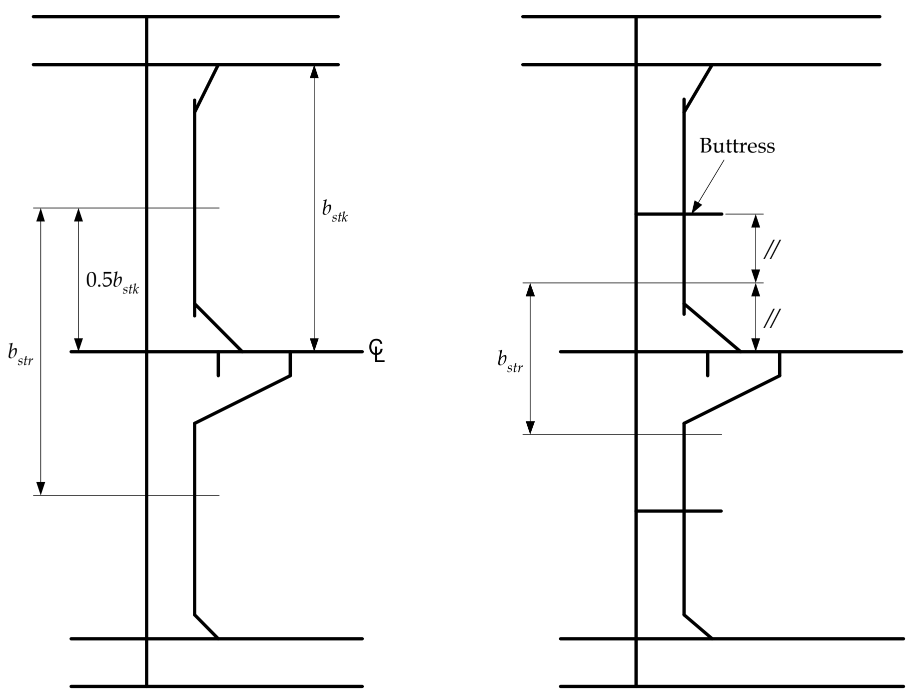
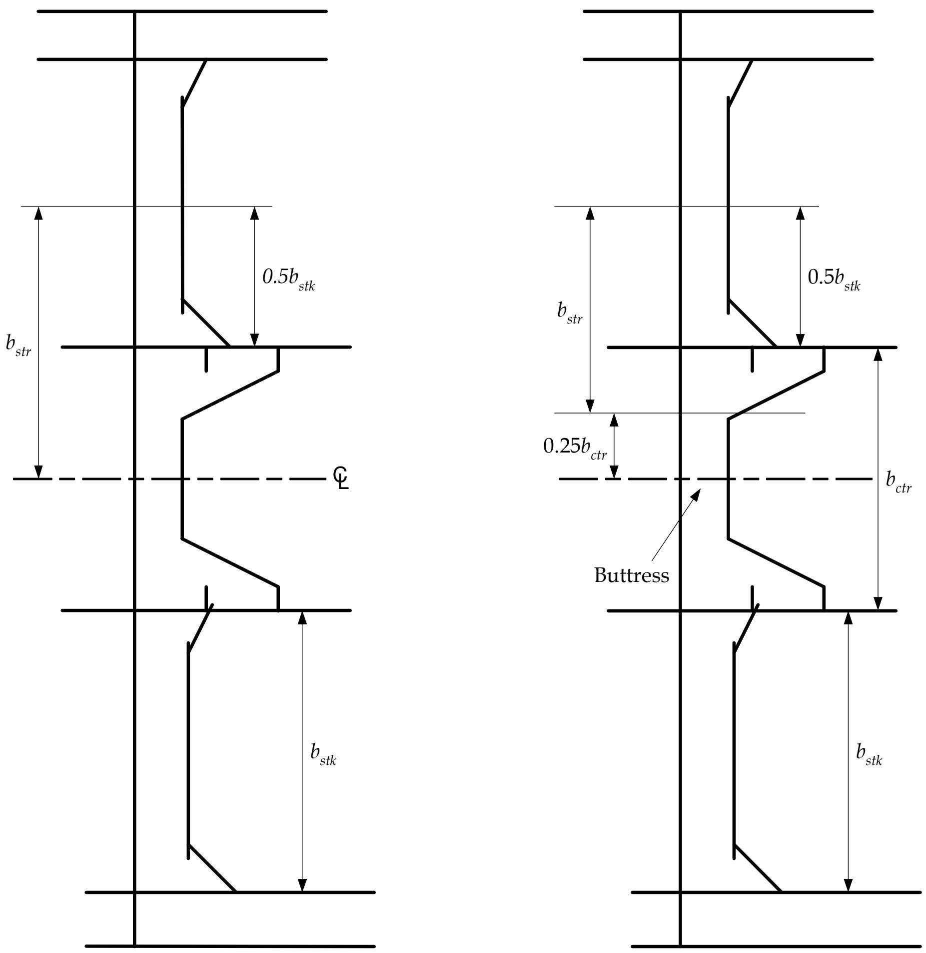


Figure 8.1.7
Load Breadth of Stringers for Ships with a Centreline Bulkhead



1.3.4.3 Where reinforcement is provided to meet the above requirement, the reinforced area based on t_{str-k} is to extend longitudinally for the full length of the stringer connection and a minimum of one frame spacing forward and aft of the bulkhead. The reinforced area shall extend vertically from above the stringer level and down to $0.5h_k$ below the stringer, where h_k, the vertical distance from the considered stringer to the stringer below is as defined in *1.3.4.2*. For the lowermost stringer the plate thickness requirement t_{str-k} is to extend down to the inner bottom, see *Figure 8.1.6*.

Figure 8.1.8
Load Breadth of Stringers for Ships with Two Inner Longitudinal Bulkheads



Notes
1. b_{stk} is the breadth of wing cargo tank, in m.
2. b_{ctr} is the breadth of centre cargo tank, in m.

1.4 Hull Girder Buckling Strength

1.4.1 General

1.4.1.1 These requirements apply to plate panels and longitudinals subject to hull girder compression and shear stresses. These stresses are to be based on the permissible values for still water bending and shear forces given in *Section 7/2.1,* and wave bending moments and shear forces given in *Section 7/3.4*.

1.4.1.2 The hull girder buckling strength requirements apply along the full length of the ship, from A.P to F.P.

1.4.1.3 For the purposes of assessing the hull girder buckling strength in this sub-section, the following are to be considered separately:

(a) axial hull girder compressive stress to satisfy requirements in *1.4.2.6* and *1.4.2.8*

(b) hull girder shear stress to satisfy requirements in *1.4.2.7*.

1.4.2 Buckling assessment

1.4.2.1 The buckling assessment of plate panels and longitudinals is to be determined according to *Section 10/3.1* with hull girder stresses calculated on net hull girder sectional properties.

1.4.2.2 The buckling strength for the buckling assessment is to be derived using local net scantlings, t_{net}, as follows:

$$t_{net} = t_{grs} - 1.0t_{corr} \quad \text{mm}$$

Where:

t_{grs} gross plate thickness, in mm

t_{corr} corrosion addition, in mm, as defined in *Section 6/3.2*

1.4.2.3 The hull girder compressive stress due to bending, $\sigma_{hg-net50}$, for the buckling assessment is to be calculated using net hull girder sectional properties and is to be taken as the greater of the following:

$$\sigma_{hg-net50} = \left| \frac{(z - z_{NA-net50})(M_{sw-perm-sea} + M_{wv-v})}{I_{v-net50}} \right| 10^{-3} \quad \text{N/mm}^2$$

$$\sigma_{hg-net50} = \frac{30}{k} \quad \text{N/mm}^2$$

Where:

$M_{sw-perm-sea}$ permissible still water bending moment for seagoing operation, in kNm, as defined in *Section 7/2.1.1,* with signs as given in *1.4.2.4*

M_{wv-v} hogging and sagging vertical wave bending moments, in kNm, as defined in *Section 7/3.4.1*, with signs as given in *1.4.2.4*

M_{wv-v} is to be taken as:

M_{wv-hog} for assessment with the hogging still water bending moment

M_{wv-sag} for assessment with the sagging still water bending moment

z distance from the structural member under consideration to the baseline, in m

$z_{NA-net50}$ distance from the baseline to the horizontal neutral, in m, see *Figure 8.1.1*

$I_{v-net50}$ net vertical hull girder section moment of inertia, in m^4, as defined in *Section 4/2.6.1.1*

k higher strength steel factor, as defined in *Section 6/1.1.4.1*

1.4.2.4 The sagging bending moment values of $M_{sw-perm-sea}$ and M_{wv-v} are to be taken for members above the neutral axis. The hogging bending moment values are to be taken for members below the neutral axis.

1.4.2.5 The design hull girder shear stress for the buckling assessment, $\tau_{hg-net50}$, is to be calculated based on net hull girder sectional properties and is to be taken as:

$$\tau_{hg-net50} = \left| \left(Q_{sw-perm-sea} + Q_{wv} \right) \left(\frac{1000 q_v}{t_{ij-net50}} \right) \right| \quad \text{N/mm}^2$$

Where:

$Q_{sw-perm-sea}$ positive and negative still water permissible shear force for seagoing operation, in kN, as defined in *Section 7/2.1.3*

Q_{wv} positive or negative vertical wave shear, in kN, as defined in *Section 7/3.4.3.*

Q_{vw} is to be taken as:

Q_{wv-pos} for assessment with the positive permissible still water shear force

Q_{wv-neg} for assessment with the negative permissible still water shear force

$t_{ij-net50}$ net thickness for the plate *ij*, in mm

$= t_{ij-grs} - 0.5 t_{corr}$

t_{ij-grs} gross plate thickness of plate *ij*, in mm. The gross plate thickness for corrugated bulkheads is to be taken as the minimum of t_{w-grs} and t_{f-grs}, in mm

t_{w-grs} gross thickness of the corrugation web, in mm

t_{f-grs} gross thickness of the corrugation flange, in mm

t_{corr} corrosion addition, in mm, as defined in *Section 6/3.2*

q_v unit shear per mm for the plate being considered as defined in *1.3.2.2*

Note

1. Maximum of the positive shear (still water + wave) and negative shear (still water + wave) is to be used as the basis for calculation of design shear stress
2. All plate elements ij that contribute to the hull girder shear capacity are to be assessed. See also *Table 8.1.4* and *Figure 8.1.2*
3. The gross rule required thicknesses is to be calculated considering shear force correction.
4. For longitudinal bulkheads between cargo tanks, $t_{ij-net50}$ is to be taken as $t_{sfc-net50}$ and t_{str-k} as appropriate.

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1.4.2.6 The compressive buckling strength, of plate panels, is to satisfy the following criteria:

$\eta \leq \eta_{allow}$

Where:

η buckling utilisation factor

$\frac{\sigma_{hg-net50}}{\sigma_{cr}}$

$\sigma_{hg-net50}$ hull girder compressive stress based on net hull girder sectional properties, in N/mm² as defined in *1.4.2.3*

σ_{cr} critical compressive buckling stress, σ_{xcr} or σ_{ycr} as appropriate, in N/mm², as specified in *Section 10/3.2.1.3*. The critical compressive buckling stress is to be calculated for the effects of hull girder compressive stress only. The effects of other membrane stresses and lateral pressure are to be ignored. The net thickness given as $t_{grs} - t_{corr}$ as described in *Section 6/3.3.2.2* is to be used for the calculation of σ_{cr}.

η_{allow} allowable buckling utilisation factor:

= 1.0 for plate panels at or above 0.5*D*

= 0.90 for plate panels below 0.5*D*

t_{grs} gross plate thickness, in mm

t_{corr} corrosion addition, in mm, as defined in *Section 6/3.2*

(RCN 1, effective from 1 April 2007)

1.4.2.7 The shear buckling strength, of plate panels, is to satisfy the following criteria:

$\eta \leq \eta_{allow}$

Where:

η buckling utilisation factor

$\frac{\tau_{hg-net50}}{\tau_{cr}}$

$\tau_{hg-net50}$ design hull girder shear stress, in N/mm², as defined in *1.4.2.5*

τ_{cr} critical shear buckling stress, in N/mm², as specified in *Section 10/3.2.1.3*. The critical shear buckling stress is to be calculated for the effects of hull girder shear stress only. The effects of other membrane stresses and lateral pressure are to be ignored. The net thickness given as $t_{grs} - t_{corr}$ as described in *Section 6/3.3.2.2* is to be used for the calculation of τ_{cr}

η_{allow} allowable buckling utilisation factor

= 0.95

t_{grs} gross plate thickness, in mm

t_{corr} corrosion addition, in mm, as defined in *Section 6/3.2*

1.4.2.8 The compressive buckling strength of longitudinal stiffeners is to satisfy the following criteria:

$\eta \leq \eta_{allow}$

Where:

η greater of the buckling utilisation factors given in *Section 10/3.3.2.1* and *Section 10/3.3.3.1*. The buckling utilisation factor is to be calculated for the effects of hull girder compressive stress only. The effects of other membrane stresses and lateral pressure are to be ignored.

η_{allow} allowable buckling utilisation factor:

= 1.0 for stiffeners at or above 0.5D

= 0.90 for stiffeners below 0.5D

(RCN 1, effective from 1 April 2007)

1.5 Hull Girder Fatigue Strength

1.5.1 General

1.5.1.1 The following provides a simplified fatigue control measure against the dynamic hull girder stresses in the longitudinal deck structure.

1.5.1.2 The requirements in *1.5.1.3* are not mandatory, but are recommended to be applied in the early design phase in order to give an indication of the required hull girder section modulus for compliance with the mandatory fatigue requirements specified in *Section 9/3* and *Appendix C*.

1.5.1.3 The fatigue life for the deck structure as required by *Section 9/3* and *Appendix C* is normally satisfied providing the net vertical hull girder section modulus at the moulded deck line at side, $Z_{v\text{-}net50}$, as defined in *Section 4/2.6.1.1*, is not less than the required hull girder section modulus, $Z_{v\text{-}fat}$, defined as:

$$Z_{v-fat} = \frac{M_{wv-hog} - M_{wv-sag}}{1000 R_{al}} \quad \text{m}^3$$

Where:

$M_{wv\text{-}hog}$ hogging vertical wave bending moment for fatigue, in kNm, as defined in *Section 7/3.4.1*

$M_{wv\text{-}sag}$ sagging vertical wave bending moment for fatigue, in kNm, as defined in *Section 7/3.4.1*

R_{al} allowable stress range, in N/mm²

= 0.17L + 86 for class F-details

= 0.15L + 76 for class F2-details

L rule length, in m, as defined in *Section 4/1.1.1.1*

1.6 Tapering and Structural Continuity of Longitudinal Hull Girder Elements

1.6.1 Tapering based on minimum hull girder section property requirements

1.6.1.1 Scantlings of all continuous longitudinal members of the hull girder based on the moment of inertia and section modulus requirements given in *1.2.2* are to be maintained within 0.4L of amidships.

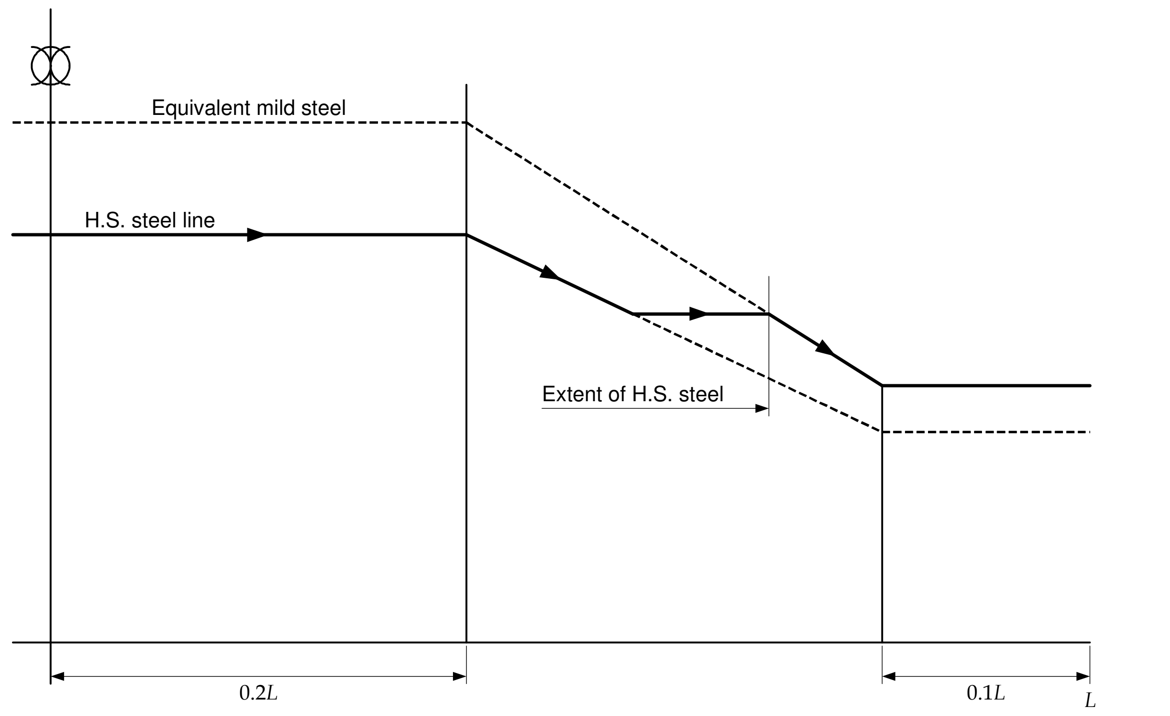
1.6.1.2 Scantlings outside of 0.4L amidships as required by the rule minimum moment of inertia and section modulus as given in *1.2.2* may be gradually reduced to the local

requirements at the ends provided the hull girder bending and buckling requirements, along the full length of the ship, as given in *1.2.3* and *1.4* are complied with. For tapering of higher strength steel, see *1.6.2* and *1.6.3*..

1.6.2 Longitudinal extent of higher strength steel

1.6.2.1 Where used, the application of higher strength steel is to be continuous over the length of the ship up to locations where the longitudinal stress levels are within the allowable range for mild steel structure, see *Figure 8.1.9*.

Figure 8.1.9
Longitudinal Extent of Higher Strength Steel



1.6.3 Vertical extent of higher strength steel

1.6.3.1 The vertical extent of higher strength steel, z_{hts}, used in the deck or bottom and measured from the moulded deck line at side or keel is not to be taken less than the following, see also *Figure 8.1.10*.

$$z_{hts} = z_1\left(1-\frac{\sigma_{perm}}{\sigma_1}\right) \quad \text{m}$$

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Where:

z_1 distance from horizontal neutral axis to moulded deck line or keel respectively, in m

σ_1 to be taken as σ_{dk} or σ_{kl} for the hull girder deck and keel respectively, in N/mm²

σ_{dk} hull girder bending stress at moulded deck line given by:

$$= \frac{\left|M_{sw-perm-sea} + M_{wv-v}\right|}{I_{v-net50}}(z_{dk-side} - z_{NA-net50})\cdot 10^{-3} \quad \text{N/mm}^2$$

σ_{kl} hull girder bending stress at keel given by:

$$= \frac{\left|M_{sw-perm-sea} + M_{wv-v}\right|}{I_{v-net50}} (z_{NA-net50} - z_{kl}) \cdot 10^{-3} \quad \text{N/mm}^2$$

σ_{perm} permissible hull girder bending stress as given in Table 8.1.3 for design load combination S+D, in N/mm^2

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$M_{sw-perm-sea}$ permissible hull girder still water bending moment for seagoing operation, in kNm, as defined in *Section 7/2.1.1*

M_{wv-v} hogging and sagging vertical wave bending moments, in kNm, as defined in *Section 7/3.4.1*

M_{wv-v} is to be taken as:

M_{wv-hog} for assessment with respect to hogging vertical wave bending moment

M_{wv-sag} for assessment with respect to sagging vertical wave bending moment

$I_{v-net50}$ net vertical hull girder moment of inertia, in m^4, as defined in *Section 4/2.6.1.1*

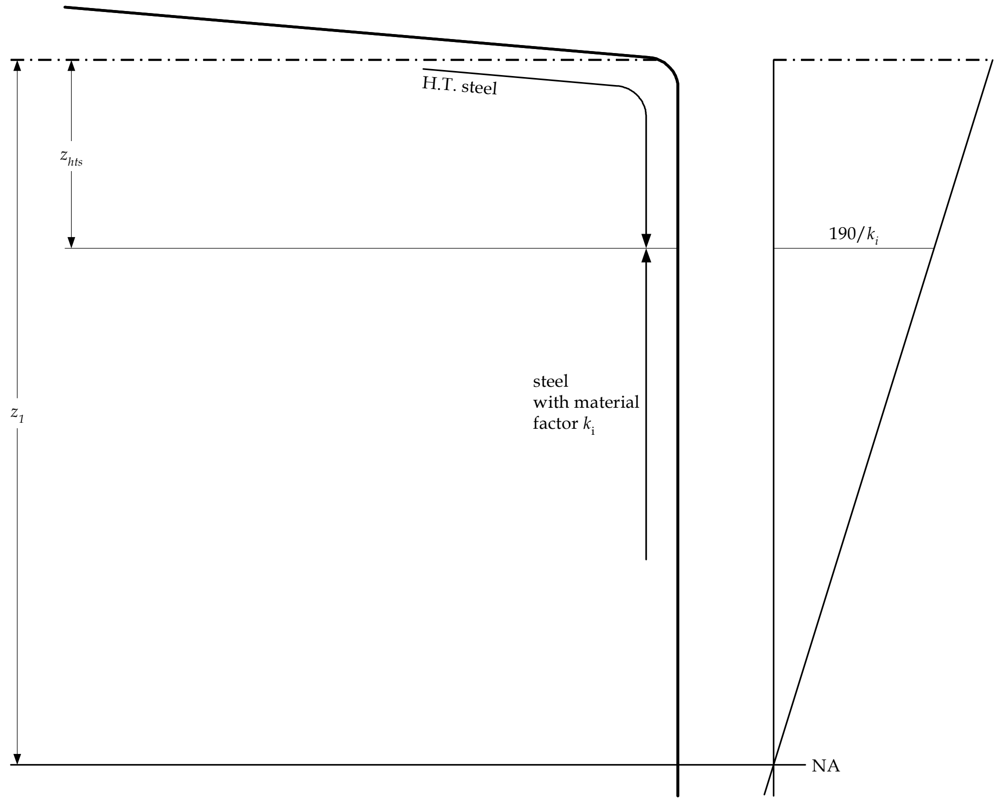
$z_{dk-side}$ distance from baseline to moulded deck line at side, in m

z_{kl} vertical distance from the baseline to the keel, in m

$z_{NA-net50}$ distance from baseline to horizontal neutral axis, in m

k_i higher strength steel factor for the area i defined in *Figure 8.1.10*. The factor, k, is defined in *Section 6/1.1.4*

Figure 8.1.10
Vertical Extent of Higher Strength Steel



1.6.4 Tapering of plate thickness due to hull girder shear requirement

1.6.4.1 Longitudinal tapering of shear reinforcement is permitted, provided that for any longitudinal position the requirements given in *1.3.2* are complied with. Control of the shear strength at intermediate positions is to be carried out by linear interpolation of permissible shear limits at the bulkhead and in the middle of the tank.

1.6.5 Structural continuity of longitudinal bulkheads

1.6.5.1 Suitable scarphing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes. In particular longitudinal bulkheads are to be terminated at an effective transverse bulkhead and large transition brackets shall be fitted in line with the longitudinal bulkhead.

1.6.6 Structural continuity of longitudinal stiffeners

1.6.6.1 Where longitudinal stiffeners terminate, and are replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover.

1.6.6.2 Where a deck longitudinal stiffener is cut, in way of an opening, compensation is to be arranged to ensure structural continuity of the area. The compensation area is to extend well beyond the forward and aft end of the opening and not be less than the area of the longitudinal that is cut. Stress concentration in way of the stiffener termination and the associated buckling strength of the plate and panel are to be considered.

2 CARGO TANK REGION

2.1 General

2.1.1 Application

2.1.1.1 The requirements of this Sub-Section apply to the hull structure within the cargo tank region of the ship, for the shell, deck, inner bottom and bulkhead plating, stiffeners and primary support members.

2.1.2 Basis of scantlings

2.1.2.1 The net scantlings described in this Sub-Section are related to gross scantlings as follows:

(a) for application of the minimum thickness requirements specified in *2.1.5* and *2.1.6*, the gross thickness is obtained from the applicable requirements by adding the full corrosion additions specified in *Section 6/3*

(b) for plating and local support members, the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in *Section 6/3*

(c) for primary support members, the gross shear area, gross section modulus, and other gross cross sectional properties are obtained from the applicable requirements by adding one half of the relevant full corrosion addition specified in *Section 6/3*

(d) for application of the buckling requirements of *Section 10/3*, the gross thickness and gross cross-sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in *Section 6/3*.

2.1.3 Evaluation of scantlings

2.1.3.1 The following scantling requirements are based on the assumption that all structural joints and welded details are designed and fabricated, such that they are to be compatible with the anticipated working stress levels at the locations considered. The loading patterns, stress concentrations and potential failure modes of structural joints and details during the design of highly stressed regions are to be considered. Structural design details are to comply with the requirements given in *Section 4/3*.

2.1.3.2 The scantlings are to be assessed to ensure that the strength criteria are satisfied at all longitudinal positions, where applicable.

2.1.3.3 Local scantling increases are to be applied where applicable to cover local variations, such as increased spacing, increased stiffener spans and green sea pressure loads. Local scantling increases may also be required to cover fore end strengthening requirements, see *Section 8/3*.

2.1.4 General scantling requirements

2.1.4.1 The hull structure is to comply with the applicable requirements of:

(a) hull girder longitudinal strength, see *Section 8/1*

(b) strength against sloshing and impact loads, see *Section 8/6*

(c) hull girder ultimate strength, see *Section 9*

(d) strength assessment (FEM), see *Section 9*

(e) fatigue strength, see Section 9/3

(f) buckling and ultimate strength, see *Section 10.*

2.1.4.2 The net section modulus, shear areas and other sectional properties of the local and primary support members are to be determined in accordance with *Section 4/2*.

2.1.4.3 The section modulus, shear areas and other sectional properties of the local and primary support members apply to the areas clear of the end brackets.

2.1.4.4 The spans of the local and primary support members are defined in *Section 4/2.1*.

2.1.4.5 The moments of inertia for the primary support members are to be determined in association with the effective attached plating at the mid span as specified in *Section 4/2.3.2.3*.

2.1.4.6 Limber, drain and air holes are to be cut in all parts of the structure, as required, to ensure the free flow to the suction pipes and escape of air to the vents. See also *Section 4/3*.

2.1.4.7 All shell frames and tank boundary stiffeners are in general to be continuous, or are to be bracketed at their ends, except as permitted in *Sections 4/3.2.4* and *4/3.2.5*.

2.1.4.8 Enlarged stiffeners (with or without web stiffening) used for Permanent Means of Access (PMA) are to comply with the following requirements:

a) Buckling strength including proportion (slenderness ratio) requirements for primary support members as follows:

- For stiffener web, see *Section 10/2.3.1.1 (a), 10/3.2.*
- For stiffener flange, see *Section 10/2.3.1.1 (b), 10/2.3.3.1.*
- For web stiffeners, see *Section 10/2.3.2.1, 10/2.3.2.2, 10/3.3.*

Note: Note 1 of table 10.2.1 is not applicable.

b) Buckling strength of longitudinal PMA platforms without web stiffeners may also be ensured using the criteria for local support members in *Section 10/2.2* and *Section 10/3.3,* including Note 1 of *Table 10.2.1,* provided shear buckling strength of web is verified in line with *Section 10/3.2.*

c) All other requirements for local support members as follows:

- Corrosion additions: requirements for local support members
- Minimum thickness: requirements for local support members
- Fatigue: requirements for local support members

Note: For primary support members (or part of it) used as a PMA platform the requirements for primary support members are to be applied.

2.1.5 Minimum thickness for plating and local support members

2.1.5.1 The thickness of plating and stiffeners in the cargo tank region is to comply with the appropriate minimum thickness requirements given in *Table 8.2.1*.

Table 8.2.1
Minimum Net Thickness for Plating and Local Support Members in the Cargo Tank Region

Scantling Location			Net Thickness (mm)
Plating	**Shell**	Keel plating	$6.5+0.03L_2$
		Bottom shell/bilge/side shell	$4.5+0.03L_2$
	Upper Deck		$4.5+0.02L_2$
	Other structure	Hull internal tank boundaries	$4.5+0.02L_2$
		Non-tight bulkheads, bulkheads between dry spaces and other plates in general	$4.5+0.01L_2$
Local support members	Local support members on tight boundaries		$3.5+0.015L_2$
	Local support members on other structure		$2.5+0.015L_2$
Tripping brackets			$5.0+0.015L_2$

Where:
L_2 rule length, L, as defined in *Section 4/1.1.1.1*, but need not be taken greater than 300m

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2.1.6 Minimum thickness for primary support members

2.1.6.1 The thickness of web plating and face plating of primary support members in the cargo tank region is to comply with the appropriate minimum thickness requirements given in *Table 8.2.2*.

Table 8.2.2
Minimum Net Thickness for Primary Support Members in Cargo Tank Region

Scantling Location	Net Thickness (mm)
Double bottom centreline girder	$5.5+0.025L_2$
Other double bottom girders	$5.5+0.02L_2$
Double bottom floors, web plates of side transverses and stringers in double hull	$5.0+0.015L_2$
Web and flanges of vertical web frames on longitudinal bulkheads, horizontal stringers on transverse bulkhead, deck transverses (above and below upper deck) and cross ties.	$5.5+0.015L_2$

Where:
L_2 rule length, L, as defined in *Section 4/1.1.1.1*, but need not be taken greater than 300m

2.2 Hull Envelope Plating

2.2.1 Keel plating

2.2.1.1 Keel plating is to extend over the flat of bottom for the complete length of the ship. The breadth, b_{kl}, is not to be less than:

$$b_{kl} = 800 + 5L_2 \quad \text{mm}$$

Where:

L_2 rule length, L, as defined in *Section 4/1.1.1.1*, but not to be taken greater than 300m

2.2.1.2 The thickness of the keel plating is to comply with the requirements given in *2.2.2*.

2.2.2 Bottom shell plating

2.2.2.1 The thickness of the bottom shell plating is to comply with the requirements in *Table 8.2.4*.

2.2.3 Bilge plating

2.2.3.1 The thickness of bilge plating is not to be less than that required for the adjacent bottom shell, see *2.2.2.1,* or adjacent side shell plating, see *2.2.4.1*, whichever is the greater.

2.2.3.2 The net thickness of bilge plating, t_{net}, without longitudinal stiffening is not to be less than:

$$t_{net} = \frac{\sqrt[3]{r^2 S_t P_{ex}}}{100} \quad \text{mm}$$

Where:

P_{ex} design sea pressure for the design load set 1 calculated at the lower turn of bilge, in kN/m²

r effective bilge radius

$= r_0 + 0.5(a+b)$ mm

r_0 radius of curvature, in mm. See *Figure 8.2.1*

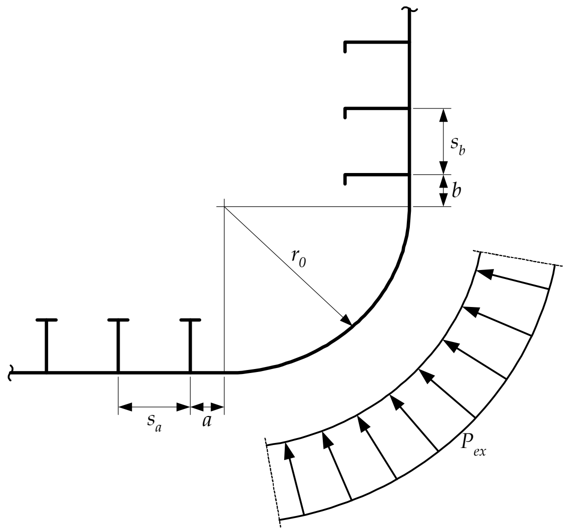
S_t distance between transverse stiffeners, webs or bilge brackets, in m

a distance between the lower turn of bilge and the outermost bottom longitudinal, in mm, see *Figure 8.2.1* and *2.3.1.2*. Where the outermost bottom longitudinal is within the curvature, this distance is to be taken as zero.

b distance between the upper turn of bilge and the lowest side longitudinal, in mm, see *Figure 8.2.1* and *2.3.1.2*. Where the lowest side longitudinal is within the curvature, this distance is to be taken as zero.

Where plate seam is located in the straight plate just below the lowest stiffener on the side shell, any increased thickness required for the bilge plating does not have to extend to the adjacent plate above the bilge provided that the plate seam is not more than $s_b/4$ below the lowest side longitudinal. Similarly for flat part of adjacent bottom plating, any increased thickness for the bilge plating does not have to be applied provided that the plate seam is not more than $s_a/4$ beyond the outboard bottom longitudinal. Regularly longitudinally stiffened bilge plating is to be assessed as a stiffened plate. The bilge keel is not considered as “longitudinal stiffening” for the application of this requirement.

Figure 8.2.1
Unstiffened Bilge Plating



2.2.3.3 Where bilge longitudinals are omitted, the bilge plate thickness outside 0.4L amidships will be considered in relation to the support derived from the hull form and internal stiffening arrangements. In general, outside of 0.4L amidships the bilge plate scantlings and arrangement are to comply with the requirements of ordinary side or bottom shell plating in the same region. Consideration is to be given where there is increased loading in the forward region.

2.2.4 Side shell plating

2.2.4.1 The thickness of the side shell plating is to comply with the requirements in *Table 8.2.4*.

2.2.4.2 The net thickness, t_{net}, of the side plating within the range as specified in *2.2.4.3* is not to be less than:

$$t_{net} = 26\left(\frac{s}{1000}+0.7\right)\left(\frac{BT_{sc}}{\sigma_{yd}^{\ 2}}\right)^{0.25} \quad \text{mm}$$

Where:

s	stiffener spacing, in mm, as defined in *Section 4/2.2*
B	moulded breadth, in m as defined in *Section 4/1.1.3.1*
T_{sc}	scantling draught, in m, as defined in *Section 4/1.1.5.5*
σ_{yd}	specified minimum yield stress of the material, in N/mm^2

2.2.4.3 The thickness in *2.2.4.2* is to be applied to the following extent of the side shell plating, see *Figure 8.2.2*:

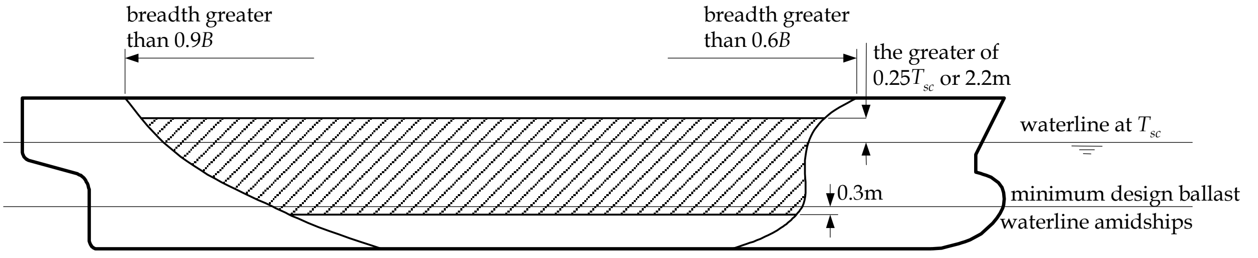
(a) longitudinal extent:

- between a section aft of amidships where the breadth at the waterline exceeds 0.9B, and a section forward of amidships where the breadth at the waterline exceeds 0.6B

(b) vertical extent:

- between 300mm below the minimum design ballast waterline, T_{bal}, amidships to 0.25T_{sc} or 2.2m, whichever is greater, above the draught T_{sc}.

Figure 8.2.2
Extent of Side Shell Plating



2.2.5 Sheer strake

2.2.5.1 The sheer strake is to comply with the requirements in *2.2.4*.

2.2.5.2 The welding of deck fittings to rounded sheer strakes is to be avoided within 0.6*L* of amidships.

2.2.5.3 Where the sheer strake extends above the deck stringer plate, the top edge of the sheer strake is to be kept free from notches and isolated welded fittings, and is to be smooth with rounded edges Grinding may be required if the cutting surface is not smooth. Drainage openings with a smooth transition in the longitudinal direction may be permitted.

2.2.6 Deck plating

2.2.6.1 The thickness of the deck plating is to comply with the requirements given in *Table 8.2.4*.

2.3 Hull Envelope Framing

2.3.1 General

2.3.1.1 The bottom shell, inner bottom and deck are to be longitudinally framed in the cargo tank region. The side shell, inner hull bulkheads and longitudinal bulkheads are generally to be longitudinally framed. Where the side shell is longitudinally framed, the inner hull bulkheads are to be similarly constructed. Suitable alternatives which take account of resistance to buckling will be specially considered.

2.3.1.2 Where longitudinals are omitted in way of the bilge, a longitudinal is to be fitted at the bottom and at the side close to the position where the curvature of the bilge plate starts. The distance between the lower turn of bilge and the outermost bottom longitudinal, *a*, is generally not to be greater than one-third of the spacing between the two outermost bottom longitudinals, s_a. Similarly, the distance between the upper turn of the bilge and the lowest side longitudinal, *b*, is generally not to be greater than one-third of the spacing between the two lowest side longitudinals, s_b. *See Figure 8.2.1*.

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2.3.1.3 The longitudinals are to comply with the requirements of continuity given in *Section 4/3.2*.

2.3.2 Scantling criteria

2.3.2.1 The section modulus, and thickness, of the hull envelope framing is to comply with the requirements given in *Tables 8.2.5* and *8.2.6*.

2.3.2.2 Where the side shell longitudinal or the vertical stiffener is inclined to the longitudinal or vertical axis, respectively, the span is to be taken in accordance with *Section 4/2.1.3*.

2.3.2.3 For curved stiffeners, the span is to be taken in accordance with *Section 4/2.1.3*.

2.4 Inner Bottom

2.4.1 Inner bottom plating

2.4.1.1 The thickness of the inner bottom plating is to comply with the requirements given in *Table 8.2.4*.

2.4.1.2 In way of a welded hopper knuckle, the inner bottom is to be scarfed to ensure adequate load transmission to surrounding structure and reduce stress concentrations.

2.4.1.3 In way of corrugated bulkhead stools, where fitted, particular attention is to be given to the through-thickness properties, and arrangements for continuity of strength, at the connection of the bulkhead stool to the inner bottom. For requirements for plates with specified through-thickness properties, see *Section 6/1.1.5*.

2.4.2 Inner bottom longitudinals

2.4.2.1 The section modulus and web plate thickness of the inner bottom longitudinals are to comply with the requirements given in *Tables 8.2.5* and *8.2.6*.

2.5 Bulkheads

2.5.1 General

2.5.1.1 The inner hull and longitudinal bulkheads are generally to be longitudinally framed, and plane. Corrugated bulkheads are to comply with the requirements given in *2.5.6*.

2.5.1.2 Where bulkheads are penetrated by cargo or ballast piping, the structural arrangements in way are to be adequate for the loads imparted to the bulkheads by the hydraulic forces in the pipes.

2.5.2 Longitudinal tank boundary bulkhead plating

2.5.2.1 The thickness of the longitudinal tank boundary bulkhead plating is to comply with the requirements given in *Table 8.2.4*.

2.5.2.2 Inner hull and longitudinal bulkheads are to extend as far forward and aft as practicable and are to be effectively scarfed into the adjoining structure.

2.5.3 Hopper side structure

2.5.3.1 Knuckles in the hopper tank plating are to be supported by side girders and stringers, or by a deep longitudinal.

2.5.4 Transverse tank boundary bulkhead plating

2.5.4.1 The thickness of the transverse tank boundary bulkhead plating is to comply with the requirements given in *Table 8.2.4*.

2.5.5 Tank boundary bulkhead stiffeners

2.5.5.1 The section modulus and web thickness of stiffeners, on longitudinal or transverse tank boundary bulkheads, are to comply with the requirements given in *Tables 8.2.5* and *8.2.6*.

2.5.6 Corrugated bulkheads

2.5.6.1 The scantling requirements relating to corrugated bulkheads defined in *2.5.6* and *2.5.7* are net requirements. The gross scantling requirements are obtained from the applicable requirements by adding the full corrosion additions specified in *Section 6/3*.

2.5.6.2 In general, corrugated bulkheads are to be designed with the corrugation angles, ϕ, between 55 and 90 degrees, see *Figure 8.2.3*.

2.5.6.3 The global strength of corrugated bulkheads, lower stools and upper stools, where fitted, and attachments to surrounding structures are to be verified with the cargo tank FEM model in the midship region, see *Section 9/2*. The global strength of corrugated bulkheads outside of midship region are to be considered based on results from the cargo tank FEM model and using the appropriate pressure for the bulkhead being considered. Additional FEM analysis of cargo tank bulkheads forward and aft of the midship region may be necessary if the bulkhead geometry, structural details and support arrangement details differ significantly from bulkheads within the mid cargo tank region.

2.5.6.4 The net thicknesses, t_{net}, of the web and flange plates of corrugated bulkheads are to be taken as the greatest value calculated for all applicable design load sets, as given in *Table 8.2.7*, and given by:

$$t_{net} = 0.0158\, b_p \sqrt{\frac{|P|}{C_a\, \sigma_{yd}}} \quad \text{mm}$$

Where:

P design pressure for the design load set being considered, calculated at the load point defined in *Section 3/5.1*, in kN/m²

b_p breadth of plate:

= b_f for flange plating, in mm. See *Figure 8.2.3*

= b_w for web plating, in mm. See *Figure 8.2.3*

C_a permissible bending stress coefficient:

= 0.75 for acceptance criteria set AC1

= 0.90 for acceptance criteria set AC2

σ_{yd} specified minimum yield stress of the material, in N/mm²

2.5.6.5 Where the corrugated bulkhead is built with flange and web plate of different thickness, then the thicker net plating thickness, $t_{m\text{-}net}$, is to be taken as the greatest value calculated for all applicable design load sets, as given in *Table 8.2.7*, and given by:

$$t_{m-net} = \sqrt{\frac{0.0005\, b_p^{\,2}\, |P|}{C_a\, \sigma_{yd}} - t_{n-net}^{\,2}} \quad \text{mm}$$

Where:

t_{n-net} net thickness of the thinner plating, either flange or web, in mm

b_p breadth of thicker plate, either flange or web, in mm

P design pressure for the design load set being considered, calculated at the load point defined in *Section 3/5.1*, in kN/m²

C_a permissible bending stress coefficient:

= 0.75 for acceptance criteria set AC1

= 0.90 for acceptance criteria set AC2

σ_{yd} specified minimum yield stress of the material, in N/mm²

2.5.7 Vertically corrugated bulkheads

2.5.7.1 In addition to the requirements of *2.5.6*, vertically corrugated bulkheads are also to comply with the requirements of *2.5.7*.

2.5.7.2 The net plate thicknesses as required by *2.5.7.5* and *2.5.7.6* are to be maintained for two thirds of the corrugation length, l_{cg}, from the lower end, where l_{cg} is as defined in *2.5.7.3*. Above that, the net plate thickness may be reduced by 20%.

2.5.7.3 The net web plating thickness of the lower 15% of the corrugation, t_{w-net}, is to be taken as the greatest value calculated for all applicable design load sets, as given in *Table 8.2.7*, and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool, see *2.5.7.9*.

$$t_{w-net} = \frac{1000\left|Q_{cg}\right|}{d_{cg}\, C_{t-cg}\, \tau_{yd}} \quad \text{mm}$$

Where:

Q_{cg} design shear force imposed on the web plating at the lower end of the corrugation

$$= \frac{s_{cg}\, l_{cg}\, |3P_l + P_u|}{8000} \quad \text{kN}$$

P_l design pressure for the design load set being considered, calculated at the lower end of the corrugation, in kN/m²

P_u design pressures for the design load set being considered, calculated at the upper end of the corrugation, in kN/m²

s_{cg} spacing of corrugation, in mm. See *Figure 8.2.3*

l_{cg} length of corrugation, which is defined as the distance between the lower stool and the upper stool or the upper end where no upper stool is fitted, in m, see *Figure 8.2.3*

d_{cg} depth of corrugation, in mm. See *2.5.7.4* and *Figure 8.2.3*

C_{t-cg} permissible shear stress coefficient

= 0.75 for acceptance criteria set AC1

= 0.90 for acceptance criteria set AC2

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm²

σ_{yd} specified minimum yield stress of the material, in N/mm²

2.5.7.4 The depth of the corrugation, d_{cg}, is not to be less than:

$$d_{cg} = \frac{1000\, l_{cg}}{15} \quad \text{mm}$$

Where:

l_{cg} length of corrugation, which is defined as the distance between the lower stool or the inner bottom if no lower stool is fitted and the upper stool or the upper end where no upper stool is fitted, in m, see *Figure 8.2.3*

2.5.7.5 The net thicknesses of the flanges of corrugated bulkheads, $t_{f\text{-}net}$, for two thirds of the corrugation length from the lower end are to be taken as the greatest value calculated for all applicable design load sets, as given in *Table 8.2.7*, and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool, see *2.5.7.9*.

$$t_{f-net} = \frac{0.00657\, b_f \sqrt{\sigma_{bdg-max}}}{C_f} \quad \text{mm}$$

Where:

$\sigma_{bdg\text{-}max}$ maximum value of the vertical bending stresses in the flange. The bending stress is to be calculated at the lower end and at the mid span of the corrugation length

$= \dfrac{1000 M_{cg}}{Z_{cg-act-net}}$ N/mm²

M_{cg} as defined in *2.5.7.6*

$Z_{cg\text{-}act\text{-}net}$ actual net section modulus at the lower end and at the mid length of the corrugation, in cm³

b_f breadth of flange plating, in mm. See *Figure 8.2.3*

b_w breadth of web plating, in mm. See *Figure 8.2.3*

C_f coefficient

$= 7.65 - 0.26 \left(\dfrac{b_w}{b_f}\right)^2$

2.5.7.6 The net section modulus at the lower and upper ends and at the mid length of the corrugation ($l_{cg}/2$) of a unit corrugation, $Z_{cg\text{-}net}$, are to be taken as the greatest value calculated for all applicable design load sets, as given in *Table 8.2.7*, and given by the following.

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$$Z_{cg-net} = \frac{1000\,M_{cg}}{C_{s-cg}\,\sigma_{yd}} \quad \text{cm}^3$$

Where:

M_{cg} $= \dfrac{C_i |P| s_{cg}\, l_o^{\,2}}{12000}$ kNm

P $= \dfrac{P_u + P_l}{2}$ kN/m²

P_l, P_u design pressure for the design load set being considered, calculated at the lower and upper ends of the corrugation, respectively, in kN/m²:

(a) for transverse corrugated bulkheads, the pressures are to be calculated at a section located at $b_{tk}/2$ from the longitudinal bulkheads of each tank

(b) for longitudinal corrugated bulkheads, the pressures are to be calculated at the ends of the tank, i.e., the intersection of the forward and aft transverse bulkheads and the longitudinal bulkhead

b_{tk} maximum breadth of tank under consideration measured at the bulkhead, in m

s_{cg} spacing of corrugation, in mm. See *Figure 8.2.3*

l_o effective bending span of the corrugation, measured from the mid depth of the lower stool to the mid depth of the upper stool, or upper end where no upper stool is fitted, in m, see *Figure 8.2.3*

l_{cg} length of corrugation, which is defined as the distance between the lower stool and the upper stool or the upper end where no upper stool is fitted, in m, see *Figure 8.2.3*

C_i the relevant bending moment coefficients as given in *Table 8.2.3*

C_{s-cg} permissible bending stress coefficient

at the mid length of the corrugation length, l_{cg}:

= c_e, but not to be taken as greater than 0.75 for acceptance criteria set AC1

= c_e, but not to be taken as greater than 0.90 for acceptance criteria set AC2

at the lower and upper ends of corrugation length, l_{cg}:

= 0.75 for acceptance criteria set AC1

= 0.90 for acceptance criteria set AC2

c_e $= \dfrac{2.25}{\beta} - \dfrac{1.25}{\beta^2}$ for $\beta \geq 1.25$

= 1.0 for $\beta < 1.25$

β $= \dfrac{b_f}{t_{f-net}} \sqrt{\dfrac{\sigma_{yd}}{E}}$

b_f breadth of flange plating, in mm, see *Figure 8.2.3*

$t_{f\text{-}net}$ net thickness of the corrugation flange, in mm

E modulus of elasticity, in N/mm²

σ_{yd} specified minimum yield stress of the material, in N/mm²

Table 8.2.3
Values of C_i

Bulkhead	**At lower end of l_{cg}**	**At mid length of l_{cg}**	**At upper end of l_{cg}**
Transverse Bulkhead	C_1	C_{m1}	$0.65C_{m1}$
Longitudinal Bulkhead	C_3	C_{m3}	$0.65C_{m3}$

Where:

C_1 $= a_1 + b_1\sqrt{\dfrac{A_{dt}}{b_{dk}}}$ but is not to be taken as less than 0.60

$= a_1 - b_1\sqrt{\dfrac{A_{dt}}{b_{dk}}}$ for transverse bulkhead with no lower stool, but is not to be taken as less than 0.55

a_1 $= 0.95 - \dfrac{0.41}{R_{bt}}$

= 1.0 for transverse bulkhead with no lower stool

b_1 $= -0.20 + \dfrac{0.078}{R_{bt}}$

= 0.13 for transverse bulkhead with no lower stool

C_{m1} $= a_{m1} + b_{m1}\sqrt{\dfrac{A_{dt}}{b_{dk}}}$ but is not to be taken as less than 0.55

$= a_{m1} - b_{m1}\sqrt{\dfrac{A_{dt}}{b_{dk}}}$ for transverse bulkhead with no lower stool, but is not to be taken as less than 0.60

a_{m1} $= 0.63 + \dfrac{0.25}{R_{bt}}$

= 0.85 for transverse bulkhead with no lower stool

b_{m1} $= -0.25 - \dfrac{0.11}{R_{bt}}$

= 0.34 for transverse bulkhead with no lower stool

C_3 $= a_3 + b_3\sqrt{\dfrac{A_{dl}}{l_{dk}}}$ but is not to be taken as less than 0.60

$= a_3 - b_3\sqrt{\dfrac{A_{dl}}{l_{dk}}}$ for longitudinal bulkhead with no lower stool, but is not to be taken as less than 0.55

a_3 $= 0.86 - \dfrac{0.35}{R_{bl}}$

= 1.0 for longitudinal bulkhead with no lower stool

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Table 8.2.3 (Continued)
Values of C_i

b_3	$= -0.17 + \frac{0.10}{R_{bl}}$	
	$= 0.13$	for longitudinal bulkhead with no lower stool
C_{m3}	$= a_{m3} + b_{m3}\sqrt{\frac{A_{dl}}{l_{dk}}}$	but is not to be taken as less than 0.55
	$= a_{m3} - b_{m3}\sqrt{\frac{A_{dl}}{l_{dk}}}$	for longitudinal bulkhead with no lower stool, but is not to be taken as less than 0.60
a_{m3}	$= 0.32 + \frac{0.24}{R_{bl}}$	
	$= 0.85$	for longitudinal bulkhead with no lower stool
b_{m3}	$= -0.12 - \frac{0.10}{R_{bl}}$	
	$= 0.19$	for longitudinal bulkhead with no lower stool
R_{bt}	$= \frac{A_{bt}}{b_{ib}}\left(1+\frac{l_{ib}}{b_{ib}}\right)\left(1+\frac{b_{av-t}}{h_{st}}\right)$	for transverse bulkheads
R_{bl}	$= \frac{A_{bl}}{l_{ib}}\left(1+\frac{l_{ib}}{b_{ib}}\right)\left(1+\frac{b_{av-l}}{h_{sl}}\right)$	for longitudinal bulkheads
A_{dt}	cross sectional area enclosed by the moulded lines of the transverse bulkhead upper stool, in m^2 = 0 if no upper stool is fitted	
A_{dl}	cross sectional area enclosed by the moulded lines of the longitudinal bulkhead upper stool, in m^2 = 0 if no upper stool is fitted	
A_{bt}	cross sectional area enclosed by the moulded lines of the transverse bulkhead lower stool, in m^2	
A_{bl}	cross sectional area enclosed by the moulded lines of the longitudinal bulkhead lower stool, in m^2	
b_{av-t}	average width of transverse bulkhead lower stool, in m. See *Figure 8.2.3*	
b_{av-l}	average width of longitudinal bulkhead lower stool, in m. See *Figure 8.2.3*	
h_{st}	height of transverse bulkhead lower stool, in m. See *Figure 8.2.3*	
h_{sl}	height of longitudinal bulkhead lower stool, in m. See *Figure 8.2.3*	
b_{ib}	breadth of cargo tank at the inner bottom level between hopper tanks, or between the hopper tank and centreline lower stool, in m. See *Figure 8.2.3*	
b_{dk}	breadth of cargo tank at the deck level between upper wing tanks, or between the upper wing tank and centreline deck box or between the corrugation flanges if no upper stool is fitted, in m. See *Figure 8.2.3*	
l_{ib}	length of cargo tank at the inner bottom level between transverse lower stools, in m. See *Figure 8.2.3*	
l_{dk}	length of cargo tank at the deck level between transverse upper stools or between the corrugation flanges if no upper stool is fitted, in m. See *Figure 8.2.3*	

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2.5.7.7 For tanks with effective sloshing breadth, b_{slh}, greater than $0.56B$ or effective sloshing length l_{slh}, greater than $0.13L$, additional sloshing analysis is to be carried out to assess the section modulus of the unit corrugation in accordance with the requirements of the individual Classification Society.

2.5.7.8 For ships with a moulded depth, see *Section 4/1.1.4*, equal to or greater than 16m, a lower stool is to be fitted in compliance with the following requirements:

(a) general:

- the height and depth are not to be less than the depth of the corrugation
- the lower stool is to be fitted in line with the double bottom floors or girders
- the side stiffeners and vertical webs (diaphragms) within the stool structure are to align with the structure below, as far as is practicable, to provide appropriate load transmission to structures within the double bottom.

(b) stool top plating:

- the net thickness of the stool top plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation
- the extension of the top plate beyond the corrugation is not to be less than the as-built flange thickness of the corrugation.

(c) stool side plating and internal structure:

- within the region of the corrugation depth from the stool top plate the net thickness of the stool side plate is not to be less than 90% of that required by *2.5.7.2* for the corrugated bulkhead flange at the lower end and is to be of at least the same material yield strength
- the net thickness of the stool side plating and the net section modulus of the stool side stiffeners is not to be less than that required by *2.5.2*, *2.5.4* and *2.5.5* for transverse or longitudinal bulkhead plating and stiffeners
- the ends of stool side vertical stiffeners are to be attached to brackets at the upper and lower ends of the stool
- continuity is to be maintained, as far as practicable, between the corrugation web and supporting brackets inside the stool. The bracket net thickness is not to be less than 80% of the required thickness of the corrugation webs and is to be of at least the same material yield strength
- scallops in the diaphragms in way of the connections of the stool sides to the inner bottom and to the stool top plate are not permitted.

2.5.7.9 For ships with a moulded depth, see *Section 4/1.1.4,* less than 16m, the lower stool may be eliminated provided the following requirements, in addition to the requirements of *2.5.7.6*, are complied with:

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(a) general:

- double bottom floors or girders are to be fitted in line with the corrugation flanges for transverse or longitudinal bulkheads, respectively
- brackets/carlings are to be fitted below the inner bottom and hopper tank in line with corrugation webs. Where this is not practicable gusset plates with shedder plates are to be fitted, see item (c) below and *Figure 8.2.3*
- the corrugated bulkhead and its supporting structure is to be assessed by Finite Element (FE) analysis in accordance with *Section 9/2*. In addition the local scantlings requirements of *2.5.6.4* and *2.5.6.5* and the minimum corrugation depth requirement of *2.5.7.4* are to be applied.

(b) inner bottom and hopper tank plating:

- the inner bottom and hopper tank in way of the corrugation is to be of at least the same material yield strength as the attached corrugation, and 'Z' grade steels as given in Section 6/1.1.5 are to be used unless plate through thickness properties are documented for approval.

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(c) supporting structure:

- within the region of the corrugation depth below the inner bottom the net thickness of the supporting double bottom floors or girders is not to be less than the net thickness of the corrugated bulkhead flange at the lower end and is to be of at least the same material yield strength
- the upper ends of vertical stiffeners on supporting double bottom floors or girders are to be bracketed to adjacent structure
- brackets/carlings arranged in line with the corrugation web are to have a depth of not less than 0.5 times the corrugation depth and a net thickness not less than 80% of the net thickness of the corrugation webs and are to be of at least the same material yield strength
- cut outs for stiffeners in way of supporting double bottom floors and girders in line with corrugation flanges are to be fitted with full collar plates
- where support is provided by gussets with shedder plates, the height of the gusset plate, see h_g in *Figure 8.2.3*, is to be at least equal to the corrugation depth, and gussets with shedder plates are to be arranged in every corrugation. The gusset plates are to be fitted in line with and between the corrugation flanges. The net thickness of the gusset and shedder plates are not to be less than 100% and 80%, respectively, of the net thickness of the corrugation flanges and are to be of at least the same material yield strength. Also see *2.5.7.11*.
- scallops in brackets, gusset plates and shedder plates in way of the connections to the inner bottom or corrugation flange and web are not permitted.

2.5.7.10 In general, an upper stool is to be fitted in compliance with the following requirements:

(a) general:

- where no upper stool is fitted, finite element analysis is to be carried out to demonstrate the adequacy of the details and arrangements of the bulkhead support structure to the upper deck structure
- side stiffeners and vertical webs (diaphragms) within the stool structure are to align with adjoining structure to provide for appropriate load transmission
- brackets are to be arranged in the intersections between the upper stool and the structure on deck

(b) stool bottom plating:

- the net thickness of the stool bottom plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation
- the extension of the bottom plate beyond the corrugation is not to be less than the attached as-built flange thickness of the corrugation.

(c) stool side plating and internal structure:

- within the region of the corrugation depth above the stool bottom plate the net thickness of the stool side plate is to be not less than 80% of that required by *2.5.7.2* for the corrugated bulkhead flange at the upper end where the same material is used. If material of different yield strength is used the required thickness is to be adjusted by the ratio of the two material factors (k). k is defined in *Section 6/1.1.4.1*
- the net thickness of the stool side plating and the net section modulus of the stool side stiffeners is not to be less than that required by *2.5.2*, *2.5.4* and *2.5.5* for the transverse or longitudinal bulkhead plating and stiffeners
- the ends of stool side vertical stiffeners are to be attached to brackets at the upper and lower ends of the stool
- scallops in the diaphragms in way of the connections of the stool sides to the deck and to the stool bottom plate are not permitted.

2.5.7.11 Where gussets with shedder plates or shedder plates (slanting plates) are fitted at the end connection of the corrugation to the lower stool or to the inner bottom, appropriate means are to be provided to prevent the possibility of gas pockets being formed by these plates.

2.5.7.12 Welding for all connections and joints is to comply with *Section 6/5*.

2.5.8 Non-tight bulkheads

2.5.8.1 Non-tight bulkheads (wash bulkheads), where fitted, are to be in line with transverse webs, bulkheads or similar structures. They are to be of plane construction, horizontally or vertically stiffened, and are to comply with the sloshing requirements given in *6.2*. In general, openings in the non-tight bulkheads are to have generous radii and their aggregate area is not to be less than 10% of the area of the bulkhead.

Figure 8.2.3
Definition of Parameters for Corrugated Bulkhead
(Tankers with Longitudinal Bulkhead at Centreline)

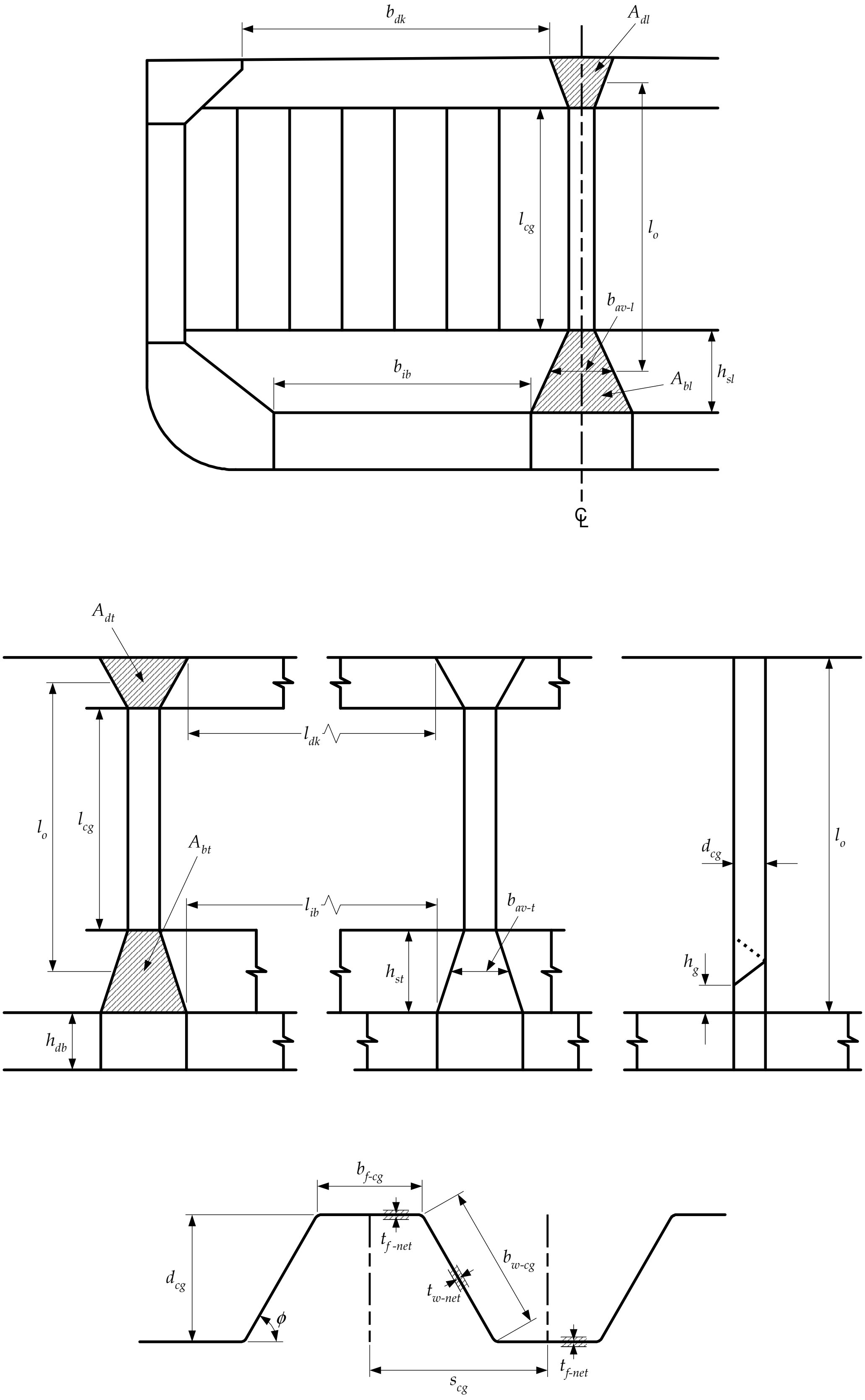


Table 8.2.4
Thickness Requirements for Plating

The minimum net thickness, t_{net}, is to be taken as the greatest value for all applicable design load sets, as given in *Table 8.2.7*, and given by:

$$t_{net} = 0.0158\, a_p\, s \sqrt{\frac{|P|}{C_a \sigma_{yd}}} \quad \text{mm}$$

Where:

P design pressure for the design load set being considered and calculated at the load calculation point defined in *Section 3/5.1*, in kN/m²

α_p correction factor for the panel aspect ratio

$$= 1.2 - \frac{s}{2100\, l_p} \quad \text{but is not to be taken as greater than 1.0}$$

s as defined in *Section 4/2.2*, in mm

l_p length of plate panel, to be taken as the spacing of primary support members, S, unless carlings are fitted, in m

σ_{yd} specified minimum yield stress of the material, in N/mm²

C_a permissible bending stress coefficient for the design load set being considered

$$= \beta_a - \alpha_a \frac{|\sigma_{hg}|}{\sigma_{yd}} \quad \text{but not to be taken greater than } C_{a-max}$$

Acceptance Criteria Set	Structural Member		β_a	α_a	C_{a-max}
AC1	Longitudinal Strength Members	Longitudinally stiffened plating	0.9	0.5	0.8
		Transversely or vertically stiffened plating	0.9	1.0	0.8
	Other members		0.8	0	0.8
AC2	Longitudinal Strength Members	Longitudinally stiffened plating	1.05	0.5	0.95
		Transversely or vertically stiffened plating	1.05	1.0	0.95
	Other members, including watertight boundary plating		1.0	0	1.0

σ_{hg} hull girder bending stress for the design load set being considered and calculated at the load calculation point defined in *Section 3/5.1.2*

$$= \left(\frac{(z - z_{NA-net50})\, M_{v-total}}{I_{v-net50}} - \frac{y\, M_{h-total}}{I_{h-net50}} \right) 10^{-3} \quad \text{N/mm}^2$$

$M_{v-total}$ design vertical bending moment at the longitudinal position under consideration for the design load set being considered, in kNm. The still water bending moment, $M_{sw-perm}$, is to be taken with the same sign as the simultaneously acting wave bending moment, M_{wv}, see *Table 7.6.1*

$M_{h-total}$ design horizontal bending moment at the longitudinal position under consideration for the design load set being considered, in kNm

$I_{v-net50}$ net vertical hull girder moment of inertia, at the longitudinal position being considered, as defined in *Section 4/2.6.1*, in m⁴

$I_{h-net50}$ net horizontal hull girder moment of inertia, at the longitudinal position being considered, as defined in *Section 4/2.6.2*, in m⁴

y transverse coordinate of load calculation point, in m

z vertical coordinate of the load calculation point under consideration, in m

$z_{NA-net50}$ distance from the baseline to the horizontal neutral axis, as defined in *Section 4/2.6.1*, in m

Table 8.2.5
Section Modulus Requirements for Stiffeners

The minimum net section modulus, Z_{net}, is to be taken as the greatest value calculated for all applicable design load sets, as given in *Table 8.2.7*, and given by:

$$Z_{net} = \frac{|P| s\, l_{bdg}^{\ 2}}{f_{bdg}\, C_s\, \sigma_{yd}} \quad \text{cm}^3$$

Where:

P design pressure for the design load set being considered and calculated at the load calculation point defined in *Section 3/5.2*, in kN/m²

f_{bdg} bending moment factor:
for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having as fixed ends:
= 12 for horizontal stiffeners
= 10 for vertical stiffeners
for stiffeners with reduced end fixity see *Sub-section 7.*

l_{bdg} effective bending span, in m, as defined in *Section 4/2.1.1*

s as defined in *Section 4/2.2*, in mm

σ_{yd} specified minimum yield stress of the material, see also *Section 3/5.2.6.5*, in N/mm²

C_s permissible bending stress coefficient for the design load set being considered, to be taken as:

Sign of Hull Girder Bending Stress, σ_{hg}	Side Pressure Acting On	Acceptance Criteria
Tension (+ve)	Stiffener side	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{\sigma_{yd}}$ but not to be taken greater than C_{s-max}
Compression (-ve)	Plate side	
Tension (+ve)	Plate side	$C_s = C_{s-max}$
Compression (-ve)	Stiffener side	

Acceptance Criteria Set	Structural Member	β_s	α_s	C_{s-max}
AC1	Longitudinal strength member	0.85	1.0	0.75
	Transverse or vertical member	0.75	0	0.75
AC2	Longitudinal strength member	1.0	1.0	0.9
	Transverse or vertical member	0.9	0	0.9
	Watertight boundary Stiffeners	0.9	0	0.9

σ_{hg} hull girder bending stress for the design load set being considered and calculated at the reference point defined in *Section 3/5.2.2.5*

$$= \left(\frac{(z - z_{NA-net50})\, M_{v-total}}{I_{v-net50}} - \frac{y\, M_{h-total}}{I_{h-net50}} \right) 10^{-3} \quad \text{N/mm}^2$$

$M_{v-total}$ design vertical bending moment at longitudinal position under consideration for the design load set being considered, in kNm.
$M_{v-total}$ is to be calculated in accordance with *Table 7.6.1* using the permissible hogging or sagging still water bending moment, $M_{sw-perm}$, to be taken as:

Stiffener Location	$M_{sw-perm}$	
	Pressure acting on Plate Side	**Pressure acting on Stiffener Side**
Above Neutral Axis	Sagging SWBM	Hogging SWBM
Below Neutral Axis	Hogging SWBM	Sagging SWBM

$M_{h-total}$ design horizontal bending moment at longitudinal position under consideration for the design load set being considered, see *Table 7.6.1*, in kNm

$I_{v-net50}$ net vertical hull girder moment of inertia, at the longitudinal position being considered, as defined in *Section 4/2.6.1*, in m⁴

$I_{h-net50}$ net horizontal hull girder moment of inertia, at the longitudinal position being considered, as defined in *Section 4/2.6.2*, in m⁴

y transverse coordinate of the reference point defined in *Section 3/5.2.2.5*, in m

z vertical coordinate of the reference point defined in *Section 3/5.2.2.5*, in m

$z_{NA-net50}$ distance from the baseline to the horizontal neutral axis, as defined in *Section 4/2.6.1*, in m

Table 8.2.6
Web Thickness Requirements for Stiffeners

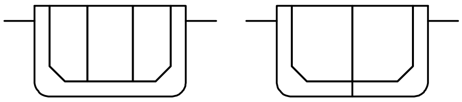
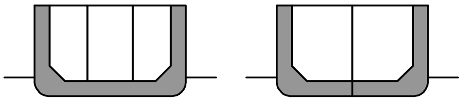
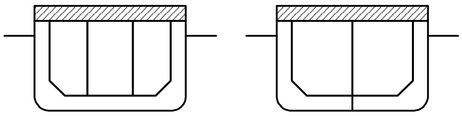
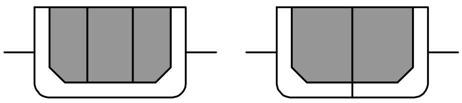
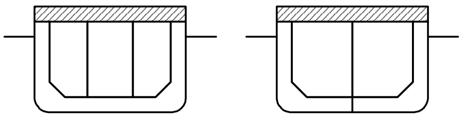
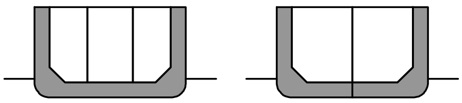
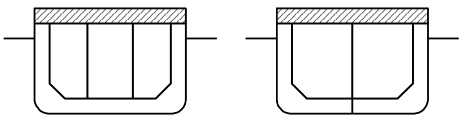
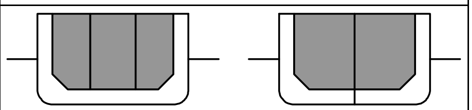
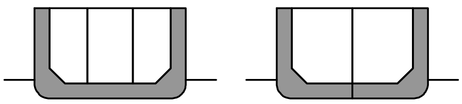
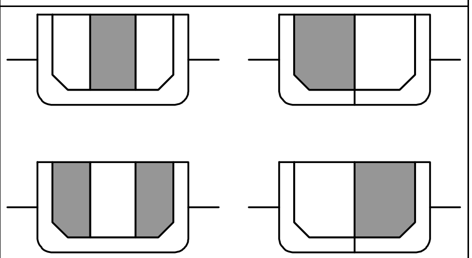
The minimum net web thickness, t_{w-net}, is to be taken as the greatest value calculated for all applicable design load sets, as given in *Table 8.2.7*, and given by:

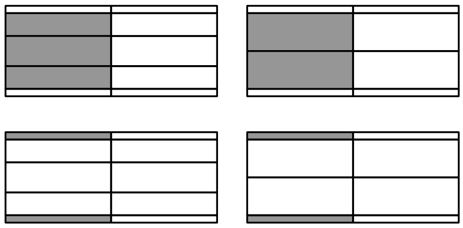
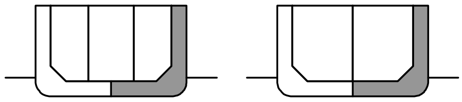
$$t_{w-net} = \frac{f_{shr} \left| P \right| s \, l_{shr}}{d_{shr} \, C_t \, \tau_{yd}} \quad \text{mm}$$

Where:

P	design pressure for the design load set being considered and calculated at the load calculation point defined in *Section 3/5.1*, in kN/m²
f_{shr}	shear force distribution factor: for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having as fixed ends: = 0.5 for horizontal stiffeners = 0.7 for vertical stiffeners for stiffeners with reduced end fixity, see *Sub-section 7*
d_{shr}	as defined in *Section 4/2.4.2.2*, in mm
C_t	permissible shear stress coefficient for the design load set being considered, to be taken as: = 0.75 for acceptance criteria set AC1 = 0.90 for acceptance criteria set AC2
s	as defined in *Section 4/2.2,* in mm
l_{shr}	effective shear span, in m, see *Section 4/2.1.2*
τ_{yd}	$= \frac{\sigma_{yd}}{\sqrt{3}}$ N/mm²
σ_{yd}	specified minimum yield stress of the material, in N/mm²

Table 8.2.7
Design Load Sets for Plating and Local Support Members

Structural Member		Design Load Set (1, 2, 3)	Load Component	Draught	Comment	Diagrammatic Representation
Keel, Bottom Shell, Bilge, Side Shell, Sheer strake		1	P_{ex}	T_{sc}	Sea pressure only	
		2	P_{ex}	T_{sc}		
		7	$P_{in} - P_{ex}$	T_{bal}	Net pressure difference between water ballast pressure and sea pressure	
		8	$P_{in} - P_{ex}$	$0.25T_{sc}$		
Deck	In way of cargo tanks	1	P_{ex}	T_{sc}	Green sea pressure only or other loads on deck	
		3	P_{in}	$0.6T_{sc}$	Cargo pressure only	
		4	P_{in}	-		
		11	$P_{in\text{-}flood}$	-		
	In way of other tanks	1	P_{ex}	T_{sc}	Green sea pressure only or other loads on deck	
		5	P_{in}	T_{bal}	Water ballast or other liquid pressure only	
		6	P_{in}	$0.25T_{sc}$		
		11	$P_{in\text{-}flood}$	-		
	Any location	9	P_{dk}	T_{bal}	Distributed or concentrated loads only. Simultaneously occurring green sea pressure may be ignored	
		10	P_{dk}	-		
Inner Bottom, Inner hull, Hopper side		3	P_{in}	$0.6T_{sc}$	Cargo pressure only	
		4	P_{in}	-		
		5	P_{in}	T_{bal}	Water ballast or other liquid pressure only	
		6	P_{in}	$0.25T_{sc}$		
		11	$P_{in\text{-}flood}$	-		
Longitudinal Bulkhead, Centreline Bulkhead		3	P_{in}	$0.6T_{sc}$	Pressure from one side only. Full cargo tank with adjacent cargo tank empty. Two cases are to be evaluated: 1. Inner empty, outer full 2. Inner full, outer empty	
		4	P_{in}	-		
		11	$P_{in\text{-}flood}$	-		

<table>
<tr><th colspan="7">Table 8.2.7 (Continued)
Design Load Sets for Plating and Local Support Members</th></tr>
<tr><th colspan="2">Structural Member</th><th>Design Load Set (1, 2, 3)</th><th>Load Component</th><th>Draught</th><th>Comment</th><th>Diagrammatic Representation</th></tr>
<tr><td rowspan="6">Transverse Bulkhead</td><td rowspan="3">In way of cargo tanks</td><td>3</td><td>P_{in}</td><td>$0.6T_{sc}$</td><td rowspan="6">Pressure from one side only.
Full cargo tank with adjacent fwd or aft cargo tank empty.
Need to evaluate 2 cases
1) Fwd empty, aft full
2) Fwd full, aft empty</td><td rowspan="6"></td></tr>
<tr><td>4</td><td>P_{in}</td><td>-</td></tr>
<tr><td>11</td><td>$P_{in-flood}$</td><td>-</td></tr>
<tr><td rowspan="3">In way of other tanks</td><td>5</td><td>P_{in}</td><td>T_{bal}</td></tr>
<tr><td>6</td><td>P_{in}</td><td>$0.25T_{sc}$</td></tr>
<tr><td>11</td><td>$P_{in-flood}$</td><td>-</td></tr>
<tr><td colspan="2" rowspan="3">Other tank boundaries, e.g. Girders, Floors, Stringers</td><td>5</td><td>P_{in}</td><td>T_{bal}</td><td rowspan="3">Pressure from one side only.
Full tank with adjacent tank empty.
Need to evaluate 2 cases, see above</td><td rowspan="3"></td></tr>
<tr><td>6</td><td>P_{in}</td><td>$0.25T_{sc}$</td></tr>
<tr><td>11</td><td>$P_{in-flood}$</td><td>-</td></tr>
</table>

Where:

T_{sc} scantling draught, in m, as defined in *Section 4/1.1.5.5*

T_{bal} minimum design ballast draught, in m, as defined in *Section 4/1.1.5.2*

Notes

1. Specification of design load combination, load component, acceptance criteria and other load parameters for each design load set are given in *Table 8.2.8*
2. When the ship's configuration cannot be described by the above, then the applicable Design Load Sets to determine the scantling requirements of structural boundaries are to be selected so as to specify a full tank on one side with the adjacent tank or space empty. The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents and are to maximise the pressure on the structural boundary, the draught to use is to be taken in accordance with the Design Load Set and this table. Design Load Sets covering the S and S+D design load combinations are to be selected. See Note 4 and *Table 8.2.8*.
3. The boundaries of void and dry space not forming part of the hull envelope are to be evaluated using Design Load Set 11. See Note 2.
4. Design load sets (DLS) for some structural members not covered by the above:
   For the boundaries of a stool water ballast tank with the cargo tank:
   - DLSs 5, 6 and 11 are to be applied for pressure from the WB tank side
   - DLSs 3, 4 and 11 for pressure from the cargo tank side

   For a double bottom girder separating two water ballast tanks or separating a water ballast and fuel oil tank:
   - DLSs 5, 6 and 11 are to be applied for pressure from each side in turn

   For the boundary of a stool void space to the cargo tank:
   - DLSs 3, 4 and 11 for pressure from the cargo tank side
   - DLS 11 for pressure from the void space side

Table 8.2.8
Specification of Design Load Combination, Acceptance Criteria and other Load Parameters for each Design Load Set

Design Load Set	Load Component (1)	Design Load Combination (2)	Acceptance Criteria Set	Parameters for Calculating Load Components		
				DLCF (3)	*GM*	$r_{roll\text{-}gyr}$
Hull envelope (*PSM* and *LSM*)						
1	Sea pressures P_{ex}	*S+D*	AC2	Loaded *DLCF*	0.12*B*	0.35*B*
2		*S*	AC1			
Cargo tank boundaries (*PSM* and *LSM*)						
3	Cargo pressures P_{in}	*S+D*	AC2	Loaded *DLCF*	0.24*B*	0.40*B*
4		*S*	AC1			
Boundaries of water ballast and other tanks (*PSM* and *LSM*)						
5	Water ballast or other liquid tank pressures P_{in}	*S+D*	AC2	Ballast *DLCF*	0.33*B*	0.45*B*
6		*S*	AC1			
7	Net water ballast minus sea pressures $P_{in} - P_{ex}$	*S+D*	AC2	Ballast *DLCF*	0.33*B*	0.45*B*
8		*S*	AC1			
Decks (*LSM* and *PSM*)						
9	Distributed and concentrated loads on deck P_{dk}	*S+D*	AC2	Ballast *DLCF*	0.33*B*	0.45*B*
10		*S*	AC1			
Watertight boundaries (*LSM* and *PSM*)						
11	Accidental flooding $P_{in\text{-}flood}$	*A*	AC2			
Hull envelope (*PSM*)						
12	Net cargo pressure minus sea pressure $P_{in} - P_{ex}$	*S+D*	AC2	Loaded *DLCF*	0.24*B*	0.40*B*
13		*S*	AC1			
14	Average cargo and sea pressure $(P_{in} + P_{ex})/2$	*S+D*	AC2	Loaded *DLCF*	0.12*B*	0.35*B*
15		*S+D*	AC2	Loaded *DLCF*	0.24*B*	0.40*B*
16		*S*	AC1			

Where:

PSM	Primary Support Members
LSM	Local Support Members
DLCF	Dynamic Load Combination Factors
P_{in} P_{ex} P_{dk} $P_{in\text{-}flood}$	as given in *Table 7.6.1* and as shown in *Table 8.2.7* or *Table 8.2.9*
B	moulded breadth, in m, as defined in *Section 4/1.1.3.1*

Note

1. Structural members are to be designed using all design load sets which are applicable. This table gives the pressure load component of the design load set. The hull girder bending moments are given in *Tables 8.2.4* and *8.2.5* for local support members.
2. This column specifies which column in the design load combination table is to be applied for each design load set, see *Table 7.6.1*. Where *S* denotes the static design load combination, *S+D* denotes the static plus dynamic design load combination and *A* denotes the accidental design load combination.
3. This column specifies which dynamic load combination factor table is to be used for the deviation of the pressure components and global load components, see *Table 7.6.1*

2.6 Primary Support Members

2.6.1 General

2.6.1.1 The scantlings of the primary support members in the cargo tank region for the extents shown in *Figure 8.2.4* are to be in accordance with the requirements of *2.6.1.2* to *2.6.1.7*.

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2.6.1.2 The section modulus and shear area criteria for primary support members contained in *2.6* apply to structural configurations shown in *Figure 2.3.1* and are applicable to the following structural elements:

(a) floors and girders within the double bottom;

(b) deck transverses fitted below the upper deck;

(c) side transverses within double side structure;

(d) vertical web frames on longitudinal bulkheads with or without cross ties;

(e) horizontal stringers on transverse bulkheads, except those fitted with buttresses or other intermediate supports; and

(f) cross ties in wing cargo and centre cargo tanks.

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2.6.1.3 The scantlings of primary support members are to be verified by the Finite Element (FE) cargo tank structural analysis defined in *Section 9/2*.

2.6.1.4 The section modulus and/or shear area of a primary support member and/or the cross sectional area of a primary support member cross tie may be reduced to 85% of the prescriptive requirements provided that the reduced scantlings comply with the FE cargo tank structural analysis and with *2.1.6*.

2.6.1.5 In general, primary support members are to be arranged in one plane to form continuous transverse rings. Brackets forming connections between primary support members of the ring are to be designed in accordance with *Section 4/3.3.3*.

2.6.1.6 Webs of the primary support members are to be stiffened in accordance with *Section 10/2.3*.

2.6.1.7 Webs of the primary support members are to have a depth of not less than given by the requirements of *2.6.4.1*, *2.6.6.1* and *2.6.7.1*, as applicable. Lesser depths may be accepted where equivalent stiffness is demonstrated. See *3/5.3.3.4*. Primary support members that have open slots for stiffeners are to have a depth not less than 2.5 times the depth of the slots.

2.6.1.8 The scantlings of the first primary support members from the transverse bulkhead are to be in accordance with *Section 8/7, 2.6.1.3, 2.6.1.4, 2.6.1.5, 2.6.1.6, 2.6.4.3* and *2.6.4.4*. In the application of *2.6.4.3* and *2.6.4.4* only the design green sea pressure is to be considered.

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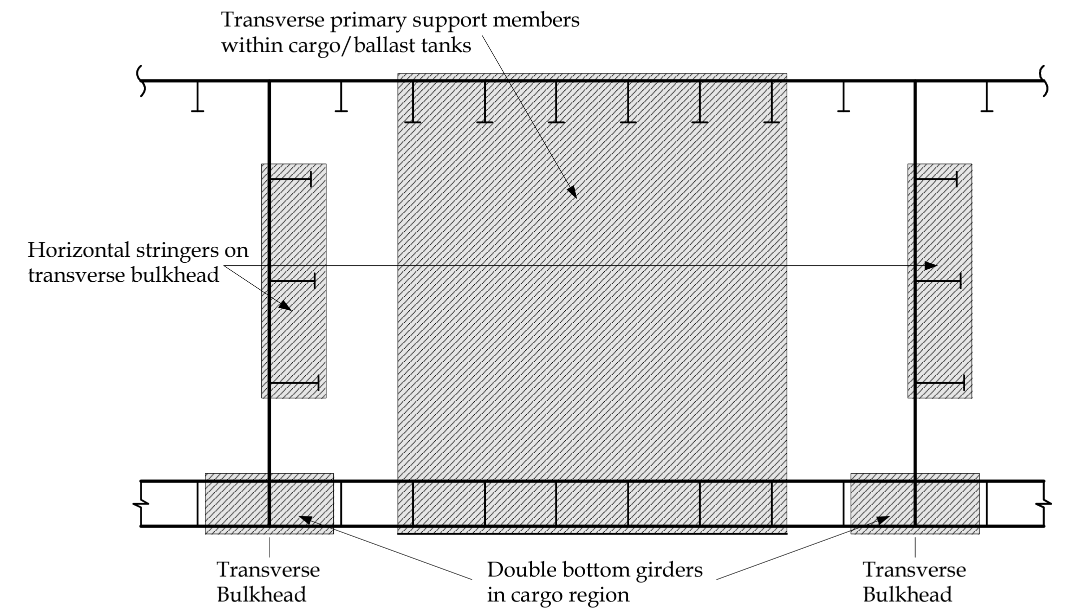
Figure 8.2.4
Depiction of Applicable Extents



2.6.2 Design load sets and permissible stress coefficients for primary support members

2.6.2.1 The design load sets for the evaluation of the primary support members are given in *Table 8.2.9*.

2.6.2.2 The permissible bending and shear stress coefficients for the evaluation of the primary support members are given in *Table 8.2.10*.

Table 8.2.9
Design Load Sets for Primary Support Members

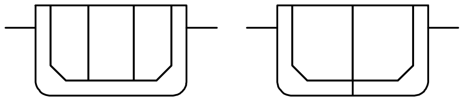
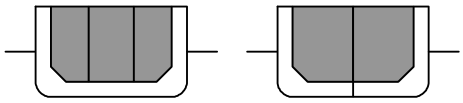
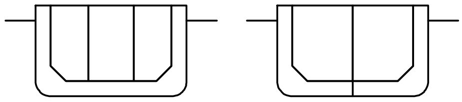
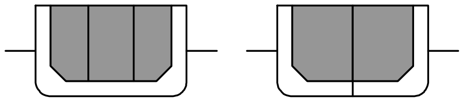
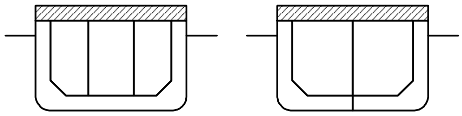
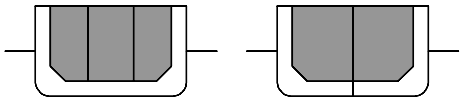
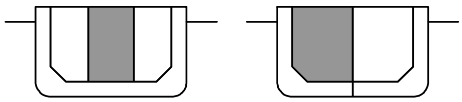
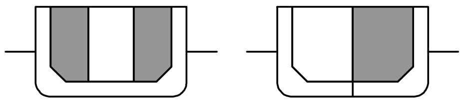
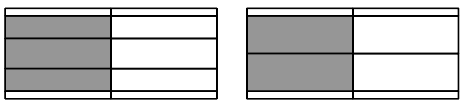
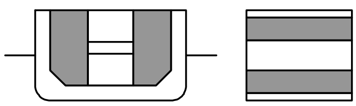
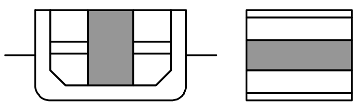
Structural Member	Design Load Set (1, 5, 6)	Load Component	Draught	Comment	Diagrammatic Representation
Double bottom floors and girders (3)	1	P_{ex}	$0.9T_{sc}$ (2)	Sea pressure only	
	2	P_{ex}	T_{sc}		
	12	$P_{in} - P_{ex}$	$0.6T_{sc}$	Net pressure difference between cargo pressure and sea pressure	
	13	$P_{in} - P_{ex}$	(4)		
Side transverses (3)	1	P_{ex}	$0.9T_{sc}$	Sea pressure only	
	2	P_{ex}	T_{sc}		
	3	P_{in}	$0.6T_{sc}$	Cargo pressure only	
	4	P_{in}	-		
Deck transverses	1	P_{ex}	T_{sc}	Green sea pressure only or other loads on deck	
	3	P_{in}	$0.6T_{sc}$	Cargo pressure only	
	4	P_{in}	-		
Vertical web frames on longitudinal bulkheads	3	P_{in}	$0.6T_{sc}$	Pressure from one side only. Full cargo tank with adjacent cargo tank empty	
	4	P_{in}	-		
	3	P_{in}	$0.6T_{sc}$	Pressure from one side only. Full cargo tank with adjacent cargo tank empty	
	4	P_{in}	-		
Horizontal stringers on transverse bulkhead	3	P_{in}	$0.6T_{sc}$	Pressure from one side only. Full cargo tank with adjacent forward or aft cargo tank empty. Two cases are to be evaluated: 1. forward empty/aft full 2. forward full/aft empty	
	4	P_{in}	-		
	11	$P_{in\text{-}flood}$	-		
Cross ties in centre tanks	3	$\frac{P_{in-pt} + P_{in-stb}}{2}$	$0.6T_{sc}$	Full wing cargo tanks, centre tank empty.	
	4	P_{in}	-		
Cross ties in wing tanks	14	$\frac{P_{in} + P_{ex}}{2}$	T_{sc}	Full centre tank, wing cargo tanks empty.	
	15	$\frac{P_{in} + P_{ex}}{2}$	$0.6T_{sc}$		
	16	$\frac{P_{in} + P_{ex}}{2}$	T_{sc}		

Table 8.2.9 (Continued)
Design Load Sets for Primary Support Members

Where:

P_{in-pt} design pressure from port side wing cargo tank, in kN/m²

P_{in-stb} design pressure from starboard side wing cargo tank, in kN/m²

T_{sc} scantling draught, in m, as defined in *Section 4/1.1.5.5*

T_{bal} minimum design ballast draught, in m, as defined in *Section 4/1.1.5.2*

Notes

1. Specification of design load combination, load component, acceptance criteria set and other load parameters for each design load set are given in *Table 8.2.8.*

2. See *1.1.2.9(b)*

3. Draughts specified for bottom floors, girders and side transverses are based on operational limits specified in *1.1.2*. Where the optional loading conditions exceed the minimum Rule required loading conditions the draughts will be subject to special consideration.

4. For tankers with two oil-tight longitudinal bulkheads, the draught is to be taken as $0.25T_{sc}$. For tankers with a centreline bulkhead, the draught is to be taken as $0.33T_{sc}$.

5. When the ship's configuration cannot be described by the structural members or structural configurations identified above, then the applicable Design Load Sets to determine the scantling requirements of primary support member are to be selected so as to specify all applicable cases from the following:
   - a full tank on one side of the member with the tank or space on the other side empty
   - a full tank on one side of the member with the external pressure minimised
   - external pressure maximised with the adjacent tank or space empty

   The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents and are to maximise the net pressure on the structural boundary, the draught to use is to be taken in accordance with the Design Load Set and this table. Design Load Sets covering the S and S+D design load combinations are to be selected. Design Load Set 11 may also need to be applied, depending on the particular structural configuration. See Note 4 on *Table 8.2.7* and *Table 8.2.8.*

6. For a void or dry space, the pressure component from the void side is to be ignored, except where Design Load Set 11 needs to be applied.

Table 8.2.10
Permissible Stress Coefficients, C_{s-pr} and C_{t-pr}, for Primary Support Members

Acceptance criteria set	Permissible bending stress coefficient, C_{s-pr}	Permissible shear stress coefficient, C_{t-pr}
AC1	0.70	0.70
AC2	0.85	0.85

2.6.3 Floors and girders in double bottom

2.6.3.1 Continuous double bottom girders are to be arranged at the centreline or duct keel, at the hopper side and in way of longitudinal bulkheads and bulkhead stools. Plate floors are to be arranged in way of transverse bulkheads and bulkhead stools.

2.6.3.2 The net shear area, $A_{shr-net50}$, of the floors at any position in the floor is not to be less than:

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\,\tau_{yd}} \quad \text{cm}^2$$

Where:

Q design shear force

$= f_{shr} P\, S\, l_{shr}$ kN

f_{shr} shear force distribution factor

$= f_{shr-i}\left(1 - \frac{2y_i}{l_{shr}}\right)$ but not to be taken as less than 0.2

f_{shr-i} shear force distribution factor at the end of the span, l_{shr}, as given in *Table 8.2.11*

l_{shr} effective shear span, of the double bottom floor, in m, as shown in *Figure 8.2.6.* In way of bracket ends, the effective shear span is measured to the toes of the effective end bracket, as defined in *Section 4/2.1.5*. Where the floor ends on a girder at a hopper or stool structure, the effective shear span is measured to a point that is one-half of the distance from the girder to the adjacent bottom and inner-bottom longitudinal, as shown in *Figure 8.2.6.*

y_i distance from the considered cross-section of the floor to the nearest end of the effective shear span, l_{shr}, in m

S primary support member spacing, in m, as defined in *Section 4/2.2.2*

P design pressure for the design load set being considered, calculated at mid point of effective shear span, l_{shr}, of a floor located midway between transverse bulkheads or transverse bulkhead and wash bulkhead, where fitted, in kN/m^2

C_{t-pr} permissible shear stress coefficient for primary support member as given in *Table 8.2.10*

τ_{yd} $= \frac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Table 8.2.11
Shear Force Distribution Factors of Floors

Structural Configuration	Centre tank (f_{shr3} in *Figure 8.2.5*)	Wing Tank	
		At inboard end (f_{shr2} in *Figure 8.2.5*)	At hopper knuckle end (f_{shr1} in *Figure 8.2.5*)
Ships with centreline longitudinal bulkhead	-	0.4	0.6
Ships with two longitudinal bulkheads	0.5	0.50	0.65

Figure 8.2.5
Floor Shear Force Distribution Factors of Floors

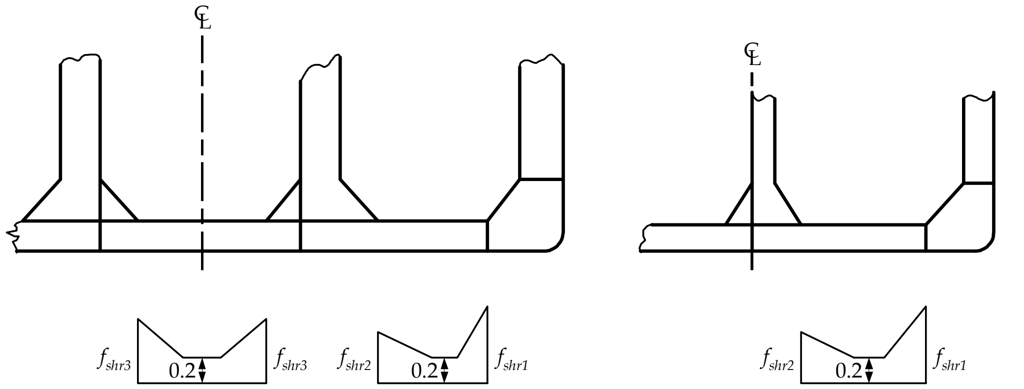
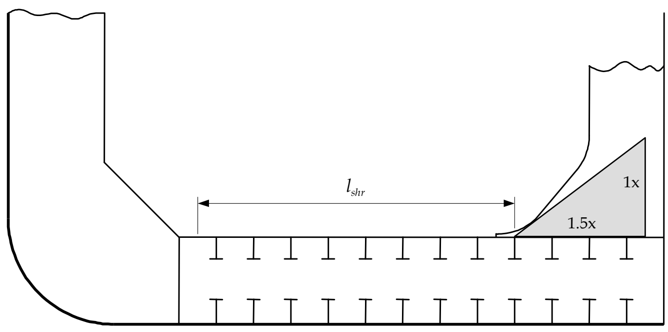
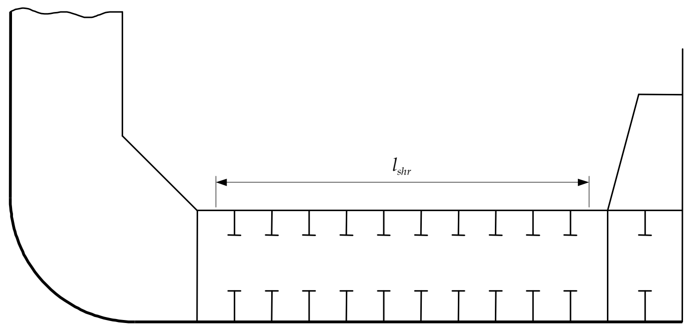


Figure 8.2.6
Effective Shear Span of Floors



Typical arrangement with hopper and end bracket



Typical arrangement with hopper and stool

2.6.3.3 For double bottom centre girders where no longitudinal bulkhead is fitted above, the net shear area, $A_{shr-net50}$, of the double bottom centre girder in way of the first bay from each transverse bulkhead and wash bulkhead, where fitted, is not to be less than:

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\,\tau_{yd}} \quad \text{cm}^2$$

Where:

Q design shear force

$= 0.21\, n_1\, n_2\, P\, l_{shr}^{\;2}$ kN

l_{shr} effective shear span, of the double bottom floor, in m, as shown in *Figure 8.2.6.* In way of bracket ends, the effective shear span is measured to the toes of the effective end bracket, as defined in *Section 4/2.1.5*. Where the floor ends on a girder at a hopper or stool structure, the effective shear span is measured to a point that is one-half of the distance from the girder to the adjacent bottom and inner-bottom longitudinal, as shown in *Figure 8.2.6.*

P design pressure for the design load set being considered, calculated at mid point of effective shear span, l_{shr}, of a floor

located midway between transverse bulkheads or transverse bulkhead and wash bulkhead, where fitted, in kN/m²

n_1 $= 0.00935\left(\frac{l_{shr}}{S}\right)^2 - 0.163\left(\frac{l_{shr}}{S}\right) + 1.289$

n_2 $= 1.3 - \left(\frac{S}{12}\right)$

S double bottom floor spacing, in m, as defined in *Section 4/2.2.2*

C_{t-pr} permissible shear stress coefficient for primary support member as given in *Table 8.2.10*

τ_{yd} $= \frac{\sigma_{yd}}{\sqrt{3}}$ N/mm²

σ_{yd} specified minimum yield stress of the material, in N/mm²

2.6.3.4 For double bottom side girders where no longitudinal bulkhead is fitted above, the net shear area, $A_{shr-net50}$, of the double bottom side girder in way of the first bay from each transverse bulkhead and wash bulkhead, where fitted, is not to be less than:

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\,\tau_{yd}} \quad \text{cm}^2$$

Where:

Q design shear force

$= 0.14\, n_3\, n_4\, P\, l_{shr}^2$ kN

n_3 $= 1.072 - 0.0357\left(\frac{l_{shr}}{S}\right)$

n_4 $= 1.2 - \left(\frac{S}{18}\right)$

l_{shr} effective shear span, of the double bottom floor, in m, as shown in *Figure 8.2.6*. In way of bracket ends, the effective shear span is measured to the toes of the effective end bracket, as defined in *Section 4/2.1.5*. Where the floor ends on a girder at a hopper or stool structure, the effective shear span is measured to a point that is one-half of the distance from the girder to the adjacent bottom and inner-bottom longitudinal, as shown in *Figure 8.2.6.*

S double bottom floor spacing, in m, as defined in *Section 4/2.2.2*

P design pressure for the design load set being considered, calculated at mid point of effective shear span, l_{shr}, of a floor located midway between transverse bulkheads or transverse bulkhead and wash bulkhead, where fitted, in kN/m²

C_{t-pr} permissible shear stress coefficient for primary support member as given in *Table 8.2.10*

τ_{yd} $= \frac{\sigma_{yd}}{\sqrt{3}}$ N/mm²

σ_{yd} specified minimum yield stress of the material, in N/mm²

2.6.4 Deck transverses

2.6.4.1 The web depth of deck transverses is not to be less than:

(a) $0.20\ l_{bdg-dt}$ for deck transverses in the wing cargo tanks of ships with two longitudinal bulkheads

(b) $0.13\ l_{bdg-dt}$ for deck transverses in the centre cargo tanks of ships with two longitudinal bulkheads. The web depth of deck transverses in the centre cargo tank is not to be less than 90% of that of the deck transverses in the wing cargo tank

(c) $0.10\ l_{bdg-dt}$ for the deck transverses of ships with a centreline longitudinal bulkhead.

(d) See also *2.6.1.7*

Where:

l_{bdg-dt} effective bending span of the deck transverse, in m, see *Section 4/2.1.4* and *Figure 8.2.7*, but is not to be taken as less than 60% of the breadth of the tank at the location being considered

2.6.4.2 The moment of inertia of the deck transverses, with associated deck plating, is to comply with *Section 10/2.3.2.3* to control the overall deflection of the deck structure.

2.6.4.3 The net section modulus of deck transverses is not to be less than $Z_{in-net50}$ and $Z_{ex-net50}$ as given by the following. The net section modulus of the deck transverses in the wing cargo tanks is also not to be less than required for the deck transverses in the centre tanks.

$$Z_{in-net50} = \frac{1000\,M_{in}}{C_{s-pr}\,\sigma_{yd}} \quad \text{cm}^3$$

$$Z_{ex-net50} = \frac{1000\,M_{ex}}{C_{s-pr}\,\sigma_{yd}} \quad \text{cm}^3$$

Where:

M_{in} design bending moment due to cargo pressure, in kNm, to be taken as:

(a) for deck transverses in wing cargo tanks of ships with two longitudinal bulkheads, and for deck transverses in cargo tanks of ships with a centreline longitudinal bulkhead:

$= 0.042\,\varphi_t\,P_{in-dt}\,S\,l_{bdg-dt}^{\ 2} + M_{st}$ but is not to be taken as less than M_o

(b) for deck transverses in centre cargo tank of ships with two longitudinal bulkheads:

$= 0.042\,\varphi_t\,P_{in-dt}\,S\,l_{bdg-dt}^{\ 2} + M_{vw}$ but is not to be taken as less than M_o

M_{st} bending moment transferred from the side transverse

$= c_{st}\,\beta_{st}\,P_{in-st}\,S\,l_{bdg-st}^{\ 2}$ kNm

where a cross tie is fitted in a wing cargo tank and $l_{bdg-st-ct}$ is greater than $0.7l_{bdg-st}$, then l_{bdg-st} in the above formula may be

taken as $l_{bdg\text{-}st\text{-}ct}$.

M_{vw} bending moment transferred from the vertical web frame on the longitudinal bulkhead

$= c_{vw}\,\beta_{vw}\,P_{in-vw}\,S\,l_{bdg-vw}{}^{2}$ kNm

where $l_{bdg\text{-}vw\text{-}ct}$ is greater than $0.7l_{bdg\text{-}vw}$, then $l_{bdg\text{-}vw}$ in the above formula may be taken as $l_{bdg\text{-}vw\text{-}ct}$.

for vertically corrugated bulkheads, M_{vw} is to be taken equal to bending moment in upper end of corrugation over the spacing between deck transverses

M_0 minimum bending moment

$= 0.083\,P_{in-dt}\,S\,l_{bdg-dt}{}^{2}$ kNm

M_{ex} design bending moment due to green sea pressure

$= 0.067\,P_{ex-dt}\,S\,l_{bdg-dt}{}^{2}$ kNm

$P_{in\text{-}dt}$ design cargo pressure for the design load set being considered, calculated at mid point of effective bending span, $l_{bdg\text{-}dt}$, of the deck transverse located at mid tank, in kN/m²

$P_{in\text{-}st}$ corresponding design cargo pressure in wing cargo tank for the design load set being considered, calculated at the mid point of effective bending span, $l_{bdg\text{-}st}$, of the side transverse located at mid tank, in kN/m²

$P_{in\text{-}vw}$ corresponding design cargo pressure in the centre cargo tank of ships with two longitudinal bulkheads for the design load set being considered, calculated at mid point of effective bending span, $l_{bdg\text{-}vw}$, of the vertical web frame on the longitudinal bulkhead located at mid tank, in kN/m²

$P_{ex\text{-}dt}$ design green sea pressure for the design load set being considered, calculated at mid point of effective bending span, $l_{bdg\text{-}dt}$, of the deck transverse located at mid tank, in kN/m²

φ_t $= 1 - 5\left(\dfrac{y_{toe}}{l_{bdg-dt}}\right)$ but is not to be taken as less than 0.6

y_{toe} distance from the end of effective bending span, $l_{bdg\text{-}dt}$, to the toe of the end bracket of the deck transverse, in m

β_{st} $= 0.9\left(\dfrac{l_{bdg-st}}{l_{bdg-dt}}\right)\left(\dfrac{I_{dt}}{I_{st}}\right)$ but is not to be taken as less than 0.10 or greater than 0.65

β_{vw} $= 0.9\left(\dfrac{l_{bdg-vw}}{l_{bdg-dt}}\right)\left(\dfrac{I_{dt}}{I_{vw}}\right)$ but is not to be taken as less than 0.10 or greater than 0.50

S primary support member spacing, in m, as defined in *Section 4/2.2.2*

$l_{bdg\text{-}dt}$ effective bending span of the deck transverse, in m, see *Section 4/2.1.4* and *Figure 8.2.7*, but is not to be taken as less than 60% of the breadth of the tank at the location being considered

l_{bdg-st} effective bending span of the side transverse, in m, between the deck transverse and the bilge hopper, see *Section 4/2.1.4* and *Figure 8.2.7*

$l_{bdg-st-ct}$ effective bending span of the side transverse, in m, between the deck transverse and the mid depth of the cross tie, where fitted in wing cargo tank, see *Section 4/2.1.4*

l_{bdg-vw} effective bending span of the vertical web frame on the longitudinal bulkhead, in m, between the deck transverse and the bottom structure, see *Section 4/2.1.4* and *Figure 8.2.7*.

$l_{bdg-vw-ct}$ effective bending span of the vertical web frame on longitudinal bulkhead, in m, between the deck transverse and the mid depth of the cross tie, see *Section 4/2.1.4*

I_{dt} net moment of inertia of the deck transverse with an effective breadth of attached plating specified in *Section 4/2.3.2.3*, in cm^4

I_{st} net moment of inertia of the side transverse with an effective breadth of attached plating specified in *Section 4/2.3.2.3*, in cm^4

I_{vw} net moment of inertia of the longitudinal bulkhead vertical web frame with an effective breadth of attached plating specified in *Section 4/2.3.2.3*, in cm^4

c_{st} as defined in *Table 8.2.12*

c_{vw} as defined in *Table 8.2.12*

C_{s-pr} permissible bending stress coefficient for primary support member as given in *Table 8.2.10*

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Table 8.2.12
Values of c_{st} and c_{vw} for Deck Transverses

Structural Configuration			c_{st}	c_{vw}
Ships with centreline longitudinal bulkhead			0.056	-
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank	M_{vw} based on $l_{bdg-vw-ct}$	-	0.044
		M_{st} based on l_{bdg-st} or M_{vw} based on l_{bdg-vw}	0.044	0.016
	Cross ties in wing cargo tanks	M_{st} based on $l_{bdg-st-ct}$ or M_{vw} based on $l_{bdg-vw-ct}$	0.044	0.044
		M_{st} based on l_{bdg-st} or M_{vw} based on l_{bdg-vw}	0.041	0.015

2.6.4.4 The net shear area of deck transverses is not to be less than $A_{shr-in-net50}$ and $A_{shr-ex-net50}$ as given by:

$$A_{shr-in-net50} = \frac{10 Q_{in}}{C_{t-pr}\,\tau_{yd}} \quad \text{cm}^2$$

$$A_{shr-ex-net50} = \frac{10 Q_{ex}}{C_{t-pr}\,\tau_{yd}} \quad \text{cm}^2$$

Where:

Q_{in} design shear force due to cargo pressure

$= 0.65\, P_{in-dt}\, S\, l_{shr} + c_1\, D\, b_{ctr}\, S\, \rho\, g$ kN

Q_{ex} design shear force due to green sea pressure

$= 0.65\, P_{ex-dt}\, S\, l_{shr}$ kN

P_{in-dt} design cargo pressure for the design load set being considered, calculated at mid point of effective bending span, l_{bdg-dt}, of the deck transverse located at mid tank, in kN/m^2

P_{ex-dt} design green sea pressure for the design load set being considered, calculated at mid point of effective bending span, l_{bdg-dt}, of the deck transverse located at mid tank, in kN/m^2

S primary support member spacing, in m, as defined in *Section 4/2.2.2*

l_{shr} effective shear span, of the deck transverse, in m, see *Section 4/2.1.5*

l_{bdg-dt} effective bending span of the deck transverse, in m, see *Section 4/2.1.4* and *Figure 8.2.7*, but is not to be taken as less than 60% of the breadth of the tank at the location being considered

c_1 = 0.04 in way of wing cargo tanks of ships with two longitudinal bulkheads

= 0.00 in way of centre tank of ships with two longitudinal bulkheads

= 0.00 for ships with a centreline longitudinal bulkhead

D moulded depth, in m, as defined in *Section 4/1.1.4*

b_{ctr} breadth of the centre tank, in m

ρ density of liquid in the tank, in tonnes/m^3, not to be taken less than 1.025, see *Section 2/3.1.8*

g acceleration due to gravity, 9.81 m/s^2

C_{t-pr} permissible shear stress coefficient for primary support member as given in *Table 8.2.10*

τ_{yd} $= \frac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Figure 8.2.7
Definition of Spans of Deck, Side Transverses, Vertical Web Frames on Longitudinal Bulkheads and Horizontal Stringers on Transverse Bulkheads

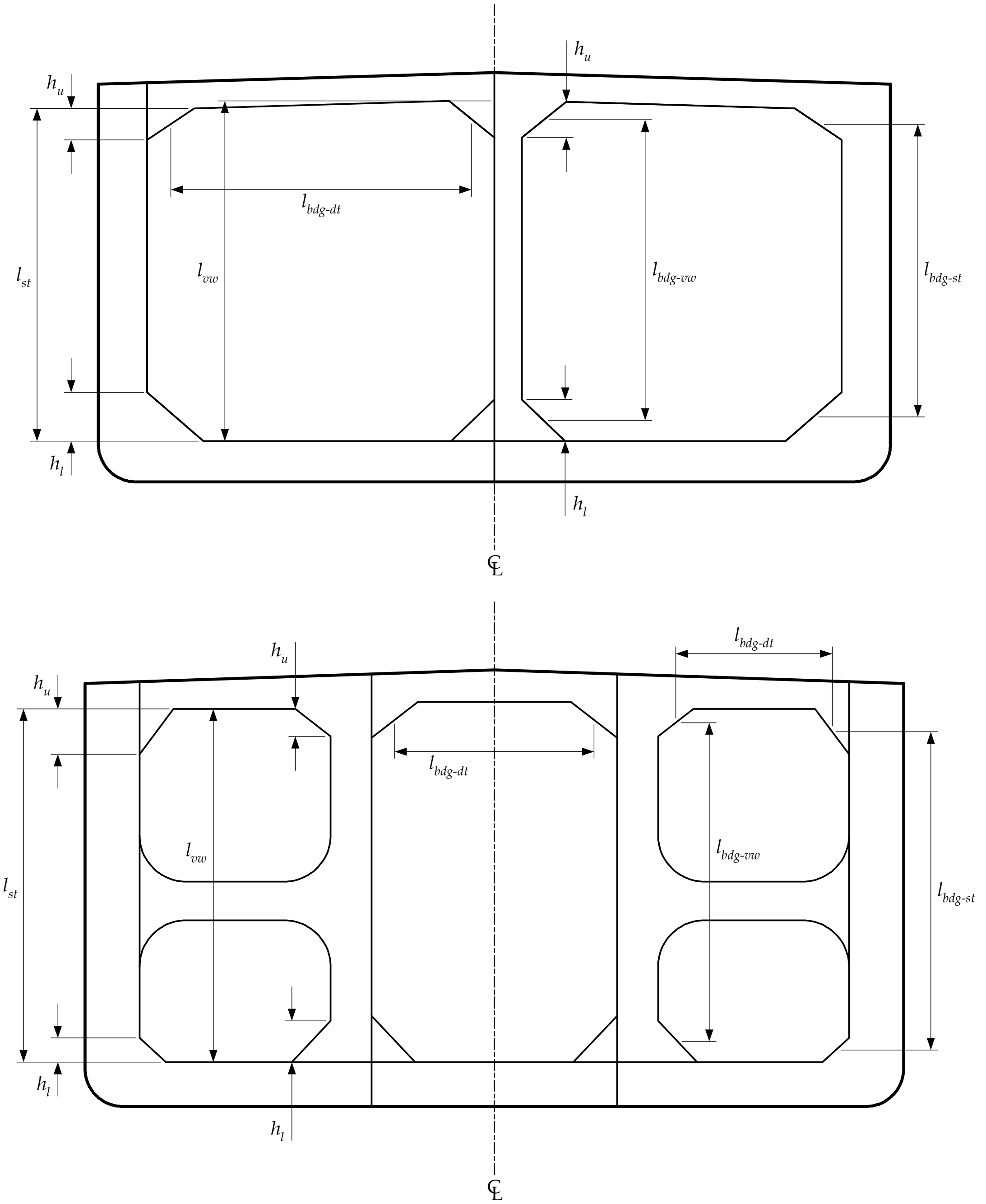
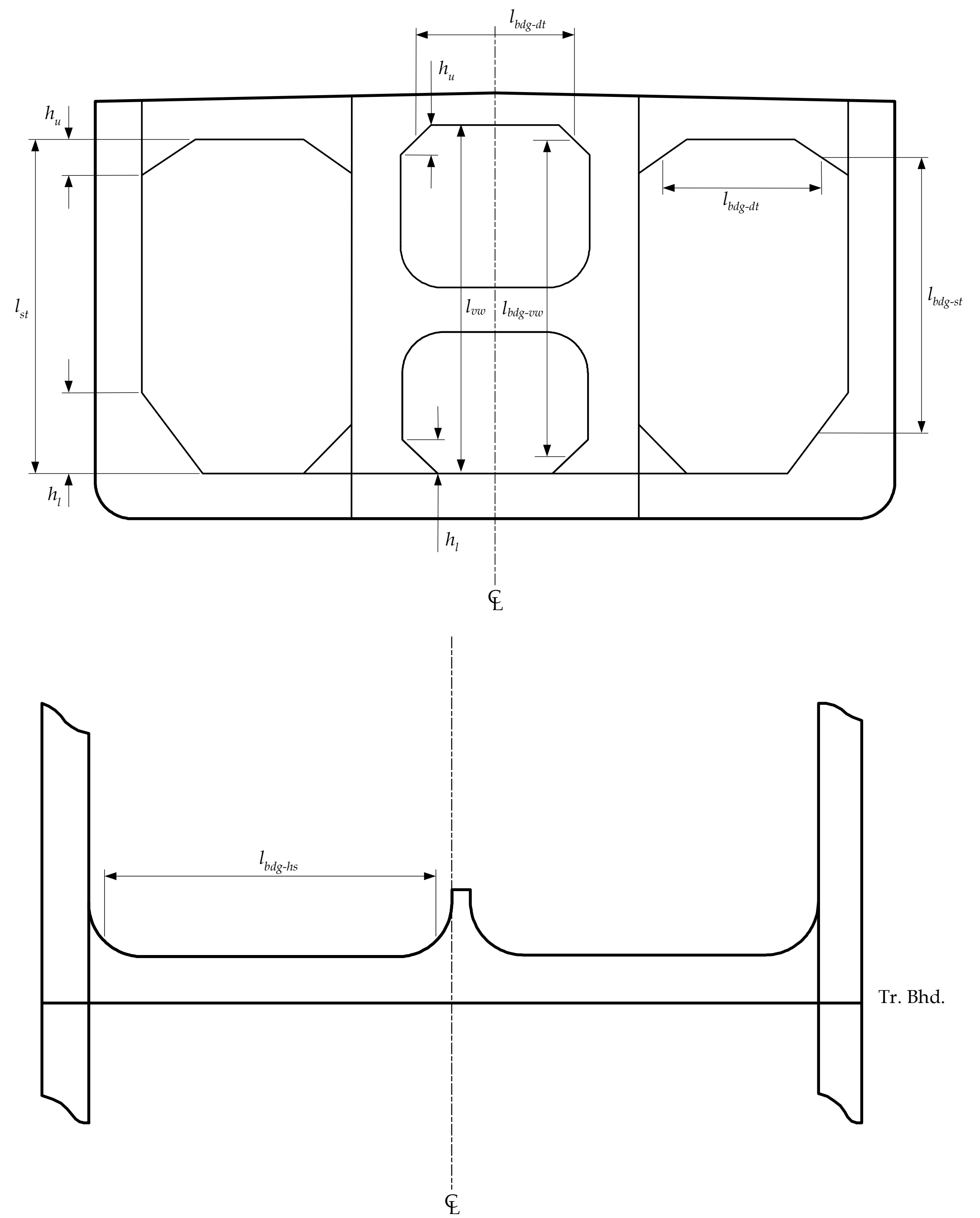


Figure 8.2.7 (Continued)
Definition of Spans of Deck, Side Transverses, Vertical Web Frames on Longitudinal Bulkheads and Horizontal Stringers on Transverse Bulkheads



2.6.5 Side transverses

2.6.5.1 The net shear area, $A_{shr\text{-}net50}$, of side transverses is not to be less than:

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\ \tau_{yd}} \quad \text{cm}^2$$

Where:

Q design shear force as follows, in kN:

= Q_u for upper part of the side transverse

= Q_l for lower part of the side transverse

Q_u = $S\,[c_u\, l_{st}\, (P_u + P_l) - h_u\, P_u]$

where a cross tie is fitted in a wing cargo tank and $l_{st\text{-}ct}$ is greater than $0.7 l_{st}$, then l_{st} in the above formula is to be taken as $l_{st\text{-}ct}$.

Q_l to be taken as the greater of the following:

(a) $S\,[c_l\, l_{st}\, (P_u + P_l) - h_l\, P_l]$

(b) $0.35\, c_l\, S\, l_{st}\, (P_u + P_l)$

(c) $1.2\, Q_u$

where a cross tie is fitted in a wing cargo tank and $l_{st\text{-}ct}$ is greater than $0.7 l_{st}$, then l_{st} in the above formula is to be taken as $l_{st\text{-}ct}$.

P_u design pressure for the design load set being considered, in kN/m^2, calculated at mid tank as follows:

(a) where deck transverses are fitted below deck, P_u is to be calculated at mid height of upper bracket of the side transverse, h_u

(b) where deck transverses are fitted above deck, P_u is to be calculated at the elevation of the deck at side, except in cases where item (c) applies

(c) where deck transverses are fitted above deck and the inner hull longitudinal bulkhead is arranged with a top wing structure as follows:

- the breadth at top of the wing structure is greater than 1.5 times the breadth of the double side and
- the angle along a line between the point at base of the slope plate at its intersection with the inner hull longitudinal bulkhead and the point at the intersection of top wing structure and deck is 30 degrees or more to vertical

P_u is to be calculated at mid depth of the top wing structure

P_l corresponding design pressure for the design load set being considered, calculated at mid height of bilge hopper, h_l, located at mid tank, in kN/m^2.

l_{st} length of the side transverse, in m, and is to be taken as follows:

(a) where deck transverses are fitted below deck, l_{st} is the length between the flange of the deck transverse and the inner bottom, see *Figure 8.2.7*

(b) where deck transverses are fitted above deck, l_{st} is the length between the elevation of the deck at side and the inner bottom

$l_{st\text{-}ct}$ length of the side transverse, in m, and is to be taken as follows:

(a) where deck transverses are fitted below deck, l_{st} is the length between the flange of the deck transverse and mid depth of cross tie, where fitted in wing cargo tank

(b) where deck transverses are fitted above deck, l_{st} is the length between the elevation of the deck at side and mid depth of the cross tie, where fitted in wing cargo tank

S primary support member spacing, in m, as defined in *Section 4/2.2.2*

h_u effective length of upper bracket of the side transverse, in m, and is to be taken as follows:

(a) where deck transverses are fitted below deck, h_u is as shown in Figure 8.2.7 and as described in *Section 4/2.1.5*.

(b) where deck transverses are fitted above deck, h_u is to be taken as 0.0, except in cases where item (c) applies.

(c) where deck transverses are fitted above deck and the inner hull longitudinal bulkhead is arranged with a top wing structure as follows:

- the breadth at top of the wing structure is greater than 1.5 times the breadth of the double side, and
- the angle along a line between the point at base of the slope plate at its intersection with the inner hull longitudinal bulkhead and the point at the intersection of top wing structure and the deck is 30 degrees or more to vertical

h_u is to be taken as the distance between the deck at side and the lower end of slope plate of the top wing structure.

h_l height of bilge hopper, in m, as shown in *Figure 8.2.7*

c_u and c_l as defined in *Table 8.2.13*

C_{t-pr} permissible shear stress coefficient for primary support member as given in *Table 8.2.10*

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm²

σ_{yd} specified minimum yield stress of the material, in N/mm²

<table>
<tr><th colspan="7">Table 8.2.13
Values of c_u and c_l for Side Transverses</th></tr>
<tr><th colspan="3">Structural Configuration</th><th colspan="2">c_u</th><th colspan="2">c_l</th></tr>
<tr><td colspan="3">Number of side stringers</td><td>Less than three</td><td>Equal to or greater than three</td><td>Less than three</td><td>Equal to or greater than three</td></tr>
<tr><td colspan="3">Ships with a centreline longitudinal bulkhead</td><td rowspan="3">0.12</td><td rowspan="3">0.09</td><td rowspan="3">0.29</td><td rowspan="3">0.21</td></tr>
<tr><td rowspan="3">Ships with two longitudinal bulkheads</td><td colspan="2">Cross tie in centre cargo tank</td></tr>
<tr><td rowspan="2">Cross ties in wing cargo tanks</td><td>Q_u or Q_l based on l_{st-ct}</td></tr>
<tr><td>Q_u or Q_l based on l_{st}</td><td colspan="2">0.08</td><td colspan="2">0.20</td></tr>
</table>

2.6.5.2 The shear area over the length of the side transverse is to comply with the following:

(a) the required shear area for the upper part is to be maintained over the upper $0.2\,l_{shr}$

(b) the required shear area for the lower part is to be maintained over the lower $0.2\,l_{shr}$

(c) where Q_u and Q_l are determined based on l_{st-ct}, the required shear area for the lower part is also to be maintained below the cross tie

(d) for ships without cross ties in the wing cargo tanks, the required shear area between the upper and lower parts is to be reduced linearly towards 50% of the required shear area for the lower part at mid span

(e) for ships with cross ties in the wing cargo tanks, the required shear area along the span is to be tapered linearly between the upper and lower parts

Note

When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress

Where:

l_{shr} effective shear span of the side transverse, in m

$= l_{st} - h_u - h_l$ where Q_u and Q_l are determined based on l_{st}

$= l_{st-ct} - h_u$ where Q_u and Q_l are determined based on l_{st-ct}

l_{st}, l_{st-ct}, h_u, h_l, Q_u and Q_l as defined in *2.6.5.1*

2.6.6 Vertical web frames on longitudinal bulkhead

2.6.6.1 The web depth of the vertical web frame on the longitudinal bulkhead is not to be less than:

(a) $0.14\,l_{bdg-vw}$ for ships with a centreline longitudinal bulkhead

(b) $0.09\,l_{bdg-vw}$ for ships with two longitudinal bulkheads

(c) see also *2.6.1.7*

Where:

l_{bdg-vw} effective bending span of the vertical web frame on the longitudinal bulkhead, see *2.6.6.2* and *Figure 8.2.7*

2.6.6.2 The net section modulus, Z_{net50}, of the vertical web frame is not to be less than:

$$Z_{net50} = \frac{1000\,M}{C_{s-pr}\,\sigma_{yd}} \quad \text{cm}^3$$

Where:

M design bending moment, in kNm, as follows:

$= c_u P S l_{bdg-vw}{}^2$ for upper part of the web frame

$= c_l P S l_{bdg-vw}{}^2$ for lower part of the web frame

where a cross tie is fitted and $l_{bdg-vw-ct}$ is greater than $0.7 l_{bdg-vw}$, then l_{bdg-vw} in the above formula is to be taken as $l_{bdg-vw-ct}$.

P design pressure for the design load set being considered, calculated at mid point of the effective bending span, l_{bdg-vw}, of the vertical web frame located at mid tank, in kN/m²

l_{bdg-vw} effective bending span of the vertical web frame on the longitudinal bulkhead, between the deck transverse and the bottom structure, in m, see *Section 4/2.1.4* and *Figure 8.2.7*.

$l_{bdg-vw-ct}$ effective bending span of the vertical web frame on longitudinal bulkhead, between the deck transverse and mid depth of the cross tie on ships with two longitudinal bulkheads, in m, see *Section 4/2.1.4*

S primary support member spacing, in m, as defined in *Section 4/2.2.2*

C_{s-pr} permissible bending stress coefficient as given in *Table 8.2.10*

σ_{yd} specified minimum yield stress of the material, in N/mm²

c_u and c_l as defined in *Table 8.2.14*

Table 8.2.14
Values of c_u and c_l for Vertical Web Frame on Longitudinal Bulkheads

Structural Configuration			c_u	c_l
Ships with a centreline longitudinal bulkhead			0.057	0.071
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank	M based on $l_{bdg-vw-ct}$	0.057	0.071
		M based on l_{bdg-vw}	0.012	0.028
	Cross ties in wing cargo tanks	M based on $l_{bdg-vw-ct}$	0.057	0.071
		M based on l_{bdg-vw}	0.016	0.032

2.6.6.3 The section modulus over the length of the vertical web frame on the longitudinal bulkhead is to comply with the following:

(a) the required section modulus for the upper part is to be maintained over the upper $0.2\,l_{bdg-vw}$ or $0.2\,l_{bdg-vw-ct}$, as applicable

(b) the required section modulus for the lower part is to be maintained over the lower $0.2\,l_{bdg-vw}$ or $0.2\,l_{bdg-vw-ct}$, as applicable

(c) where the required section modulus is determined based on $l_{bdg-vw-ct}$, the required section modulus for the lower part is also to be maintained below the cross tie

(d) the required section modulus between the upper and lower parts is to be reduced linearly to 70% of the required section modulus for the lower part at mid span

Note

When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

Where:

l_{bdg-vw} and $l_{bdg-vw-ct}$ as defined in *2.6.6.2*

2.6.6.4 The net shear area, $A_{shr-net50}$, of the vertical web frame is not to be less than:

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\,\tau_{yd}} \quad \text{cm}^2$$

Where:

Q design shear force as follows, in kN:

$= Q_u$ for upper part of the web frame

$= Q_l$ for lower part of the web frame

Q_u $= S\ [c_u\, l_{vw}\, (P_u + P_l) - h_u\, P_u]$

where a cross tie is fitted in a centre or wing cargo tank and l_{vw-ct} is greater than $0.7l_{vw}$, then l_{vw} in the above formula is to be taken as l_{vw-ct}.

Q_l to be taken as the greater of the following:

(a) $S[c_l\, l_{vw}\, (P_u + P_l) - h_l\, P_l]$

(b) $c_w\, S\, c_l\, l_{vw}\, (P_u + P_l)$

(c) $1.2\, Q_u$

where a cross tie is fitted in a centre or wing cargo tank and l_{vw-ct} is greater than $0.7l_{vw}$, then l_{vw} in the above formula is to be taken as l_{vw-ct}.

P_u design pressure for the design load set being considered, calculated at mid height of upper bracket of the vertical web frame, h_u, located at mid tank, in kN/m^2

P_l design pressure for the design load set being considered, calculated at mid height of lower bracket of the vertical web frame, h_l, located at mid tank, in kN/m^2

l_{vw} length of the vertical web frame, in m, between the flange of the deck transverse and the inner bottom, see *Figure 8.2.7*

l_{vw-ct} length of the vertical web frame, in m, between the flange of the deck transverse and mid depth of the cross tie, where fitted

S primary support member spacing, in m, as defined in *Section 4/2.2.2*

h_u effective length of upper bracket of the vertical web frame, in m, as shown in *Figure 8.2.7* and as described in *Section 4/2.1.5*

h_l effective length of lower bracket of the vertical web frame, in m,

as shown in *Figure 8.2.7* and as described in *Section 4/2.1.5*

c_u and c_l as defined in *Table 8.2.15*

c_w 0.57 for ships with a centreline longitudinal bulkhead

0.50 for ships with two longitudinal bulkheads

C_{t-pr} permissible shear stress coefficient for primary support member as given in *Table 8.2.10*

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm²

σ_{yd} specified minimum yield stress of the material, in N/mm²

Table 8.2.15
Values of c_u and c_l for Vertical Web Frame on Longitudinal Bulkhead

Structural Configuration		c_u	c_l
Ships with a centreline longitudinal bulkhead		0.17	0.28
Ships with two longitudinal bulkheads	Q_u or Q_l based on l_{vw-ct}		
	Q_u or Q_l based on l_{vw}	0.075	0.18

2.6.6.5 The shear area over the length of the vertical web frame on the longitudinal bulkhead is to comply with the following:

(a) the required shear area for the upper part is to be maintained over the upper $0.2\,l_{shr}$

(b) the required shear area for the lower part is to be maintained over the lower $0.2\,l_{shr}$

(c) where Q_u and Q_l are determined based on l_{vw-ct}, the required shear area for the lower part is also to be maintained below the cross tie

(d) for ships without cross ties in the wing or centre cargo tanks, the required shear area between the upper and lower parts is to be reduced linearly towards 50% of the required shear area for the lower part at mid span

(e) for ships with cross ties in the wing or centre cargo tanks, the required shear area along the span is to be tapered linearly between the upper and lower parts

Note

When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

Where:

l_{shr} effective shear span of the side transverse

$= l_{vw} - h_u - h_l$ where Q_u and Q_l are determined based on l_{vw}

$= l_{vw-ct} - h_u$ where Q_u and Q_l are determined based on l_{vw-ct}

l_{vw}, l_{vw-ct}, h_u, h_l, Q_u and Q_l as defined in *2.6.6.4*

2.6.7 Horizontal stringers on transverse bulkheads

2.6.7.1 The web depth of horizontal stringers on transverse bulkhead is not to be less than:

(a) $0.28\, l_{bdg\text{-}hs}$ for horizontal stringers in wing cargo tanks of ships with two longitudinal bulkheads

(b) $0.20\, l_{bdg\text{-}hs}$ for horizontal stringers in centre tanks of ships with two longitudinal bulkheads, but the web depth of horizontal stringers in centre tank is not to be less than required depth for a horizontal stringer in wing cargo tanks

(c) $0.20\, l_{bdg\text{-}hs}$ for horizontal stringers of ships with a centreline longitudinal bulkhead

(d) see also *2.6.1.7*.

Where:

$l_{bdg\text{-}hs}$ effective bending span of the horizontal stringer, in m, but is not to be taken as less than 50% of the breadth of the tank at the location being considered, see *Section 4/2.1.4* and *Figure 8.2.7*

2.6.7.2 The net section modulus, Z_{net50}, of the horizontal stringer over the end $0.2 l_{bdg\text{-}hs}$ is not to be less than:

$$Z_{net50} = \frac{1000\, M}{C_{s-pr}\, \sigma_{yd}} \quad \text{cm}^3$$

Where:

M design bending moment:

$= c\, P\, S\, l_{bdg-hs}{}^2$ kNm

P design pressure for the design load set being considered, calculated at mid point of effective bending span, $l_{bdg\text{-}hs}$, and at mid point of the spacing, S, of the horizontal stringer, in kN/m^2

S sum of the half spacing (distance between stringers) on each side of the horizontal stringer under consideration, in m

$l_{bdg\text{-}hs}$ effective bending span of the horizontal stringer, in m, but is not to be taken as less than 50% of the breadth of the tank at the location being considered, see *Section 4/2.1.4* and *Figure 8.2.7*

c
- 0.073 for horizontal stringers in cargo tanks of ships with a centreline bulkhead
- 0.083 for horizontal stringers in wing cargo tanks of ships with two longitudinal bulkheads
- 0.063 for horizontal stringers in the centre tank of ships with two longitudinal bulkheads

$C_{s\text{-}pr}$ permissible bending stress coefficient as given in *Table 8.2.10*

σ_{yd} specified minimum yield stress of the material, in N/mm^2

2.6.7.3 The required section modulus at mid effective bending span is to be taken as 70% of that required at the ends, intermediate values are to be obtained by linear

interpolation. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

2.6.7.4 The net shear area, $A_{shr-net50}$, of the horizontal stringer over the end 0.2 l_{shr} is not to be less than:

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\,\tau_{yd}} \quad \text{cm}^2$$

Where:

Q design shear force

$= 0.5\,P\,S\,l_{shr}$ kN

P design pressure for the design load set being considered, calculated at mid point of effective bending span, l_{bdg-hs}, and at mid point of the spacing, S, of the horizontal stringer, in kN/m²

S sum of the half spacing (distance between stringers), on each side of the horizontal stringer under consideration, in m

l_{shr} effective shear span of the horizontal stringer, in m, see *Section 4/2.1.5*

C_{t-pr} permissible shear stress coefficient as given in *Table 8.2.10*

τ_{yd} $= \frac{\sigma_{yd}}{\sqrt{3}}$ N/mm²

σ_{yd} specified minimum yield stress of the material, in N/mm²

2.6.7.5 The required shear area at mid effective shear span is to be taken as 50% of that required in the ends, intermediate values are to be obtained by linear interpolation. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

2.6.8 Cross ties

2.6.8.1 The maximum applied design axial load on cross ties, W_{ct}, is to be less than or equal to the permissible load, $W_{ct-perm}$, as given by:

$$W_{ct} \le W_{ct-perm}$$

Where:

W_{ct} applied axial load

$= P\,b_{ct}\,S$ kN

$W_{ct-perm}$ permissible load

$= 0.1\,A_{ct-net50}\,\eta_{ct}\,\sigma_{cr}$ kN

P maximum design pressure for all the applicable design load sets being considered, calculated at centre of the area supported by the cross tie located at mid tank, in kN/m²

b_{ct} where cross tie is fitted in centre cargo tank:

$= 0.5\,l_{bdg-vw}$

where cross ties are fitted in wing cargo tanks:

$= 0.5\,l_{bdg-vw}$, for design cargo pressure from the centre cargo

tank

$= 0.5\, l_{bdg-st}$ for design sea pressure

l_{bdg-vw} effective bending span of the vertical web frame on the longitudinal bulkhead, in m, see *Section 4/2.1.4* and *Figure 8.2.7*.

l_{bdg-st} effective bending span of the side transverse, in m, see *Section 4/2.1* and *Figure 8.2.7*.

S primary support member spacing, in m, as defined in *Section 4/2.2.2*

η_{ct} utilisation factor, to be taken as:

$= 0.65$ for acceptance criteria set AC1

$= 0.75$ for acceptance criteria set AC2

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σ_{cr} critical buckling stress in compression of the cross tie, in N/mm^2, as calculated using the net sectional properties in accordance with *Section 10/3.5.1*, where the effective length of the cross tie is to be taken as follows, in m:

(a) for cross tie in centre tank:

distance between the flanges of longitudinal stiffeners on the starboard and port longitudinal bulkheads to which the cross tie's horizontal stiffeners are attached

(b) for cross tie in wing tank:

distance between the flanges of longitudinal stiffeners on the longitudinal bulkhead to which the cross tie's horizontal stiffeners are attached, and the inner hull plating

$A_{ct-net50}$ net cross sectional area of the cross tie, in cm^2

2.6.8.2 Special attention is to be paid to the adequacy of the welded connections for the transmission of the forces, and also to the stiffening arrangements, in order to provide effective means for transmission of the compressive forces into the webs. Particular attention is to be paid to the welding at the toes of all end brackets of the cross ties.

2.6.8.3 Horizontal stiffeners are to be located in line with, and attached to, the longitudinals at the ends of the cross ties.

2.6.9 Primary support members located beyond 0.4*L* amidships

2.6.9.1 If a cargo tank FE analysis is not available for the region outside of 0.4*L* amidships, the requirements given in *2.6.9.2* and *2.6.9.3* may be used to obtain the scantlings of primary support members located beyond 0.4*L* of amidships. Scantlings used for the 0.4*L* amidships are to be those required by *Sections 8/2* and *Section 9/2*, see *2.6.1.3* and *2.6.1.4*.

2.6.9.2 The net section modulus of primary support members, $Z_{end-net50}$, located beyond 0.4*L* of amidships is not to be less than:

$$Z_{end-net50} = \frac{Z_{mid-net50}\,\sigma_{yd-mid}\,M_{end}}{\sigma_{yd-end}\,M_{mid}} \qquad \text{cm}^3$$

Where:

M_{end} bending moment, in kNm, for the structural member under consideration located beyond 0.4*L* amidships, calculated in accordance with corresponding requirements of *2.6.3* to *2.6.8* and using the design pressure specified for the given location

M_{mid} bending moment, in kNm, for the corresponding structural member and location of cross section, amidships, obtained from the corresponding requirements of *2.6.2* to *2.6.8*

$Z_{mid-net50}$ net section modulus at the flange of the corresponding structural member and location of cross section amidships, in cm^3

σ_{yd-end} specified minimum yield stress of the flange of the structural member under consideration located beyond 0.4*L* amidships, in N/mm^2

σ_{yd-mid} specified minimum yield stress of the flange of the structural member under consideration amidships, in N/mm^2

2.6.9.3 The net shear area for primary support members, $A_{shr-end-net50}$, located beyond 0.4*L* amidships is not to be less than:

$$A_{shr-end-net50} = \frac{A_{shr-mid-net50}\,\tau_{yd-mid}\,Q_{end}}{\tau_{yd-end}\,Q_{mid}} \qquad \text{cm}^2$$

Where:

Q_{end} shear force, in kN, for the structural member under consideration located beyond 0.4*L* of amidships, calculated in accordance with the corresponding requirements of *2.6.3* to *2.6.8* and using the design pressure, specified for the given location

Q_{mid} shear force, in kN, for the corresponding structural member and corresponding location of cross section, amidships, obtained from the requirements of *2.6.2* to *2.6.8*

$A_{shr-mid-net50}$ shear area of corresponding structural member and location of cross section amidships, in cm^2

τ_{yd-end} $= \dfrac{\sigma_{yd-end}}{\sqrt{3}}$

τ_{yd-mid} $= \dfrac{\sigma_{yd-mid}}{\sqrt{3}}$

σ_{yd-end} specified minimum yield stress of the structural member under consideration located beyond 0.4*L* amidships, in N/mm^2

σ_{yd-mid} specified minimum yield stress of the structural member under consideration amidships, in N/mm^2

3 FORWARD OF THE FORWARD CARGO TANK

3.1 General

3.1.1 Application

3.1.1.1 The requirements of this Sub-Section apply to structure forward of the forward end of the foremost cargo tank. Where the forward end of the foremost cargo tank is aft of 0.1*L* of the ship's length, measured from the F.P., special consideration will be given to the applicability of these requirements and the requirements of *Section 8/2*.

3.1.1.2 The net scantlings described in this Sub-Section are related to gross scantlings as follows:

(a) for application of the minimum thickness requirements of *3.1.4*, the gross thickness is obtained from the applicable requirements by adding the full corrosion additions specified in *Section 6/3*.

(b) for plating and local support members, the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in Section 6/3

(c) for primary support members, the gross shear area, gross section modulus and other gross cross sectional properties are obtained from the applicable requirements by adding one half of the relevant full corrosion additions specified in Section 6/3

(d) for application of buckling requirements of Section 10/2 the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in *Section 6/3*.

3.1.2 General scantling requirements

3.1.2.1 The hull structure is to comply with the applicable requirements of:

(a) hull girder longitudinal strength, see Section 8/1

(b) strength against sloshing and impact loads, see Section 8/6

(c) buckling/ultimate strength, see *Section 10*.

3.1.2.2 The deck plating thickness and supporting structure are to be suitably reinforced in way of the anchor windlass and other deck machinery, and in way of cranes, masts and derrick posts. See *Section 11/3*.

3.1.2.3 The net section modulus, shear area and other sectional properties of local and primary support members are to be determined in accordance with *Section 4/2*.

3.1.2.4 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus and cross sectional shear areas of the primary support members are to be applied as required in the notes to *Table 8.3.5*.

3.1.2.5 The scantling criteria are based on assumptions that all structural joints and welded details are designed and fabricated such that they are compatible with the anticipated working stress levels at the locations considered. The loading patterns, stress concentrations and potential failure modes of structural joints and details during the design of highly stressed regions are to be considered. Structural design details are to comply with the requirements in *Section 4/3*.

3.1.2.6 Limber, drain and air holes are to be cut in all parts of the structure, as required, to ensure free flow to the suction pipes and the escape of air to the vents.

Arrangements are to be made for draining the spaces above deep tanks. See also *Section 4/3*.

3.1.2.7 Web stiffeners are to be fitted on primary support members at each longitudinal on the side and bottom shell. Alternative arrangements may be accepted where adequacy of stiffener end connections and strength of adjoining web and bulkhead plating is demonstrated.

3.1.3 Structural continuity

3.1.3.1 Scantlings of the shell envelope, upper deck and inner bottom are to be tapered towards the forward end. See also *1.6*.

3.1.3.2 In the transition zone aft of the fore peak into the forward cargo tank, due consideration is to be given to the arrangement of major longitudinal members in order to avoid abrupt changes in section. Structures within the fore peak, such as flats, decks, horizontal ring frames or side stringers, are to be scarphed effectively into the structure aft into the cargo tank. Where such structures are in line with longitudinal members aft of the forward cargo tank bulkhead fitting of tapered transition brackets may be used.

3.1.3.3 Where inner hull or longitudinal bulkhead structures terminate at the forward bulkhead of the forward cargo tank, adequate backing structure is to be provided together with tapering brackets to ensure continuity of strength.

3.1.3.4 Longitudinal framing of the strength deck is to be carried as far forward as practicable.

3.1.3.5 All shell frames and tank boundary stiffeners are to be continuous, or are to be bracketed at their ends, except as permitted in *Sections 4/3.2.4* and *4/3.2.5*.

3.1.4 Minimum thickness

3.1.4.1 In addition to the thickness, section modulus and stiffener web shear area requirements as given in this Sub-Section, the thickness of plating and stiffeners in the forward region are to comply with the appropriate minimum thickness requirements given in *Table 8.3.1*.

3.2 Bottom Structure

3.2.1 Plate keel

3.2.1.1 A flat plate keel is to extend as far forward as practical and is to satisfy the scantling requirements given in *2.2.1*.

3.2.2 Bottom shell plating

3.2.2.1 The thickness of the bottom shell plating is to comply with the requirements in *3.9.2.1*.

3.2.3 Bottom longitudinals

3.2.3.1 Bottom longitudinals are to be carried as far forward as practicable. Beyond this, suitably stiffened frames are to be fitted.

3.2.3.2 The section modulus and thickness of the bottom longitudinals are to comply with the requirements in *3.9.2.2* and *3.9.2.3*.

Table 8.3.1
Minimum Net Thickness of Structure Forward of the Forward Cargo Tank

Scantling Location			Net Thickness (mm)
Plating	**Shell**	Keel plating	See *2.1.5.1*
		Bottom shell/bilge/side shell plating	See *2.1.5.1*
	Upper Deck		See *2.1.5.1*
	Other structure	Hull internal tank boundaries	See *2.1.5.1*
		Non-tight bulkheads, bulkheads between dry spaces and other plates in general	See *2.1.5.1*
		Pillar bulkheads	7.5
		Breasthooks	6.5
Floors and bottom girders			$5.5 + 0.02L_2$
Web plating of primary support members			$6.5 + 0.015L_2$
Local support members			See *2.1.5.1*
Tripping brackets			See *2.1.5.1*

Where:

L_2 rule length, L, in m, as defined in *Section 4/1.1.1.1*, but need not be taken greater than 300m

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3.2.4 Bottom floors

3.2.4.1 Bottom floors are to be fitted at each web frame location. The minimum depth of the floor at the centreline is to be not to be less than the required depth of the double bottom of the cargo tank region. See *Section 5/3.2.1.1*.

3.2.5 Bottom girders

3.2.5.1 A supporting structure is to be provided at the centreline either by extending the centreline girder to the stem or by providing a deep girder or centreline bulkhead.

3.2.5.2 Where a centreline girder is fitted, the minimum depth and thickness is not to be less than that required for the depth of the double bottom in the cargo tank region, and the upper edge is to be stiffened. Where a centreline wash bulkhead is fitted, the lowest strake is to have thickness not less than required for a centreline girder.

3.2.5.3 Where a longitudinal wash bulkhead supports bottom transverses, the details and arrangements of openings in the bulkhead are to be configured to avoid areas of high stresses in way of the connection of the wash bulkhead with bottom transverses.

3.2.6 Plate stems

3.2.6.1 Plate stems are to be supported by stringers and flats, and by intermediate breasthook diaphragms spaced not more than 1500mm apart, measured along the stem. Where the stem radius is large, a centreline support structure is to be fitted.

3.2.6.2 Between the minimum design ballast draught, T_{bal} at the stem and the scantling draught, T_{sc}, the plate stem net thickness, $t_{stem\text{-}net}$, is not to be less than:

$$t_{stem-net} = \frac{L_2 \sqrt{\frac{235}{\sigma_{yd}}}}{12}$$ mm, but need not be taken as greater than 21mm

Where:

L_2 rule length, L, in m, as defined in *Section 4/1.1.1.1*, but need not be taken greater than 300m

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Above the scantling draught the thickness of the stem plate may be tapered to the requirements for the shell plating at the upper deck.

Below the minimum design ballast draught the thickness of the stem plate may be tapered to the requirements for the plate keel.

3.2.7 Floors and girders in spaces aft of the collision bulkhead

3.2.7.1 Floors and girders which are aft of the collision bulkhead and forward of the forward cargo tank, are to comply with the requirements in *3.2.4* and *3.2.5* and are to comply with the shear area requirements in *3.9.3.3*.

3.3 Side Structure

3.3.1 Side shell plating

3.3.1.1 The thickness of the side shell plating is to comply with the requirements in *3.9.2.1*. Where applicable, the thickness of the side shell plating is to comply with the requirements in *2.2.4.2*.

3.3.1.2 Where a forecastle is fitted, the side shell plating requirements are to be applied to the plating extending to the forecastle deck elevation.

3.3.2 Side shell local support members

3.3.2.1 Longitudinal framing of the side shell is to be carried as far forward as practicable.

3.3.2.2 The section modulus and thickness of the hull envelope framing is to comply with the requirements in *3.9.2.2* and *3.9.2.3*.

3.3.2.3 End connections of longitudinals at transverse bulkheads are to provide adequate fixity, lateral support, and where not continuous are to be provided with soft-nosed brackets. Brackets lapped onto the longitudinals are not to be used.

3.3.3 Side shell primary support structure

3.3.3.1 In general, the spacing of web frames, S as defined in *Section 4/2.2.2*, is to be taken as:

$S = 2.6 + 0.005L_2$ m, but not to be taken greater than 3.5m

Where:

L_2 rule length, L, as defined in *Section 4/1.1.1.1*, but is not to be taken greater than 300m

3.3.3.2 In general, the transverse framing forward of the collision bulkhead stringers are to be spaced approximately 3.5m apart. Stringers are to have an effective span not greater than 10m, and are to be adequately supported by web frame structures. Aft of the collision bulkhead, where transverse framing is adopted, the spacing of stringers may be increased.

3.3.3.3 Perforated flats are to be fitted to limit the effective span of web frames to not greater than 10m.

3.3.3.4 The scantlings of web frames supporting longitudinal frames, and stringers and/or web frames supporting transverse frames in the forward region are to be determined from *3.9.3*, with the following additional requirements:

(a) where no cross ties are fitted:

- the required section modulus of the web frame is to be maintained for 60% of the effective span for bending, measured from the lower end. The value of the bending moment used for calculation of the required section modulus of the remainder of the web frame may be appropriately reduced, but not greater than 20%
- the required shear area of the lower part of the web frame is to be maintained for 60% of the shear span measured from the lower end.

(b) where one cross tie is fitted:

- the effective spans for bending and shear of a web frame or stringer are to be taken ignoring the presence of the cross tie. The shear forces and bending moments may be reduced to 50% of the values that are calculated ignoring the presence of the cross ties. For a web frame, the required section modulus and shear area of the lower part of the web frame is to be maintained up to the cross tie, and the required section modulus and shear area of the upper part of the web frame is to be maintained for the section above the cross tie
- cross ties are to satisfy the requirements of *2.6.8* using the design loads specified in *Table 8.3.8.*

(c) configurations with multiple cross ties are to be specially considered, in accordance with *3.3.3.4(d)*

(d) where complex grillage structures are employed the suitability of the scantlings of the primary support members is to be determined by more advanced calculation methods.

3.3.3.5 The web depth of primary support members is not to be less than 14% of the bending span and is to be at least 2.5 times as deep as the slots for stiffeners if the slots are not closed.

3.4 Deck Structure

3.4.1 Deck plating

3.4.1.1 The thickness of the deck plating is to comply with the requirements in *3.9.2.1* with the applicable lateral pressure, green sea and deck loads.

3.4.1.2 (void)

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3.4.2 Deck stiffeners

3.4.2.1 The section modulus and thickness of deck stiffeners are to comply with the requirements in *3.9.2.2* and *3.9.2.3*, with the applicable lateral pressure, green sea and deck loads.

3.4.3 Deck primary support structure

3.4.3.1 The section modulus and shear area of primary support members are to comply with the requirements in *3.9.3*.

3.4.3.2 The web depth of primary support members is not to be less than 10% and 7% of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2.5 times the depth of the slots if the slots are not closed. Unsupported span in bending is bending span as defined in *Section 4/2.1.4* or in case of a grillage structure, the distance between connections to other primary support members.

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3.4.3.3 In way of concentrated loads from heavy equipment, the scantlings of the deck structure are to be determined based on the actual loading. See also *Section 11/3*.

3.4.4 Pillars

3.4.4.1 Pillars are to be fitted in the same vertical line wherever possible and effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

3.4.4.2 Tubular and hollow square pillars are to be attached at their heads and heels by efficient brackets or doublers/insert plates, where applicable, to transmit the load effectively. Pillars are to be attached at their heads and heels by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be distributed by brackets or other equivalent means.

3.4.4.3 Pillars in tanks are to be of solid section. Where the hydrostatic pressure may result in tensile stresses in the pillar, the tensile stress in the pillar and its end connections is not to exceed 45% of the specified minimum yield stress of the material.

3.4.4.4 The scantlings of pillars are to comply with the requirements in *3.9.5*.

3.4.4.5 Where the loads from heavy equipment exceed the design load of *3.9.5*, the pillar scantlings are to be determined based on the actual loading.

3.5 Tank Bulkheads

3.5.1 General

3.5.1.1 Tanks may be required to have divisions or deep wash plates in order to minimise the dynamic stress on the structure.

3.5.2 Construction

3.5.2.1 In no case are the scantlings of tank boundary bulkheads to be less than the requirements for watertight bulkheads.

3.5.3 Scantlings of tank boundary bulkheads

3.5.3.1 The thickness of tank boundary plating is to comply with the requirements in *3.9.2.1*.

3.5.3.2 The section modulus and thickness of stiffeners are to comply with the requirements in *3.9.2.2* and *3.9.2.3*.

3.5.3.3 The section modulus and shear area of primary support members are to comply with the requirements in *3.9.3*.

3.5.3.4 Web plating of primary support members is to have a depth of not less than 14% of the unsupported span in bending, and is not to be less than 2.5 times the depth of the slots if the slots are not closed.

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3.5.3.5 Scantlings of corrugated bulkheads are to comply with the requirements in *3.9.4*.

3.6 Watertight Boundaries

3.6.1 General

3.6.1.1 Watertight boundaries are to be fitted in accordance with *Section 5/2*.

3.6.2 Collision bulkhead

3.6.2.1 The scantlings of structural components of the collision bulkheads are to comply with the requirements in *3.6.3*, as applicable. Additionally, the collision bulkhead is to comply with the requirements in *3.6.2.2* to *3.6.2.4*.

3.6.2.2 The position of the collision bulkhead is to be in accordance with *Section 5/2.2*.

3.6.2.3 Doors, manholes, permanent access openings or ventilation ducts are not to be cut in the collision bulkhead below the freeboard deck. Where the collision bulkhead is extended above the freeboard deck, the number of openings in the extension is to be kept to a minimum compatible with the design and proper working of the ship. The openings are to be fitted with weathertight closing appliances. The collision bulkhead may be pierced by pipes necessary for dealing with the contents of tanks forward of the bulkhead, provided the pipes are fitted with valves capable of being operated from above the freeboard deck. The valves are generally to be fitted on the collision bulkhead inside the fore peak and are not to be fitted inside the cargo tank.

3.6.2.4 Compartments forward of the collision bulkhead may not be arranged for the carriage of flammable liquids.

3.6.3 Scantlings of watertight boundaries

3.6.3.1 The thickness of boundary plating is to comply with the requirements in *3.9.2.1*.

3.6.3.2 The section modulus and thickness of stiffeners are to comply with the requirements in *3.9.2.2* and *3.9.2.3*.

3.6.3.3 The section modulus and shear area of primary support members are to comply with the requirements in *3.9.3*.

3.6.3.4 Web plating of primary support members is to have a depth of not less than 10% of the unsupported span in bending, and is not to be less than 2.5 times the depth of the slots if the slots are not closed.

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3.6.3.5 Scantlings of corrugated bulkheads are to comply with the requirements in *3.9.4*.

3.7 Superstructure

3.7.1 Forecastle structure

3.7.1.1 Forecastle structures are to be supported by girders with deep beams and web frames, and in general, arranged in complete transverse belts and supported by lines of pillars extending down into the structure below. Deep beams and girders are to be arranged, where practicable, to limit the spacing between deep beams, web frames, and/or girders to about 3.5m. Pillars are to be provided as required by *3.4.4*. Main structural intersections are to be carefully developed with special attention given to pillar head and heel connections, and to the avoidance of stress concentrations.

3.7.2 Forecastle end bulkhead

3.7.2.1 The details and scantlings of the forecastle end bulkhead are to meet the requirements of *Section 11/1.4.*

3.8 Miscellaneous Structures

3.8.1 Pillar bulkheads

3.8.1.1 Bulkheads that support girders, or pillars and longitudinal bulkheads which are fitted in lieu of girders, are to be stiffened to provide supports not less effective than required for stanchions or pillars. The acting load and the required net cross sectional area of the pillar section are to be determined using the requirements of *3.4.4*. The net moment of inertia of the stiffener is to be calculated with a width of $40t_{net}$, where t_{net} is the net thickness of plating, in mm.

3.8.1.2 Pillar bulkheads are to comply with the following requirements:

(a) the distance between bulkhead stiffeners is not to exceed 1500mm

(b) where corrugated, the depth of the corrugation is not to be less than 100mm.

3.8.2 Bulbous bow

3.8.2.1 Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure.

3.8.2.2 At the forward end of the bulb the structure is generally to be supported by horizontal diaphragm plates spaced about 1m apart in conjunction with a deep centreline web.

3.8.2.3 In general, vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing.

3.8.2.4 In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is generally to be fitted.

3.8.2.5 In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or substantial web frames is to be fitted.

3.8.2.6 The shell plating is to be increased in thickness at the forward end of the bulb and also in areas likely to be subjected to contact with anchors and chain cables during anchor handling. The increased plate thickness is to be the same as that required for plated stems given in *3.2.6*.

3.8.3 Chain lockers

3.8.3.1 Chain lockers are to meet the requirements of *Section 11/4.2.9*.

3.8.4 Bow thruster tunnels

3.8.4.1 The net thickness of the tunnel plating, $t_{tun-net}$, is not to be less than as required for the shell plating in the vicinity of the bow thruster. In addition, $t_{tun-net}$ is not to be taken less than:

$$t_{tun-net} = 0.008 d_{tun} + 1.8 \quad \text{mm}$$

Where:

d_{tun} inside diameter of the tunnel, in mm, but not to be taken less than 970mm

3.8.4.2 Where the outboard ends of the tunnel are provided with bars or grids, the bars or grids are to be effectively secured.

3.9 Scantling Requirements

3.9.1 General

3.9.1.1 The design load sets are to be applied to the structural requirements for the local support and primary support members as given in *Table 8.3.8*. The static and dynamic load components are to be combined in accordance with *Table 7.6.1* and the procedure given in *Section 7/6.3*.

3.9.2 Plating and local support members

3.9.2.1 For plating subjected to lateral pressure, the net plating thickness, t_{net}, is to be taken as the greatest value calculated for all applicable design load sets, as given in *Table 8.3.8*, and given by:

$$t_{net} = 0.0158\alpha_p s\sqrt{\frac{|P|}{C_a\sigma_{yd}}} \quad \text{mm}$$

Where:

α_p correction factor for the panel aspect ratio

$= 1.2 - \dfrac{s}{2100 l_p}$, but not to be greater than 1.0

P design pressure for the design load set being considered, calculated at the load calculation point defined in *Section 3/5.1.2*, in kN/m^2

s stiffener spacing, in mm , as defined in *Section 4/2.2*

l_p length of plate panel, to be taken as the spacing of primary support members, unless carlings are fitted, in m

C_a permissible bending stress coefficient for the acceptance criteria set being considered, as given in *Table 8.3.2*

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Table 8.3.2
Permissible Bending Stress Coefficient for Plating

Acceptance criteria set	Structural member	C_a
AC1	All plating	0.80
AC2	Hull envelope plating	0.95
	Internal boundary plating (1)	1.00

Note

1. Collision bulkhead plating is to be evaluated for design load set 11 (accidental flooding) using acceptance criteria set AC1

3.9.2.2 For stiffeners subjected to lateral pressure, the net section modulus, Z_{net}, is to be taken as the greatest value calculated for all applicable design load sets, as given in *Table 8.3.8*, and given by:

$$Z_{net} = \frac{|P| s\, l_{bdg}{}^2}{f_{bdg} C_s \sigma_{yd}} \quad \text{cm}^3$$

Where:

P design pressure for the design load set being considered, calculated at the load calculation point defined in *Section 3/5.2.2*, in kN/m²

s stiffener spacing, in mm , as defined in *Section 4/2.2*

l_{bdg} effective bending span, as defined in *Section 4/2.1.1*, in m

f_{bdg} bending moment factor:

for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having fixed ends:

12 for horizontal stiffeners

10 for vertical stiffeners

for other configurations the bending moment factor may be taken as in *Table 8.3.5.*

C_s permissible bending stress coefficient for the acceptance criteria set being considered, as given in *Table 8.3.3*

σ_{yd} specified minimum yield stress of the material, in N/mm²

Table 8.3.3
Permissible Bending Stress Coefficient for Stiffeners

Acceptance criteria set	Structural member	C_s
AC1	All stiffeners	0.75
AC2	All stiffeners (1)	0.90

Note

1. Collision bulkhead stiffeners are to be evaluated for design load set 11 (accidental flooding) using acceptance criteria set AC1

3.9.2.3 For stiffeners subjected to lateral pressure, the net web thickness based on shear area requirements, t_{w-net}, is to be taken as the greatest value calculated for all applicable design load sets, as given in *Table 8.3.8*, and given by:

$$t_{w-net} = \frac{f_{shr} |P| s\, l_{shr}}{d_{shr} C_t \tau_{yd}} \quad \text{mm}$$

Where:

P design pressure for the design load set being considered, calculated at the load calculation point defined in *Section 3/5.2.2*, in kN/m²

f_{shr} shear force factor:

for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having fixed ends:

0.5 for horizontal stiffeners

0.7 for vertical stiffeners

for other configurations the shear force factor may be taken as in *Table 8.3.5.*

s stiffener spacing, in mm , as defined in *Section 4/2.2*

l_{shr} effective shear span, as defined in *Section 4/2.1.2*, in m

d_{shr} effective web depth of stiffeners, in mm, as defined in *Section 4/2.4.2.2*

C_t permissible shear stress coefficient for the acceptance criteria set being considered, as given in *Table 8.3.4*

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm²

σ_{yd} specified minimum yield stress of the material, in N/mm²

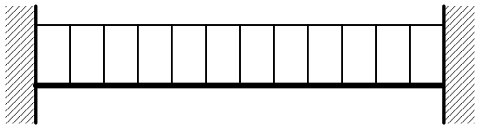
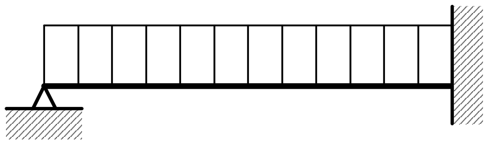
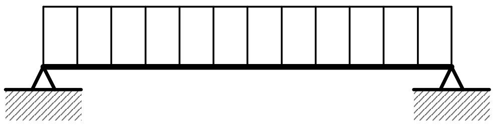
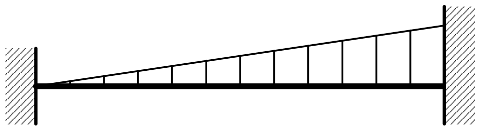
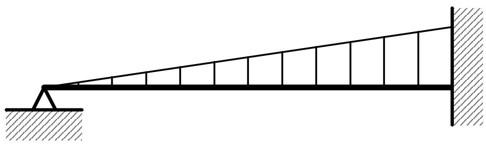
Table 8.3.4
Permissible Shear Stress Coefficient for Stiffeners

Acceptance criteria set	Structural member	C_t
AC1	All stiffeners	0.75
AC2	All stiffeners (1)	0.90

Note

1. Collision bulkhead stiffeners are to be evaluated for design load set 11 (accidental flooding) using acceptance criteria set AC1

Table 8.3.5
Bending Moment and Shear Force Factors, f_{bdg} and f_{shr}

Load and boundary condition				Bending moment and shear force factor (based on load at mid span, where load varies)		
Position				1	2	3
Load model	1 Support	2 Field	3 Support	f_{bdg1} f_{shr1}	f_{bdg2} -	f_{bdg3} f_{shr3}
A				12.0 0.50	24.0 -	12.0 0.50
B				- 0.38	14.2 -	8.0 0.63
C				- 0.50	8.0 -	- 0.50
D				15.0 0.30	23.3 -	10.0 0.70
E				- 0.20	16.8 -	7.5 0.80

Note

1. The bending moment factor f_{bdg} for the support positions are applicable for a distance of $0.2l_{bdg}$ from the end of the effective bending span for both local and primary support members.
2. The shear force factor f_{shr} for the support positions are applicable for a distance of $0.2l_{shr}$ from the end of the effective shear span for both local and primary support members.
3. Application of f_{bdg} and f_{shr} for local support members:
   (a) the section modulus requirement of local support members is to be determined using the lowest value of f_{bdg1} , f_{bdg2} and f_{bdg3}
   (b) the shear area requirement of local support members is to be determined using the greatest value of f_{shr1} and f_{shr3}.
4. Application of f_{bdg} and f_{shr} for primary support members:
   (a) the section modulus requirement within $0.2l_{bdg}$ from the end of the effective span is generally to be determined using the applicable f_{bdg1} and f_{bdg3}, however f_{bdg} is not to be taken greater than 12
   (b) the section modulus of mid span area is to be determined using f_{bdg} =24, or f_{bdg2} from the table if lesser
   (c) the shear area requirement of end connections within $0.2l_{shr}$ from the end of the effective span is to be determined using f_{shr} = 0.5 or the applicable f_{shr1} or f_{shr3}, whichever is greater
   (d) for models A through E the value of f_{shr} may be gradually reduced outside of $0.2l_{shr}$ towards $0.5f_{shr}$ at mid span where f_{shr} is the greater value of f_{shr1} and f_{shr3}.
5. For other load models see *Table 8.7.1.*

3.9.3 Primary support members

3.9.3.1 For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include allowance for the curvature of the hull. For side transverse frames, the requirements may be reduced due to the presence of cross ties, see *3.3.3.4*.

3.9.3.2 For primary support members subjected to lateral pressure, the net section modulus, Z_{net50}, is to be taken as the greatest value for all applicable design load sets, as given in *Table 8.3.8*, and given by:

$$Z_{net50} = 1000 \frac{|P| S \, l_{bdg}^2}{f_{bdg} C_s \, \sigma_{yd}} \quad \text{cm}^3$$

Where:

P design pressure for the design load set being considered, calculated at the load calculation point defined in *Section 3/5.3.3*, in kN/m²

S primary support member spacing, in m, as defined in *Section 4/2.2.2*

l_{bdg} effective bending span, as defined in *Section 4/2.1.4*, in m

f_{bdg} bending moment factor, as given in *Table 8.3.5*

C_s permissible bending stress coefficient for the acceptance criteria set being considered, as given in *Table 8.3.6*

σ_{yd} specified minimum yield stress of the material, in N/mm²

Table 8.3.6
Permissible Bending Stress Coefficient for Primary Support Members

Acceptance criteria set	Structure attached to primary support member	C_s
AC1	All boundaries, including decks and flats	0.70
AC2	All boundaries, including decks and flats (1)	0.85

Note
1. Collision bulkhead primary support members are to be evaluated for design load set 11 (accidental flooding) using acceptance criteria set AC1

3.9.3.3 For primary support members subjected to lateral pressure, the effective net shear area, $A_{shr\text{-}net50}$, is to be taken as the greatest value for all applicable design load sets, as given in *Table 8.3.8*, and given by:

$$A_{shr-net50} = 10 \frac{f_{shr} |P| S \, l_{shr}}{C_t \, \tau_{yd}} \quad \text{cm}^2$$

Where:

P design pressure for the design load set being considered, calculated at the load calculation point defined in *Section 3/5.3.2*, in kN/m²

S primary support member spacing, in m, as defined in *Section 4/2.2.2*

l_{shr} effective shear span, as defined in *Section 4/2.1.5*, in m

f_{shr} shear force factor, as given in *Table 8.3.5*

C_t permissible shear stress coefficient for the acceptance criteria set being considered, as given in *Table 8.3.7*

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm²

σ_{yd} specified minimum yield stress of the material, in N/mm²

Table 8.3.7
Permissible Shear Stress Coefficient for Primary Support Members

Acceptance criteria set	Structure attached to primary support member	C_t
AC1	All boundaries, including decks and flats	0.70
AC2	All boundaries, including decks and flats (1)	0.85

Note
1. Collision bulkhead primary support members are to be evaluated for design load set 11 (accidental flooding) using acceptance criteria set AC1

3.9.3.4 Primary support members are to generally be analysed with the specific methods as described for the particular structure type. More advanced calculation methods may be necessary to ensure that nominal stress level for all primary support members are less than the permissible stresses and stress coefficients given in *3.9.3.2* and *3.9.3.3* when subjected to the applicable design load sets.

3.9.4 Corrugated bulkheads

3.9.4.1 Special consideration will be given to the approval of corrugated bulkheads where fitted.

Guidance Note

Scantling requirements of corrugated bulkheads in the cargo tank region may be used as a basis, see *2.5.6* and *2.5.7.*

3.9.5 Pillars

3.9.5.1 The maximum load on a pillar, W_{pill}, is to be taken as the greatest value calculated for all applicable design load sets, as given in *Table 8.3.8*, and is to be less than or equal to the permissible pillar load as given by the following equation, where $W_{pill-perm}$ is based on the net properties of the pillar.

$$W_{pill} \leq W_{pill-perm}$$

Where:

W_{pill} applied axial load on pillar

$= P\, b_{a-\sup}\, l_{a-\sup} + W_{pill-upr}$ kN

$W_{pill-perm}$ permissible load on a pillar

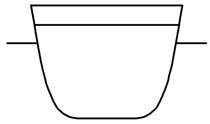
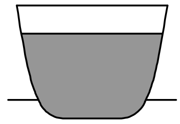
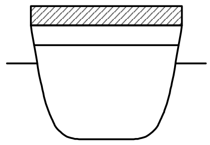
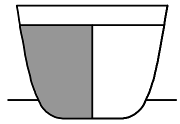
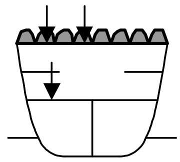
$= 0.1 A_{pill-net50}\, \eta_{pill}\, \sigma_{crb}$ kN

P design pressure for the design load set being considered, calculated at centre of the deck area supported by the pillar being considered, in kN/m²

b_{a-sup} mean breadth of area supported, in m

$l_{a\text{-}sup}$	mean length of area supported, in m
$W_{pill\text{-}upr}$	axial load from pillar or pillars above, in kN
$A_{pill\text{-}net50}$	net cross section area of the pillar, in cm^2
η_{pill}	utilisation factor for the design load set being considered: = 0.5 for acceptance criteria set AC1 = 0.6 for acceptance criteria set AC2
σ_{crb}	critical buckling stress in compression of pillar based on the net sectional properties calculated in accordance with *Section 10/3.5.1*, in N/mm^2

Table 8.3.8
Design Load Sets for Plating, Local Support Members and Primary Support Members

Type of Local Support and Primary Support Member	Design Load Set (1)	Load Component	External Draught	Comment	Diagrammatic Representation
Shell Envelope	1	P_{ex}	T_{sc}	Sea pressure only	
	2	P_{ex}	T_{sc}		
	5	P_{in}	T_{bal}	Tank pressure only. Sea pressure to be ignored	
	6	P_{in}	$0.25T_{sc}$		
External Decks	1	P_{ex}	T_{sc}	Green sea pressure only	
Tank Boundaries and/or Watertight Boundaries	5	P_{in}	T_{bal}	Pressure from one side only Full tank with adjacent tank empty	
	6	P_{in}	$0.25T_{sc}$		
	11	$P_{in\text{-}flood}$	-		
Internal and External Decks or Flats	9	P_{dk}	T_{bal}	Distributed or concentrated loads only. Adjacent tanks empty. Green sea pressure may be ignored	
	10	P_{dk}	T_{bal}		

Where:

T_{sc} scantling draught, in m, as defined in *Section 4/1.1.5.5*

T_{bal} minimum design ballast draught, in m, as defined in *Section 4/1.1.5.2*

Notes

1. The specification of design load combinations and other load parameters for the design load sets are given in *Table 8.2.8*
2. When the ship's configuration cannot be described by the above, then the applicable Design Load Sets to determine the scantling requirements of structural boundaries are to be selected so as to specify a full tank on one side with the adjacent tank or space empty. The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents and are to maximise the pressure on the structural boundary, the draught to use is to be taken in accordance with the Design Load Set and this table. Design Load Sets covering the S and S+D design load combinations are to be selected. See Note 4 on *Table 8.2.7* and *Table 8.2.8.*
3. The boundaries of void and dry space not forming part of the hull envelope are to be evaluated using Design Load Set 11. See Note 2.

4 MACHINERY SPACE

4.1 General

4.1.1 Application

4.1.1.1 The requirements of this Sub-Section apply to machinery spaces situated in the aft end region, aft of the aftermost cargo tank bulkhead and forward of, and including, the aft peak bulkhead.

4.1.1.2 The net scantlings described in this Sub-Section are related to gross scantlings as follows:

(a) for application the minimum thickness requirements of *4.1.5*, the gross thickness is obtained from the applicable requirements by adding the full corrosion additions as specified in *Section 6/3*.

(b) for plating and local support members, the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions as specified in *Section 6/3*.

(c) for primary support members, the gross shear area, gross section modulus and other gross cross sectional properties are obtained from the applicable requirements by adding one half of the relevant full corrosion additions as specified in *Section 6/3*.

(d) for application of buckling requirements of *Section 10/2* the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions as specified in *Section 6/3*.

4.1.2 General scantling requirements

4.1.2.1 The hull structure is to comply with the applicable requirements of:

(a) hull girder longitudinal strength, see *Section 8/1*

(b) strength against sloshing and impact loads, see *Section 8/6*

(c) buckling/ultimate strength, see *Section 10*.

4.1.2.2 The net section modulus, shear area and other sectional properties of local and primary support members are to be determined in accordance with *Section 4/2*.

4.1.2.3 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus and cross sectional shear areas of the primary support members are to be applied as required in the notes to *Table 8.3.5*.

4.1.2.4 The scantling criteria are based on assumptions that all structural joints and welded details are designed and fabricated such that they are compatible with the anticipated working stress levels at the locations considered. The loading patterns, stress concentrations and potential failure modes of structural joints and details during the design of highly stressed regions are to be considered. Structure design details are to comply with the requirements in *Section 4/3*.

4.1.2.5 Limber, drain and air holes are to be cut in all parts of the structure, as required, to ensure the free flow to the suction pipes and the escape of air to the vents. Arrangements are to be made for draining the spaces above tanks. See also *Section 4/3*.

4.1.3 Structural continuity

4.1.3.1 Scantlings of the shell envelope, upper deck and inner bottom are to be properly tapered towards the aft end. See also *1.6*.

4.1.3.2 Suitable arrangements are to be made to ensure continuity of strength and the avoidance of abrupt discontinuities when structure that contributes to the main longitudinal strength of the ship is omitted in way of the machinery space.

4.1.3.3 Where inner hull or longitudinal bulkhead structures terminate at the forward engine room bulkhead, adequate backing structure is to be provided together with tapering brackets to ensure continuity of strength.

4.1.3.4 All shell frames and tank boundary stiffeners are to be continuous throughout, or are to be bracketed at their ends, except as permitted in *Sections 4/3.2.4* and *4/3.2.5*.

4.1.3.5 Longitudinal primary support members, lower decks, and bulkheads arranged in the engine room are to be aligned with similar structures in the cargo tank region, as far as practicable. Where direct alignment is not possible, suitable scarphing arrangements such as taper brackets are to be provided.

4.1.4 Arrangements

4.1.4.1 Where openings in decks/bulkheads are provided in the machinery space, the arrangements are to ensure support for deck, side, and bottom structure.

4.1.4.2 All parts of the machinery, shafting, etc., are to be supported to distribute the loads into the ship's structure. The adjacent structure is to be suitably stiffened.

4.1.4.3 Primary support members are to be positioned giving consideration to the provision of through stiffeners and in-line pillar supports to achieve an efficient structural design.

4.1.4.4 These requirements are formulated assuming conventional single screw, single engine propulsion arrangements. Twin-screw or multi-engine vessels, or vessels of higher power, may require additions to the scantlings of the structure and the area of attachments, which are proportional to the weight, power and proportions of the machinery especially where the engines are positioned relatively high in proportion to the width of the bed plate.

4.1.4.5 The foundations for main propulsion units, reduction gears, shaft and thrust bearings, and the structure supporting those foundations are to maintain the required alignment and rigidity under all anticipated conditions of loading. Consideration is to be given to the submittal of the following plans to the machinery manufacturer for review:

(a) foundations for main propulsion units

(b) foundations for reduction gears

(c) foundations for thrust bearings

(d) structure supporting (a), (b) and (c).

4.1.4.6 A cofferdam is to be provided to separate the cargo tanks from the machinery space. Pump room, ballast tanks, or fuel oil tanks may be considered as cofferdams for this purpose.

4.1.5 Minimum thickness

4.1.5.1 In addition to the requirements for thickness, section modulus and shear area, as given in *4.2* to *4.8*, the thickness of plating and stiffeners in the machinery space is to comply with applicable minimum thickness requirements given in *Table 8.4.1*.

Table 8.4.1
Minimum Net Thickness of Structure in the Machinery Space

Scantling Location			Net Thickness (mm)
Plating	**Shell**	Keel plating	See *2.1.5.1*
		Bottom shell/bilge/side shell plating	See *2.1.5.1*
	Upper deck		See *2.1.5.1*
	Other structure	Hull internal tank boundaries	See *2.1.5.1*
		Non-tight bulkheads, bulkheads between dry spaces and other plates in general	See *2.1.5.1*
		Lower decks and flats	$3.3 + 0.0067s$
		Inner bottom	$6.5 + 0.02L_2$
Bottom centreline girder			See *2.1.6.1*
Floors and bottom longitudinal girders off centreline			$5.5 + 0.02L_2$
Web plating of primary support members			$5.5 + 0.015\,L_2$
Local support members			See *2.1.5.1*
Tripping brackets			See *2.1.5.1*

Where:

L_2 rule length, L, as defined in *Section 4/1.1.1.1*, but need not be taken greater than 300m

s stiffener spacing, in mm, as defined in *Section 4/2.2*

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4.2 Bottom Structure

4.2.1 General

4.2.1.1 In general, a double bottom is to be fitted in the machinery space. The depth of the double bottom is to be at least the same as required in the cargo tank region, see *Section 5/3.2.1*. Where the depth of the double bottom in the machinery space differs from that in the adjacent spaces, continuity of the longitudinal material is to be maintained by sloping the inner bottom over a suitable longitudinal extent. Lesser double bottom height may be accepted in local areas provided that the overall strength of the double bottom structure is not thereby impaired.

(RCN 2, effective from 1 July 2008)

4.2.2 Bottom shell plating

4.2.2.1 The keel plate breadth is to comply with the requirements in *Section 8/2.2.1.1*.

4.2.2.2 The thickness of the bottom shell plating (including keel plating) is to comply with the requirements in *4.8.1.1*.

4.2.3 Bottom shell stiffeners

4.2.3.1 The section modulus and thickness of bottom shell stiffeners are to comply with the requirements in *4.8.1.2* and *4.8.1.3*.

4.2.4 Girders and floors

4.2.4.1 The double bottom is to be arranged with a centreline girder.

(RCN 2, effective from 1 July 2008)

4.2.4.2 Full depth bottom girders are to be arranged in way of the main machinery to effectively distribute its weight, and to ensure rigidity of the structure. The girders are to be carried as far forward and aft as practicable, and suitably supported at their ends to provide distribution of loads from the machinery. The girders are to be tapered beyond their required extent.

4.2.4.3 Where fitted, side girders are to align with the bottom side girders in the adjacent space.

4.2.4.4 Where the double bottom is transversely framed, plate floors are to be fitted at every frame.

4.2.4.5 Where the double bottom is longitudinally framed, plate floors are to be fitted at every frame under the main engine and thrust bearing. Outboard of the engine and bearing seatings, the floors may be fitted at alternate frames.

4.2.4.6 Where heavy equipment is mounted directly on the inner bottom, the thickness of the floors and girders is to be suitably increased.

4.2.5 Inner bottom plating

4.2.5.1 Where main engines or thrust bearings are bolted directly to the inner bottom, the net thickness of the inner bottom plating is to be at least 19mm. Hold-down bolts are to be arranged as close as possible to floors and longitudinal girders. Plating thickness and the arrangements of hold-down bolts are also to consider the manufacturer's recommendations.

4.2.6 Sea chests

4.2.6.1 Where the inner bottom or double bottom structure forms part of a sea chest, the thickness of the plating is not to be less than that required for the shell at the same location, taking into account the maximum unsupported width of the plating.

4.3 Side Structure

4.3.1 General

4.3.1.1 The scantlings of the side shell plating and longitudinals are to be properly tapered from the midship region towards the aft end.

4.3.1.2 A suitable scarphing arrangement of the longitudinal framing is to be arranged where the longitudinal framing terminates and is replaced by transverse framing.

4.3.1.3 Stiffeners and primary support members are to be supported at their ends.

4.3.2 Side shell plating

4.3.2.1 The thickness of the side shell plating is to comply with the requirements in *4.8.1.1*. Where applicable, the thickness of the side shell plating is to comply with the requirements in *2.2.4.2*.

4.3.3 Side shell local support members

4.3.3.1 The section modulus and thickness of side longitudinal and vertical stiffeners are to comply with the requirements in *4.8.1.2* and *4.8.1.3*.

4.3.3.2 (void)

4.3.3.3 End connections of longitudinals at transverse bulkheads are to provide fixity, lateral support, and when not continuous are to be provided with soft-nosed brackets. Brackets lapped onto the longitudinals are not to be fitted.

4.3.4 Side shell primary support members

4.3.4.1 Web frames are to be connected at the top and bottom to members of suitable stiffness, and supported by deck transverses.

4.3.4.2 The spacing of web frames in way of transversely framed machinery spaces is generally not to exceed five transverse frame spaces.

4.3.4.3 The section modulus and shear area of primary support members are to comply with the requirements in *4.8.2*.

4.3.4.4 The web depth is to be not less than 2.5 times the web depth of the adjacent frames if the slots are not closed.

4.3.4.5 Web plating of primary support members is to have a depth of not less than 14% of the unsupported span in bending.

4.4 Deck Structure

4.4.1 General

4.4.1.1 All openings are to be framed. Attention is to be paid to structural continuity. Abrupt changes of shape, section or plate thickness are to be avoided.

4.4.1.2 The corners of the machinery space openings are to be of suitable shape and design to minimise stress concentrations.

4.4.1.3 In way of machinery openings, deck or flats are to have sufficient strength where they are intended as effective supports for side transverse frames or web frames.

4.4.1.4 Where a transverse framing system is adopted, deck stiffeners are to be supported by a suitable arrangement of longitudinal girders in association with pillars or pillar bulkheads. Where fitted, deck transverses are to be arranged in line with web frames to provide end fixity and transverse continuity of strength.

4.4.1.5 Where a longitudinal framing system is adopted, deck longitudinals are to be supported by deck transverses in line with web frames in association with pillars or pillar bulkheads.

4.4.1.6 Machinery casings are to be supported by a suitable arrangement of deck transverses and longitudinal girders in association with pillars or pillar bulkheads. In way of particularly large machinery casing openings, cross ties may be required. These are to be arranged in line with deck transverses.

4.4.1.7 The structural scantlings are to be not less than the requirement for tank boundaries if the deck forms the boundary of a tank.

4.4.1.8 The structural scantlings are to be not less than the requirement for watertight bulkheads if the deck forms the boundary of a watertight space.

4.4.2 Deck scantlings

4.4.2.1 The plate thickness of deck plating is to comply with the requirements in *4.8.1.1*.

4.4.2.2 The section modulus and thickness of deck stiffeners are to comply with the requirements in *4.8.1.2* and *4.8.1.3*.

4.4.2.3 The web depth of deck stiffeners is to be not less than 60mm.

4.4.2.4 The section modulus and shear area of primary support members are to comply with the requirements in *4.8.2*.

4.4.2.5 The web depth of primary support members is not to be less than 10% and 7% of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2.5 times the depth of the slots if the slots are not closed. Unsupported span in bending is bending span as defined in *Section 4/2.1.4* or in case of a grillage structure the distance between connections to other primary support members.

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4.4.2.6 In way of concentrated loads from heavy equipment, the scantlings of the deck structure are to be determined based on the actual loading.

4.4.3 Pillars

4.4.3.1 Pillars are to be fitted in the same vertical line wherever possible, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

4.4.3.2 Tubular and hollow square pillars are to be attached at their heads and heels by efficient brackets, or doublers/insert plates, where applicable, to transmit the load effectively. Pillars are to be attached at their heads and heels by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be distributed by brackets or other equivalent means.

4.4.3.3 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars.

4.4.3.4 Pillars in tanks are to be of solid section. Where the hydrostatic pressure may result in tensile stresses in the pillar, the tensile stress in the pillar and its end connections is not to exceed 45%of the specified minimum yield stress of the material.

4.4.3.5 The scantlings of pillars are to comply with the requirements in *4.8.4*.

4.4.3.6 Where the pillar loads from heavy equipment exceed the design load required by *4.8.4*, the pillar scantlings are to be determined based on the actual loading.

4.5 Machinery Foundations

4.5.1 General

4.5.1.1 Main engines and thrust bearings are to be effectively secured to the hull structure by foundations of strength that is sufficient to resist the various gravitational, thrust, torque, dynamic, and vibratory forces which may be imposed on them.

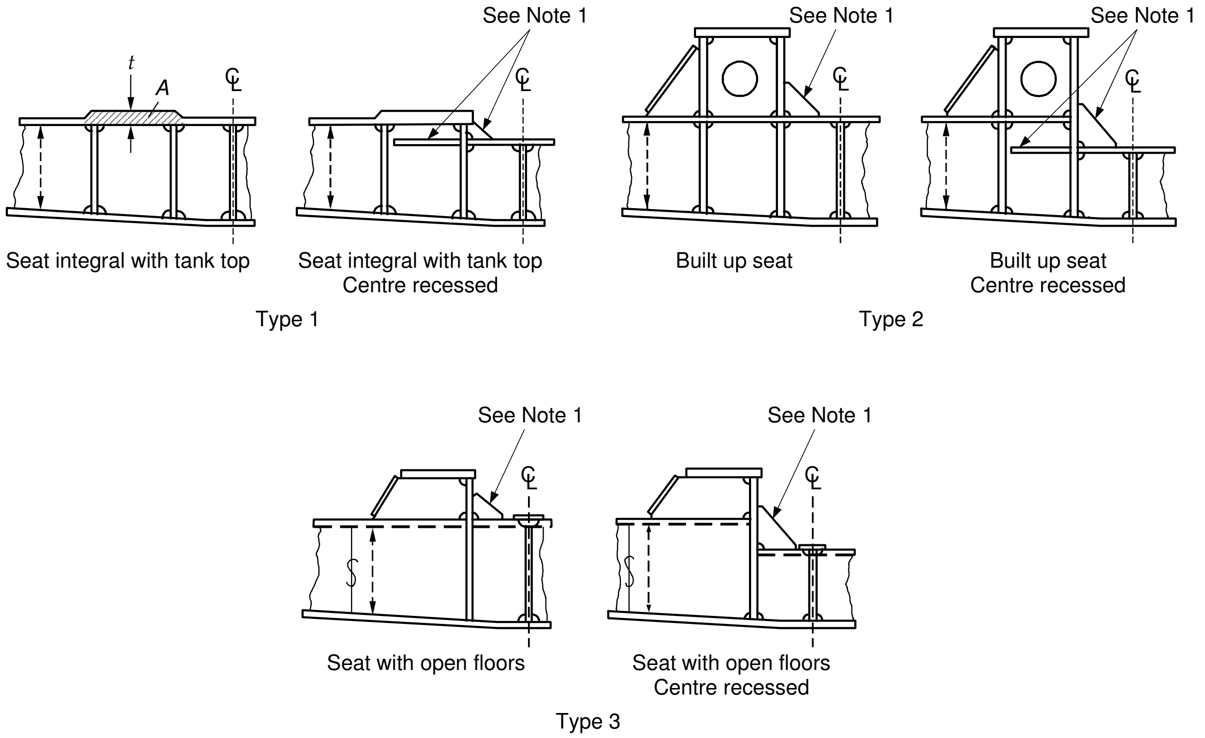
4.5.1.2 In the case of higher power internal combustion engines or turbine installations, the foundations are generally to be integral with the double bottom structure. Consideration is to be given to substantially increase the inner bottom plating thickness in way of the engine foundation plate or the turbine gear case, and the thrust bearing, see *Figure 8.4.1*, Type 1.

4.5.1.3 For main machinery supported on foundations of Type 2, as shown in *Figure 8.4.1*, the forces from the engine into the adjacent structure are to be distributed as

uniformly as possible. Longitudinal members supporting the foundation are to be aligned with girders in the double bottom, and transverse stiffening is to be arranged in line with the floors, see *Figure 8.4.1*, Type 2.

4.5.1.4 For ships with open floors in the machinery space, the foundations are generally to be arranged above the level of the top of the floors and securely bracketed, see *Figure 8.4.1*, Type 3.

Figure 8.4.1
Machinery Foundations



Note

1. Brackets are to be as large as possible. Brackets may be omitted to avoid interference with the girders of the engine foundation, in accordance with recommendations of the engine manufacturer.

4.5.2 Foundations for internal combustion engines and thrust bearings

4.5.2.1 In determining the scantlings of foundations for internal combustion engines and thrust bearings, consideration is to be given to the general rigidity of the engine and to its design characteristics with regard to out of balance forces.

4.5.2.2 Generally two girders are to be fitted in way of the foundation for internal combustion engines and thrust bearings.

Guidance Note

In general, the gross thickness of foundation top plates is not to be less than 45mm, where the maximum continuous output of the propulsion machinery is 3500kw or greater.

4.5.3 Auxiliary foundations

4.5.3.1 Auxiliary machinery is to be secured on foundations that are of suitable size and arrangement to distribute the loads from the machinery evenly into the supporting structure.

4.6 Tank Bulkheads

4.6.1 General

4.6.1.1 Tanks may be required to have divisions or deep wash plates to minimise the dynamic stress on the structure.

4.6.2 Construction

4.6.2.1 In no case are the scantlings of tank boundary bulkheads to be less than the requirements for watertight bulkheads.

4.6.3 Scantlings of tank boundary bulkheads

4.6.3.1 The thickness of tank boundary plating is to comply with the requirements in *4.8.1.1*.

4.6.3.2 The section modulus and thickness of stiffeners are to comply with the requirements in *4.8.1.2* and *4.8.1.3*.

4.6.3.3 The section modulus and shear area of primary support members are to comply with the requirements in *4.8.2*.

4.6.3.4 Web plating of primary support members is to have a depth of not less than 14% of the unsupported span in bending and not less than 2.5 times the depth of the slots if the slots are not closed.

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4.7 Watertight Boundaries

4.7.1 General

4.7.1.1 Watertight boundaries within the machinery space are to be fitted in accordance with *Section 5/2*.

4.7.2 Scantlings of watertight boundaries

4.7.2.1 The thickness of watertight boundary plating is to comply with the requirements in *4.8.1.1*.

4.7.2.2 The section modulus and thickness of stiffeners are to comply with the requirements in *4.8.1.2* and *4.8.1.3*.

4.7.2.3 The section modulus and shear area of primary support members are to comply with the requirements in *4.8.2*.

4.7.2.4 Web plating of primary support members is to have a depth of not less than 10% of the unsupported span in bending and not less than 2.5 times the depth of the slots if the slots are not closed.

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4.8 Scantling Requirements

4.8.1 Plating and local support members

4.8.1.1 For plating subjected to lateral pressure the net plating thickness is to comply with the requirements in *3.9.2.1*, but using the permissible bending stress coefficient, C_a, defined in *Table 8.4.2*.

4.8.1.2 For stiffeners subjected to lateral pressure the net section modulus requirement is to comply with the requirements in *3.9.2.2*, but using the permissible bending stress coefficient, C_s, defined in *Table 8.4.3*.

4.8.1.3 For stiffeners subjected to lateral pressure the net web thickness based on shear area requirements is to comply with the requirements in *3.9.2.3*.

Table 8.4.2
Permissible Bending Stress Coefficient for Plating

The permissible bending stress coefficient, C_a, for the design load set being considered is to be taken as:

$$C_a = \beta_a - \alpha_a \frac{|\sigma_{hg}|}{\sigma_{yd}}$$ but not to be taken greater than C_{a-max}

Where:

β_a, α_a, C_{a-max}

<table>
<tr><th>Acceptance Criteria Set</th><th colspan="2">Structural Member</th><th>β_a</th><th>α_a</th><th>C_{a-max}</th></tr>
<tr><td rowspan="3">AC1</td><td rowspan="2">Longitudinal Strength Members</td><td>Longitudinally stiffened plating</td><td>0.9</td><td>0.5</td><td>0.8</td></tr>
<tr><td>Transversely or vertically stiffened plating</td><td>0.9</td><td>1.0</td><td>0.8</td></tr>
<tr><td colspan="2">Other members</td><td>0.8</td><td>0</td><td>0.8</td></tr>
<tr><td rowspan="3">AC2</td><td rowspan="2">Longitudinal Strength Members</td><td>Longitudinally stiffened plating</td><td>1.05</td><td>0.5</td><td>0.95</td></tr>
<tr><td>Transversely or vertically stiffened plating</td><td>1.05</td><td>1.0</td><td>0.95</td></tr>
<tr><td colspan="2">Other members, including watertight boundary plating</td><td>1.0</td><td>0</td><td>1.0</td></tr>
</table>

σ_{hg} hull girder bending stress for the design load set being considered and calculated at the load calculation point defined in *Section 3/5.1.2*

$$= \frac{(z - z_{NA-net50})\, M_{v-total}}{I_{v-net50}} 10^{-3} \quad \text{N/mm}^2$$

$M_{v-total}$ design vertical bending moment at the longitudinal position under consideration for the design load set being considered, in kNm. The still water bending moment, $M_{sw-perm}$, is to be taken with the same sign as the simultaneously acting wave bending moment, M_{wv}, see *Table 7.6.1*

$I_{v-net50}$ net vertical hull girder moment of inertia, at the longitudinal position being considered, as defined in *Section 4/2.6.1*, in m^4

z vertical coordinate of the load calculation point under consideration, in m

$z_{NA-net50}$ distance from the baseline to the horizontal neutral axis, as defined in *Section 4/2.6.1*, in m

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Table 8.4.3
Permissible Bending Stress Coefficient for Stiffeners

The permissible bending stress coefficient C_s is to be taken as:

Sign of Hull Girder Bending Stress, σ_{hg}	Side that Pressure is Acting On	Acceptance Criteria
Tension (+ve)	Stiffener side	$C_s = \beta_s - \alpha_s \dfrac{\lvert\sigma_{hg}\rvert}{\sigma_{yd}}$ but not to be taken greater than C_{s-max}
Compression (-ve)	Plate side	
Tension (+ve)	Plate side	$C_s = C_{s-max}$
Compression (-ve)	Stiffener side	

Where:

β_s , α_s , C_{s-max} permissible bending stress factors and are to be taken as:

Acceptance Criteria Set	Structural Member	β_s	α_s	C_{s-max}
AC1	Longitudinally effective stiffeners	0.85	1.0	0.75
	Other stiffeners	0.75	0	0.75
AC2	Longitudinally effective stiffeners	1.0	1.0	0.9
	Other stiffeners	0.9	0	0.9
	Watertight boundary stiffeners	0.9	0	0.9

σ_{hg} hull girder bending stress for the design load set being considered and calculated at the reference point defined in *Section 3/5.2.2.5*

$$= \left(\frac{(z - z_{NA-net50})\, M_{v-total}}{I_{v-net50}} \right) 10^{-3} \quad \text{N/mm}^2$$

$M_{v-total}$ design vertical bending moment at longitudinal position under consideration for the design load set being considered, in kNm

$M_{v-total}$ is to be calculated in accordance with *Table 7.6.1* using the sagging or hogging still water bending moment

Stiffener Location	$M_{sw-perm}$	
	Pressure acting on Plate Side	**Pressure acting on Stiffener Side**
Above Neutral Axis	Sagging SWBM	Hogging SWBM
Below Neutral Axis	Hogging SWBM	Sagging SWBM

$I_{v-net50}$ net vertical hull girder moment of inertia, at the longitudinal position being considered, as defined in *Section 4/2.6.1*, in m^4

z vertical coordinate of the reference point defined in *Section 3/5.2.2.5*, in m

$z_{NA-net50}$ distance from the baseline to the horizontal neutral axis, as defined in *Section 4/2.6.1*, in m

σ_{yd} specified minimum yield stress of the material, in N/mm^2

4.8.2 Primary support members

4.8.2.1 For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include allowance for the curvature of the hull.

4.8.2.2 For primary support members subjected to lateral pressure the net section modulus requirement is to comply with the requirements in *3.9.3.2*.

4.8.2.3 For primary support members subjected to lateral pressure the net cross sectional area of the web is to comply with the requirements in *3.9.3.3*.

4.8.2.4 Primary support members are to generally be analysed with the specific methods as described for the particular structure type. More advanced calculation methods may be required to ensure that nominal stress level for all primary support members are less than permissible stresses and stress coefficients given in *3.9.3.2* and *3.9.3.3* when subjected to the applicable design load sets.

4.8.3 Corrugated bulkheads

4.8.3.1 Special consideration will be given to the approval of corrugated bulkheads where fitted.

Guidance Note

Scantling requirements of corrugated bulkheads in the cargo tank region may be used as a basis, see *2.5.6* and *2.5.7.*

4.8.4 Pillars

4.8.4.1 The maximum load on a pillar is to be less than the permissible pillar load as given by the requirements in *3.9.5*.

5 AFT END

5.1 General

5.1.1 Application

5.1.1.1 The requirements of this Sub-Section apply to structure located between the aft peak bulkhead and the aft end of the ship.

5.1.1.2 The requirements of this Sub-Section do not apply to the following:

(a) rudder horns

(b) structures which are not integral with the hull, such as rudders, steering nozzles and propellers

(c) other appendages permanently attached to the hull.

Where such items are fitted, the requirements of the individual Classification Society are to be complied with.

5.1.1.3 The net scantlings described in *5.1* to *5.7* are related to gross scantlings as follows:

(a) for application the minimum thickness requirements of *5.1.4*, the gross thickness is obtained from the applicable requirements by adding the full corrosion additions specified in *Section 6/3.*

(b) for plating and local support members, the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in *Section 6/3*

(c) for primary support members, the gross shear area, gross section modulus and other gross cross sectional properties are obtained from the applicable requirements by adding one half of the relevant full corrosion additions specified in *Section 6/3*

(d) for application of buckling requirements of *Section 10/2* the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in *Section 6/3*.

5.1.2 General scantling requirements

5.1.2.1 The hull structure is to comply with the applicable requirements of:

(a) hull girder longitudinal strength, see *Section 8/1*

(b) strength against sloshing and impact loads, see *Section 8/6*

(c) buckling/ultimate strength, see *Section 10*.

5.1.2.2 The deck plating thickness and supporting structure are to be suitably reinforced for the steering gear, mooring windlasses, and other deck machinery. See *Section 11/3*.

5.1.2.3 The net section modulus, shear area and other sectional properties of local and primary support members are to be determined in accordance with *Section 4/2.*

5.1.2.4 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus and cross sectional shear areas of the primary support members are to be applied as required in the notes to *Table 8.3.5*.

5.1.2.5 The scantling criteria are based on assumptions that all structural joints and welded details are designed and fabricated such that they are compatible with the anticipated working stress levels at the locations considered. The loading patterns, stress concentrations and potential failure modes of structural joints and details

during the design of highly stressed regions are to be considered. Structure design details are to comply with the requirements in *Section 4/3*.

5.1.2.6 Limber, drain and air holes are to be cut in all parts of the structure, as required, to ensure the free flow to the suction pipes and the escape of air to the vents. Arrangements are to be made for draining the spaces above deep tanks. See also *Section 4/3*.

5.1.3 Structural continuity

5.1.3.1 Scantlings of the shell envelope, upper deck and inner bottom are to be tapered towards the aft end. See also *1.6*.

5.1.3.2 In transition zones forward of the aft peak into the machinery space, due consideration is to be given to the tapering of primary support members.

5.1.3.3 Longitudinal framing of the strength deck is to be carried aft to the stern.

5.1.3.4 All shell frames and tank boundary stiffeners are in general to be continuous, or are to be bracketed at their ends, except as permitted in *Sections 4/3.2.4* and *4/3.2.5*.

5.1.4 Minimum thickness

5.1.4.1 In addition to the thickness, section modulus and stiffener web shear area requirements as given in *5.2* to *5.7*, the thickness of plating and stiffeners in the aft end region is to comply with the appropriate minimum thickness requirements given in *Table 8.5.1*.

<table>
<tr><th colspan="4">Table 8.5.1
Minimum Net Thickness of Structure Aft of the Aft Peak Bulkhead</th></tr>
<tr><th colspan="3">Scantling Location</th><th>Net Thickness (mm)</th></tr>
<tr><td rowspan="6">Plating</td><td rowspan="2">Shell</td><td>Keel plating</td><td>See 2.1.5.1</td></tr>
<tr><td>Bottom shell/bilge/side shell plating</td><td>See 2.1.5.1</td></tr>
<tr><td colspan="2">Upper Deck</td><td>See 2.1.5.1</td></tr>
<tr><td rowspan="3">Other structure</td><td>Hull internal tank boundaries</td><td>See 2.1.5.1</td></tr>
<tr><td>Non-tight bulkheads, bulkheads between dry spaces and other plates in general</td><td>See 2.1.5.1</td></tr>
<tr><td>Pillar bulkheads</td><td>7.5</td></tr>
<tr><td colspan="3">Bottom girders and aft peak floors</td><td>$5.5 + 0.02L_2$</td></tr>
<tr><td colspan="3">Web plating of primary support members</td><td>$6.5 + 0.015L_2$</td></tr>
<tr><td colspan="3">Local support members</td><td>See 2.1.5.1</td></tr>
<tr><td colspan="3">Tripping brackets</td><td>See 2.1.5.1</td></tr>
<tr><td colspan="4">Where:
L_2 rule length, L, as defined in Section 4/1.1.1.1, but need not be taken greater than 300m</td></tr>
</table>

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5.2 Bottom Structure

5.2.1 General

5.2.1.1 Floors are to be fitted at each frame space in the aft peak and carried to a height at least above the stern tube. Where floors do not extend to flats or decks they are to be stiffened by flanges at their upper end.

5.2.1.2 The centreline bottom girder is to extend as far aft as is practicable and is to be attached to the stern frame.

5.2.2 Aft peak floors and girders

5.2.2.1 The height of stiffeners, h_{stf}, on the floors and girders are to be not less than:

$h_{stf} = 80.0\, l_{stf}$ mm, for flat bar stiffeners

$h_{stf} = 70.0\, l_{stf}$ mm, for bulb profiles and flanged stiffeners

Where:

l_{stf} length of stiffener as shown in *Figure 8.5.1*, in m

5.2.2.2 In conjunction with the requirements of *5.2.2.1*, stiffeners are to be provided with end brackets as follows:

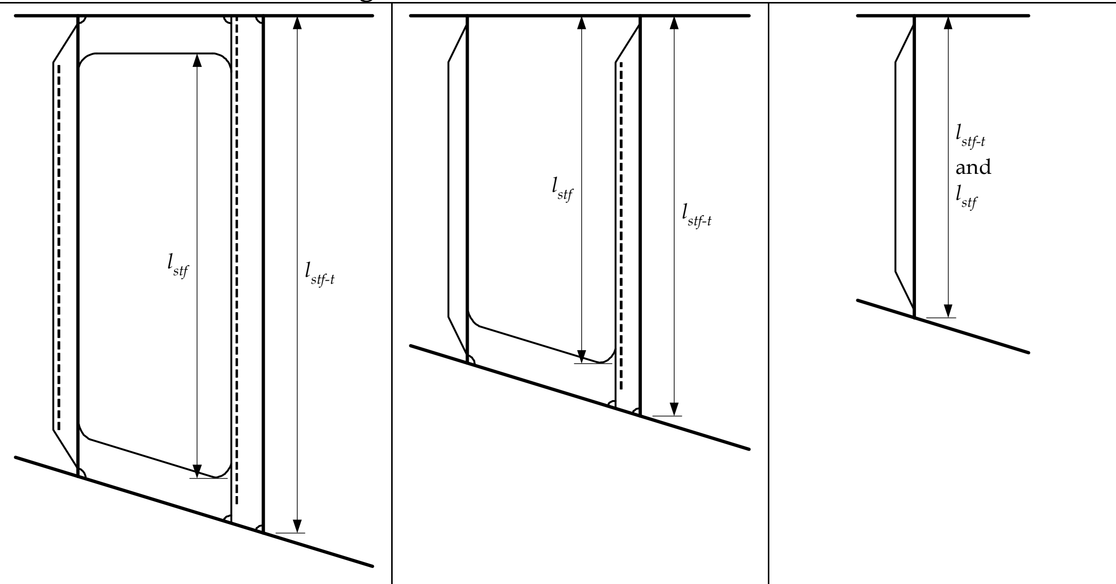
(a) brackets are to be fitted at the lower and upper ends when l_{stf-t} exceeds 4m

(b) brackets are to be fitted at the lower end when l_{stf-t} exceeds 2.5m.

Where:

l_{stf-t} total length of stiffener as shown in *Figure 8.5.1*, in m

Figure 8.5.1
Stiffening of Floors and Girders in the Aft Peak



a) when $l_{stf-t} > 4$ b) when $l_{stf-t} > 2.5$ c) when $l_{stf-t} \leq 2.5$

5.2.2.3 Heavy plate floors are to be fitted in way of the aft face of the horn and in line with the webs in the rudder horn. They may be required to be carried up to the first deck or flat. In this area, cut outs, scallops or other openings are to be kept to a minimum.

5.2.3 Stern frames

5.2.3.1 Stern frames may be fabricated from steel plates or made of cast steel. For applicable material specifications and steel grades see *Table 6.1.3*. Stern frames of other material or construction will be specially considered.

5.2.3.2 Scantlings below the propeller boss on stern frames for single screw vessels are to comply with the requirements in *5.2.3.3* or *5.2.3.4*, as applicable.

5.2.3.3 Fabricated stern frames are to satisfy the following criteria:

(a) $t_{grs} \geq 2.25\sqrt{L}$ mm

(b) $w_{stn} \geq 450$ mm

(c) $$t_{grs} \geq \frac{C_f L^{1.5}}{w_{stn}^{\;2}\sqrt{1+\left(\frac{2l_{stn}}{w_{stn}}\right)^2}} \quad \text{mm}$$

Where:

t_{grs} gross thickness of side plating, in mm

w_{stn} width of stern frame, in mm, see *Figure 8.5.2a*

l_{stn} length of stern frame, in mm, see *Figure 8.5.2a*

L rule length, as defined in *Section 4/1.1.1.1*

C_f = 9600

5.2.3.4 Cast stern frames are to satisfy the following criteria:

(a) $t_{1-grs} \geq 3.0\sqrt{L}$ mm, but not to be less than 25mm

(b) $t_{2-grs} \geq 1.25 t_{1-grs}$ mm

(c) $$\frac{(t_{1-grs} + t_{2-grs})}{2} \geq \frac{C_f L^{1.5}}{w_{stn}^{\;2}\sqrt{1+\left(\frac{2l_{stn}}{w_{stn}}\right)^2}}$$

Where:

$t_{1\text{-}grs}$ gross thickness of casting at end, in mm, see *Figure 8.5.2b*

$t_{2\text{-}grs}$ gross thickness of casting at mid length, in mm, see *Figure 8.5.2b*

w_{stn} width of stern frame, in mm, see *Figure 8.5.2b*

l_{stn} length of stern frame, in mm, see *Figure 8.5.2b*

L rule length, as defined in *Section 4/1.1.1.1*

C_f = 8400

The thickness of butt welding to shell plating may be tapered below t_1 with a length of taper that is at least three times the offset. The castings are to be cored out to avoid large masses of thick material likely to contain defects and are to maintain a

relatively uniform section throughout. Suitable radii are to be provided in way of changes in section.

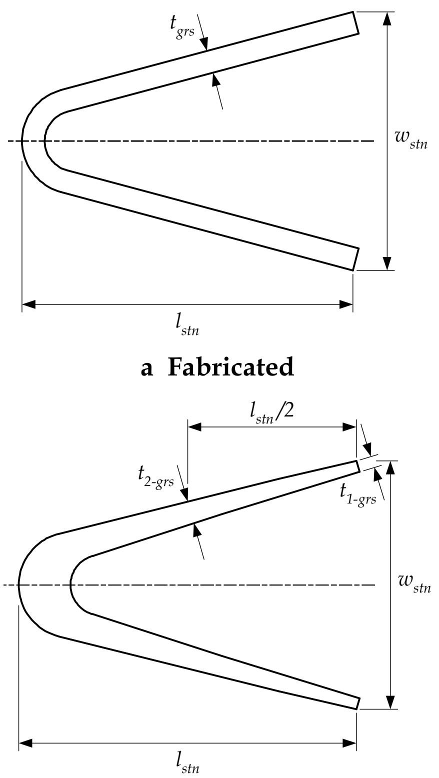
5.2.3.5 Above the propeller boss, the scantlings are to be in accordance with *5.2.3.2* to *5.2.3.4* except that in the upper part of the propeller aperture, where the hull form is full and centreline supports are provided, the thickness may be reduced to 80% of the applicable requirements in *5.2.3.2* to *5.2.3.4*.

5.2.3.6 Where round bars are used at the aft edge of stern frames, their scantlings and connection details are to facilitate welding.

5.2.3.7 Ribs or horizontal brackets of thickness not less than $0.8t_{grs}$ or $0.8t_{1\text{-}grs}$ are to be provided at suitable intervals, where t_{grs} and $t_{1\text{-}grs}$ are as defined in *5.2.3.3* and *5.2.3.4*. When t_{grs} or $t_{1\text{-}grs}$ is reduced in accordance with *5.2.3.5*, a proportionate reduction in the thickness of ribs or horizontal brackets may be made.

5.2.3.8 Rudder gudgeons are to be an integral part of the stern frame and are to meet the requirements of the individual Classification Society.

Figure 8.5.2
Stern Frame



a Fabricated

b Cast

5.3 Shell Structure

5.3.1 Shell plating

5.3.1.1 The net thickness of the side shell and transom plating, t_{net}, is to comply with the requirements in *3.9.2.1* and is not to be less than:

$$t_{net} = 0.035(L_2 - 42) + 0.009s \quad \text{mm}$$

Where:

L_2 rule length, L, as defined in *Section 4/1.1.1.1*, but need not be taken greater than 300m

s stiffener spacing, in mm, as defined in *Section 4/2.2*

5.3.1.2 The net plating thickness of shell, t_{net}, attached to the stern frame is to comply with the requirements in *3.9.2.1* and is not to be less than:

$$t_{net} = 0.094(L_2 - 43) + 0.009s \quad \text{mm}$$

Where:

L_2 rule length, L, as defined in *Section 4/1.1.1.1*, but need not be taken greater than 300m

s stiffener spacing, in mm, as defined in *Section 4/2.2*

5.3.1.3 In way of the boss and heel plate, the shell net plating thickness, t_{net}, is not to be less than:

$$t_{net} = 0.105(L_2 - 47) + 0.011s \quad \text{mm}$$

Where:

L_2 rule length, L, as defined in *Section 4/1.1.1.1*, but need not be taken greater than 300m

s stiffener spacing, in mm, as defined in *Section 4/2.2*

5.3.1.4 Within the extents specified in *2.2.4.3*, the thickness of the side shell plating is to comply with the requirements in *2.2.4.2*.

5.3.1.5 Heavy shell plates are to be fitted locally in way of the heavy plate floors as required by *5.2.2.3*. Outboard of the heavy floors, the heavy shell plates may be reduced in thickness in as gradual a manner as practicable. Where the horn plating is radiused into the shell plating, the radius at the shell connection, r, is not to be less than:

$$r = 150 + 0.8L_2 \quad \text{mm}$$

Where:

L_2 rule length, L, as defined in *Section 4/1.1.1.1*, but need not be taken greater than 300m

5.3.2 Shell local support members

5.3.2.1 The section modulus and thickness of the hull envelope framing are to comply with the requirements in *3.9.2.2* and *3.9.2.3*.

5.3.3 Shell primary support members

5.3.3.1 The requirements of *5.3.3* apply to single side skin construction supported by system of vertical webs and/or horizontal stringers or flats.

5.3.3.2 Where a longitudinal framing system is adopted, longitudinals are to be supported by vertical primary support members extending from the floors to the upper deck. Deck transverses are to be fitted in line with the web frames.

5.3.3.3 Where a transverse framing system is adopted, frames are to be supported by horizontal primary support members spanning between the vertical primary support members.

5.3.3.4 The scantlings of web frames supporting; longitudinal framing, stringers and transverse framing are to be determined from *3.9.3*.

5.3.3.5 The web depth of primary support members is not to be less than 14% of the bending span and is to be at least 2.5 times as deep as the slots for stiffeners if the slots are not closed.

5.4 Deck Structure

5.4.1 Deck plating

5.4.1.1 The thickness of the deck plating is to comply with the requirements in *3.9.2.1*.

5.4.1.2 (void)

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5.4.2 Deck stiffeners

5.4.2.1 The section modulus and thickness of deck stiffeners are to comply with the requirements in *3.9.2.2* and *3.9.2.3*.

5.4.3 Deck primary support members

5.4.3.1 The section modulus and shear area of primary support members are to comply with the requirements in *3.9.3*.

5.4.3.2 The web depth of primary support members is not to be less than 10% and 7% of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2.5 times the depth of the slots if the slots are not closed. Unsupported span in bending is bending span as defined in *Section 4/2.1.4* or in case of a grillage structure the distance between connections to other primary support members.

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5.4.3.3 In way of concentrated loads from heavy equipment, the scantlings of the deck structure are to be determined based on the actual loading. See also *Section 11/3*.

5.4.4 Pillars

5.4.4.1 Pillars are to be fitted in the same vertical line wherever possible and effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

5.4.4.2 Tubular and hollow square pillars are to be attached at their heads and heels by efficient brackets, or doublers/insert plates, where applicable, to transmit the load effectively. Pillars are to be attached at their heads and heels by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be distributed by brackets or other equivalent means.

5.4.4.3 Pillars in tanks are to be of solid section. Where the hydrostatic pressure may result in tensile stresses in the pillar, the tensile stress in the pillar and its end connections is not to exceed 45%of the specified minimum yield stress of the material.

5.4.4.4 The scantlings of pillars are to comply with the requirements in *3.9.5*.

5.4.4.5 Where the loads from heavy equipment exceed the design load of *3.9.5*, the pillar scantlings are to be determined based on the actual loading.

5.5 Tank Bulkheads

5.5.1 General

5.5.1.1 Tanks may be required to have divisions or deep wash structures to minimise the dynamic stress on the structure.

5.5.2 Construction

5.5.2.1 In no case are the scantlings of tank boundary bulkheads to be less than the requirements for watertight bulkheads.

5.5.3 Scantlings of tank boundary bulkheads

5.5.3.1 The thickness of tank boundary plating is to comply with the requirements in *3.9.2.1*.

5.5.3.2 The section modulus and thickness of stiffeners are to comply with the requirements in *3.9.2.2* and *3.9.2.3*.

5.5.3.3 The section modulus and shear area of primary support members are to comply with the requirements in *3.9.3*.

5.5.3.4 Web plating of primary support members is to have a depth of not less than 14% of the unsupported span in bending and not less than 2.5 times the depth of the slots if the slots are not closed.

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5.6 Watertight Boundaries

5.6.1 General

5.6.1.1 Watertight boundaries are to be fitted in accordance with *Section 5/2*.

5.6.1.2 The number of openings in watertight bulkheads is to be kept to a minimum compatible with the design and operation of the ship. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity.

5.6.2 Aft peak bulkhead

5.6.2.1 An aft peak bulkhead complying with *Section 5/2.3* is to be provided.

5.6.2.2 The scantlings of structural components of the aft peak bulkhead are to comply with the requirements in *5.5* and *5.6.3*, as applicable.

5.6.3 Scantlings of watertight boundaries

5.6.3.1 The thickness of boundary plating is to comply with the requirements in *3.9.2.1*.

5.6.3.2 The section modulus and thickness of stiffeners are to comply with the requirements in *3.9.2.2* and *3.9.2.3*.

5.6.3.3 The section modulus and shear area of primary support members are to comply with the requirements in *3.9.3*.

5.6.3.4 Web plating of primary support members is to have a depth of not less than 10% of the unsupported span in bending and not less than 2.5 times the depth of the slots if the slots are not closed.

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5.7 Miscellaneous Structures

5.7.1 Pillar bulkheads

5.7.1.1 Bulkheads that support girders, or pillars and longitudinal bulkheads which are fitted in lieu of girders, are to be stiffened to provide supports not less effective than required for stanchions or pillars. The acting load and the required net cross sectional area of the pillar section is to be determined using the requirements of *5.4.4*. The net moment of inertia of the stiffener is to be calculated with a width of $40t_{net}$ of the plating, where t_{net} is net plating thickness in mm.

5.7.1.2 Pillar bulkheads are to meet the following requirements:

(a) the distance between bulkhead stiffeners is not to exceed 1500mm

(b) where corrugated, the depth of the corrugation is not to be less than 100mm.

5.7.2 Rudder trunk

5.7.2.1 The scantlings of the rudder trunk are to be in accordance with the shell plating and framing in *5.3.1* and *5.3.2*. Where the rudder trunk is open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline to prevent water from entering the steering gear compartment.

5.7.3 Stern thruster tunnels

5.7.3.1 The net thickness of the tunnel plating, $t_{tun-net}$, is not to be less than required for shell plating in the vicinity of the thruster. In addition $t_{tun-net}$ is not to be taken less than:

$$t_{tun-net} = 0.008 d_{tun} + 1.8 \quad \text{mm}$$

Where:

d_{tun} inside diameter of the tunnel, in mm, but not to be taken less than 970 mm

5.7.3.2 Where the outboard ends of the tunnel are provided with bars or grids, the bars or grids are to be effectively secured.

6 EVALUATION OF STRUCTURE FOR SLOSHING AND IMPACT LOADS

6.1 General

6.1.1 Application

6.1.1.1 The requirements of this Sub-Section cover the strengthening requirements for localised sloshing loads that may occur in tanks carrying liquid and local impact loads that may occur in the forward structure. The sloshing and impact loads to be applied in *6.2* to *6.4* are described in *Section 7/4*.

6.1.1.2 The net scantlings described in this Sub-Section are related to gross scantlings as follows:

(a) for plating and local support members, the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in *Section 6/3*

(b) for primary support members, the gross sectional area, gross section modulus and other gross cross sectional properties are obtained from the applicable requirements by adding one half of the full corrosion additions specified in *Section 6/3*.

6.1.2 General scantling requirements

6.1.2.1 The requirements of *6.2* to *6.4* are to be applied in addition to the applicable requirements in *Section 8*.

6.1.2.2 Local scantling increases due to impact or sloshing loads are to be made with due consideration given to details and avoidance of hard spots, notches and other harmful stress concentrations.

6.2 Sloshing in Tanks

6.2.1 Scope and limitations

6.2.1.1 The requirements of *6.2* specify the scantling requirements for boundary and internal structure of tanks subject to sloshing loads, as given in *Section 7/4.2*, due to the free movement of liquid in tanks.

6.2.1.2 The structure of cargo tanks, slop tanks, ballast tanks and large deep tanks, e.g. fuel oil bunkering tanks and main fresh water tanks, are to be assessed for sloshing. Small tanks do not need to be assessed for sloshing pressures.

6.2.1.3 All cargo and ballast tanks are to have scantlings suitable for unrestricted filling heights.

6.2.1.4 The following structural members are to be assessed:

(a) plates and stiffeners forming boundaries of tanks

(b) plates and stiffeners on wash bulkheads

(c) web plates and web stiffeners of primary support members located in tanks

(d) tripping brackets supporting primary support members in tanks.

6.2.1.5 For tanks with effective sloshing breadth, b_{slh}, greater than $0.56B$ or effective sloshing length, l_{slh}, greater than $0.13L$, an additional sloshing impact assessment is to be carried out in accordance with the individual Classification Society's procedures. The effective sloshing length, l_{slh}, and breadth, b_{slh}, are defined in *Section 7/4.2.2* and *Section 7/4.2.3* respectively.

6.2.2 Application of sloshing pressure

6.2.2.1 The following tanks are to be assessed for the design sloshing pressures $P_{slh-lng}$ and P_{slh-t} in accordance with *6.2.2.2* to *6.2.2.5*:

(a) cargo and slop tanks

(b) fore peak and aft peak ballast tanks

(c) other tanks which allow free movement of liquid, except as follows:

- where the effective sloshing length is less than 0.03*L*, calculations involving $P_{slh-lng}$ are not required and
- where the effective sloshing breadth is less than 0.32*B*, calculations involving P_{slh-t} are not required.

The design sloshing pressure for other tanks mentioned in *6.2.1.2* is to be taken as the minimum sloshing pressure, $P_{slh-min}$, as defined in *Section 7/4.2.4.*

6.2.2.2 The design sloshing pressure due to longitudinal liquid motion, $P_{slh-lng}$, as defined in *Section 7/4.2.2.1* is to be applied to the following members as shown in *Figure 8.6.1*:

(a) transverse tight bulkheads

(b) transverse wash bulkheads

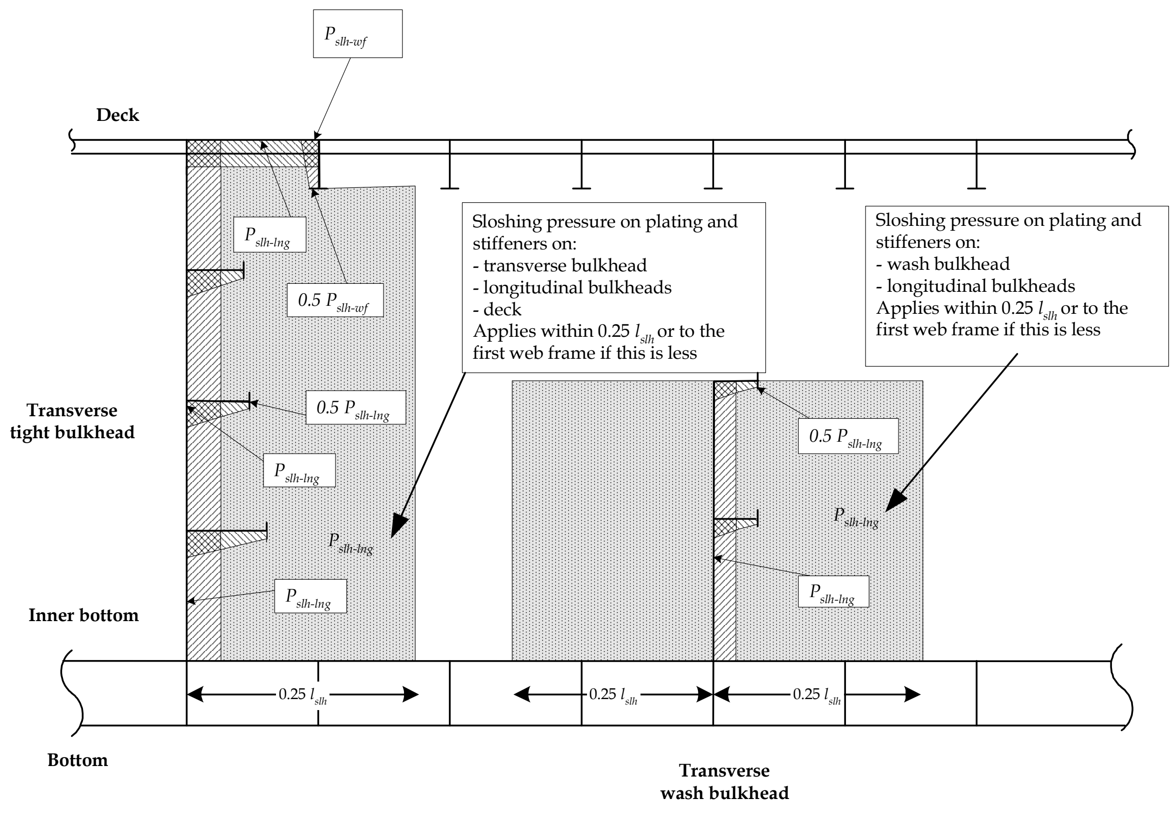
(c) stringers on transverse tight and wash bulkheads

(d) plating and stiffeners on the longitudinal bulkheads, deck and inner hull which are between the transverse bulkhead and the first web frame from the bulkhead or the bulkhead and $0.25l_{slh}$, whichever is lesser.

6.2.2.3 In addition to *6.2.2.2,* the first web frame next to a transverse tight or wash bulkhead if the web frame is located within $0.25l_{slh}$ from the bulkhead, as shown in *Figure 8.6.1,* is to be assessed for the web frame reflected sloshing pressure, P_{slh-wf}, as defined in *Section 7/4.2.2.5*.

6.2.2.4 The minimum sloshing pressure, $P_{slh-min}$, as defined in *Section 7/4.2.4* is to be applied to all other members.

Figure 8.6.1
Application of Sloshing Loads due to Longitudinal Liquid Motion



6.2.2.5 The design sloshing pressure due to transverse liquid motion, P_{shl-t}, as defined in *Section 7/4.2.3.1,* is to be applied to the following members as shown in *Figure 8.6.2*:

(a) longitudinal tight bulkhead

(b) longitudinal wash bulkhead

(c) horizontal stringers on longitudinal tight and wash bulkheads

(d) plating and stiffeners on the transverse tight bulkheads including stringers and deck which are between the longitudinal bulkhead and the first girder from the bulkhead or the bulkhead and $0.25b_{slh}$ whichever is lesser.

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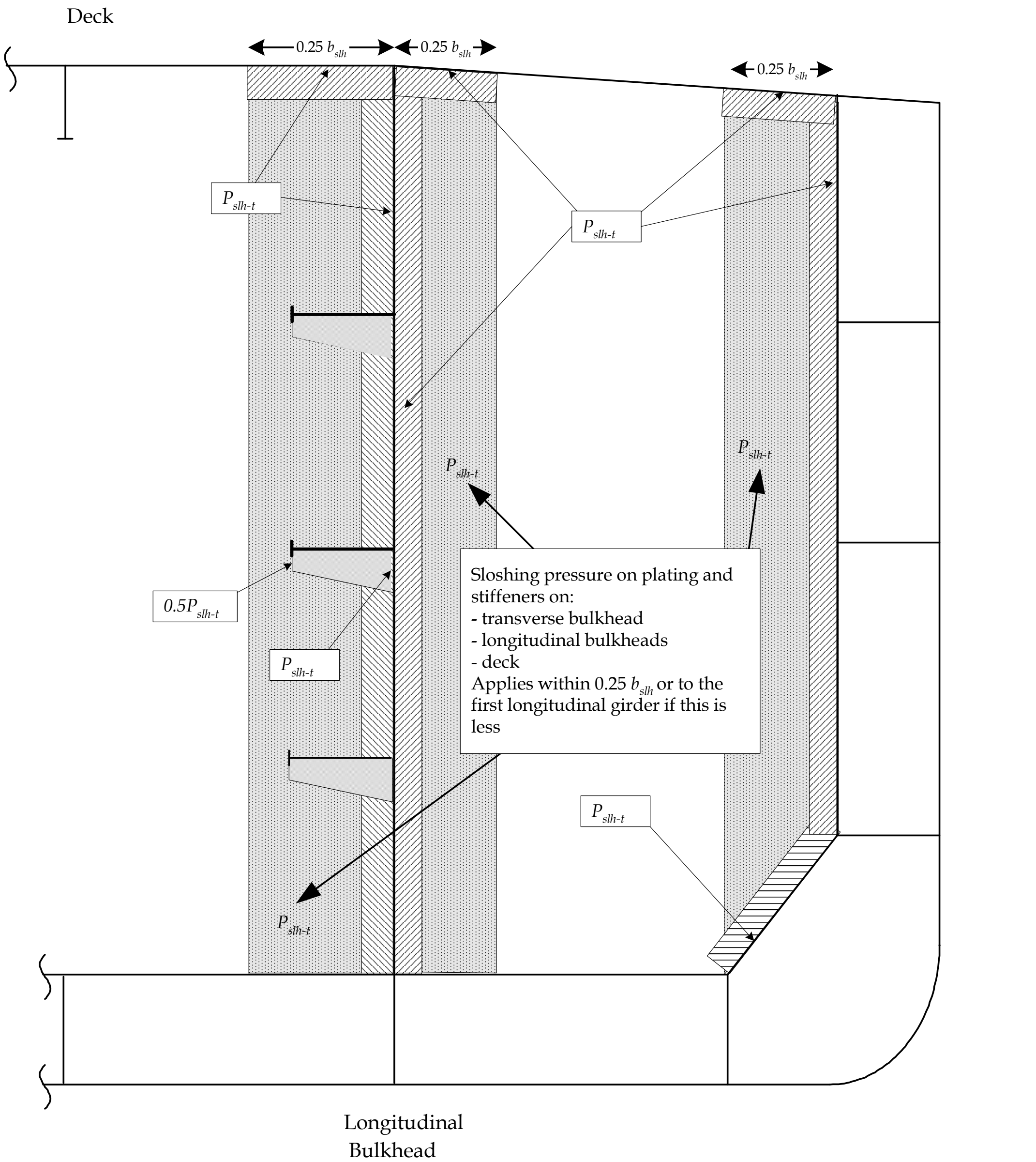
6.2.2.6 In addition to *6.2.2.5*, the first girder next to longitudinal tight or wash bulkhead if the girder is located within $0.25b_{slh}$ from the longitudinal bulkhead, as shown in *Figure 8.6.2*, is to be assessed for the reflected sloshing pressure, $P_{slh-grd}$ as defined in *Section 7/4.2.3.5*.

Figure 8.6.2
Application of Sloshing Loads due to Transverse Liquid Motion



6.2.2.7 The minimum sloshing pressure, $P_{slh-min}$, as defined in *Section 7/4.2.4*, is to be applied to all other members.

6.2.2.8 The sloshing pressures due to transverse and longitudinal fluid motion are assumed to act independently. Structural members are therefore to be evaluated based on the greatest sloshing pressure due to longitudinal and transverse fluid motion.

6.2.3 Sloshing assessment of plating forming tank boundaries and wash bulkheads

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6.2.3.1 The net thickness of plating forming tank boundaries and wash bulkheads, t_{net}, subjected to sloshing pressures is not to be less than:

$$t_{net} = 0.0158\alpha_p\, s\sqrt{\frac{P_{slh}}{C_a\sigma_{yd}}} \quad \text{mm}$$

Where:

α_p correction factor for the panel aspect ratio

$= 1.2 - \dfrac{s}{2100\, l_p}$ but not to be taken as greater than 1.0

s stiffener spacing, in mm, as defined in *Section 4/2.2*

l_p length of plate panel, to be taken as the spacing of primary support members, S, unless carlings are fitted, in m

P_{slh} the greater of $P_{slh\text{-}lng}$, $P_{slh\text{-}t}$ or $P_{slh\text{-}min}$ as specified in *6.2.2*

C_a permissible plate bending stress coefficient as given in *Table 8.6.1*

σ_{yd} specified minimum yield stress of the material, in N/mm^2

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6.2.4 Sloshing assessment of stiffeners on tank boundaries and wash bulkheads

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6.2.4.1 The net section modulus, Z_{net}, of stiffeners on tank boundaries and wash bulkheads subjected to sloshing pressures is not to be less than:

$$Z_{net} = \frac{P_{slh}\ s\ l_{bdg}^{\ 2}}{f_{bdg}\ C_s\ \sigma_{yd}} \quad \text{cm}^3$$

Where:

l_{bdg} effective bending span, of stiffener, as defined in *Section 4/2.1*, in m

C_s permissible bending stress coefficient as given in *Table 8.6.2*

P_{slh} the greater of $P_{slh\text{-}lng}$, $P_{slh\text{-}t}$ or $P_{slh\text{-}min}$ as specified in *6.2.2*

s stiffener spacing, in mm, as defined in *Section 4/2.2*

σ_{yd} specified minimum yield stress of the material, in N/mm^2

f_{bdg} bending moment factor:

= 12 for stiffeners fixed against rotation at each end. This is generally to be applied for scantlings of all continuous stiffeners

= 8 for stiffeners with one or both ends not fixed against rotation. This is generally to be applied to discontinuous stiffeners

for other configurations the bending moment factor may be taken as given in *Table 8.3.5*

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6.2.5 Sloshing assessment of primary support members

6.2.5.1 Web plating, web stiffeners and tripping brackets on stringers, girders and web frames in cargo and ballast tanks are to be assessed based on sloshing pressures as given in *6.2.2*.

6.2.5.2 The web plating net thickness of primary support members, t_{net}, is not to be less than:

$$t_{net} = 0.0158\alpha_p s\sqrt{\frac{P_{slh}}{C_a\sigma_{yd}}} \quad \text{mm}$$

Where:

α_p correction factor for the panel aspect ratio

$= 1.2 - \dfrac{s}{2100 l_p}$ but not to be taken as greater than 1.0

s stiffener spacing, in mm, as defined in *Section 4/2.2*

l_p length of plate panel, mean spacing between local support members on the long edges of the panel, typically between tripping brackets, in m

P_{slh} the greater of $P_{slh-lng}$, P_{slh-t}, P_{slh-wf}, $P_{slh-grd}$ or $P_{slh-min}$ as specified in *6.2.2*. The pressure is to be calculated at the load application point, defined in *Section 3/5.1.2*, taking into account the distribution over the height of the member, as shown in *Figure 8.6.1*

C_a permissible plate bending stress coefficient as given in *Table 8.6.1*

σ_{yd} specified minimum yield stress of the material, in N/mm^2

6.2.5.3 The net section modulus, Z_{net}, of each individual stiffener on the web plating of primary support members subjected to sloshing pressures is not to be less than:

$$Z_{net} = \frac{P_{slh}\ s\ l_{bdg}^{\ 2}}{f_{bdg}\ C_s\ \sigma_{yd}} \quad \text{cm}^3$$

Where:

P_{slh} the greater of $P_{slh-lng}$, P_{slh-t}, P_{slh-wf}, $P_{slh-grd}$ or $P_{slh-min}$ as specified in *6.2.2*. The pressure is to be calculated at the load application point taking into account the distribution over the height of the member, as shown in *Figure 8.6.1* and *8.6.2*.

s stiffener spacing, in mm, as defined in *Section 4/2.2*

l_{bdg} effective bending span, in m, of web stiffener as defined in *Section 4/2.1*

C_s permissible bending stress coefficient as given in *Table 8.6.2*

f_{bdg} bending moment factor

= 12 for stiffeners fixed against rotation at each end. This is generally to be applied for scantlings of all continuous stiffeners

= 8 for stiffeners with one or both ends not fixed against rotation. This is generally to be applied to discontinuous stiffeners

for other configurations the bending moment factor may be taken as given in *Table 8.3.5*

σ_{yd} specified minimum yield stress of the material, in N/mm^2

6.2.5.4 The net section modulus, Z_{net}, in way of the base of tripping brackets supporting primary support members in cargo and ballast tanks is not to be less than:

$$Z_{net} = \frac{1000\, P_{slh}\; s_{trip}\; l_{trip}^2}{2\, C_s\, \sigma_{yd}} \quad \text{cm}^3$$

Where:

P_{slh} the greater of $P_{slh\text{-}lng}$, $P_{slh\text{-}t}$, $P_{slh\text{-}wf}$, $P_{slh\text{-}grd}$ and $P_{slh\text{-}min}$ as defined in *6.2.2*. The average pressure may be calculated at mid point of the tripping bracket taking into account the distribution as shown in *Figure 8.6.1* and *8.6.2*

s_{trip} mean spacing, between tripping brackets or other primary support members or bulkheads, in m

l_{trip} length of tripping bracket, see *Figure 8.6.3,* in m

C_s permissible bending stress coefficient for tripping brackets = 0.75

σ_{yd} specified minimum yield stress of the material, in N/mm²

6.2.5.4bis The effective breadth of the attached plate to be used for calculating the section modulus of the tripping bracket supporting primary support members is to be taken as 1/3 the length of the tripping bracket, l_{trip}, as given in *8/6.2.5.4*.

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6.2.5.5 The net shear area, $A_{shr\text{-}net}$, after deduction of cut-outs and slots, of tripping brackets supporting primary support members in cargo and ballast tanks is not to be less than:

$$A_{shr-net} = 10\frac{P_{slh}\; s_{trip}\; l_{trip}}{C_t\, \tau_{yd}} \quad \text{cm}^2$$

Where:

P_{slh} the greater of $P_{slh\text{-}lng}$, $P_{slh\text{-}t}$, $P_{slh\text{-}wf}$, $P_{slh\text{-}grd}$ and $P_{slh\text{-}min}$ as defined in *6.2.2*. The average pressure may be calculated at mid point of the tripping bracket taking into account the distribution as shown in *Figure 8.6.1* and *8.6.2*

s_{trip} mean spacing, between tripping brackets or other primary support members or bulkheads, in m

l_{trip} length of tripping bracket, see *Figure 8.6.3,* in m

C_t permissible shear stress coefficient, as given in *Table 8.6.3*

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm²

σ_{yd} specified minimum yield stress of the material, in N/mm²

Figure 8.6.3
Effective Length of Tripping Bracket

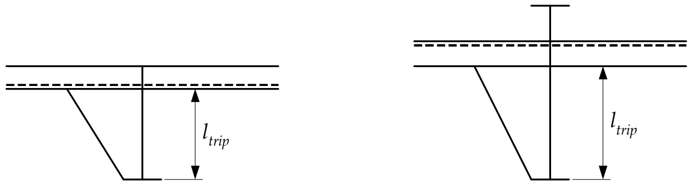

Table 8.6.1
Allowable Plate Bending Stress Coefficient, C_a, for Assessment of Sloshing on Plates

The permissible bending stress coefficient for the design load set being considered is to be taken as:

$$C_a = \beta_a - \alpha_a \frac{|\sigma_{hg}|}{\sigma_{yd}}$$ but not to be taken greater than C_{a-max}

Where:

α_a, β_a, C_{a-max} permissible bending stress factors and are to be taken as follows

<table>
<tr><th>Acceptance Criteria Set</th><th colspan="2">Structural Member</th><th>β_a</th><th>α_a</th><th>C_{a-max}</th></tr>
<tr><td rowspan="3">AC1</td><td rowspan="2">Longitudinal strength members in the cargo tank region including but not limited to :
- deck
- longitudinal plane bulkhead
- horizontal corrugated longitudinal bulkhead
- longitudinal girders and stringers within the cargo tank region</td><td>Longitudinally stiffened plating</td><td>0.9</td><td>0.5</td><td>0.8</td></tr>
<tr><td>Transversely or vertically stiffened plating</td><td>0.9</td><td>1.0</td><td>0.8</td></tr>
<tr><td colspan="2">Other strength members including:
- vertical corrugated longitudinal bulkhead
- transverse plane bulkhead
- transverse corrugated bulkhead
- transverse stringers and web frames
- plating of tank boundaries and primary support members outside the cargo tank region</td><td>0.8</td><td>0</td><td>0.8</td></tr>
</table>

σ_{hg} hull girder bending stress for the design load set being considered and calculated at the load calculation point defined in *Section 3/5.1.2*

$$= \left(\frac{(z - z_{NA-net50})\, M_{sw-perm-sea}}{I_{v-net50}} \right) 10^{-3} \quad \text{N/mm}^2$$

z vertical coordinate of the load calculation point under consideration, in m

$z_{NA-net50}$ distance from the baseline to the horizontal neutral axis, as defined in *Section 4/2.6.1*, in m

$M_{sw-perm-sea}$ permissible hull girder hogging and sagging still water bending moment for seagoing operation at the location being considered, in kNm. The greatest of the sagging and hogging bending moment is to be used, see *Section 7/2.1.*

$I_{v-net50}$ net vertical hull girder moment of inertia, at the longitudinal position being considered, as defined in *Section 4/2.6.1*, in m^4

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Table 8.6.2
Allowable Bending Stress Coefficient, C_s, for Assessment of Sloshing on Stiffeners

The permissible bending stress coefficient for the design load set being considered is to be taken as:

$$C_s = \beta_s - \alpha_s \frac{|\sigma_{hg}|}{\sigma_{yd}}$$ but not to be taken greater than C_{s-max}

Where:

α_s, β_s, C_{s-max} permissible bending stress factors and are to be taken as follows:

Acceptance Criteria Set	Structural Member		β_s	α_s	C_{s-max}
AC1	Longitudinal strength members in the cargo tank region including but not limited to: - deck stiffeners - stiffeners on longitudinal bulkheads - stiffeners on longitudinal girders and stringers within the cargo tank region	Longitudinal stiffeners	0.85	1.0	0.75
		Transverse or vertical stiffeners	0.7	0	0.7
	Other strength members including: - stiffeners on transverse bulkheads - stiffeners on transverse stringers and web frames - stiffeners on tank boundaries and primary support members outside the cargo tank region		0.75	0	0.75

σ_{hg} hull girder bending stress for the design load set being considered at the reference point defined in *Section 3/5.2.2.5*

$$= \left(\frac{(z - z_{NA-net50})\,M_{sw-perm-sea}}{I_{v-net50}}\right)10^{-3} \quad \text{N/mm}^2$$

z vertical coordinate of the reference point defined in *Section 3/5.2.2.5*, in m

$z_{NA-net50}$ distance from the baseline to the horizontal neutral axis, as defined in *Section 4/2.6.1*, in m

$M_{sw-perm-sea}$ permissible hull girder hogging and sagging still water bending moment for seagoing operation at the location being considered, in kNm.

Stiffener Location	$M_{sw-perm-sea}$	
	Pressure acting on Plate Side	**Pressure acting on Stiffener Side**
Above Neutral Axis	Sagging SWBM	Hogging SWBM

$I_{v-net50}$ net vertical hull girder moment of inertia, at the longitudinal position being considered, as defined in *Section 4/2.6.1*, in m^4

σ_{yd} specified minimum yield stress of the material, in N/mm^2

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Table 8.6.3
Permissible Shear Stress Coefficient

Acceptance Criteria Set	Structural member	C_t
AC1	Tripping brackets	0.75

6.3 Bottom Slamming

6.3.1 Application

6.3.1.1 Where the minimum draughts forward, $T_{FP\text{-}mt}$ or $T_{FP\text{-}full}$, as specified in *Section 7/4.3.2.1*, is less than 0.045*L*, the bottom forward is to be additionally strengthened to resist bottom slamming pressures.

6.3.1.2 The draughts for which the bottom has been strengthened are to be indicated on the shell expansion plan and loading guidance information, see *1.1*.

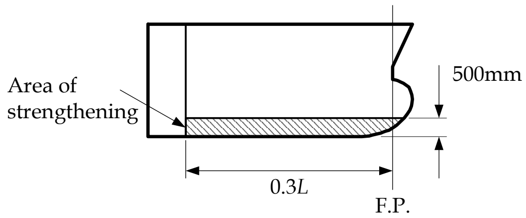
6.3.1.3 The scantlings described in *6.3* are net scantlings, which are related to gross scantlings as described in *6.1.1.2*. The section modulus and shear area of the primary support members is to be determined as specified in *Section 4/2.5*.

6.3.1.4 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The cross sectional shear areas of primary support members are to be applied as required by *6.3.7.3* and *6.3.7.4*.

6.3.2 Extent of strengthening

6.3.2.1 The strengthening is to extend forward of 0.3*L* from the F.P. over the flat of bottom and adjacent plating with attached stiffeners up to a height of 500mm above the baseline, see *Figure 8.6.4*.

Figure 8.6.4
Extent of strengthening against bottom slamming



6.3.2.2 Outside the region strengthened to resist bottom slamming the scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.

6.3.3 Design to resist bottom slamming loads

6.3.3.1 The design of end connections of stiffeners in the bottom slamming region is to ensure end fixity, either by making the stiffeners continuous through supports or by providing end brackets complying with *Section 4/3.2.3*. Where it is not practical to comply with this requirement the net plastic section modulus, $Z_{pl\text{-}alt\text{-}net}$, for alternative end fixity arrangements is not to be less than:

$$Z_{pl\text{-}alt\text{-}net} = \frac{16 Z_{pl-net}}{f_{bdg}} \quad \text{cm}^3$$

Where:

$Z_{pl\text{-}net}$ net plastic section modulus, in cm^3, as required by *6.3.5.1*

f_{bdg} bending moment factor

$$= 8\left(1 + \frac{n_s}{2}\right)$$

n_s = 0 for both ends with low end fixity (simply supported)
= 1 for one end equivalent to built in and one end simply supported

6.3.3.2 Scantlings and arrangements at primary support members, including bulkheads, are to comply with *6.3.7*.

6.3.4 Hull envelope plating

6.3.4.1 The net thickness of the hull envelope plating, t_{net}, is not to be less than:

$$t_{net} = \frac{0.0158\,\alpha_p\, s}{C_d}\sqrt{\frac{P_{slm}}{C_a \sigma_{yd}}} \quad \text{mm}$$

Where:

α_p correction factor for the panel aspect ratio

$= 1.2 - \frac{s}{2100 l_p}$ but not to be taken as greater than 1.0

s stiffener spacing, in mm, as defined in *Section 4/2.2*

l_p length of plate panel, to be taken as the spacing between primary support members (see *Section 4/2.2.2*) or panel breakers, in m

P_{slm} bottom slamming pressure as given in *Section 7/4.3* and calculated at the load calculation point defined in *Section 3/5.1.2*, in kN/m^2

C_d plate capacity correction coefficient
= 1.3

C_a permissible bending stress coefficient
= 1.0 for acceptance criteria set AC3

σ_{yd} specified minimum yield stress of the material, in N/mm^2

6.3.5 Hull envelope stiffeners

6.3.5.1 The net plastic section modulus, Z_{pl-net}, of each individual stiffener, is not to be less than:

$$Z_{pl-net} = \frac{P_{slm}\, s l_{bdg}^{\;2}}{f_{bdg}\, C_s\, \sigma_{yd}} \quad \text{cm}^3$$

Where:

P_{slm} bottom slamming pressure as given in *Section 7/4.3* and calculated at the load calculation point defined in *Section 3/5.2.2*, in kN/m^2

s stiffener spacing, in mm, as defined in *Section 4/2.2*

l_{bdg} effective bending span, as defined in *Section 4/2.1.1*, in m

f_{bdg} bending moment factor

$$= 8\left(1 + \frac{n_s}{2}\right)$$

n_s = 2.0 for continuous stiffeners or where stiffeners are bracketed at both ends

see *6.3.3.1* for alternative arrangements

C_s permissible bending stress coefficient

= 0.9 for acceptance criteria set AC3

σ_{yd} specified minimum yield stress of the material, in N/mm²

6.3.5.2 The net web thickness, t_{w-net}, of each longitudinal is not to be less than:

$$t_{w-net} = \frac{P_{slm}\, s l_{shr}}{2 d_{shr} C_t \tau_{yd}} \quad \text{mm}$$

Where:

l_{shr} effective shear span, as defined in *Section 4/2.1.2*, in m

s stiffener spacing, in mm, as defined in *Section 4/2.2*

P_{slm} bottom slamming pressure as given in *Section 7/4.3* and calculated at the load calculation point defined in *Section 3/5.2.2*, in kN/m²

d_{shr} effective web depth of stiffener, in mm, as defined in *Section 4/2.4.2.2*

C_t permissible shear stress coefficient

= 1.0 for acceptance criteria set AC3

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm²

σ_{yd} specified minimum yield stress of the material, in N/mm²

6.3.5.3 The slenderness ratio of each longitudinal is to comply with *Section 10/2.*

6.3.6 Definition of idealised bottom slamming load area for primary support members

6.3.6.1 The scantlings of items in *6.3.7* are based on the application of the slamming pressure defined in *Section 7/4.3* to an idealised area of hull envelope plating, the slamming load area, A_{slm}, given by:

$$A_{slm} = \frac{1.1 L B C_b}{1000} \quad \text{m}^2$$

Where:

L rule length, as defined in *Section 4/1.1.1.1*

B moulded breadth, in m, as defined in *Section 4/1.1.3.1*

C_b block coefficient, as defined in *Section 4/1.1.9.1*

6.3.7 Primary support members

6.3.7.1 The size and number of openings in web plating of the floors and girders is to be minimised considering the required shear area as given in *6.3.7.2*.

6.3.7.2 The net shear area, $A_{shr-net50}$, of each primary support member web at any position along its span is not to be less than:

$$A_{shr-net50} = 10 \frac{Q_{slm}}{C_t \tau_{yd}} \quad \text{cm}^2$$

Where:

Q_{slm} the greatest shear force due to slamming for the position being considered, in kN, based on the application of a patch load, F_{slm} to the most onerous location, as determined in accordance with *6.3.7.3*

C_t permissible shear stress coefficient
= 0.9 for acceptance criteria set AC3

τ_{yd} $= \frac{\sigma_{yd}}{\sqrt{3}}$ N/mm²

σ_{yd} specified minimum yield stress of the material, in N/mm²

6.3.7.3 For simple arrangements of primary support members, where the grillage affect may be ignored, the shear force, Q_{slm}, is given by:

$$Q_{slm} = f_{pt} f_{dist} F_{slm} \quad \text{kN}$$

Where:

f_{pt} Correction factor for the proportion of patch load acting on a single primary support member
$= 0.5\left(f_{slm}^{\ 3} - 2 f_{slm}^{\ 2} + 2\right)$

f_{slm} patch load modification factor
$= 0.5 \frac{b_{slm}}{S}$, but not to be greater than 1.0

f_{dist} factor for the greatest shear force distribution along the span, see *Figure 8.6.5*

F_{slm} $= P_{slm}\, l_{slm}\, b_{slm}$

P_{slm} bottom slamming pressure as given in *Section 7/4.3* and calculated at the load calculation point defined in *Section 3/5.3.2*, in kN/m²

l_{slm} extent of slamming load area along the span
$= \sqrt{A_{slm}}$ m, but not to be greater than l_{shr}

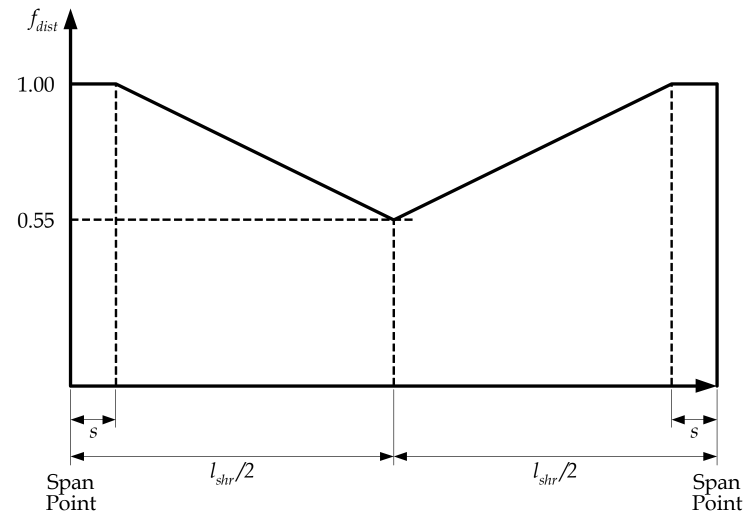
l_{shr} effective shear span, as defined in *Section 4/2.1.5*, in m

b_{slm} breadth of impact area supported by primary support member
$= \sqrt{A_{slm}}$ m, but not to be greater than S

A_{slm} as defined in *6.3.6.1*

S primary support member spacing, in m, as defined in *Section 4/2.2.2*

Figure 8.6.5
Distribution of f_{dist} along the Span of Simple Primary Support Members



Where:

s	stiffener spacing
l_{shr}	effective shear span, in m, as defined in *Section 4/2.1.5*

6.3.7.4 For complex arrangements of primary support members, the greatest shear force, Q_{slm}, at any location along the span of each primary support member is to be derived by direct calculation in accordance with *Table 8.6.4*.

Table 8.6.4
Direct Calculation Methods for Derivation of Q_{slm}

Type of analysis	Beam theory	Double bottom grillage
Model extent	Overall span of member between effective bending supports	Longitudinal extent to be one cargo tank length Transverse extent to be between inner hopper knuckle and centreline
Assumed end fixity of floors	Fixed at ends	Floors and girders to be fixed at boundaries of the model

Note
1. The envelope of greatest shear force along each primary support member is to be derived by applying the load patch to a number of locations along the span, see *6.3.7.2*.

6.3.7.5 The net web thickness, $t_{w\text{-}net}$, of primary support members adjacent to the shell is not to be less than:

$$t_{w-net} = \frac{s_w}{70}\sqrt{\frac{\sigma_{yd}}{235}} \text{ mm}$$

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Where:

s_w plate breadth, in mm, taken as the spacing between the web stiffening

σ_{yd} specified minimum yield stress of the material, in N/mm^2

6.3.8 Connection of longitudinals to primary support members

6.3.8.1 Longitudinals are, in general, to be continuous. Where this not practicable end brackets complying with *4/3.2.3* are to be provided.

6.3.8.2 The scantlings in way of the end connections of each longitudinal are to comply with the requirements of *Section 4/3.4*.

6.4 Bow Impact

6.4.1 Application

6.4.1.1 The side structure in the area forward of 0.1L from the F.P. is to be strengthened against bow impact pressures.

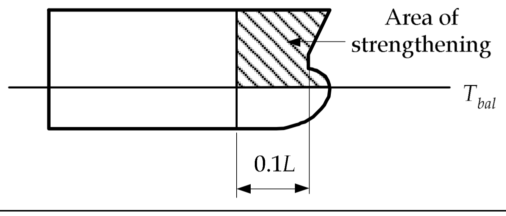
6.4.1.2 The scantlings described in *6.4* are net scantlings, which are related to gross scantlings as described in *6.1.1.2*.

6.4.1.3 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus of the primary support member is to apply along the bending span clear of end brackets and cross sectional areas of the primary support member is to be applied at the ends/supports and may be gradually reduced along the span and clear of the ends/supports following the distribution of f_{dist} indicated in *Figure 8.6.5*.

6.4.2 Extent of strengthening

6.4.2.1 The strengthening is to extend forward of 0.1L from the F.P. and vertically above the minimum design ballast draught, T_{bal}, defined in *Section 4/1.1.5.2*. See *Figure 8.6.6*.

Figure 8.6.6
Extent of Strengthening Against Bow Impact



6.4.2.2 Outside the strengthening region as given in *6.4.2.1* the scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.

6.4.3 Design to resist bow impact loads

6.4.3.1 In the bow impact region, longitudinal framing is to be carried as far forward as practicable.

6.4.3.2 The design of end connections of stiffeners in the bow impact region are to ensure end fixity, either by making the stiffeners continuous through supports or by providing end brackets complying with *Section 4/3.2.3*. Where it is not practical to

comply with this requirement the net plastic section modulus, $Z_{pl-alt-net}$, for alternative end fixity arrangements is not to be less than:

$$Z_{pl-alt-net} = \frac{16 Z_{pl-net}}{f_{bdg}} \quad \text{cm}^3$$

Where:

Z_{pl-net} effective net plastic section modulus, required by *6.4.5,* in cm^3

f_{bdg} bending moment factor

$= 8\left(1 + \frac{n_s}{2}\right)$

n_s = 0 for both ends with low end fixity (simply supported)

= 1.0 for one end equivalent to built in and one end simply supported

6.4.3.3 Scantlings and arrangements at primary support members, including decks and bulkheads, are to comply with *6.4.7*. In areas of greatest bow impact load the adoption of web stiffeners arranged perpendicular to the hull envelope plating and the provision of double sided lug connections are, in general to be applied.

6.4.3.4 The main stiffening direction of decks and bulkheads supporting shell framing is to be arranged parallel to the span direction of the supported shell frames, to protect against buckling.

6.4.4 Side shell plating

6.4.4.1 The net thickness of the side shell plating, t_{net}, is not to be less than:

$$t_{net} = 0.0158\, a_p\, s \sqrt{\frac{P_{im}}{C_a \sigma_{yd}}} \quad \text{mm}$$

Where:

α_p correction factor for the panel aspect ratio

$= 1.2 - \frac{s}{2100\, l_p}$ but is not to be taken as greater than 1.0

s stiffener spacing, in mm, as defined in *Section 4/2.2*

l_p length of plate panel, to be taken as the spacing between the primary support members, see *Section 4/2.2.2,* or panel breakers, in m

P_{im} bow impact pressure as given in *Section 7/4.4* and calculated at the load calculation point defined in *Section 3/5.1.2*, in kN/m^2

C_a permissible bending stress coefficient

= 1.0 for acceptance criteria set AC3

σ_{yd} specified minimum yield stress of the material, in N/mm^2

6.4.5 Side shell stiffeners

6.4.5.1 The effective net plastic section modulus, Z_{pl-net}, of each stiffener, in association with the effective plating to which it is attached, is not to be less than:

$$Z_{pl-net} = \frac{P_{im}\ s l_{bdg}^{\ 2}}{f_{bdg}\ C_s\ \sigma_{yd}} \quad \text{cm}^3$$

Where:

P_{im} bow impact pressure as given in *Section 7/4.4* and calculated at the load calculation point defined in *Section 3/5.2.2*, in kN/m²

s stiffener spacing, in mm, as defined in *Section 4/2.2*

l_{bdg} effective bending span, as defined in *Section 4/2.1.1*, in m

f_{bdg} bending moment factor

$$= 8\left(1 + \frac{n_s}{2}\right)$$

n_s = 2.0 for continuous stiffeners or where stiffeners are bracketed at both ends

see *6.4.3.2* for alternative arrangements

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C_s permissible bending stress coefficient

= 0.9 for acceptance criteria set AC3

σ_{yd} specified minimum yield stress of the material, in N/mm²

6.4.5.2 The net web thickness, t_{w-net}, of each stiffener is not to be less than:

$$t_{w-net} = \frac{P_{im}\ s l_{shr}}{2 d_{shr} C_t \tau_{yd}} \quad \text{mm}$$

Where:

l_{shr} effective shear span, as defined in *Section 4/2.1.2*, in m

s stiffener spacing, in mm, as defined in *Section 4/2.2*

P_{im} bow impact pressure as given in *Section 7/4.4* and calculated at the load calculation point defined in *Section 3/5.2.2*, in kN/m²

d_{shr} effective web depth of stiffener, in mm, as defined in *Section 4/2.4.2.2*

C_t permissible shear stress coefficient

= 1.0 for acceptance criteria set AC3

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm²

σ_{yd} specified minimum yield stress of the material, in N/mm²

6.4.5.3 The slenderness ratio of each longitudinal is to comply with *Section 10/2.*

6.4.5.4 The minimum net thickness of breasthooks/diaphragm plates, t_{w-net}, is not to be less than:

$$t_{w-net} = \frac{s}{70}\sqrt{\frac{\sigma_{yd}}{235}} \quad \text{mm}$$

Where:

s spacing of stiffeners on the web, as defined in *Section 4/2.2*, in mm. Where no stiffeners are fitted s is to be taken as the depth of the web

σ_{yd} specified minimum yield stress of the material, in N/mm²

6.4.6 Definition of idealised bow impact load area for primary support members

6.4.6.1 The scantlings of items in *6.4.7* are based on the application of the bow impact pressure, as defined in *Section 7/4.4,* to an idealised area of hull envelope plating, where the bow impact load area, A_{slm}, is given by:

$$A_{slm} = \frac{1.1 LBC_b}{1000} \quad \text{m}^2$$

Where:

L rule length, as defined in *Section 4/1.1.1.1*

B moulded breadth, in m, as defined in *Section 4/1.1.3.1*

C_b block coefficient, as defined in *Section 4/1.1.9.1*

6.4.7 Primary support members

6.4.7.1 Primary support members in the bow impact region are to be configured to ensure effective continuity of strength and the avoidance of hard spots.

6.4.7.2 To limit the deflections under extreme bow impact loads and ensure boundary constraint for plate panels, the spacing, S, measured along the shell girth of web frames supporting longitudinal framing or stringers supporting transverse framing is not to be greater than:

$$S = 3+0.008L_2 \quad \text{m}$$

Where:

L_2 rule length, L, as defined in *Section 4/1.1.1.1*, but not to be taken greater than 300m

6.4.7.3 End brackets of primary support members are to be suitably stiffened along their edge. Consideration is to be given to the design of bracket toes to minimise abrupt changes of cross-section.

6.4.7.4 Tripping arrangements are to comply with *Section 10/2.3.3*. In addition, tripping brackets are to be fitted at the toes of end brackets and at locations where the primary support member flange is knuckled or curved.

6.4.7.5 The net section modulus of each primary support member, Z_{net50}, is not to be less than:

$$Z_{net50} = 1000 \frac{f_{bdg-pt} P_{im}\, b_{slm} f_{slm} l_{bdg}^{\ 2}}{f_{bdg} C_s \sigma_{yd}} \quad \text{cm}^3$$

Where:

f_{bdg-pt} correction factor for the bending moment at the ends and considering the patch load

$$= 3 f_{slm}^{\ 3} - 8 f_{slm}^{\ 2} + 6 f_{slm}$$

f_{slm} patch load modification factor

$$= \frac{l_{slm}}{l_{bdg}}$$

l_{slm} extent of bow impact load area along the span

$= \sqrt{A_{slm}}$ m, but not to be taken as greater than l_{bdg}

A_{slm} bow impact load area, in m², as defined in *6.4.6.1*

l_{bdg} effective bending span, as defined in *Section 4/2.1.4*, in m

P_{im} bow impact pressure as given in *Section 7/4.4* and calculated at the load calculation point defined in *Section 3/5.3.1*, in kN/m²

RCN 1 to July 2010 version (effective from 1 July 2012)

b_{slm} breadth of impact load area supported by the primary support member, to be taken as the spacing between primary support members as defined in *Section 4/2.2.2*, but not to be taken as greater than l_{slm}, in m

f_{bdg} bending moment factor

= 12 for primary support members with end fixed continuous face plates, stiffeners or where stiffeners are bracketed in accordance with *Section 4/3.3* at both ends

C_s permissible bending stress coefficient

= 0.8

σ_{yd} specified minimum yield stress of the material, in N/mm²

RCN 2 to July 2008 version (effective from 1 July 2010)

6.4.7.6 The net shear area of the web, $A_{sh\text{-}net50}$, of each primary support member at the support/toe of end brackets is not to be less than:

$$A_{shr-net50} = \frac{5 f_{pt} P_{im} b_{slm} l_{shr}}{C_t \tau_{yd}} \quad \text{cm}^2$$

Where:

f_{pt} patch load modification factor

$$= \frac{l_{slm}}{l_{shr}}$$

l_{slm} extent of bow impact load area along the span

$= \sqrt{A_{slm}}$ m, but not to be taken as greater than l_{shr}

l_{shr} effective shear span, as defined in *Section 4/2.1.5*, in m

P_{im} bow impact pressure as given in *Section 7/4.4* and calculated at the load calculation point defined in *Section 3/5.3.2*, in kN/m²

b_{slm} breadth of impact load area supported by the primary support member, to be taken as the spacing between primary support members as defined in *Section 4/2.2.2*, but not to be taken as greater than l_{slm}, in m

C_t permissible shear stress coefficient

= 0.75 for acceptance criteria set AC3

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm²

σ_{yd} specified minimum yield stress of the material, in N/mm²

6.4.7.7 The net web thickness of each primary support member, $t_{w\text{-}net}$, including decks/bulkheads in way of the side shell is not to be less than:

$$t_{w-net} = \frac{P_{im}\, b_{slm}}{\sin \varphi_w\, \sigma_{crb}} \quad \text{mm}$$

Where:

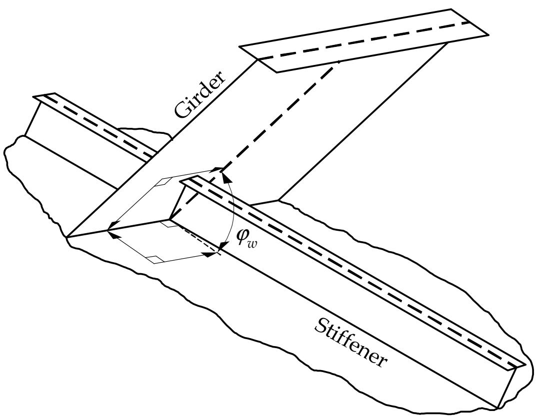
P_{im} bow impact pressure as given in *Section 7/4.4* and calculated at the load calculation point defined in *Section 3/5.3*.2 or at the intersection of the side shell with the deck/bulkhead, in kN/m²

b_{slm} breadth of impact load area supported by the primary support member, to be taken as spacing between primary support members as defined in *Section 4/2.2.2*, but not to be taken as greater than l_{slm}, in m

φ_w angle, in degrees, between the primary support member web and the shell plate, see *Figure 8.6.7*

σ_{crb} critical buckling stress in compression of the web of the primary support member or deck/bulkhead panel in way of the applied load given by *Section 10/3.2.1*, in N/mm²

Figure 8.6.7
Angle between Shell Primary Member and Shell Plate



6.4.8 Connection of stiffeners to primary support members

6.4.8.1 Stiffeners are, in general, to be continuous. Where this not practicable end brackets complying with *Section 4/3.2.3* are to be provided.

6.4.8.2 The scantlings of the end connection of each stiffener are to comply with *Section 4/3.4*.

7 APPLICATION OF SCANTLING REQUIREMENTS TO OTHER STRUCTURE

7.1 General

7.1.1 Application

7.1.1.1 The requirements of this Sub-Section apply to plating, local and primary support members where the basic structural configurations or strength models assumed in *Section 8/2* to *8/5* are not appropriate. These are general purpose strength requirements to cover various load assumptions and end support conditions. These requirements are not to be used as an alternative to the requirements of *Section 8/2* to *8/5* where those sections can be applied.

7.1.1.2 The net scantlings described in *7.2* are related to gross scantlings as follows:

(a) for plating and local support members, the gross thickness and gross cross-sectional properties are obtained from the requirements of *7.2.2* by adding the full corrosion additions specified in *Section 6/3*.

(b) for primary support members, the gross shear area, gross section modulus and other gross cross-sectional properties are obtained from the requirements of *7.2.3* by adding one half of the relevant full corrosion additions specified in *Section 6/3*.

7.1.1.3 These requirements are to be applied in conjunction with all other appropriate requirements in *Sections 8, 9* and *10* for the particular structural member under consideration, including longitudinal strength, minimum thickness, proportions and structural stability, strength assessment (FEM), fatigue and hull girder ultimate strength.

7.1.1.4 The requirements for local and primary support members are to be specially considered when the member is:

(a) part of a grillage structure

(b) subject to large relative deflection between end supports

(c) where the load model or end support condition is not given in *Table 8.7.1.*

7.1.1.5 The application of alternative or more advanced calculation methods will be specially considered.

7.2 Scantling Requirements

7.2.1 General

7.2.1.1 The design load sets to be applied to the structural requirements for the local and primary support members are given in *Table 8.7.2*, as applicable for the particular structure under consideration. The static and dynamic load components are to be combined in accordance with *Table 7.6.1* and the requirements given in *Section 7/6.3*.

7.2.2 Plating and local support members

7.2.2.1 For plating subjected to lateral pressure the net thickness, t_{net}, is to be taken as the greatest value for all applicable design load sets given in *Table 8.7.2,* and given by:

$$t_{net} = 0.0158\, a_p s \sqrt{\frac{|P|}{C_a \sigma_{yd}}} \quad \text{mm}$$

Where:

α_p correction factor for the panel aspect ratio

$$= 1.2 - \frac{s}{2100\, l_p}$$

P design pressure for the design load set being considered, calculated at the load calculation point defined in *Section 3/5.1.2*, in kN/m²

s stiffener spacing, in mm, as defined in *Section 4/2.2*

l_p length of plate panel, to be taken as the spacing of primary support members, S, unless carlings are fitted, in m

C_a permissible bending stress coefficient for the design load set being considered, as given in *Tables 8.2.4*, *8.3.2* or *8.4.2*, as applicable for the individual member being considered

σ_{yd} specified minimum yield stress of the material, in N/mm²

7.2.2.2 For stiffeners subjected to lateral pressure, point loads, or some combination thereof, the net section modulus requirement, Z_{net}, is to be taken as the greatest value for all applicable design load sets given in *Table 8.7.2*, and given by:

$$Z_{net} = \frac{|P|\, s\, l_{bdg}^2}{f_{bdg} C_s\, \sigma_{yd}} \quad \text{cm}^3\text{, for lateral pressure loads}$$

$$Z_{net} = \frac{1000\ |F|\, l_{bdg}}{f_{bdg}\, C_s\, \sigma_{yd}} \quad \text{cm}^3\text{, for point loads}$$

$$Z_{net} = \frac{\left| \sum \frac{P_i\, s\, l_{bdg}^2}{f_{bdg-i}} + \sum \frac{1000 F_j\, l_{bdg}}{f_{bdg-j}} \right|}{C_s\, \sigma_{yd}} \quad \text{cm}^3\text{, for a combination of loads}$$

Where:

P design pressure for the design load set being considered, calculated at the load calculation point defined in *Section 3/5.2.2*, in kN/m²

s stiffener spacing, in mm, as defined in *Section 4/2.2*

l_{bdg} effective bending span, as defined in *Section 4/2.1.1*

f_{bdg} bending moment factor

for continuous stiffeners and where end connections are fitted consistent with idealization of the stiffener as having fixed ends:

= 12 for horizontal stiffeners

= 10 for vertical stiffeners

for other configurations the bending moment factor may be taken as in *Table 8.7.1*

C_s permissible bending stress coefficient for the design load set being considered as given in *Tables 8.2.5*, *8.3.3* or *8.4.3*, as applicable for the individual member being considered

σ_{yd} specified minimum yield stress of the material, in N/mm²

F point load for the design load set being considered, in kN

i indices for load component i

j indices for load component j

7.2.2.3 For stiffeners subjected to lateral pressure, point loads, or some combination thereof, the net web thickness, t_{w-net}, based on shear area requirements is to be taken as the greatest value for all applicable design load sets given in *Table 8.7.2*, and given by:

$$t_{w-net} = \frac{f_{shr}\,|P|\,s\,l_{shr}}{d_{shr}\,C_t\,\tau_{yd}}$$ mm, for lateral pressure loads

$$t_{w-net} = \frac{1000 f_{shr}\,|F|}{d_{shr}\,C_t\tau_{yd}}$$ mm, for point loads

$$t_{w-net} = \frac{\left|\sum f_{shr-i}\,P_i\,s\,l_{shr} + \sum 1000 f_{shr-j}\,F_j\right|}{d_{shr}\,C_t\tau_{yd}}$$ mm, for a combination of loads

Where:

P design pressure for the design load set being considered, calculated at the load calculation point defined in *Section 3/5.2.2*, in kN/m²

f_{shr} shear force factor

for continuous stiffeners and where end connections are fitted consistent with idealization of the stiffener as having fixed ends:

= 0.5 for horizontal stiffeners

= 0.7 for vertical stiffeners

for other configurations the shear force factor may be taken as in *Table 8.7.1.*

s stiffener spacing, in mm, as defined in *Section 4/2.2*

l_{shr} effective shear span, as defined in *Section 4/2.1.2*

d_{shr} as defined in *Section 4/2.4.2.2*

C_t permissible shear stress coefficient for the design load set being considered as given in *Tables 8.2.6* or *8.3.4*, as applicable for the individual member being considered

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm²

σ_{yd} specified minimum yield stress of the material, in N/mm²

F point load for the design load set being considered, in kN

i indices for load component i

j indices for load component j

7.2.3 Primary support members

7.2.3.1 The requirements in *7.2.3* are applicable where the primary support member is idealised as a simple beam. More advanced calculation methods may be required to ensure that nominal stress level for all primary support members are less than the permissible stresses and stress coefficients given in *7.2.3.4* and *7.2.3.5* when subjected to the applicable design load sets. See also *7.1.1.4*.

7.2.3.2 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus and cross sectional shear areas of the primary support member are to be applied as required in the notes of *Table 8.7.1*.

7.2.3.3 For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include an allowance for the curvature of the hull.

7.2.3.4 For primary support members the net section modulus requirement, Z_{net50}, is to be taken as the greatest value for all applicable design load sets given in *Table 8.7.2*, and given by:

$$Z_{net50} = \frac{1000\,|P|\,S\,l_{bdg}^2}{f_{bdg}\,C_s\,\sigma_{yd}} \quad \text{cm}^3\text{, for lateral pressure loads}$$

$$Z_{net50} = \frac{1000\,|F|\,l_{bdg}}{f_{bdg}\,C_s\,\sigma_{yd}} \quad \text{cm}^3\text{, for point loads}$$

$$Z_{net50} = \frac{\left|\sum \frac{1000 P_i\,S\,l_{bdg}^2}{f_{bdg-i}} + \sum \frac{1000 F_j\,l_{bdg}}{f_{bdg-j}}\right|}{C_s\,\sigma_{yd}} \quad \text{cm}^3\text{, for a combination of loads}$$

Where:

P	design pressure for the design load set being considered, calculated at the load calculation point defined in *Section 3/5.3.3*, in kN/m²
S	primary support member spacing, in m, as defined in *Section 4/2.2.2*
l_{bdg}	effective bending span, as defined in *Section 4/2.1.4*
f_{bdg}	bending moment factor, as given in *Table 8.7.1.*
C_s	permissible bending stress coefficient for the design load set being considered as given in *Tables 8.2.10* or *8.3.6*, as applicable for the individual member being considered
σ_{yd}	specified minimum yield stress of the material, in N/mm²
F	point load for the design load set being considered, in kN
i	indices for load component i
j	indices for load component j

7.2.3.5 For primary support members the net shear area of the web, $A_{shr-net50}$, is to be taken as the greatest value for all applicable design load sets given in *Table 8.7.2,* and given by:

$$A_{shr-net50} = \frac{10 f_{shr} |P| S l_{shr}}{C_t \tau_{yd}} \quad \text{cm}^2\text{, for lateral pressure loads}$$

$$A_{shr-net50} = \frac{10 f_{shr} |F|}{C_t \tau_{yd}} \quad \text{cm}^2\text{, for point loads}$$

$$A_{shr-net50} = \frac{\left| \sum 10 f_{shr-i} P_i l_{shr} + \sum 10 f_{shr-j} F_j \right|}{C_t \tau_{yd}} \quad \text{cm}^2\text{, for a combination of}$$

loads

Where:

P	design pressure for the design load set being considered, calculated at the load calculation point defined in *Section 3/5.3.2*, in kN/m^2
S	primary support member spacing, in m, as defined in *Section 4/2.2.2*
l_{shr}	effective shear span, as defined in *Section 4/2.1.5*
f_{shr}	shear force factor, as given in *Table 8.7.1*
C_t	permissible shear stress coefficient for the design load set being considered as given in *Tables 8.2.10* or *8.3.7*, as applicable for the individual member being considered
τ_{yd}	$= \frac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2
σ_{yd}	specified minimum yield stress of the material, in N/mm^2
F	point load for the design load set being considered, in kN
i	indices for load component i
j	indices for load component j

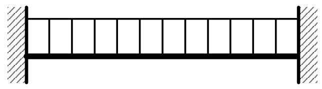
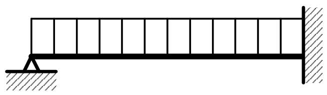
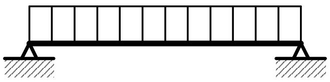
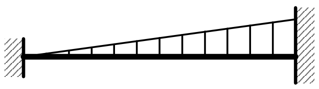
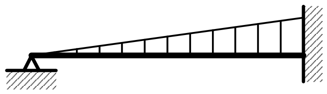
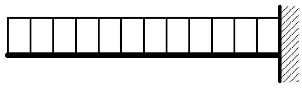
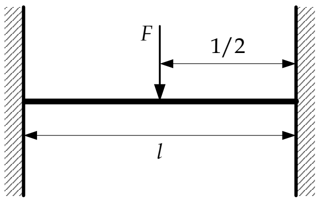
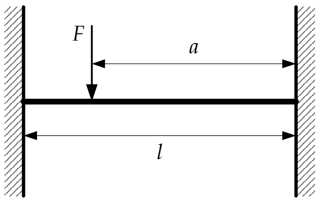
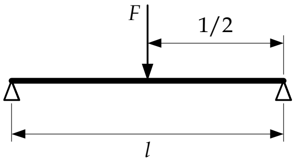
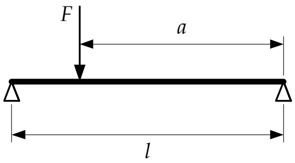
<table>
<tr><th colspan="8">Table 8.7.1
Values of f_{bdg} and f_{shr}</th></tr>
<tr><th colspan="4">Load and boundary conditions</th><th colspan="3">Bending moment and shear force factor (based on load at mid span where load varies)</th><th rowspan="3">Application</th></tr>
<tr><td rowspan="2">Load model</td><td colspan="3">Position (1)</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td>1
Support</td><td>2
Field</td><td>3
Support</td><td>f_{bdg1}
f_{shr1}</td><td>f_{bdg2}
-</td><td>f_{bdg3}
f_{shr3}</td></tr>
<tr><td>A</td><td colspan="3"></td><td>12.0
0.50</td><td>24.0
-</td><td>12.0
0.50</td><td>Built in at both ends.
Uniform pressure distribution</td></tr>
<tr><td>B</td><td colspan="3"></td><td>-
0.38</td><td>14.2
-</td><td>8.0
0.63</td><td>Built in one end plus simply supported one end.
Uniform pressure distribution</td></tr>
<tr><td>C</td><td colspan="3"></td><td>-
0.50</td><td>8.0
-</td><td>-
0.50</td><td>Simply supported, (both ends are free to rotate).
Uniform pressure distribution</td></tr>
<tr><td>D</td><td colspan="3"></td><td>15.0
0.30</td><td>23.3
-</td><td>10.0
0.70</td><td>Built in both ends.
Linearly varying pressure distribution</td></tr>
<tr><td>E</td><td colspan="3"></td><td>-
0.20</td><td>16.8
-</td><td>7.5
0.80</td><td>Built in one end plus simply supported one end.
Linearly varying pressure distribution</td></tr>
<tr><td>F</td><td colspan="3"></td><td>-
-</td><td>-
-</td><td>2.0
1.0</td><td>Cantilevered beam.
Uniform pressure distribution</td></tr>
<tr><td>G</td><td colspan="3"></td><td>8.0
0.5</td><td>8.0
-</td><td>8.0
0.5</td><td>Built in at both ends.
Single point load in the centre of the span</td></tr>
<tr><td>H</td><td colspan="3"></td><td>$\frac{l^3}{a^2(l-a)}$
$\frac{a^2(3l-2a)}{l^3}$</td><td>$\frac{l^4}{2a^2(l-a)^2}$
-</td><td>$\frac{l^3}{a(l-a)^2}$
$\frac{(l-a)^2(l+2a)}{l^3}$</td><td>Built in at both ends.
Single point load, with load anywhere in the span</td></tr>
</table>

Table 8.7.1 (Continued)
Values of f_{bdg} and f_{shr}

Load and boundary conditions				Bending moment and shear force factor (based on load at mid span where load varies)			Application
Load model	Position (1)			1	2	3	
	1 Support	2 Field	3 Support	f_{bdg1} f_{shr1}	f_{bdg2} -	f_{bdg3} f_{shr3}	
I				- 0.5	4 -	- 0.5	Simply supported. Single point load in the centre of the span
J				- $\frac{a}{l}$	$\frac{l^2}{a(l-a)}$ -	- $\frac{l-a}{l}$	Simply supported. Single point load, load anywhere along the span

<u>Note</u>

1. The bending moment factor f_{bdg} for the support positions are applicable for a distance of $0.2l_{bdg}$ from the end of the effective bending span for both local and primary support members.
2. The shear force factor f_{shr} for the support positions are applicable for a distance of $0.2l_{shr}$ from the end of the effective shear span for both local and primary support members.
3. Application of f_{bdg} and f_{shr} for local support members:
   (a) the section modulus requirement of local support members is to be determined using the lowest value of f_{bdg1} , f_{bdg2} and f_{bdg3}
   (b) the shear area requirement of local support members is to be determined using the greatest value of f_{shr1} and f_{shr3}.
4. Application of f_{bdg} and f_{shr} for primary support members:
   (a) the section modulus requirement within $0.2l_{bdg}$ from the end of the effective span is generally to be determined using the applicable f_{bdg1} and f_{bdg3}, however f_{bdg} is not to be taken greater than 12
   (b) the section modulus of mid span area is to be determined using f_{bdg} =24, or f_{bdg2} from the table if lesser
   (c) the shear area requirement of end connections within $0.2l_{shr}$ from the end of the effective span is to be determined using f_{shr} = 0.5 or the applicable f_{shr1} or f_{shr3}, whichever is greater
   (d) for models A through F the value of f_{shr} may be gradually reduced outside of $0.2l_{shr}$ towards $0.5f_{shr}$ at mid span where f_{shr} is the greater value of f_{shr1} and f_{shr3}.

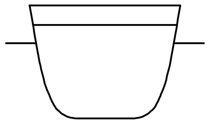
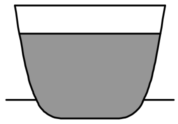
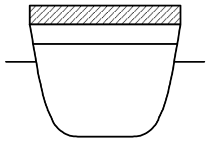
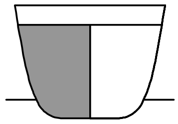
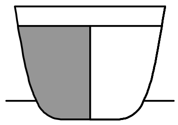
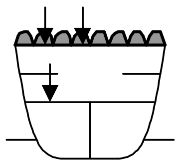
Where:

l effective span, l_{bdg} and l_{shr} as applicable

l_{bdg} as defined in *Section 4/2.1.1* for local support members and *Section 4/2.1.4* for primary support members

l_{shr} as defined in *Section 4/2.1.2* for local support members and *Section 4/2.1.5* for primary support members

Table 8.7.2
Design Load Sets for Plating, Local Support Members and Primary Support Members

Type of Local Support and Primary Support Member	Design Load Set (1)	Load Component	External Draught	Comment	Diagrammatic Representation
Shell Envelope	1	P_{ex}	T_{sc}	Sea pressure only	
	2	P_{ex}	T_{sc}		
	5	P_{in}	T_{bal}	Tank pressure only. Sea pressure to be ignored	
	6	P_{in}	$0.25T_{sc}$		
External Decks	1	P_{ex}	T_{sc}	Green sea pressure only	
Cargo Tank Boundaries	3	P_{in}	$0.6T_{sc}$	Pressure from one side only Full tank with adjacent tank empty	
	4	P_{in}	-		
	11	$P_{in\text{-}flood}$	-		
Other Tank Boundaries or Watertight Boundaries	5	P_{in}	T_{bal}	Pressure from one side only Full tank with adjacent tank empty	
	6	P_{in}	$0.25T_{sc}$		
	11	$P_{in\text{-}flood}$	-		
Internal and External Decks or Flats	9	P_{dk}	T_{bal}	Distributed or concentrated loads only. Adjacent tanks empty. Green sea pressure may be ignored	
	10	P_{dk}	T_{bal}		

Where:

T_{sc} scantling draught, in m, as defined in *Section 4/1.1.5.5*

T_{bal} minimum design ballast draught, in m, as defined in *Section 4/1.1.5.2*

Notes

1. The specification of design load combinations, and other load parameters for the design load sets are given in *Table 8.2.8*
2. When the ship's configuration cannot be described by the above, then the applicable Design Load Sets to determine the scantling requirements of structural boundaries are to be selected so as to specify a full tank on one side with the adjacent tank or space empty. The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents and are to maximise the pressure on the structural boundary, the draught to use is to be taken in accordance with the Design Load Set and this table. Design Load Sets covering the S and S+D design load combinations are to be selected. See Note 4 on *Table 8.2.7* and *Table 8.2.8.*
3. The boundaries of void and dry space not forming part of the hull envelope are to be evaluated using Design Load Set 11. See Note 2.

SECTION 9

DESIGN VERIFICATION

1 HULL GIRDER ULTIMATE STRENGTH

1.1 General

1.1.1 Application

1.1.1.1 The hull girder ultimate bending capacity in sagging is to be evaluated and checked to ensure it satisfies the following criteria. The criteria are applicable to intact ship structures, in extreme at sea conditions. They do not cover hogging, harbour or damaged conditions.

1.1.1.2 The scantling requirements in this Sub-Section are to be applied to any cross section along the entire vessel's length and are in addition to all other requirements within the rules.

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1.1.1.3 Outside the $0.4L$ region of amidships the plate and stiffeners may be gradually reduced towards the local requirements at the ends.

1.2 Rule Criteria

1.2.1 Vertical hull girder ultimate bending capacity

1.2.1.1 The vertical hull girder ultimate bending capacity is to satisfy the following criteria:

$$\gamma_S M_{sw} + \gamma_W M_{wv-sag} \leq \frac{M_U}{\gamma_R}$$

Where:

M_{sw} sagging still water bending moment, in kNm, to be taken as specified in *Table 9.1.1*.

$M_{wv\text{-}sag}$ sagging vertical wave bending moment, in kNm, to be taken as the midship sagging value defined in *Section 7/3.4.1.1*

M_U sagging vertical hull girder ultimate bending capacity, in kNm, as defined in *Appendix A/1.1.1*

γ_S, γ_W, γ_R are the partial safety factors for the design load combinations given in *1.4*

1.3 Hull Girder Bending Moment Capacity

1.3.1 Calculation of capacity

1.3.1.1 The hull girder ultimate bending capacity, M_U, in sagging is to be calculated according to *Appendix A/1.1.1*.

1.3.1.2 The effective area for the hull girder ultimate strength capacity assessment is specified in *Section 8/1.2.1*.

1.3.1.3 The capacity is to be based on net scantlings using a corrosion addition, $0.5t_{corr}$, see *Section 6/3.2*

1.4 Partial Safety Factors

1.4.1 General

1.4.1.1 The partial safety factors given in *Table 9.1.1* apply when M_U is calculated according to the single step method in *Appendix A/2.1* or the incremental method in *A/2.2*. The partial safety factors are given for two different design load combinations and both combinations are to be satisfied. Note that the definition of M_{sw} is different for each combination.

Table 9.1.1
Partial Safety Factors

Design load combination	Definition of Still Water Bending Moment, M_{sw}	γ_S	γ_W	γ_R
a)	Permissible sagging still water bending moment, $M_{sw-perm-sea}$, in kNm, see *Section 7/2.1.1*	1.0	1.2	1.1
b)	Maximum sagging still water bending moment for operational seagoing homogeneous full load condition, $M_{sw-full}$, in kNm, see note 1	1.0	1.3	1.1

Where:

γ_S partial safety factor for the sagging still water bending moment

γ_W partial safety factor for the sagging vertical wave bending moment covering environmental and wave load prediction uncertainties

γ_R partial safety factor for the sagging vertical hull girder bending capacity covering material, geometric and strength prediction uncertainties

Notes

1 The maximum sagging still water bending moment is to be taken from the departure condition with the ship homogeneously loaded at maximum draught and corresponding arrival and any mid-voyage conditions.

2 STRENGTH ASSESSMENT (FEM)

2.1 General

2.1.1 Application

2.1.1.1 A strength assessment of the hull structure using finite element analysis is mandatory.

2.1.1.2 The finite element analysis consists of two parts:

(a) cargo tank analysis to assess the strength of longitudinal hull girder structural members, primary supporting structural members and transverse bulkheads.

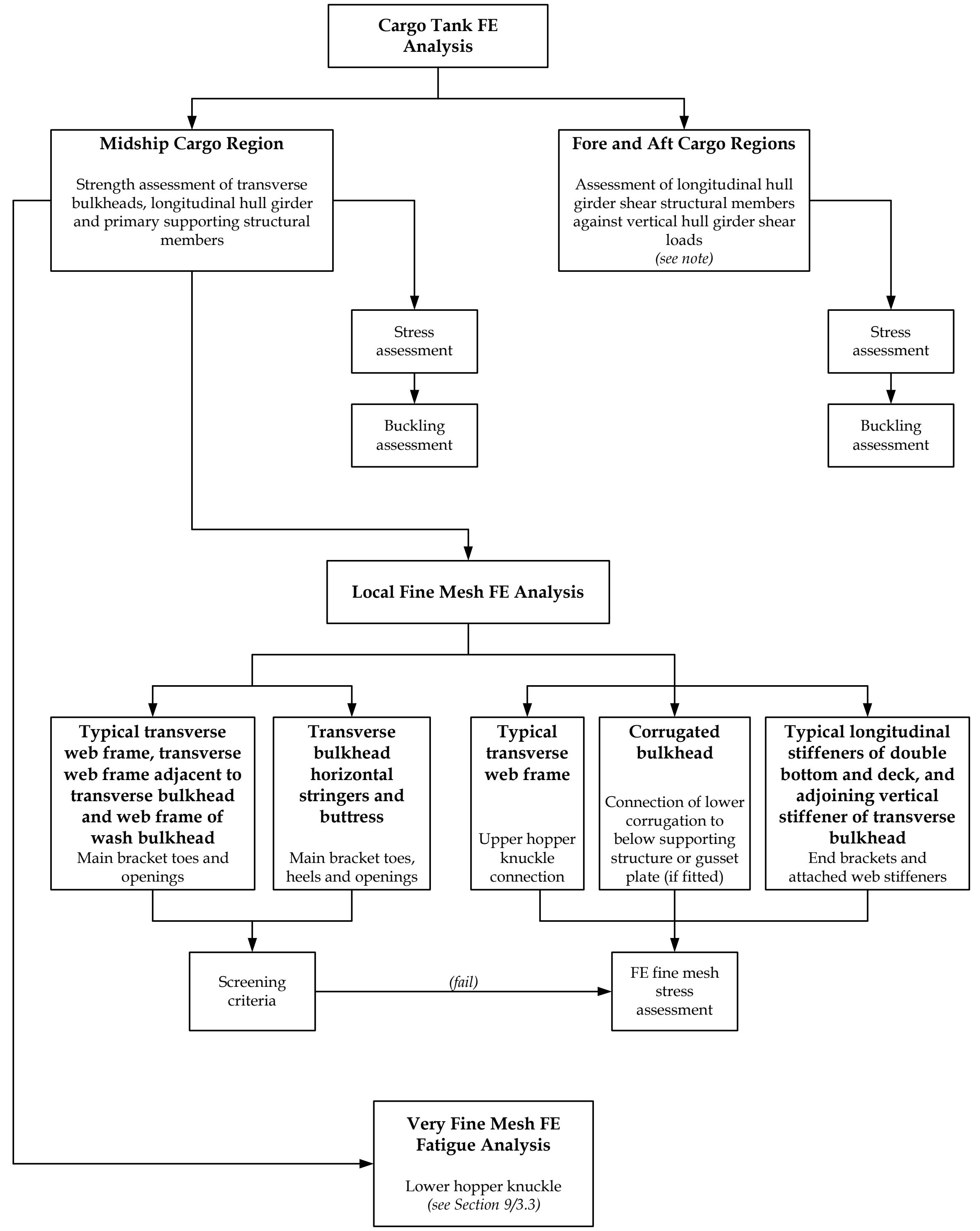
(b) fine mesh analysis to assess detailed stress levels in local structural details.

2.1.1.3 A flow diagram showing the minimum requirement of finite element analysis is shown in *Figure 9.2.1*.

2.1.1.4 The structural assessment is to be carried out in accordance with the requirements given in *Appendix B*. The structural assessment is to verify that the acceptance criteria specified in *2.2.5* and *2.3.5* are complied with.

2.1.1.5 The application of the scantlings verified by the structural assessment within the cargo tank region is to be in accordance with *2.4*.

Figure 9.2.1
Rule Minimum Requirement on Finite Element Analysis



Note

1. The strength assessment of longitudinal hull girder shear structural members, as defined in *2.2.1.1* and *Section 4/Table 4.1.1*, against hull girder vertical shear loads in way of transverse bulkheads may be based on the midship cargo tank finite element model with modification of plate and stiffener properties where appropriate, see *Appendix B/1.1.1* and *Appendix B/2.2.1*.

2.1.2 Submission of results

2.1.2.1 A detailed report of the structural analysis is to be submitted to demonstrate compliance with the specified structural design criteria. This report shall include the following information:

(a) list of plans used including dates and versions
(b) detailed description of structural modelling including all modelling assumptions and any deviations in geometry and arrangement of structure compared with plans
(c) plots to demonstrate correct structural modelling and assigned properties
(d) details of material properties, plate thickness, beam properties used in the model
(e) details of boundary conditions
(f) details of all loading conditions reviewed with calculated hull girder shear force and bending moment distributions
(g) details of applied loads and confirmation that individual and total applied loads are correct
(h) plots and results that demonstrate the correct behaviour of the structural model under the applied loads
(i) summaries and plots of global and local deflections
(j) summaries and sufficient plots of stresses to demonstrate that the design criteria are not exceeded in any member
(k) plate and stiffened panel buckling analysis and results
(l) tabulated results showing compliance, or otherwise, with the design criteria
(m) proposed amendments to structure where necessary, including revised assessment of stresses, buckling and fatigue properties showing compliance with design criteria.

2.1.3 Computer programs

2.1.3.1 In general, any finite element computation program recognised by the Classification Society may be employed to determine the stress and deflection of the hull structure, provided that the combined effects of bending, shear, axial and torsional deformations are considered.

2.1.3.2 The computer program used for the assessment of panel buckling capability is to take account of the combined interaction of bi-axial compressive stresses, shear stress and lateral pressure loads, as required by *Section 10/4*.

2.1.3.3 A computer program that has been demonstrated to produce reliable results to the satisfaction of the Classification Society is regarded as a recognised program. Where the computer programs employed are not supplied or recognised by the Classification Society, full particulars of the computer program, including calculation output, are to be submitted for approval. It is recommended that the designers consult the Classification Society on the suitability of the computer programs intended to be used prior to the commencement of any analysis work.

2.2 Cargo Tank Structural Strength Analysis

2.2.1 Objective and scope

2.2.1.1 The analysis is to cover at least the assessment of:

(a) longitudinal hull girder structural members, primary supporting structural members and transverse bulkheads in the midship cargo tank region, and

(b) longitudinal hull girder shear structural members in way of transverse bulkheads against hull girder vertical shear loads within the cargo area. These structural members include side shell, inner hull longitudinal bulkheads including upper sloped plate where fitted, hopper, longitudinal bulkheads and double bottom girders as defined in *Section 4/Table 4.1.1.* The required strengthening in way of transverse bulkheads for hull girder shear loads in the forward, midship or aft cargo region may be based on the maximum hull girder shear force within the region considered. Alternatively assessment may be carried out to determine the strengthening requirement in way of individual transverse bulkhead position. The details are given in *Appendix B/1.1.1*.

2.2.1.2 The required strengthening in way of transverse bulkheads for hull girder shear loads in the forward, midship or aft cargo region may be based on the maximum hull girder shear force within the region considered. Alternatively assessment may be carried out to determine the strengthening requirement in way of individual transverse bulkhead position. The details are given in *Appendix B/1.1.1*

2.2.1.3 The analysis is to verify that the following are within the acceptance criteria under the applied static and dynamic loads:

(a) stress level in the plating of longitudinal hull girder structural members, primary support structural members and transverse bulkheads, face plate of primary support members modelled by plate or rod elements.

(b) buckling capability of plates and stiffened panels.

2.2.2 Structural modelling

2.2.2.1 The modelling scantlings of the cargo tank finite element model are to be based on net scantlings as described in *Section 6/3.3.6.1* and *Appendix B/2.2.1.5*.

2.2.2.2 The length of the cargo tank finite element model is to cover three cargo tank lengths. Where the tanks in the midship cargo region are of different lengths, the middle tank of the finite element model is to represent the cargo tank of the greatest length. All main longitudinal and transverse structural elements are to be represented in the finite element model. These include inner and outer shell, double bottom floor and girder system, transverse and vertical web frames, stringers, transverse and longitudinal bulkhead structures. All plating and stiffeners, including web stiffeners, on these structural elements are to be modelled.

2.2.2.3 The mesh of the finite element model is to follow the stiffening system of the structure as far as practical, and is to represent the actual plate panels between stiffeners.

2.2.2.4 The structure modelling is to be in accordance with the requirements given in *Appendix B/2.2*.

2.2.3 Loads and loading conditions

2.2.3.1 The combinations of the ship static and dynamic loads which are likely to impose the most onerous load regimes on the hull structure are to be investigated in the structural analysis.

2.2.3.2 The standard load cases to be used in the structural analysis are given in *Appendix B/2.3.1*. These load cases cover seagoing conditions (design load combination S + D) and harbour/tank testing conditions (design load combination S).

2.2.3.3 Where the loading conditions specified by the designer are not covered by the standard load cases then these additional loading conditions are to be examined, see also *Appendix B/2.3.1*.

2.2.4 Load applications and boundary conditions

2.2.4.1 All simultaneously acting hull girder and local loads are to be applied to the model. The application of local and hull girder loads to the finite element model is to be in accordance with the requirement given in *Appendix B/2.4* and *B/2.5*.

2.2.4.2 The boundary conditions to be applied are given in *Appendix B/2.6*.

2.2.5 Acceptance criteria

2.2.5.1 Verification of results against the acceptance criteria is to be carried out in accordance with *Appendix B/2.7*.

2.2.5.2 Verification of results against the acceptance criteria is to be carried out for all structural members within the longitudinal extent of the middle tanks of the three tank FE model, and the regions forward and aft of the middle tanks up to the extent of the transverse bulkhead stringer and buttress structure. For the assessment of shear strength in way of transverse bulkheads against hull girder shear loads, stress level and buckling capability of inner hull longitudinal bulkheads including upper sloped plate where fitted, side shell, longitudinal bulkheads, hopper and bottom longitudinal girders are to be verified against the acceptance criteria. See also *Appendix B/2.7.1*.

2.2.5.3 The structural analysis is to demonstrate that the permissible von Mises stress criteria and utilisation factor against buckling for plate and stiffened panels specified in *Tables 9.2.1* and *9.2.2* are not exceeded.

2.2.5.4 Capacity models used for the assessment of local buckling capability of plate and stiffened panels are to be based on deduction of full corrosion addition thickness from the plate and stiffeners, as described in *Section 6/3.3.6.2* and *Appendix B/2.7.3*.

2.2.5.5 Where a lower stool is not fitted to a transverse or longitudinal corrugated bulkhead, the maximum permissible stresses and buckling utilisation factors given in *Tables 9.2.1* and *9.2.2* are to be reduced by 10% for the corrugation and below supporting structure within the extent defined as follows:

(a) Full height of the corrugation

(b) Supporting structure for a transverse corrugated bulkhead - longitudinally within half a web frame space forward and aft of the bulkhead

(c) Supporting structure for a longitudinal corrugated bulkhead – transversely within three longitudinal stiffener spacings from each side of the bulkhead.

Table 9.2.1
Maximum Permissible Stresses

Structural component	Yield utilisation factor
Internal structure in tanks	
Plating of all non-tight structural members including transverse web frame structure, wash bulkheads, internal web, horizontal stringers, floors and girders. Face plate of primary support members modelled using plate or rod elements	$\lambda_y \le 1.0$ (load combination S + D) $\lambda_y \le 0.8$ (load combination S)
Structure on tank boundaries	
Plating of deck, sides, inner sides, hopper plate, bilge plate, plane and corrugated cargo tank longitudinal bulkheads. Tight floors, girders and webs	$\lambda_y \le 0.9$ (load combination S + D) $\lambda_y \le 0.72$ (load combination S)
Plating of inner bottom, bottom, plane transverse bulkheads and corrugated bulkheads.	$\lambda_y \le 0.8$ (load combination S + D) $\lambda_y \le 0.64$ (load combination S)

Where:

λ_y yield utilisation factor

$= \dfrac{\sigma_{vm}}{\sigma_{yd}}$ for plate elements in general

$= \dfrac{\sigma_{rod}}{\sigma_{yd}}$ for rod elements in general

σ_{vm} von Mises stress calculated based on membrane stresses at element's centroid, in N/mm^2

σ_{rod} axial stress in rod element, in N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2, but not to be taken as greater than 315 N/mm^2 for load combination S + D in areas of stress concentration (2)

Note

1. Structural items given in the table are for guidance only. Stresses for all parts of the FE model specified in *2.2.5.2* are to be verified against the permissible stress criteria. See also *Appendix B/2.7.1*
2. Areas of stress concentration are corners of openings, knuckle joints, toes and heels of primary supporting structural members and stiffeners
3. Where a lower stool is not fitted to a transverse or longitudinal corrugated bulkhead, the maximum permissible stresses are to be reduced by 10% in accordance with *2.2.5.5*.
4. The yield utilisation factor for plane and corrugated longitudinal bulkheads between cargo tanks may be taken as for non-tight structural members for FE load cases where either both sides of the bulkhead are empty or both sides are loaded. The water-tight bottom girder under the longitudinal bulkhead is to be treated as a tight structural member.

(RCN 1, effective from 1 April 2007)

RCN 2 to July 2008 version (effective from 1 July 2010)

Table 9.2.2
Maximum Permissible Utilisation Factor Against Buckling

Structural component	Buckling utilisation factor
Plate and stiffened panels [(3)]	$\eta \le 1.0$ (load combination S + D) $\eta \le 0.8$ (load combination S)
Web plate in way of openings	$\eta \le 1.0$ (load combination S + D) $\eta \le 0.8$ (load combination S)
Pillar buckling of cross tie structure	$\eta \le 0.75$ (load combination S + D) $\eta \le 0.65$ (load combination S)
Corrugated bulkheads - flange buckling - column buckling	$\eta \le 0.9$ (load combination S + D) $\eta \le 0.72$ (load combination S)

Where:

η utilisation factor against buckling calculated in accordance with *Appendix D/5* and *Appendix B/2.7.3*. Also see *Section 10/3.4.1* for web plate in way of openings and *Section 10/3.5.1* for cross tie structure

Note

1. Buckling capability of curved panels (e.g. bilge plate), face plate and tripping bracket of primary supporting members are not assessed based on finite element stress result
2. Where a lower stool is not fitted to a transverse or longitudinal corrugated bulkhead, the maximum permissible buckling utilisation factors are to be reduced by 10% in accordance with *2.2.5.5*
3. Permissible buckling utilisation factors specified in this table are applicable for the reference advanced buckling method given in *Appendix D/1.1.2*. If alternative buckling procedures are used the permissible utilisation factors are to be assessed and if required adjusted to meet acceptance criteria for equivalence specified in *Appendix D/1.1.2*.

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2.3 Local Fine Mesh Structural Strength Analysis

2.3.1 Objective and scope

2.3.1.1 For tankers of conventional arrangements, as a minimum requirement, the following areas in the midship cargo region are to be investigated:

(a) main bracket toes and openings at critical locations and upper hopper knuckle joint of a typical transverse web frame located in the midship tank. Where a wash bulkhead is fitted, main bracket toes and openings at critical locations of transverse and vertical webs

(b) main bracket toes and openings at critical locations on a typical transverse web frame adjacent to a transverse bulkhead in way of the transverse bulkhead horizontal stringers

(c) main bracket toes, heels and openings at critical locations of horizontal stringers, connection of transverse bulkhead to double bottom girder or buttress of a typical transverse bulkhead

(d) connections of transverse and longitudinal corrugated bulkheads to bottom stool or inner bottom and double bottom supporting structure if a lower stool is

not fitted. If a gusset plate is fitted the connection between the corrugation and the upper corners of the gusset are to be assessed

(e) end brackets and attached web stiffeners of typical longitudinal stiffeners of double bottom and deck, and adjoining vertical stiffener of transverse bulkhead. If longitudinal stiffeners are fitted above the deck then the connection in way of the transverse bulkhead are to be assessed.

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2.3.1.2 The selection of critical locations on the structural members described in *2.3.1.1* to perform fine mesh analysis is to be in accordance with *Appendix B/3.1.*

2.3.1.3 Where the stress level in areas of stress concentration on structural members not specified in *2.3.1.1* exceeds the acceptance criteria of the cargo tank analysis, a fine mesh analysis is to be carried out to demonstrate satisfactory scantlings.

2.3.1.4 Where the geometry can not be adequately represented in the cargo tank finite element model, a fine mesh analysis may be used to demonstrate satisfactory scantlings. In such cases the average stress within an area equivalent to that specified in the cargo tank analysis (typically s by s) is to comply with the requirement given in *Table 9.2.1*. See also Note 1 of *Table 9.2.3*.

2.3.2 Structural modelling

2.3.2.1 The fine mesh structural models are to be in accordance with the requirements given in *Appendix B/3.2*.

2.3.2.2 The fine mesh analysis may be carried out by means of a separate local finite element model with fine mesh zones, in conjunction with the boundary conditions obtained from the cargo tank model, or by incorporating fine mesh zones into the cargo tank model.

2.3.2.3 The extent of the local finite element models is to be such that the calculated stresses at the areas of interest are not significantly affected by the imposed boundary conditions and application of loads. Detailed requirements on the extension of local finite element models are given in *Appendix B/3.2.*

2.3.2.4 The fine mesh zone is to represent the localised area of high stress. The finite element mesh size within the fine mesh zones is to be not greater than 50mm x 50mm. The extent of the fine mesh zone is to be in accordance with *Appendix B/3.2.*

2.3.2.5 The fine mesh models are to be based on the net scantlings in accordance with *Section 6/3.3.6.3* and *Appendix B/3.2*.

2.3.3 Loads and loading conditions

2.3.3.1 Fine mesh detailed stress analysis is to be carried out for the standard load cases, and any other specifically specified load cases, required by *2.2.3*.

2.3.4 Load applications and boundary conditions

2.3.4.1 The application of loads and boundary conditions to the finite element model is to be in accordance with the requirements given in *Appendix B/3.4*.

2.3.5 Acceptance criteria

2.3.5.1 Verification of stress results against the acceptance criteria is to be carried out in accordance with *Appendix B/3.5*.

2.3.5.2 The structural assessment is to demonstrate that the von Mises stresses obtained from the fine mesh finite element analysis do not exceed the maximum permissible stress criteria specified in *Table 9.2.3*.

Table 9.2.3
Maximum Permissible Membrane Stresses for Fine Mesh Analysis

Element stress	Yield utilisation factor
Element not adjacent to weld	$\lambda_y \le 1.7$ (load combination S + D) $\lambda_y \le 1.36$ (load combination S)
Element adjacent to weld	$\lambda_y \le 1.5$ (load combination S + D) $\lambda_y \le 1.2$ (load combination S)

Where:

λ_y yield utilisation factor

$= \dfrac{k\ \sigma_{vm}}{235}$ for plate element

$= \dfrac{k\ \sigma_{rod}}{235}$ for rod or beam element

σ_{vm} von Mises stress calculated based on membrane stress at element's centroid, in N/mm^2

σ_{rod} axial stress in rod element, in N/mm^2

k higher strength steel factor, as defined in *Section 6/1.1.4* but not to be taken as less than 0.78 for load combination S + D

Note

1. Where the von Mises stress of the elements in the cargo tank FE model in way of the area under investigation by fine mesh exceeds its permissible value specified in *Table 9.2.1*, average von Mises stress, obtained from the fine mesh analysis, calculated over an area equivalent to the mesh size of the cargo tank finite element model is to be less than the permissible value specified in *Table 9.2.1*
2. The maximum permissible stresses are based on the mesh size of 50mm x 50mm. Where a smaller mesh size is used, an average von Mises stress calculated in accordance with *Appendix B/3.5.1* over an area equal to the specified mesh size may be used to compare with the permissible stresses.
3. Average von Mises stress is to be calculated based on weighted average against element areas:

$$\sigma_{vm-av} = \frac{\sum_1^n A_i \sigma_{vm-i}}{\sum_1^n A_i}$$

where

σ_{vm-av} is the average von Mises stress

σ_{vm-i} is the von Mises stress of the ith plate element within the area considered

A_i is the area of the ith plate element within the area considered

n is the number of elements within the area considered

4. Stress averaging is not to be carried across structural discontinuities and abutting structure
5. Where a lower stool is not fitted to a transverse or longitudinal corrugated bulkhead, the maximum permissible stresses are to be reduced by 10% for the areas under investigation by fine mesh analysis.

2.4 Application of Scantlings in Cargo Tank Region

2.4.1 General

2.4.1.1 The application of the scantlings that comply with the requirements of the finite element strength assessment, to the structure within the cargo tank region, is to be in accordance with the requirements given in this sub-section.

2.4.1.2 The application given in this sub-section assumes that the same material yield strength of the structure is maintained throughout the cargo tank region. Where steel having a different yield strength is applied, the required scantlings are to be assessed.

2.4.1.3 The scaling procedure given in this sub-section is based on scantlings that satisfied the requirements given in *Section 9/2* and *Appendix B*.

2.4.1.4 The net thickness and sectional properties for plating and local support members described in this sub-section are to be based on deduction of full corrosion addition, as specified in *Section 6/Table 6.3.2*, from the gross scantlings. The gross thickness of plating, web and face plate of local support members are to be obtained by adding the full corrosion addition to the net thickness.

2.4.2 Application of scantlings to deck

2.4.2.1 The scantlings of deck plating and deck longitudinal stiffeners are to be maintained longitudinally within 0.4*L* amidships. The scantlings of deck plating and deck longitudinal stiffeners at a given transverse location within 0.4*L* amidships are not to be taken as less than the maximum of that required for the corresponding transverse location along the length of the middle tanks of the cargo tank finite element model required by *Appendix B/1.1.1.5.*

2.4.2.2 Outside 0.4*L* amidships, the scantlings of the deck plating and deck longitudinal stiffeners may be tapered to that required by *Section 8* at the ends of the cargo tank region.

2.4.3 Application of scantlings to inner bottom

2.4.3.1 The thickness of inner bottom plating may vary along the length and breadth of a tank.

2.4.3.2 The scantlings of the inner bottom plating and longitudinal stiffeners of midship cargo tanks are not to be less than that required for the corresponding location of the middle tanks of the cargo tank finite element model required by *Appendix B/1.1.1.5*. These scantlings are to be maintained for all tanks within the cargo region, other than the fore-most and aft-most cargo tanks.

2.4.3.3 For the fore-most and aft-most cargo tanks, the scantlings of the inner bottom longitudinal stiffeners are not to be less than the scantling requirements for the midship cargo tanks provided that the spacing of primary support members are not reduced in the forward and/or aft cargo tank. The minimum net thickness of the inner bottom plate, t_{ib-net}, is given by:

$$t_{ib-net} = t_{ib-net-mid}\left(\frac{l_{bdg}}{l_{bdg-mid}}\right)^{0.25}\frac{s_{ib}}{s_{ib-mid}} \quad \text{mm}$$

where:

$t_{ib\text{-}net\text{-}mid}$ required net thickness of the inner bottom plating for the corresponding location in the midship tank, in mm

l_{bdg} effective bending span, of floor at location under consideration, in accordance with *Figure 4.2.7*, in m

$l_{bdg\text{-}mid}$ effective bending span, of floor at corresponding location in midship tank, defined in accordance with *Figure 4.2.7*, in m

s_{ib} spacing between longitudinal stiffeners at location under consideration, in mm

$s_{ib\text{-}mid}$ spacing between longitudinal stiffeners at corresponding location in midship tank, in mm

2.4.4 Application of scantlings to bottom

2.4.4.1 The scantlings of bottom longitudinal stiffeners are to be maintained longitudinally within 0.4*L* amidships. The scantlings of the bottom longitudinal stiffener at a given transverse location within 0.4*L* amidships are not to be less than the maximum of that required for the corresponding transverse location along the length of the middle tanks of the cargo tank finite element model required by *Appendix B/1.1.1.5.*

2.4.4.2 Outside 0.4*L* amidships, the scantlings of the bottom longitudinal stiffeners may be tapered to that required by *Section 8* at the ends of the cargo region.

2.4.4.3 The thickness of the bottom plating may vary along the length and breadth of a tank. The bottom plate thicknesses of midship tanks are not to be less than that required for the corresponding location of the middle tanks of the cargo tank finite element model required by *Appendix B/1.1.1.5*. These thicknesses are to be maintained for all tanks within the cargo region, other than the fore-most and aft-most cargo tanks.

2.4.4.4 For the fore-most and aft-most cargo tanks, the required minimum net thickness of the bottom plating, $t_{btm\text{-}net}$, is to be obtained as follows:

$$t_{btm-net} = t_{btm-net-mid}\left(\frac{l_{bdg}}{l_{bdg-mid}}\right)^{0.25}\frac{s_{btm}}{s_{btm-mid}} \quad \text{mm}$$

where:

$t_{btm\text{-}net\text{-}mid}$ required net thickness of the bottom plating for the corresponding location in the midship tank, in mm

l_{bdg} effective bending span, of floor at location under consideration, in accordance with *Figure 4.2.7*, in m

$l_{bdg\text{-}mid}$ effective bending span, of floor at corresponding location in midship tank, defined in accordance with *Figure 4.2.7*, in m

s_{btm} spacing between longitudinal stiffeners at location under consideration, in mm

$s_{btm\text{-}mid}$ spacing between longitudinal stiffeners at corresponding location in midship tank, in mm

2.4.5 Application of scantlings to side shell, longitudinal bulkheads and inner hull longitudinal bulkheads

2.4.5.1 The scantlings of plating and longitudinal stiffeners of side shell, longitudinal bulkheads and inner longitudinal bulkheads within 0.15*D* from the deck are to be maintained longitudinally within 0.4*L* amidships. The scantlings of plating and longitudinal stiffener at a given height are not to be less than the maximum of that required for the corresponding vertical location along the length of the middle tanks of the cargo tank finite element model required by *Appendix B/1.1.1.5.* Outside 0.4*L* amidships, the scantlings of the plating and stiffeners within 0.15*D* from the deck may be tapered to that required by *Section 8* at the ends of the cargo tank region.

2.4.5.2 The plate thickness of side shell, longitudinal bulkheads and inner hull longitudinal bulkheads, including hopper plating, outside 0.15*D* from the deck may vary along the length and height of a tank. The plate thickness away from the transverse bulkheads is not to be less than that required for the corresponding location of the middle tanks of the cargo tank finite element model required by *Appendix B/1.1.1.5*. These scantlings are to be maintained for all tanks within the cargo region, other than the fore-most and aft-most cargo tanks. For the fore-most and aft-most cargo tanks, the minimum net thickness of the side shell, longitudinal bulkheads or inner hull longitudinal bulkheads (including hopper plating) plating outside 0.15*D* from the deck is given by:

$$t_{net} = t_{net-mid} \frac{s}{s_{mid}} \quad \text{mm}$$

Where:

$t_{net-mid}$ required net thickness for corresponding location in the midship tank, in mm

s spacing between longitudinal stiffeners at location under consideration, in mm

s_{mid} spacing between longitudinal stiffeners at corresponding location in midship tank, in mm

2.4.5.3 The plate thickness of side shell, longitudinal bulkheads and inner hull longitudinal bulkheads, including hopper plating, in way of transverse bulkheads required for strengthening against hull girder shear loads is not to be less than that required by *Appendix B/1.1.1.6, B/1.1.1.7* and *B/1.1.1.8*. Within 0.15*D* from the deck, the plate thicknesses in way of transverse bulkheads are not to be taken as less than that required by *2.4.5.1*. Outside 0.15*D* from the deck, the plate thicknesses in way of transverse bulkheads are not to be taken as less than that required by *2.4.5.2*.

2.4.5.4 The scantlings of longitudinal stiffeners of side shell, longitudinal bulkheads, inner longitudinal bulkheads and hopper plate at a given height, outside 0.15*D* from the deck, are not to be less than that required for the corresponding vertical location of the middle tanks of the cargo tank finite element model as required by *Appendix B/1.1.1.5*. These scantlings are to be maintained for all tanks within the cargo region.

2.4.5.5 The plate thickness required for strengthening against hull girder shear loads of the side shell, longitudinal bulkheads and inner hull longitudinal bulkheads in way of a transverse bulkhead is to be taken as the greater from the corresponding vertical location of the forward and aft transverse bulkhead of the middle tanks of the cargo tank finite element model as required by Appendix B/1.1.1.5. All relevant requirements in other sections of the Rules are also to be complied with.

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2.4.6 Application of scantlings to transverse bulkheads

2.4.6.1 The scantlings of transverse bulkhead plating, stiffeners and horizontal stringers may vary along the height and breadth of the bulkhead. The scantlings at a given location are not to be less than the maximum required at the corresponding location of both middle tank end transverse bulkheads of the cargo tank finite element model as required by *Appendix B/1.1.1.5*.

2.4.7 Application of scantlings to primary structural support members

2.4.7.1 The web thickness of primary structural support members may vary along the length, breadth and height of a tank. The scantlings of the primary structural support members are not to be less than that required for the corresponding location of the middle tanks of the cargo tank finite element model required by *Appendix B/1.1.1.5*. These scantlings are to be maintained for all tanks within the cargo region, other than the fore-most and aft-most cargo tanks.

2.4.7.2 Scantling requirements for primary support members in the fore-most and aft-most cargo tanks are to be determined by scaling the scantlings of the corresponding structural members in the midship tanks in accordance with *Section 8/2.6.9*.

2.4.8 Structural details and openings

2.4.8.1 Arrangement and scantlings of openings and structural details of primary structural members, complying with the requirements of *Appendix B/3,* are to be applied to the corresponding structural members in all tanks within the cargo tank region.

3 FATIGUE STRENGTH

3.1 Fatigue Evaluation

3.1.1 General

3.1.1.1 This Sub-Section, together with *Appendix C*, gives the minimum Rule requirements for design against fatigue failure for the structural details stipulated in these Rules. Structural details at other locations that are considered to be critical may require assessment using a procedure consistent with that contained in these Rules.

3.1.1.2 The fatigue criteria, applicable to a broad range of structural details and arrangements, are to be used for the assessment of fatigue strength utilising numerical techniques.

3.1.1.3 The fatigue analysis is to be carried out using either a '*nominal stress approach*' or a '*hot spot stress approach*' depending on the structural details, as specified in *3.4*. The procedure is illustrated in *Figure 9.3.1*.

3.1.1.4 In a *nominal stress approach*, stresses in a structural component are calculated by using either analytical methods (e.g. a beam model) or using numerical methods (e.g. a coarse finite element mesh), based on the applied loads and the structural properties of the component.

3.1.1.5 In a *hot spot stress approach*, local stresses at a critical location (hot spot) where fatigue cracks may initiate are evaluated by numerical methods (e.g. a fine mesh finite element analysis). The analysis takes into account the influence of structural discontinuities due to the geometry of the connection but excludes the effects of welds.

3.2 Fatigue Criteria

3.2.1 Corrosion model

3.2.1.1 Net thicknesses in accordance with *Section 6/3.3.7* are to be used in the fatigue assessment.

3.2.2 Loads

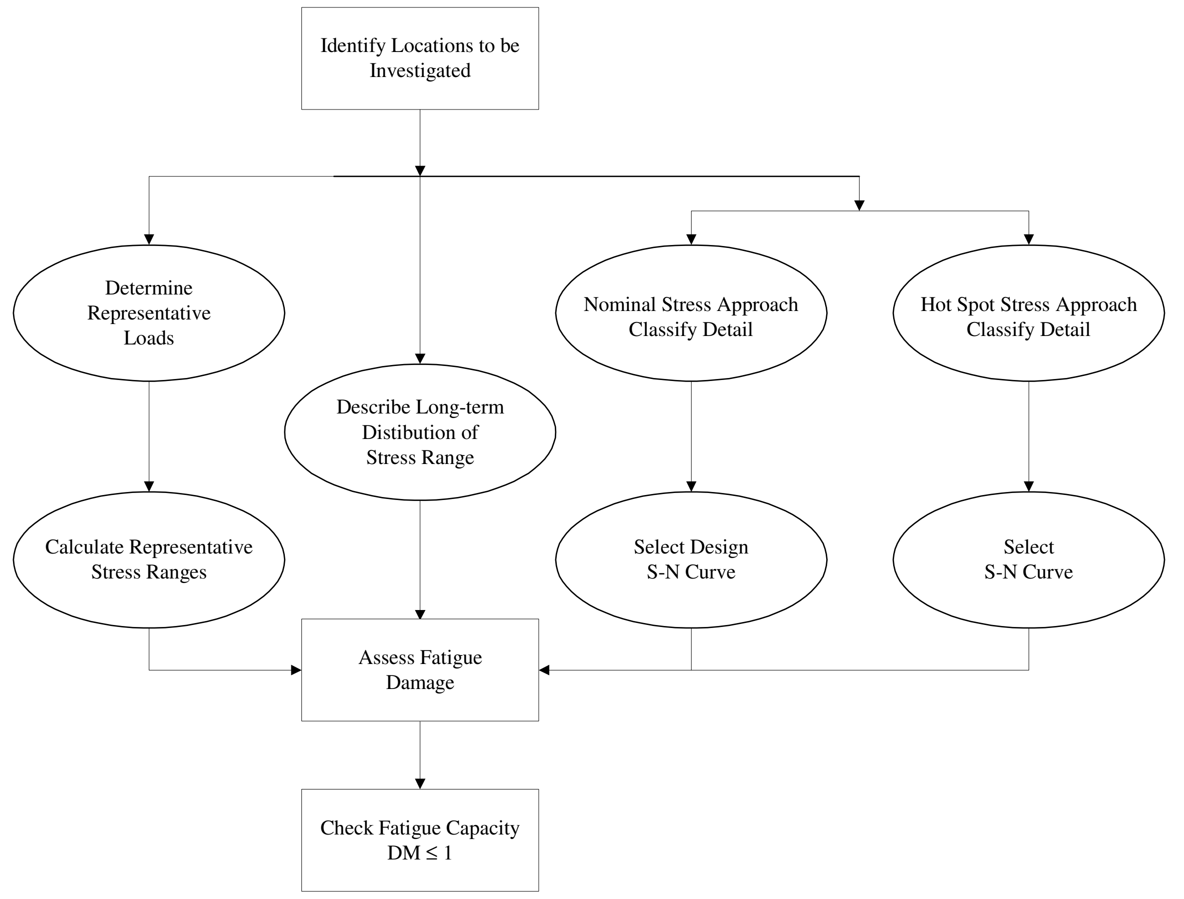
3.2.2.1 The loads specified in *Section 7/3*, which are based on the North Atlantic wave environment, are to be used for the fatigue assessment. Other secondary cyclic loading, such as slamming, low cycle, or vibration induced fatigue, which may result in significant levels of stress range over the expected lifetime of the vessel, although not within the scope of these Rules, may need to be specially considered.

3.2.2.2 These Rules assume a 10^{-4} probability level of exceedance for the purposes of load application and fatigue strength assessment.

3.2.3 Acceptance criteria

3.2.3.1 The criteria stated in this sub-section and *Appendix C* are presented as a comparison of fatigue strength of the structure (capacity), and fatigue inducing loads (demands), in the form of a fatigue damage parameter, *DM*, see *Appendix C/1.4.1.1*. The calculated fatigue damage, *DM*, is to be less than or equal to 1 for the design life of the ship, which is not to be taken as less than 25 years.

Figure 9.3.1
Schematic of Fatigue Assessment Process
(For Each Location or Structural Detail)



3.3 Locations to Apply

3.3.1 Longitudinal structure

3.3.1.1 A fatigue strength assessment is to be carried out and submitted for the end connections of longitudinal stiffeners to transverse bulkheads, including wash bulkheads and web frames within the cargo tank region, located on the bottom shell, inner bottom, side shell, inner hull longitudinal bulkheads, longitudinal bulkheads and strength deck.

3.3.1.2 A fatigue strength assessment is to be carried out for scallops in way of block joints on the strength deck within the cargo tank region.

3.3.2 Transverse structure

3.3.2.1 A fatigue strength assessment is to be carried out and submitted for the knuckle between inner bottom and hopper plate for at least one transverse frame close to amidships. The total stress range for fatigue assessment is to be determined from a fine mesh finite element analysis.

3.4 Fatigue Assessment Methods

3.4.1 Nominal stress approach

3.4.1.1 The nominal stress approach, as described in *Appendix C/1*, is to be used for the fatigue evaluation of the following items:

(a) longitudinal stiffener end connections to the transverse bulkheads, including wash bulkheads, and web frames on the bottom, inner bottom, side shell, inner hull longitudinal bulkheads, longitudinal bulkheads and strength deck.

(b) scallops in way of block joints on the strength deck as described in *Appendix C/1.6*.

3.4.2 Hot spot stress approach

3.4.2.1 The hot spot stress approach, as described in *Appendix C/2*, is to be used for the fatigue evaluation of the following items:

(a) knuckle between inner bottom and hopper plate.

3.4.3 Alternative direct calculation approach

3.4.3.1 Where it is considered necessary to carry out a fatigue assessment using an alternative direct calculation approach, not applying the loads specified in *Section 7/3*, it is to be based on the individual Classification Society's procedures. However, in no case are the scantlings to be lower than those which would be required by *3.4.1* and *3.4.2*.

SECTION 10

BUCKLING AND ULTIMATE STRENGTH

1 GENERAL

1.1 Strength Criteria

1.1.1 Scope

1.1.1.1 This Section contains the strength criteria for buckling and ultimate strength of local support members, primary support members and other structure such as pillars, corrugated bulkheads and brackets. These criteria are to be applied as specified in *Section 8* for determining the initial structural scantlings and also *Section 9* for the design verification.

1.1.1.2 All structural elements are to comply with the stiffness and proportions requirements specified in *Sub-Section 2*.

1.1.1.3 For each structural member the characteristic buckling strength is to be taken as the most unfavourable/critical buckling mode.

1.1.1.4 The strength criteria are to be based on the following assumptions and limitations in respect to buckling and ultimate strength control in design:

(a) the buckling strength of stiffeners is to be greater than the plate panels they support

(b) the primary support members supporting stiffeners are to have sufficient inertia to prevent out of plane buckling of the primary member, see *2.3.2.3*

(c) all stiffeners with their associated effective plate are to have moments of inertia to provide adequate lateral stability, see *2.2.2*

(d) the proportions of local support members and primary support members are to be such that local instability is prevented

(e) tripping of primary support members (e.g. torsional instability) is to be prevented by fitment of tripping brackets or equivalents, see in *2.3.3*

(f) the web plate of primary support members is to be such that elastic buckling of the plate between web stiffeners is prevented

(g) for plates with openings, the buckling strength of the areas surrounding the opening or cut out and any edge reinforcements are adequate, see *3.4.1* and *2.4.3*.

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2 STIFFNESS AND PROPORTIONS

2.1 Structural Elements

2.1.1 General

2.1.1.1 All structural elements are to comply with the applicable slenderness or proportional ratio requirements in *2.2* to *2.3*.

2.1.1.2 The following requirements are based on net scantlings, see also *Section 6/3*.

2.1.1.3 For structural idealisation and definitions see *Section 4/2*.

2.2 Plates and Local Support Members

2.2.1 Proportions of plate panels and local support members

2.2.1.1 The net thickness of plate panels and stiffeners is to satisfy the following criteria:

(a) plate panels

$$t_{net} \geq \frac{s}{C}\sqrt{\frac{\sigma_{yd}}{235}}$$

(b) stiffener web plate

$$t_{w-net} \geq \frac{d_w}{C_w}\sqrt{\frac{\sigma_{yd}}{235}}$$

(c) flange/face plate

$$t_{f-net} \geq \frac{b_{f-out}}{C_f}\sqrt{\frac{\sigma_{yd}}{235}}$$

Where:

s	plate breadth, in mm, taken as the spacing between the stiffeners, as defined in *Section 4/2.2.1*
t_{net}	net thickness of plate, in mm
d_w	depth of stiffener web, in mm, as given in *Table 10.2.1*
t_{w-net}	net web thickness, in mm
b_{f-out}	breadth of flange outstands, in mm, as given in *Table 10.2.1*
t_{f-net}	net flange thickness, in mm
C, C_w, C_f	slenderness coefficients, as given in *Table 10.2.1*
σ_{yd}	specified minimum yield stress of the material, in N/mm^2

Table 10.2.1
Slenderness Coefficients

Item		Coefficient
plate panel, C	hull envelope and tank boundaries	100
	other structure	125
stiffener web plate, C_w	angle and T profiles	75
	bulb profiles	41
	flat bars	22
flange/face plate[(1)], C_f	angle and T profiles	12

Note

1. The total flange breadth, b_f, for angle and T profiles is not to be less than: $b_f = 0.25d_w$
2. Measurements of breadth and depth are based on gross scantlings

Where:

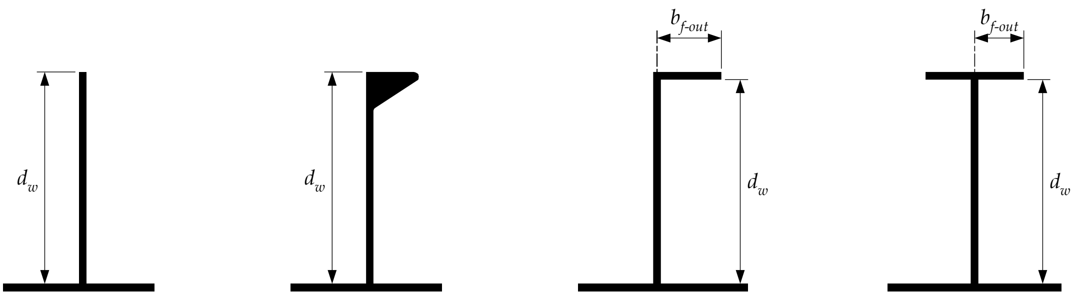
t_{net} net thickness of plate, in mm

d_w depth of web plate, in mm

$t_{w\text{-}net}$ net web thickness, in mm

$b_{f\text{-}out}$ breadth of flange outstands, in mm

$t_{f\text{-}net}$ net flange thickness, in mm



Flat bars Bulb flats Angles T bars

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2.2.2 Stiffness of stiffeners

2.2.2.1 The minimum net moment of inertia about the neutral axis parallel to the attached plate, I_{net}, of each stiffener with effective breadth of plate equal to 80% of the stiffener spacing s, is given by:

$$I_{net} = Cl_{stf}^2 A_{net} \frac{\sigma_{yd}}{235} \quad \text{cm}^4$$

Where:

l_{stf} length of stiffener between effective supports, in m

A_{net} net sectional area of stiffener including attached plate assuming effective breadth of 80% of stiffener spacing s, in cm²

s stiffener spacing, in mm, as defined in *Section 4/2.2.1*

σ_{yd} specified minimum yield stress of the material of the attached

plate, in N/mm²

C slenderness coefficient:
= 1.43 for longitudinals subject to hull girder stresses
= 0.72 for other stiffeners

2.3 Primary Support Members

2.3.1 Proportions of web plate and flange/face plate

2.3.1.1 The net thicknesses of the web plates and face plates of primary support members are to satisfy the following criteria:

(a) web plate

$$t_{w-net} \geq \frac{s_w}{C_w}\sqrt{\frac{\sigma_{yd}}{235}}$$

(b) flange/face plate

$$t_{f-net} \geq \frac{b_{f-out}}{C_f}\sqrt{\frac{\sigma_{yd}}{235}}$$

Where:

s_w plate breadth, in mm, taken as the spacing between the web stiffeners. For web plates with stiffening parallel to the attached plate the spacing may be corrected in accordance with *Appendix D/Fig. 5.6*.

t_{w-net} net web thickness, in mm

b_{f-out} breadth of flange outstand, in mm

t_{f-net} net flange thickness, in mm

C_w slenderness coefficient for the web plate
= 100

C_f slenderness coefficient for the flange/face plate
= 12

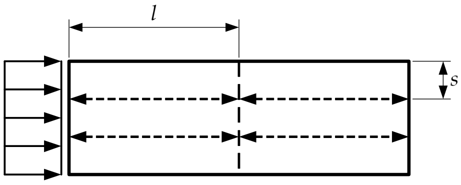
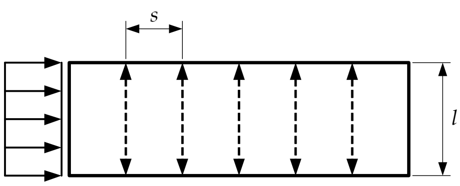
σ_{yd} specified minimum yield stress of the material, in N/mm²

2.3.2 Stiffness requirements

2.3.2.1 The web and flange net thicknesses of web stiffeners are not to be less than specified in *2.2.1*.

2.3.2.2 The net moment of inertia of each web stiffener, I_{net}, with effective breadth of plate equal to 80% of stiffener spacing s, is not to be less than as defined in *Table 10.2.2*.

Table 10.2.2
Stiffness Criteria for Web Stiffening

Mode	Inertia requirements, cm^4
(a) web stiffeners parallel to the flanges of the primary support member 	$$I_{net} = Cl^2 A_{net} \frac{\sigma_{yd}}{235}$$
(b) web stiffeners normal to flanges of the primary support member 	$$I_{net} = 1.14\text{x}10^{-5} l\ s^2 t_{w-net} \left(2.5 \frac{1000l}{s} - 2 \frac{s}{1000l} \right) \frac{\sigma_{yd}}{235}$$

Where:

C	= 1.43 for longitudinal stiffeners in cargo tank region = 0.72 for other stiffeners
l	length of web stiffener, in m. For web stiffeners welded to local support members (LSM), the length is to be measured between the flanges of the local support members. For sniped web stiffeners the length is to be measured between the lateral supports e.g. the total distance between the flanges of the primary support member as shown for Mode (b).
A_{net}	net section area of web stiffener including attached plate assuming effective breadth of 80% of stiffener spacing s, in cm^2
s	spacing of stiffeners, in mm, as defined in *Section 4/2.2.1*
t_{w-net}	net web thickness of the primary support member, in mm
σ_{yd}	specified minimum yield stress of the material of the web plate of the primary support member, in N/mm^2

2.3.2.3 The net moment of inertia for primary support members, $I_{prm-net50}$, supporting stiffeners subject to axial compressive stresses, including effective plate width at mid span, is not to be less than:

$$I_{psm-net50} = 300 \frac{l_{bdg}^4}{S^3 s} I_{net} \quad cm^4$$

Where:

l_{bdg} bending span of primary support member, in m

S distance between primary support members, in m

s spacing of stiffeners, in mm, as defined in *Section 4/2.2.1*

I_{net} maximum required moment of inertia, as given in *2.2.2.1*, for stiffeners within the central half of the bending span, in cm^4

2.3.3 Spacing between flange supports or tripping brackets

2.3.3.1 The torsional buckling mode of primary support members is to be controlled by flange supports or tripping brackets. The unsupported length of the flange of the primary support member, i.e. the distance between tripping brackets, s_{bkt}, is not to be greater than:

$$s_{bkt} = b_f C \sqrt{\frac{A_{f-net50}}{\left(A_{f-net50} + \frac{A_{w-net50}}{3}\right)} \left(\frac{235}{\sigma_{yd}}\right)}$$ m, but need not be less than $s_{bkt-min}$

Where:

b_f breadth of flange, in mm

C slenderness coefficient:

= 0.022 for symmetrical flanges

= 0.033 for one sided flanges

$A_{f-net50}$ net cross-sectional area of flange, in cm^2

$A_{w-net50}$ net cross-sectional area of the web plate, in cm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

$s_{bkt-min}$ = 3.0m for primary support members in the cargo tank region, on tank boundaries or on the hull envelope including external decks

= 4.0m for primary support members in other areas

2.4 Other Structure

2.4.1 Proportions of pillars

2.4.1.1 For I-sections the thickness of the web plate and the flange thickness is to comply with *2.2.1.1*.

2.4.1.2 The thickness of thin walled box sections is to comply with *2.2.1.1(b)*. The radius of circular tube sections is to be less than 50 times the net thickness of the pillar.

2.4.2 Proportions of brackets

2.4.2.1 The net thickness of end brackets, $t_{bkt-net}$, is except as specified in *2.4.2.2* not to be less than:

$$t_{bkt-net} = \frac{d_{bkt}}{C} \sqrt{\frac{\sigma_{yd}}{235}} \quad \text{mm}$$

Where:

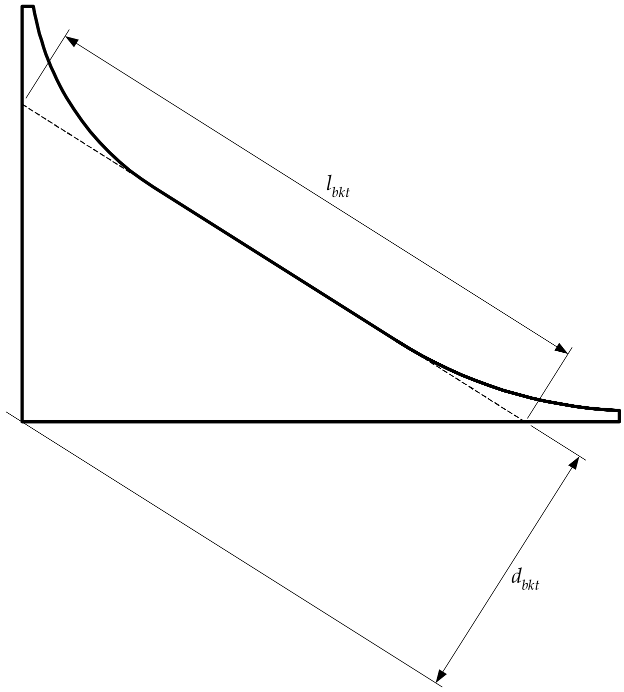
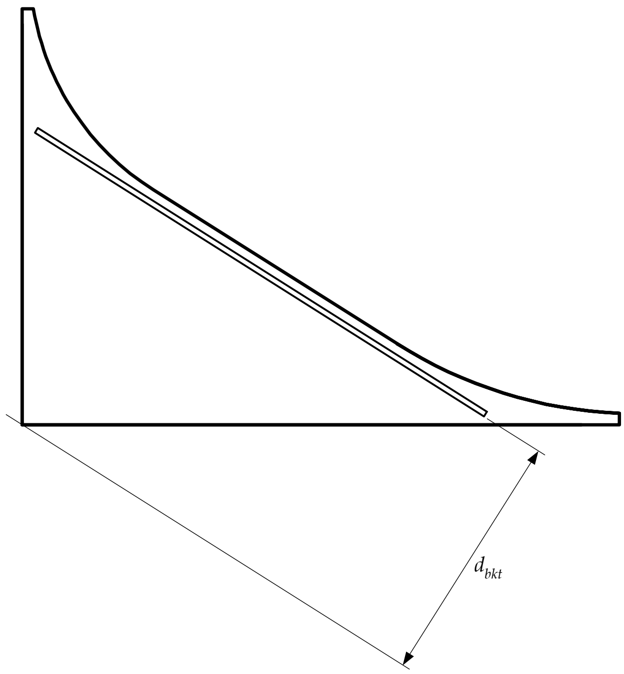
d_{bkt} depth of brackets, in mm. See *Table 10.2.3*

C slenderness coefficient as defined in *Table 10.2.3*

σ_{yd} specified minimum yield stress of the material, in N/mm^2

2.4.2.2 Where it can be demonstrated that the bracket is only subjected to tensile stresses, e.g. in way of internal brackets in a tank surrounded by void space, the requirement in *2.4.2.1* need not be complied with.

Table 10.2.3
Buckling Coefficient, *C*, for Proportions of Brackets

Mode	C
(a) Brackets without edge stiffener 	$C = 20\left(\frac{d_{bkt}}{l_{bkt}}\right) + 16$ Where: $0.25 \le \frac{d_{bkt}}{l_{bkt}} \le 1.0$
(b) Brackets with edge stiffener 	$C = 70$

Where:

l_{bkt} effective length of edge of bracket, in mm

2.4.2.3 Tripping brackets on primary support members are to be stiffened by a flange or edge stiffener if the effective length of the edge, l_{bkt}, is greater than:

$$l_{bkt} = 75 t_{bkt-net} \quad \text{mm}$$

Where:

$t_{bkt-net}$ bracket thickness, in mm

2.4.3 Requirements to edge reinforcements in way of openings and bracket edges

2.4.3.1 The depth of stiffener web, d_w, of edge stiffeners in way of openings and bracket edges is not to be less than:

$$d_w = Cl\sqrt{\frac{\sigma_{yd}}{235}} \quad \text{mm, or 50 mm, whichever is greater}$$

Where:

l length of edge stiffener, in m

σ_{yd} specified minimum yield stress of the material, in N/mm^2

C slenderness coefficient

75 for end brackets

50 for tripping brackets

50 for edge reinforcements in way of openings

2.4.3.2 The net thickness of the web plate and flange of the edge stiffener is not to be less than that required in *2.2.1*.

3 PRESCRIPTIVE BUCKLING REQUIREMENTS

3.1 General

3.1.1 Scope

3.1.1.1 This Sub-Section contains the methods for determination of the buckling capacity, definitions of buckling utilisation factors and other measures necessary to control buckling of plate panels, stiffeners and primary support members.

3.1.1.2 The buckling utilisation factor, η, is to satisfy the following criteria:

$$\eta \leq \eta_{allow}$$

Where:

η_{allow} allowable buckling utilisation factor as defined in *Section 8* and *Section 9*

η buckling utilisation factor, as defined in *3.2.1.1*, *3.3.2.2*, *3.3.3.1*, *3.4.1.1* and *3.5.1.1*

3.1.1.3 For structural idealisation and definitions see also *Section 4/2*. The thickness and section properties of plates and stiffeners are to be taken as specified by the appropriate rule requirements.

3.2 Buckling of Plates

3.2.1 Uni-axial buckling of plates

3.2.1.1 The buckling utilisation factor, η, for uni-axial stress is to be taken as:

$$\eta = \frac{\sigma_x}{\sigma_{xcr}}$$ for compressive stresses in x-direction

$$\eta = \frac{\sigma_y}{\sigma_{ycr}}$$ for compressive stresses in y-direction

$$\eta = \frac{\tau}{\tau_{cr}}$$ for shear stress

Where:

σ_x, σ_y actual compressive stresses, in N/mm^2

τ actual shear stress, in N/mm^2

$\sigma_{xcr}, \sigma_{ycr}$ critical compressive stress, in N/mm^2, as defined in *3.2.1.3*

τ_{cr} critical shear stress, in N/mm^2, as defined in *3.2.1.3*

3.2.1.2 Reference degree of slenderness, to be taken as:

$$\lambda = \sqrt{\frac{\sigma_{yd}}{K \sigma_E}}$$

Where:

K buckling factor, see *Table 10.3.1*

σ_E reference stress, in N/mm²

$$= 0.9\,E\left(\frac{t_{net}}{l_a}\right)^2$$

E modulus of elasticity, 206 000 N/mm²

t_{net} net thickness of plate panel, in mm

l_a length of the side of the plate panel as defined in *Table 10.3.1*, in mm

σ_{yd} specified minimum yield stress of the material, in N/mm²

3.2.1.3 The critical stresses, σ_{xcr}, σ_{ycr} or τ_{cr}, of plate panels subject to compression or shear, respectively, is to be taken as:

$$\sigma_{xcr} = C_x\,\sigma_{yd}$$

$$\sigma_{ycr} = C_y\,\sigma_{yd}$$

$$\tau_{cr} = C_\tau\,\frac{\sigma_{yd}}{\sqrt{3}}$$

Where:

C_x, C_y, C_τ reduction factors, as given in *Table 10.3.1*

Table 10.3.1
Buckling Factor and Reduction Factor for Plane Plate Panels

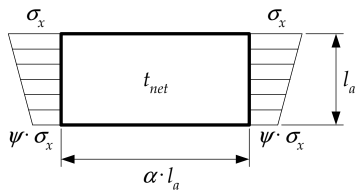
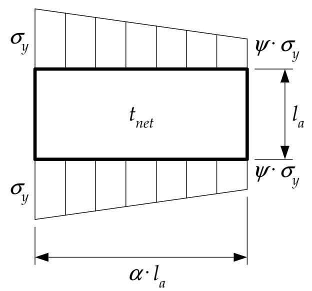
Case	Stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor C
1 	$1 \geq \psi \geq 0$	$\alpha > 1$	$K = \dfrac{8.4}{\psi + 1.1}$	$C_x = 1$ for $\lambda \leq \lambda_c$ $C_x = c\left(\dfrac{1}{\lambda} - \dfrac{0.22}{\lambda^2}\right)$ for $\lambda > \lambda_c$ Where: $c = (1.25 - 0.12\psi) \leq 1.25$ $\lambda_c = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0.88}{c}}\right)$
	$0 > \psi > -1$		$K = 7.63 - \psi\,(6.26 - 10\,\psi)$	
	$\psi \leq -1$		$K = 5.975\,(1 - \psi)^2$	
2 	$1 \geq \psi \geq 0$	$\alpha \geq 1$	$K = \left(1 + \dfrac{1}{\alpha^2}\right)^2 \dfrac{2.1}{(\psi + 1.1)}$	$C_y = c\left(\dfrac{1}{\lambda} - \dfrac{R + F^2(H - R)}{\lambda^2}\right)$ Where: $c = (1.25 - 0.12\psi) \leq 1.25$ $R = \lambda(1 - \lambda / c)$ for $\lambda < \lambda_c$ $R = 0.22$ for $\lambda \geq \lambda_c$ $\lambda_c = 0.5\,c\left(1 + \sqrt{1 - 0.88 / c}\right)$ $F = \left(1 - \left(\dfrac{K}{0.91} - 1\right) / \lambda_p^2\right) c_1 \geq 0$ $\lambda_p^2 = \lambda^2 - 0.5$ and $1 \leq \lambda_p^2 \leq 3$ $c_1 = 1$ for σ_y due to direct loads (3) $c_1 = (1 - 1 / a) \geq 0$ for σ_y due to bending (in general) (2) $c_1 = 0$ for σ_y due to bending in extreme load cases (e.g. w/t. bhds.) $H = \lambda - \dfrac{2\lambda}{c(T + \sqrt{T^2 - 4})} \geq R$ $T = \lambda + \dfrac{14}{15\lambda} + \dfrac{1}{3}$
	$0 > \psi > -1$	$1 \leq \alpha \leq 1.5$	$K = \left[1 + \dfrac{1}{\alpha^2}\right]^2 \dfrac{2.1\,(1 + \psi)}{1.1} - \dfrac{\psi}{\alpha^2}(13.9 - 10\,\psi)$	
		$\alpha > 1.5$	$K = \left[1 + \dfrac{1}{\alpha^2}\right]^2 \dfrac{2.1\,(1 + \psi)}{1.1} - \dfrac{\psi}{\alpha^2}\left(5.87 + 1.87\,\alpha^2 + \dfrac{8.6}{\alpha^2} - 10\psi\right)$	
	$\psi \leq -1$	$1 \leq \alpha \leq \dfrac{3\,(1 - \psi)}{4}$	$K = \left(\dfrac{1 - \psi}{\alpha}\right)^2 5.975$	
		$\alpha > \dfrac{3\,(1 - \psi)}{4}$	$K = \left(\dfrac{1 - \psi}{\alpha}\right)^2 3.9675 + 0.5375\left(\dfrac{1 - \psi}{\alpha}\right)^4 + 1.87$	

Table 10.3.1 (Continued)
Buckling Factor and Reduction Factor for Plane Plate Panels

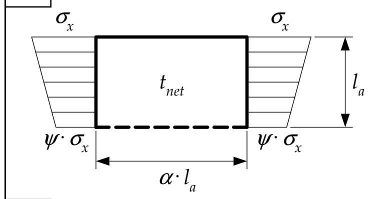
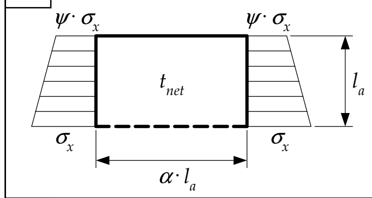
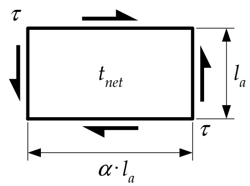
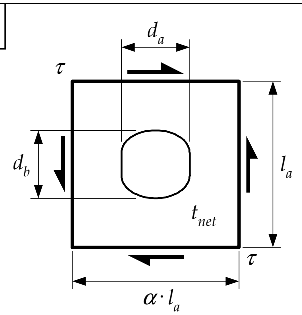
Case	Stress ratio ψ	Aspect ratio a	Buckling factor K	Reduction factor C
3 	$1 \geq \psi \geq 0$	$\alpha > 0$	$K = \dfrac{4(0.425 + 1/\alpha^2)}{3\psi + 1}$	$C_x = 1$ for $\lambda \leq 0.7$ $C_x = \dfrac{1}{\lambda^2 + 0.51}$ for $\lambda > 0.7$
	$0 > \psi \geq -1$		$K = 4\,(0.425 + 1/\alpha^2)\,(1 + \psi)$ $- 5\,\psi\,(1 - 3.42\,\psi)$	
4 	$1 \geq \psi \geq -1$	$\alpha > 0$	$K = \left(0.425 + \dfrac{1}{\alpha^2}\right)\dfrac{3 - \psi}{2}$	
5 	-		$K = K_\tau \sqrt{3}$	$C_\tau = 1$ for $\lambda \leq 0.84$ $C_\tau = \dfrac{0.84}{\lambda}$ for $\lambda > 0.84$
		$\alpha \geq 1$	$K_\tau = \left[5.34 + \dfrac{4}{\alpha^2}\right]$	
		$0 < \alpha < 1$	$K_\tau = \left[4 + \dfrac{5.34}{\alpha^2}\right]$	
6 	-		$K = K' r$ K' = K according to Case 5 r = opening red. factor $r = \left(1 - \dfrac{d_a}{\alpha l_a}\right)\left(1 - \dfrac{d_b}{l_a}\right)$ $\dfrac{d_a}{\alpha l_a} \leq 0.7$ and $\dfrac{d_b}{l_a} \leq 0.7$	

Table 10.3.1 (Continued)
Buckling Factor and Reduction Factor for Plane Plate Panels

Where:

ψ	the ratio between smallest and largest compressive stress as shown for Case 1-4
l_a	length in mm, of the shorter side of the plate panel for Cases 1 and 2
l_a	length in mm, of the side of the plate panel as defined for Cases 3, 4, 5 and 6
α	aspect ratio of the plate panel

Edge boundary conditions:

- - - - - - - - -	plate edge free
————————	plate edge simply supported

Notes

(1) Cases listed are general cases. Each stress component (σ_x, σ_y) is to be understood in local coordinates.

(2) c_1 due to bending (in general) corresponds to straight edges (uniform displacement) of a plate panel integrated in a large structure. This value is to be applied for hull girder buckling and buckling of web plate of primary support members in way of openings.

(3) c_1 for direct loads corresponds to a plate panel with edges not restrained from pull-in which may result in non-straight edges

3.3 Buckling of Stiffeners

3.3.1 Critical compressive stress

3.3.1.1 The buckling utilisation factor of stiffeners is to be taken as the maximum of the column and torsional buckling mode as given in *3.3.2* and *3.3.3*.

3.3.2 Column buckling mode

3.3.2.1 Stiffeners are to be verified against the column buckling mode as given in *3.3.2.2* with the allowable buckling utilisation factor, η_{allow}, see *3.1.1.2*. Stiffeners not subjected to lateral pressure and that have a net moment of inertia, I_{net}, complying with *3.3.2.4* have acceptable column buckling strength and need not be verified against *3.3.2.2*.

3.3.2.2 The buckling utilisation factor for column buckling of stiffeners is to be taken as:

$$\eta = \frac{\sigma_x + \sigma_b}{\sigma_{yd}}$$

Where:

σ_x compressive axial stress in the stiffener, in N/mm², in way of the midspan of the stiffener. See *Section 3/5.2.3.1*

σ_b bending stress at the midspan of the stiffener according to *3.3.2.3*, in N/mm²

σ_{yd} specified minimum yield stress of the material, in N/mm²

3.3.2.3 The bending stress, σ_b, in N/mm², in the stiffener is equal to:

$$\sigma_b = \frac{M_o + M_1}{1000\ Z_{net}}$$

Where:

Z_{net} net section modulus of stiffener, in cm³, including effective breadth of plating according to *3.3.4.1*

a) if lateral pressure is applied to the stiffener:

Z_{net} is the section modulus calculated at flange if the lateral pressure is applied on the same side as the stiffener.

Z_{net} is the section modulus calculated at attached plate if the lateral pressure is applied on the side opposite to the stiffener.

b) if no lateral pressure is applied on the stiffener:

Z_{net} is the minimum section modulus among those calculated at flange and attached plate.

M_1 bending moment, in Nmm, due to the lateral load P

$$= \frac{P s l_{stf}^{\ 2}}{24} 10^3$$

P lateral load, in kN/m²

s stiffener spacing as defined in *Section 4/2.2.1*, in mm

l_{stf} span of stiffener, in m, equal to spacing between primary support members

M_0 bending moment, in Nmm, due to the lateral deformation w of stiffener

$$= F_E \left(\frac{P_z\, w}{c_f - P_z} \right) \qquad \text{where } (c_f - P_z) > 0$$

F_E ideal elastic buckling force of the stiffener, in N

$$= \left(\frac{\pi^2}{l_{stf}^{\,2}} \right) E\, I_{net}\, 10^{-2}$$

E modulus of elasticity, 206 000 N/mm²

I_{net} moment of inertia, in cm⁴, of the stiffener including effective width of attached plating according to *3.3.4.1*. I_{net} is to comply with the following requirement:

$$I_{net} \geq \frac{s\, t_{net}^{\,3}}{12} 10^{-4}$$

t_{net} net thickness of plate flange, to be taken as the mean thickness of the two attached plate panels, in mm

P_z nominal lateral load, in N/mm², acting on the stiffener due to membrane stresses, σ_x, σ_y and τ_1, in the attached plate in way of the stiffener midspan:

$$= \frac{t_{net}}{s} \left(\sigma_{xl} \left(\frac{\pi\, s}{1000\, l_{stf}} \right)^2 + 2\, c_y\, \sigma_y + \sqrt{2}\, \tau_1 \right)$$

σ_{xl}

$$= \sigma_x \left(1 + \frac{A_{net}}{s\, t_{net}} \right) \quad \text{N/mm}^2$$

τ_1

$$= \left[\tau - t_{net} \sqrt{\sigma_{yd}\, E \left(\frac{m_1}{(1000\, l_{stf})^2} + \frac{m_2}{s^2} \right)} \right] \geq 0$$

with m_1 and m_2 taken equal to

$$m_1 = 1.47 \quad m_2 = 0.49 \ \text{for} \ \frac{1000\, l_{stf}}{s} \geq 2.0$$

$$m_1 = 1.96 \quad m_2 = 0.37 \ \text{for} \ \frac{1000\, l_{stf}}{s} < 2.0$$

σ_x compressive axial stress in the stiffener, in N/mm², in way of the midspan of the stiffener. See *Section 3/5.2.3.1*

A_{net} net sectional area of the stiffener without attached plating, in mm²

c_y factor taking into account the membrane stresses in the attached plating acting perpendicular to the stiffener's axis

$$= 0.5\,(1 + \psi) \ \text{for} \ 0 \leq \psi \leq 1$$

$$= \frac{0.5}{1 - \psi} \ \text{for} \ \psi < 0$$

ψ edge stress ratio for Case 2 according to *Table 10.3.1*

σ_y membrane compressive stress in the attached plating acting perpendicular to the stiffener's axis, in N/m²

τ shear membrane stress in the attached plating, in N/mm²

σ_{yd} specified minimum yield stress of the material, in N/mm²

w deformation of stiffener, in mm

$= w_0 + w_1$

w_0 assumed imperfection, in mm.

$$= \min\left[\frac{1000\, l_{stf}}{250},\ \frac{s}{250},\ 10\right]$$

For stiffeners sniped at both ends w_0 is not to be taken less than the distance from the midpoint of attached plating to the neutral axis of the stiffener calculated with the effective width of the attached plating according to *3.3.4.1*

w_1 deformation of stiffener at midpoint of stiffener span due to lateral load P, in mm. In case of uniformly distributed load the w_1 is to be taken as:

$$= \frac{P\, s\, l_{stf}^{\ 4}}{384 \cdot E\, I_{net}} 10^5$$

c_f elastic support provided by the stiffener, in N/mm²

$$= F_E\, \frac{\pi^2}{l_{stf}^{\ 2}} (1 + c_p) 10^{-6}$$

c_p

$$= \frac{1}{1 + \frac{0.91}{c_a}\left(\frac{12\, I_{net}\, 10^4}{s\, t_{net}^{\ 3}} - 1\right)}$$

$$c_a = \left[\frac{1000\, l_{stf}}{2s} + \frac{2s}{1000\, l_{stf}}\right]^2 \quad \text{for} \quad l_{stf} \geq \frac{2s}{1000}$$

$$c_a = \left[1 + \left(\frac{1000\ l_{stf}}{2s}\right)^2\right]^2 \quad \text{for} \quad l_{stf} < \frac{2s}{1000}$$

3.3.2.4 Stiffeners not subjected to lateral pressure are considered as complying with the requirements of *3.3.2.2* if their net moments of inertia, in cm⁴, satisfy the following requirement:

$$I_{net} \geq 100 \frac{P_z\, l_{stf}^{\ 2}}{\pi^2} \left[\frac{w_o\left(e_f - 0.5 t_{f-net}\right)}{\eta_{allow}\sigma_{yd} - \sigma_x} + \frac{l_{stf}^{\ 2}}{E \pi^2} 10^6\right]$$

Where:

e_f distance from connection to plate (C as shown in *Figure 10.3.1*) to centre of flange, in mm

$= (d_w - 0.5 t_{f-net})$ for bulb flats

$= (d_w + 0.5 t_{f-net})$ for angles and T bars

d_w depth of web plate, in mm, as shown in *Figure 10.3.1*

$t_{f\text{-}net}$ net flange thickness, in mm

η_{allow} allowable buckling utilisation factor as defined in *Section 8* and *Section 9*

Note

Other parameters are as defined in *3.3.2.3*

3.3.3 Torsional buckling mode

3.3.3.1 The torsional buckling mode is to be verified against the allowable buckling utilisation factor, η_{allow}, see *3.1.1.2*. The buckling utilisation factor for torsional buckling of stiffeners is to be taken as:

$$\eta = \frac{\sigma_x}{C_T\,\sigma_{yd}}$$

Where:

σ_x compressive axial stress in the stiffener, in N/mm², in way of the midspan of the stiffener. See *Section 3/5.2.3.1*

C_T torsional buckling coefficient

$= 1.0$ for $\lambda_T \le 0.2$

$$= \frac{1}{\Phi + \sqrt{\Phi^2 - \lambda_T^2}} \quad \text{for } \lambda_T > 0.2$$

$$\Phi = 0.5(1 + 0.21(\lambda_T - 0.2) + \lambda_T^2)$$

λ_T reference degree of slenderness for torsional buckling

$$= \sqrt{\frac{\sigma_{yd}}{\sigma_{ET}}}$$

σ_{ET} reference stress for torsional buckling, in N/mm²

$$= \frac{E}{I_{p-net}}\left(\frac{\varepsilon \pi^2 I_{\omega-net} 10^{-4}}{l_t^2} + 0.385 I_{T-net}\right)$$

RCN 1 to July 2008 version (effective from 1 February 2010)

σ_{yd} specified minimum yield stress of the material, in N/mm²

E modulus of elasticity, 206 000 N/mm²

I_{P-net} net polar moment of inertia of the stiffener about point C, in cm⁴, as shown in *Figure 10.3.1* and Table 10.3.2

RCN 1 to July 2008 version (effective from 1 February 2010)

I_{T-net} net St. Venant's moment of inertia of the stiffener, in cm⁴, as shown in *Table 10.3.2*

RCN 1 to July 2008 version (effective from 1 February 2010)

$I_{\omega-net}$ net sectorial moment of inertia of the stiffener about point C, in cm⁶ as shown in *Figure 10.3.1* and Table 10.3.2

RCN 1 to July 2008 version (effective from 1 February 2010)

ε degree of fixation

$$1 + 1000\sqrt{\frac{l_t^4}{\frac{3}{4}\pi^4 I_{\omega-net}\left(\frac{s}{t_{net}^3} + \frac{4\left(e_f - 0.5t_{f-net}\right)}{3t_{w-net}^3}\right)}}$$

RCN 1 to July 2008 version (effective from 1 February 2010)

l_t torsional buckling length to be taken equal the distance between tripping supports, in m

d_w depth of web plate, in mm

t_{w-net} net web thickness, in mm

b_f flange breadth, in mm

t_{f-net} net flange thickness, in mm

e_f distance from connection to plate (C in *Figure 10.3.1*) to centre of flange, in mm

$= (d_w - 0.5t_{f-net})$ for bulb flats

$= (d_w + 0.5t_{f-net})$ for angles and T bars

A_{w-net} net web area, in mm²

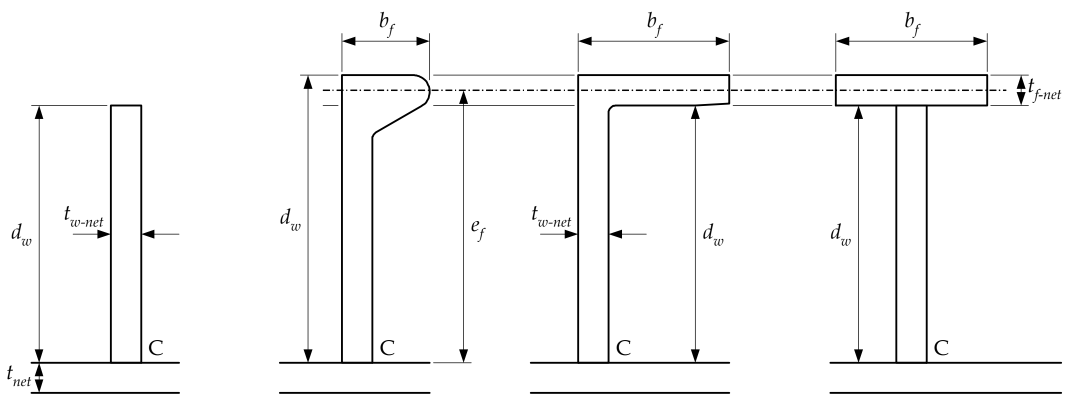
$= (e_f - 0.5t_{f-net})t_{w-net}$

A_{f-net} net flange area, in mm²

$= b_f\, t_{f-net}$

s stiffener spacing as defined in *Section 4/2.2.1*, in mm

Figure 10.3.1
Stiffener cross sections



Note:
1. Measurements of breadth and depth are based on gross scantlings as described in *Section 4/2.4.1.2*.
2. Characteristic flange data for bulb profiles are given in *Appendix C/Table C.1.2*

Table 10.3.2 Moments of Inertia		
Section property	**Flat bars**	**Bulb flats, angles and T bars**
I_{P-net}	$\dfrac{d_w^3\, t_{w-net}}{3x10^4}$	$\left(\dfrac{A_{w-net}(e_f - 0.5t_{f-net})^2}{3} + A_{f-net}\, e_f^2\right)10^{-4}$
I_{T-net}	$\dfrac{d_w\, t_{w-net}^3}{3x10^4}\left(1-0.63\dfrac{t_{w-net}}{d_w}\right)$	$\dfrac{(e_f - 0.5t_{f-net})t_{w-net}^3}{3x10^4}\left(1-0.63\dfrac{t_{w-net}}{e_f - 0.5t_{f-net}}\right)$ $+$ $\dfrac{b_f\, t_{f-net}^3}{3x10^4}\left(1-0.63\dfrac{t_{f-net}}{b_f}\right)$
$I_{\omega-net}$	$\dfrac{d_w^3\, t_{w-net}^3}{36x10^6}$	for bulb flats and angles: $\dfrac{A_{f-net}\, e_f^2\, b_f^2}{12x10^6}\left(\dfrac{A_{f-net}+2.6A_{w-net}}{A_{f-net}+A_{w-net}}\right)$ for T bars: $\dfrac{b_f^3\, t_{f-net}\, e_f^2}{12x10^6}$

3.3.4 Effective breadth of attached plating

3.3.4.1 The effective breadth of attached plating of ordinary stiffeners is to be taken as:

$$b_{eff} = \min(C_x s,\ \chi_s s)$$

Where:

$$\chi_s = 0.0035\left(\frac{1000\, l_{eff}}{s}\right)^3 - 0.0673\left(\frac{1000\, l_{eff}}{s}\right)^2 + 0.4422\left(\frac{1000\, l_{eff}}{s}\right) - 0.0056 \le 1.0$$

s	stiffener spacing as defined in *Section 4/2.2.1*, in mm
C_x	average reduction factor for buckling of the two attached plate panels, according to Case 1 in *Table 10.3.1*
l_{stf}	span of stiffener, in m, equal to spacing between primary support members
l_{eff}	effective span of stiffeners in m $l_{eff} = l_{stf}$ if simply supported at both ends $l_{eff} = 0.6 l_{stf}$ if fixed at both ends

(RCN 2, effective from 1 July 2008)

3.4 Primary Support Members

3.4.1 Buckling of web plate of primary support members in way of openings

3.4.1.1 The web plate of primary support members with openings is to be assessed for buckling based on the combined axial compressive and shear stresses. The web plate adjacent to the opening on both sides is to be considered as individual unstiffened plate panels as shown in *Table 10.3.3*. The buckling utilisation factor, η, is to be taken as:

$$\eta = \left(\frac{|\sigma_{av}|}{C\,\sigma_{yd}}\right)^{e} + \left(\frac{|\tau_{av}|\sqrt{3}}{C_\tau\,\sigma_{yd}}\right)^{e_\tau}$$

Where:

σ_{av}	average compressive stress in the area of web plate being considered according to case: 1, 2 or 3 in *Table 10.3.1*, in N/mm^2
τ_{av}	average shear stress in the area of web plate being considered according to case 5 or 6 in *Table 10.3.1*, in N/mm^2
σ_{yd}	specified minimum yield stress of the material, in N/mm^2
$e = 1 + C^4$	exponent for compressive stress
$e_\tau = 1 + C\,C_\tau^2$	exponent for shear stress
$C = C_x$	reduction factor according to Case 1 or 3, *Table 10.3.1*
$C = C_y$	reduction factor according to Case 2, *Table 10.3.1*
C_τ	reduction factor according to Case 5 or 6, *Table 10.3.1*

3.4.1.2 The reduction factors, C_x or C_y in combination with C_τ, of the plate panel(s) of the web adjacent to the opening is to be taken as shown in *Table 10.3.3.*

Table 10.3.3
Reduction Factors

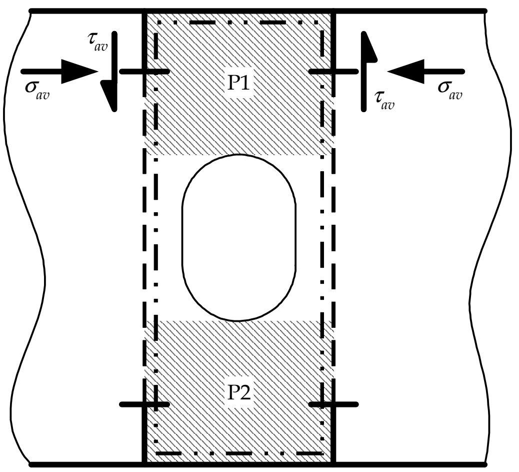
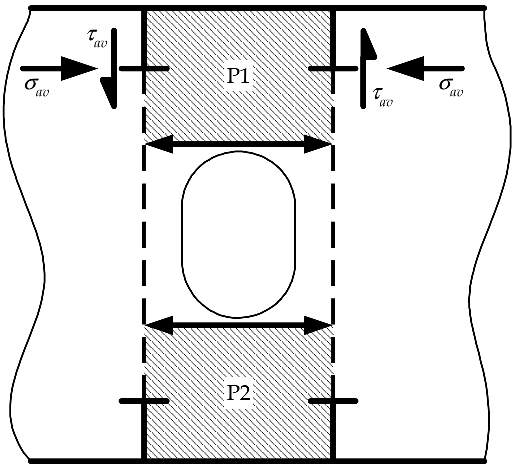
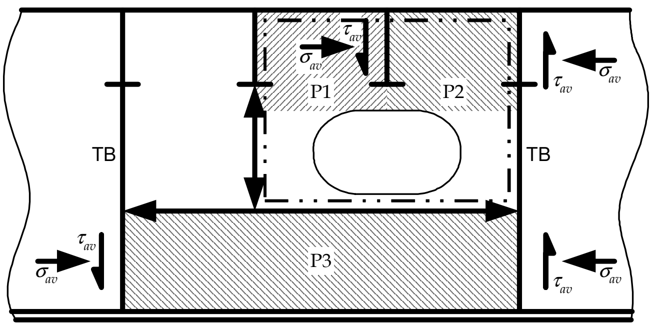
Mode	C_x, C_y	C_τ
(a) without edge reinforcements 	Separate reduction factors are to be applied to areas P1 and P2 using Case 3, *Table 10.3.1*, with edge stress ratio: $\psi = 1.0$	A common reduction factor is to be applied to areas P1 and P2 using Case 6, *Table 10.3.1* for area marked:

Table 10.3.3 (Continued)
Reduction Factors

Mode	C_x, C_y	C_τ
(b) with edge reinforcements 	Separate reduction factors are to be applied for areas P1 and P2 using: C_x for Case 1 or C_y, for Case 2, see *Table 10.3.1* with stress ratio $\psi = 1.0$	Separate reduction factors are to be applied for areas P1 and P2 using Case 5, *Table 10.3.1*
(c) example of hole in web 	Panels P1 and P2 are to be evaluated in accordance with (a). Panel P3 is to be evaluated in accordance with (b)	

Note

1. Web panels to be considered for buckling in way of openings are shown shaded and numbered P1, P2, etc.

3.5 Other Structures

3.5.1 Struts, pillars and cross ties

3.5.1.1 The critical buckling stress for axially compressed struts, pillars and cross ties is to be taken as the lesser of the column and torsional critical buckling stresses. The buckling utilisation factor, η, is to be taken as:

$$\eta = \frac{\sigma_{av}}{\sigma_{cr}}$$

Where:

σ_{av} average axial compressive stress in the member, in N/mm²

σ_{cr} minimum critical buckling stress according to *3.5.1.2*, in N/mm²

3.5.1.2 The critical buckling stress in compression, σ_{cr}, for each mode is to be taken as:

$$\sigma_{cr} = \sigma_E \text{ for } \sigma_E \le 0.5\sigma_{yd}$$

$$\sigma_{cr} = \left(1 - \frac{\sigma_{yd}}{4\sigma_E}\right)\sigma_{yd} \text{ for } \sigma_E > 0.5\sigma_{yd}$$

Where:

σ_E elastic compressive buckling stress, in N/mm², given for each buckling mode, see *3.5.1.3* to *3.5.1.5*

σ_{yd} specified minimum yield stress of the material, in N/mm²

3.5.1.3 The elastic compressive column buckling stress, σ_E, of pillars subject to axial compression is to be taken as:

$$\sigma_E = 0.001 E f_{end} \frac{I_{net50}}{A_{pill-net50} l_{pill}^2} \quad \text{N/mm}^2$$

Where:

I_{net50} net moment of inertia about the weakest axis of the cross-section, in cm⁴

$A_{pill-net50}$ net cross-sectional area of the pillar, in cm²

f_{end} end constraint factor:

1.0 where both ends are pinned

2.0 where one end is pinned and the other end is fixed

4.0 where both ends are fixed

A pillar end may be considered fixed when effective brackets are fitted. These brackets are to be supported by structural members with greater bending stiffness than the pillar.

Column buckling capacity for cross tie shall be calculated using f_{end} equal to 2.0 and span as defined in *8/2.6.8.1*

RCN 1 to July 2008 version (effective from 1 February 2010)

E modulus of elasticity, 206 000, in N/mm²

l_{pill} unsupported length of the pillar, in m

3.5.1.4 The elastic torsional buckling stress, σ_{ET}, with respect to axial compression of pillars is to be taken as:

$$\sigma_{ET} = \frac{G I_{sv-net50}}{I_{pol-net50}} + \frac{0.001 f_{end} E c_{warp}}{I_{pol-net50} l_{pill}^2} \quad \text{N/mm}^2$$

Where:

G shear modulus

$$= \frac{E}{2(1+\upsilon)}$$

E modulus of elasticity, 206 000, in N/mm²

υ Poisson's ratio, 0.3

$I_{sv-net50}$ net St. Venants moment of inertia, in cm⁴, see *Table 10.3.4*

$I_{pol-net50}$ net polar moment of inertia about the shear centre of cross section, in cm⁴

$$= I_{y-net50} + I_{z-net50} + A_{net50}\left(y_0^2 + z_0^2\right)$$

f_{end} end constraint factor:

1.0 where both ends are pinned

2.0 where one end is pinned and the other end is fixed

4.0 where both ends are fixed

Elastic torsional buckling capacity for cross tie shall be calculated using f_{end} equal to 2.0 and span as defined in *8/2.6.8.1*

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c_{warp} warping constant, in cm^6, see *Table 10.3.4*

l_{pill} unsupported length of the pillar, in m

y_0 position of shear centre relative to the cross-sectional centroid, in cm, see *Table 10.3.4*

z_0 position of shear centre relative to the cross-sectional centroid, in cm, see *Table 10.3.4*

A_{net50} net cross-sectional area, in cm^2

$I_{y-net50}$ net moment of inertia about y-axis, in cm^4

$I_{z-net50}$ net moment of inertia about z-axis, in cm^4

3.5.1.5 For cross-sections where the centroid and the shear centre do not coincide, the interaction between the torsional and column buckling mode is to be examined. The elastic torsional/column buckling stress, σ_{ETF}, with respect to axial compression is to be taken as:

$$\sigma_{ETF} = \frac{1}{2\zeta}\left[(\sigma_E + \sigma_{ET}) - \sqrt{(\sigma_E + \sigma_{ET})^2 - 4\zeta\sigma_E\sigma_{ET}}\right]$$

Where:

ζ $= 1 - \dfrac{\left(y_0{}^2 + z_0{}^2\right)A_{net50}}{I_{pol-net50}}$

y_o Position of shear centre relative to the cross-sectional centroid, in cm, see *Table 10.3.4*

z_0 position of shear centre relative to the cross-sectional centroid, in cm, see *Table 10.3.4*

A_{net50} net cross-sectional area, in cm^2

$I_{pol-net50}$ net polar moment of inertia about the shear centre of cross section, as defined in *3.5.1.4*

σ_{ET} elastic torsional buckling stress, as defined in *3.5.1.4*

σ_E elastic column compressive buckling stress, as defined in *3.5.1.3*

Table 10.3.4
Cross Sectional Properties

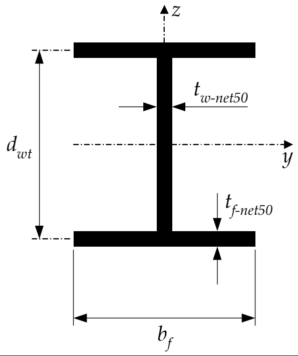
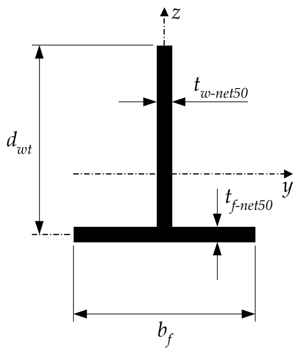
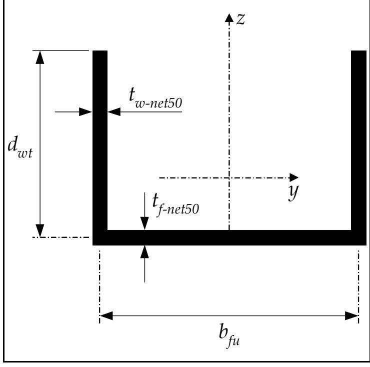
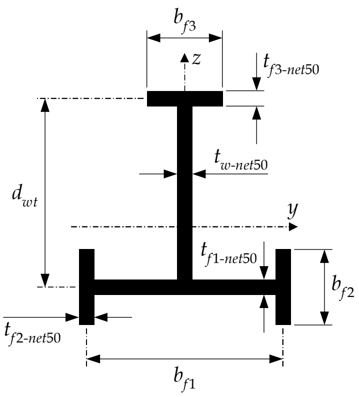
double symmetrical sections	
	$I_{sv-net50} = \frac{1}{3}\left(2b_f t_{f-net50}^3 + d_{wt} t_{w-net50}^3\right)10^{-4}$ cm⁴
	$c_{warp} = \frac{d_{wt}^2 b_f^3 t_{f-net50}}{24}10^{-6}$ cm⁶

Table 10.3.4 (Continued)
Cross Sectional Properties

single symmetrical sections	
	$I_{sv-net50} = \frac{1}{3}\left(b_f t_{f-net50}^3 + d_{wt} t_{w-net50}^3\right)10^{-4}$ cm⁴
	$y_0 = 0$ cm $z_0 = -\frac{0.5 d_{wt}^2 t_{w-net50}}{d_{wt} t_{w-net50} + b_f t_{f-net50}}10^{-1}$ cm $c_{warp} = \frac{b_f^3 t_{f-net50}^3 + 4 d_{wt}^3 t_{w-net50}^3}{144}10^{-6}$ cm⁶
	$I_{sv-net50} = \frac{1}{3}\left(b_{fu} t_{f-net50}^3 + 2d_{wt} t_{w-net50}^3\right)10^{-4}$ cm⁴
	$y_0 = 0$ cm $z_0 = -\frac{d_{wt}^2\ t_{w-net50}10^{-1}}{2d_{wt}\ t_{w-net50} + b_f\ t_{f-net50}} - \frac{0.5\, d_{wt}^2\ t_{w-net50}10^{-1}}{d_{wt}\ t_{w-net50} + b_{fu}\ t_{f-net50}/6}$ cm $c_{warp} = \frac{b_{fu}^2 d_{wt}^3 t_{w-net50}\left(3d_{wt} t_{w-net50} + 2b_{fu} t_{f-net50}\right)}{12\left(6d_{wt} t_{w-net50} + b_{fu} t_{f-net50}\right)}10^{-6}$ cm⁶

<table>
<tr>
<td rowspan="2">
</td>
<td>$$I_{sv-net50} = \frac{1}{3}\left(b_{f1}t_{f1-net50}^3 + 2b_{f2}t_{f2-net50}^3 + b_{f3}t_{f3-net50}^3 + d_{wt}t_{w-net50}^3\right)10^{-4}$$ cm4</td>
</tr>
<tr>
<td>$y_0 = 0$ cm
$$z_o = z_s - \frac{(b_{f3}\, d_{wt}\, t_{f3-net50} + 0.5 d_{wt}^2\, t_{w-net50})10^{-1}}{d_{wt}\, t_{w-net50} + b_{f1}\, t_{f1-net50} + 2b_{f2}\, t_{f2-net50} + b_{f3}\, t_{f3-net50}} \quad \text{cm}$$
$$c_{warp} = I_{f1}\, z_s^2 + \frac{I_{f2}\, b_{f1}^2}{200} + I_{f3}\left(\frac{d_{wt}}{10} - z_s\right)^2 \quad \text{cm}^6$$
$$I_{f1} = \left(\frac{(b_{f1} - t_{f2\text{-net50}})^3\, t_{f1-net50}}{12} + \frac{b_{f2}\, t_{f2-net50}\, b_{f1}^2}{2}\right)10^{-4} \quad \text{cm}^4$$
$$I_{f2} = \frac{b_{f2}^3\, t_{f2-net50}}{12}10^{-4} \quad \text{cm}^4$$
$$I_{f3} = \frac{b_{f3}^3\, t_{f3-net50}}{12}10^{-4} \quad \text{cm}^4$$
$$z_s = \frac{I_{f3}\, d_{wt}}{I_{f1} + I_{f3}}10^{-1} \quad \text{cm}$$</td>
</tr>
<tr>
<td colspan="2"><u>Note</u>
1. All dimensions of thickness, breadth and depth are in mm
2. Cross sectional properties not covered by this table are to be obtained by direct calculation.</td>
</tr>
</table>

3.5.2 Corrugated bulkheads

3.5.2.1 Local buckling of a unit flange of corrugated bulkheads is to be controlled according to *3.2.1.1*, for Case 1, as shown in *Table 10.3.1*, applying stress ratio $\psi = 1.0$.

3.5.2.2 The overall buckling failure mode of corrugated bulkheads subjected to axial compression is to be checked for column buckling according to *3.5.1* (e.g. horizontally corrugated longitudinal bulkheads, vertically corrugated bulkheads subject to localised vertical forces). End constraint factor corresponding to pinned ends is to be applied except for fixed end support to be used in way of stool with width exceeding 2 times the depth of the corrugation.

4 ADVANCED BUCKLING ANALYSES

4.1 General

4.1.1 Assessment

4.1.1.1 For the assessment of buckling of plates and stiffened panels subjected to combined stress fields, the advanced buckling assessment method is to be followed.

4.1.1.2 The advanced buckling assessment method is to consider the following effects in deriving the buckling capacity:

(a) non linear geometrical behaviour
(b) inelastic material behaviour
(c) initial imperfections (geometrical out-of flatness of plate and stiffeners)
(d) welding residual stresses
(e) interactions between structural elements; plates, stiffeners, girders etc.
(f) simultaneous acting loads; bi-axial compression/tension, shear and lateral pressure
(g) boundary conditions

4.1.1.3 All effects are to be modelled to represent a lower bound of structural strength. The modelling shape and amplitude of geometrical imperfections is to be such that they trigger the most critical failure modes.

4.1.1.4 The buckling strength is to be derived in accordance with the method described in *Appendix D*.

4.1.1.5 Alternative advanced buckling analysis tools may be used provided they give comparable results with the bench mark results obtained from implementing the advanced buckling methodology described in *Appendix D*.

4.1.1.6 Theoretical background, assumptions, models, verifications, calibrations, etc., for alternative advanced buckling analysis are to be submitted for review and acceptance.

SECTION 11

GENERAL REQUIREMENTS

1 HULL OPENINGS AND CLOSING ARRANGEMENTS

1.1 Shell and Deck Openings

1.1.1 General

1.1.1.1 For closing appliances for openings in superstructures, deck house sides and ends see *1.4*. For overflows and vents, and for discharges and inlets, see *1.5*.

1.1.1.2 For testing requirements, see *Sub-Section 5*.

1.1.2 Cargo tank hatches - materials

1.1.2.1 Covers for access hatches, tank cleaning and other openings for cargo tanks and adjacent spaces are to be manufactured from the following material:

(a) normal strength steel in accordance with *Section 6/1*

(b) non-ferrous material such as bronze or brass may be considered; however, aluminium alloy is not to be used for covers of any opening to cargo tanks and spaces adjacent thereto

(c) synthetic materials may also be considered, taking into account their fire resistance and physical and chemical properties in relation to the intended operating conditions. Details of the properties of the material, the design of the cover, and the method of manufacture are to be submitted for approval.

1.1.2.2 The hatch cover packing material is to be compatible with the cargoes that are intended to be carried and is to be effectively held in place.

1.1.3 Cargo tank access coamings

1.1.3.1 The height of the hatch coaming above the upper surface of the freeboard deck is not to be less than 600mm. Lower heights may be permitted by the Flag Administration. The top of the hatch coaming is also not to be lower than the highest point of the tank over which it is fitted and is to be of sufficient height for the purpose of damage stability.

1.1.3.2 The gross thickness of the coaming plate is not to be less than 10mm. Where the coaming height, as fitted, exceeds 600mm, the thickness may be required to be increased or edge stiffening fitted. The scantlings of coaming plates of tank access coamings that enclose an area of 1.2m^2 or more, and/or those that are not configured with a well rounded shape, may be subject to additional requirements.

1.1.4 Cargo tank access hatch covers

1.1.4.1 The gross thickness of unstiffened plate covers with an area less than 1.2m^2 is not to be less than 12.5mm. The gross thickness of covers of a larger area will need to be increased or the cover will require stiffening.

1.1.4.2 Flat and unstiffened covers on circular hatchways are to be secured by fastenings with a spacing of not more than 600mm.

1.1.4.3 On rectangular hatchways, the spacing of fastenings is generally not to be greater then 450mm and the distance between hatch corners, and adjacent fastenings, is not to be greater than 230mm.

1.1.4.4 The requirements of *1.1.4.1* to *1.1.4.3* do not apply to dished covers or covers of other specially approved design.

1.1.4.5 Where the cover is hinged, adequate stiffening of the coaming and cover in way of the hinge is to be provided. In general, hinges are not to be considered securing devices for the cover and should be designed so as to prevent the gasket from being over tightened.

1.1.5 Machinery access openings - protection

1.1.5.1 Machinery casings are generally to be protected by an enclosed poop or bridge; or by a deck house structure complying with the strength requirements of *1.4*.

1.1.5.2 Where a vessel is intended to operate at the freeboard allowed by the *International Convention on Load Lines* for Type-A freeboard vessels, the height of such structure is not to be less than 2.3m. The bulkheads at the forward ends of these structures are to have scantlings at least equivalent to those required for bridge-front bulkheads, see *1.4.9* and *1.4.13*.

1.1.6 Small hatches on the exposed fore deck

1.1.6.1 Openings to forward spaces as defined in *1.1.6.2* are to comply with the requirements of *1.1.6.3* to *1.1.6.14*.

1.1.6.2 These requirements apply to small hatches (generally openings 2.5m^2 or less) on the exposed deck within 0.25*L* from the F.P. and at a height less than 0.1*L* or 22m, whichever is less, from the summer load water line at the location of the hatch.

1.1.6.3 Hatches designed for emergency escape need not comply with *1.1.6.9(a), 1.1.6.9(b), 1.1.6.13* and *1 1.6.14*.

1.1.6.4 For small rectangular steel hatch covers, the plate thickness, stiffener arrangement and scantlings are to be in accordance with *Table 11.1.1* and *Figure 11.1.1*.

1.1.6.5 Stiffeners, where fitted, are to be aligned with the metal to metal contact points required by *1.1.6.10* and *1.1.6.11*. See also *Figure 11.1.1*. Primary stiffeners are to be continuous. All stiffeners are to be welded to the inner edge stiffener. See *Figure 11.1.2*.

1.1.6.6 The upper edge of the hatchway coaming is to be suitably reinforced by a horizontal member, normally not more than 190mm from the upper edge of the coaming.

1.1.6.7 For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement is to provide strength and stiffness equivalent to the requirements for small rectangular hatches.

1.1.6.8 For small hatch covers constructed of materials other than normal strength steel, the required scantlings are to provide equivalent strength and stiffness.

1.1.6.9 The primary securing devices are to be such that the hatch cover can be secured in place and be made weathertight by means of a closing mechanism employing any one of the following methods:

(a) butterfly nuts tightening onto forks (clamps)

(b) quick acting cleats, or

(c) a central locking device.

Dogs (twist tightening handles) with wedges are not acceptable.

1.1.6.10 The hatch cover is to be fitted with a gasket of elastic material. This is to be designed to allow a metal to metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged.

1.1.6.11 The metal to metal contacts are to be arranged close to each securing device as shown in *Figure 11.1.1*, and are to be of sufficient capacity to withstand the bearing force.

1.1.6.12 The primary securing method is to be designed and manufactured such that the designed compression pressure can be achieved by one person without the need for any tools.

1.1.6.13 For a primary securing method using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed to minimize the risk of butterfly nuts being dislodged while in use, by means of curving the forks upward and raising the surface on the free end, or a similar method. The gross plate thickness of unstiffened steel forks is not to be less than 16mm. An example arrangement is shown in *Figure 11.1.2*.

1.1.6.14 Small hatches on the exposed fore deck are to be fitted with an independent secondary securing device, e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device becomes loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

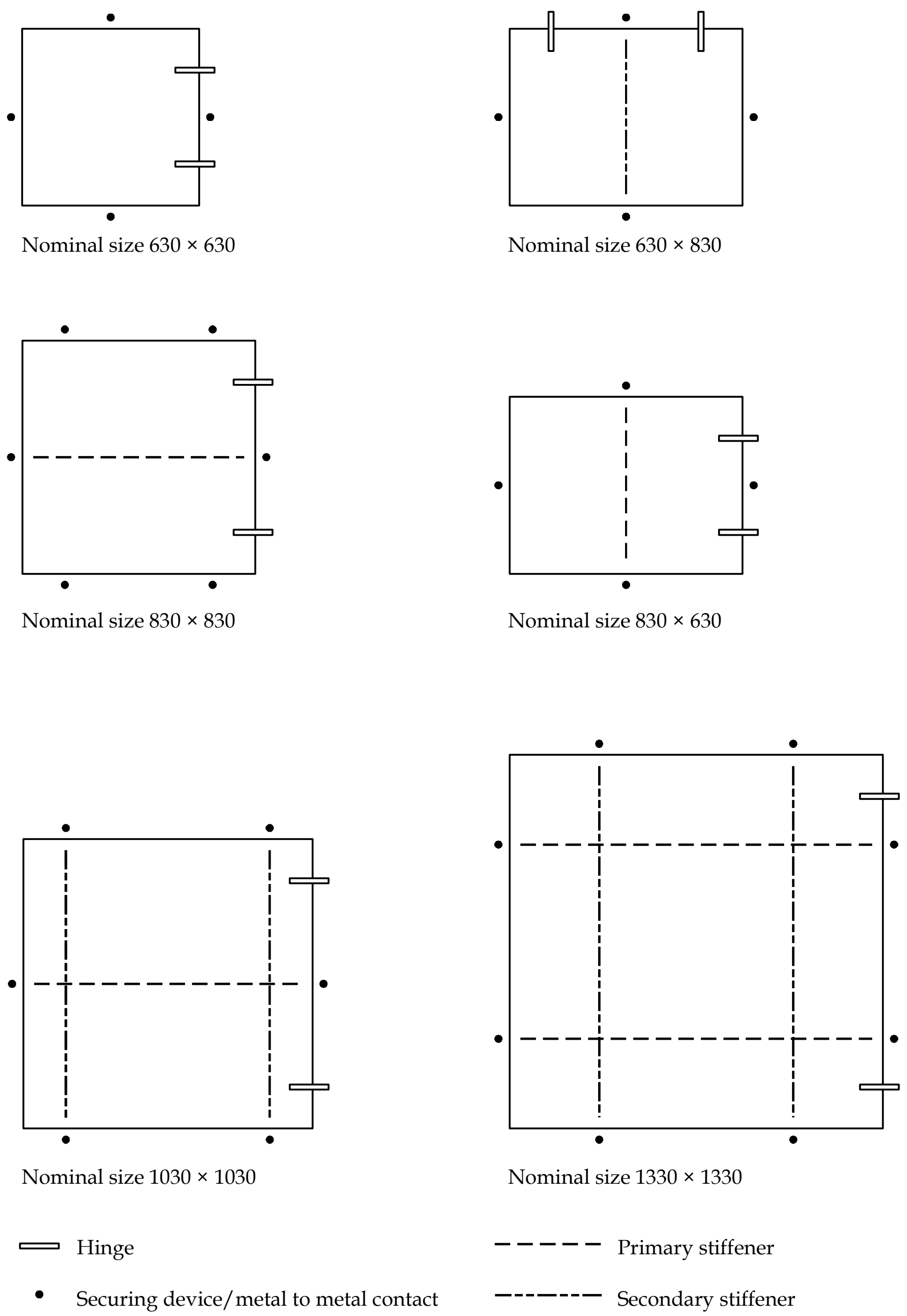
1.1.6.15 For small hatch covers located on the exposed deck within the forward 0.25L from the F.P., the hinges are to be fitted such that the predominant direction of green sea will cause the cover to close, which means that the hinges are normally to be located on the fore edge.

RCN 2 to July 2008 version (effective from 1 July 2010)

Table 11.1.1
Scantlings for Small Steel Hatch Covers on the Fore Deck

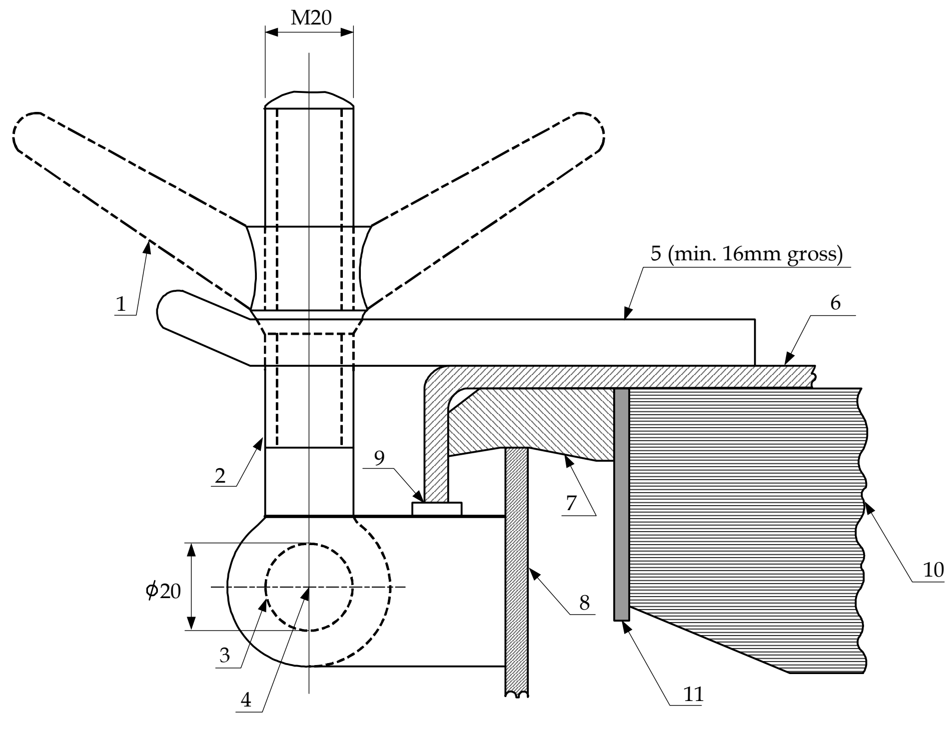
Nominal Size (mm × mm)	Cover Plate Gross Thickness (mm)	Primary Stiffeners	Secondary Stiffeners
		Gross Flat Bar Scantlings (mm × mm); number	
630 × 630	8	---	---
630 × 830	8	100 × 8; 1	---
830 × 630	8	100 × 8; 1	---
830 × 830	8	100 × 10; 1	---
1030 × 1030	8	120 × 12; 1	80 × 8; 2
1330 × 1330	8	150 × 12; 2	100 × 10; 2

Figure 11.1.1
Arrangement of Stiffeners



Note
1. Size dimensions are in millimetres

Figure 11.1.2
Example of a Primary Securing Method



(Note: Dimensions in millimeters)

1: butterfly nut
2: bolt
3: pin
4: center of pin
5: fork (clamp) plate
6: hatch cover
7: gasket
8: hatch coaming
9: bearing pad welded on the bracket of a toggle bolt for metal to metal contact
10: stiffener
11: inner edge stiffener

1.1.7 Manholes and flush deck scuttles

1.1.7.1 Manholes and flush deck scuttles in Position 1 or Position 2, as defined in *Section 4/1.2*, or within superstructures, other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight.

1.1.7.2 The strength of watertight manholes is to be equivalent to that of the deck.

1.1.7.3 Unless secured by closely spaced bolts, the covers are to be permanently attached.

1.1.8 Other openings

1.1.8.1 Openings in freeboard decks other than hatchways, machinery space openings, manholes and flush scuttles are to be protected by an enclosed superstructure, or by a deck house or companionway of equivalent strength and weathertightness. Any such opening in an exposed superstructure deck, or in the top of a deck house on the freeboard deck, which gives access to a space below the freeboard deck or a space within an enclosed superstructure, is to be protected by an efficient deck house or companionway, as defined in *1.4*.

1.1.9 Escape openings

1.1.9.1 The closing appliances of escape openings are to be readily operable from each side.

1.1.10 Rope hatches

1.1.10.1 Rope hatches may be accepted with reduced coaming height, but generally not less than 380mm, provided that they are well secured and can be opened only at the Master's discretion. The gross thickness of the coaming is to be not less than the Rule minimum gross thickness for hull envelope plating for that position, or 11mm, whichever is the lesser.

1.1.11 Portable plates

1.1.11.1 Where portable plates are required in casings or decks, for unshipping machinery or other similar reasons, they may be accepted provided that they are of equivalent strength to the un-pierced bulkhead or deck. Portable plates may be fitted with flush covers and they are to be secured by gaskets and closely spaced bolts at a distance not greater than five bolt diameters.

1.1.11.2 The sill heights of access openings and the coaming heights of deck openings, closed by covers which are kept permanently closed at sea will be specially considered.

1.1.12 Tank cleaning and ullage openings

1.1.12.1 Tank cleaning and ullage openings are to be fitted with watertight covers or an equivalent. Flush covers may be accepted for tank cleaning and ullage openings where they comply with the applicable requirements of *1.1.11*.

Table 11.1.2
900mm High Ventilator Thickness and Bracket Standards

Nominal pipe Size	Minimum fitted gross thickness, in mm	Maximum projected area of head, in cm²	Height of brackets, in mm
80A	6.3	-	460
100A	7.0	-	380
150A	8.5	-	300
200A	8.5	550	-
250A	8.5	880	-
300A	8.5	1200	-
350A	8.5	2000	-
400A	8.5	2700	-
450A	8.5	3300	-
500A	8.5	4000	-

1.2 Ventilators

1.2.1 General

1.2.1.1 Ventilators are to comply with the requirements of *1.2.2* through *1.2.6* and are also to be in accordance with any relevant requirements for machinery of the individual Classification Societies.

1.2.2 Details, arrangements and scantlings for ventilators

1.2.2.1 For standard ventilators of 900mm in height, closed by heads of not more than the tabulated projected area, the minimum pipe thickness and bracket heights are to be as specified in *Table 11.1.2*.

1.2.2.2 For ventilators of height greater than 900mm, brackets or alternative means of support are to be provided. Brackets, where fitted, are to be of suitable thickness and length according to their height.

1.2.2.3 Ventilators are to have coamings constructed of steel or other equivalent material and are to meet the requirements indicated in *Table 11.1.3*.

1.2.2.4 All component parts and connections of ventilators are to be capable of withstanding the loads defined in *1.2.3*.

1.2.2.5 Rotating type mushroom ventilator heads are not to be used for application in the areas specified in *1.2.3.1*.

1.2.2.6 Ventilators passing through superstructures, other than enclosed superstructures, are to have substantially constructed coamings of steel or other equivalent material at the freeboard deck. Ventilators of deep tanks or tunnels passing through tween decks are to be watertight with scantlings to withstand the expected pressure.

Table 11.1.3
Coamings for Ventilators

Feature	Requirement	
Height(4)	h_{coam} = 900 at Position 1 h_{coam} = 760 at Position 2(1)	
Thickness(2), (3)	$d_{coam} \leq 130$	$t_{coam\text{-}grs} = 7.5$
	$165 < d_{coam} < 320$	$t_{coam\text{-}grs} = 8.5$
	$d_{coam} \geq 470$	$t_{coam\text{-}grs} = 10.0$
	Intermediate values are to be obtained by linear interpolations	
Support(3)	Where h_{coam} exceeds 900 the coaming is to be specially supported	

Where:
h_{coam} height of coaming, in mm
d_{coam} external diameter of coaming, in mm
$t_{coam\text{-}grs}$ gross thickness of coaming, in mm

Note
1. The coaming height may need to be increased to satisfy any applicable subdivision and damage stability requirements.
2. Where the height of the ventilator exceeds that given, the gross thickness given above may be gradually reduced, above that height, to a minimum of 6.5mm.
3. See also *1.2.3* and for *1.2.4* ventilators in the forward part of the ship.
4. Heights are measured above sheathing, if fitted.

1.2.3 Applied loading on ventilators

1.2.3.1 Ventilators on an exposed deck within the forward 0.25*L*, and where the height of the exposed deck at the ventilator is less than 0.1*L* or 22m, whichever is less, from the summer load waterline are to comply with the requirements of *1.2.3.2* through *1.2.3.3* and *1.2.4.1.*

1.2.3.2 The pressures acting on ventilators, P_{vent}, and their closing devices are given by:

$$P_{vent} = 0.5 \rho_{sw} v_{sea}^2 C_1 C_2 C_3 \quad \text{kN/m}^2$$

Where:

ρ_{sw} density of sea water, 1.025 tonnes/m³

v_{sea} velocity of water over the fore deck, 13.5 m/sec

C_1 shape coefficient:

- 0.5 for pipes
- 1.3 for pipe or ventilator heads in general
- 0.8 for pipe or ventilator heads of cylindrical form with its axis in the vertical direction

C_2 slamming coefficient, 3.2

C_3 protection coefficient:

- 0.7 for pipes and ventilator heads located immediately behind a breakwater or forecastle
- 1.0 elsewhere, including immediately behind a bulwark

1.2.3.3 Forces acting in the horizontal direction on the ventilator and its closing device may be calculated from the above pressure, using the largest projected area of each component.

1.2.4 Strength requirements for ventilators and their closing devices

1.2.4.1 Bending moments and stresses in ventilators are to be calculated at critical positions:

(a) at penetration pieces

(b) at weld or flange connections

(c) at toes of supporting brackets.

Bending stresses in the net section are not to exceed $0.8\sigma_{yd}$, where σ_{yd} is the specified minimum yield stress or 0.2% proof stress of the steel at room temperature. Irrespective of corrosion protection, a corrosion addition to the net section of 2mm is then to be applied.

1.2.5 Closing appliances

1.2.5.1 Except as indicated otherwise in this paragraph, ventilator openings are to be provided with efficient, permanently attached, closing appliances. Ventilators in Position 1, the coamings of which extend to more than 4.5m above the deck, and in Position 2, the coamings of which extend to more than 2.3m above the deck, need not be fitted with closing arrangements unless unusual features of the design make it necessary. Position 1 and Position 2 are defined in *Section 4/1.2*.

1.2.6 Fire dampers

1.2.6.1 Where a fire damper is located within a ventilation coaming, an inspection port or opening at least 150mm in diameter is to be provided in the coaming to facilitate survey of the damper without disassembling the coaming or the ventilator. The closure provided for the inspection port or opening is to maintain the weathertight integrity of the coaming and, if appropriate, the fire integrity of the coaming.

1.3 Air Pipes

(RCN 2, effective from 1 July 2008)

1.3.1 General

1.3.1.1 Air pipes are to comply with the requirements of *1.3.2* through *1.3.6* and are also to be in accordance with any relevant requirements for machinery of the individual Classification Societies.

(RCN 2, effective from 1 July 2008)

1.3.2 Height

1.3.2.1 The minimum height for air pipes on decks exposed to weather is given as:

(a) 760mm for those on the freeboard deck; and

(b) 450mm for those on the superstructure deck.

The height is to be measured from the top of the sheathing, if fitted, to the point where water may have access below.

1.3.2.2 Where these heights may interfere with the working of the vessel, a lower height may be accepted subject to the fitting of an approved closing appliance at the open end of the vent.

1.3.2.3 The height may need to be increased to satisfy any applicable subdivision and damage stability requirements.

1.3.2.4 Where air pipes are led through the side of superstructures, the height of their opening is to be at least 2.3m above the summer load waterline. Automatic vent heads of approved design are to be provided.

1.3.3 Details, arrangement and scantlings for air pipes

(RCN 2, effective from 1 July 2008)

1.3.3.1 The wall thicknesses of air pipes, where exposed to weather, are not to be taken less than that given in *Table 11.1.4*.

(RCN 2, effective from 1 July 2008)

Table 11.1.4
Minimum wall Thickness for Air Pipes

External diameter, in mm	Gross minimum wall thickness, in mm
$d_{air} \leq 80$	6.0
$d_{air} \geq 165$	8.5

Where:

d_{air} external diameter of pipe, in mm

Note

1. Intermediate values are to be obtained by linear interpolations.
2. See also *1.3.4* and *1.3.5* for ventilators in forward part of the ship.

(RCN 2, effective from 1 July 2008)

1.3.3.2 For standard air pipes of 760mm in height, closed by heads of not more than the tabulated projected area, the minimum pipe thickness and bracket heights are to be as specified in *Table 11.1.5*. Where brackets are required, three or more radial brackets are to be fitted. In addition, the relevant requirements of *1.3.4* are to be applied.

1.3.3.3 Brackets are to have a gross thickness of 8mm or more, minimum length of 100mm, and height according to *Table 11.1.5*, but need not extend over the joint flange for the head. Bracket toes at the deck are to be suitably supported. In addition, loads according to *1.3.4* are to be applied. Brackets, where fitted, are to be of suitable thickness and length according to their height.

1.3.3.4 Gross pipe thickness is to be in accordance with the relevant requirements for machinery of the individual Classification Societies.

1.3.4 Applied loading on air pipes

(RCN 2, effective from 1 July 2008)

1.3.4.1 Air pipes on an exposed deck within the forward 0.25*L*, where the height of the exposed deck at the air pipe or sounding pipe is less than 0.1*L* or 22m, whichever is less, from the summer load waterline are to comply with the requirements of *1.3.4.2* through *1.3.4.3* and *1.3.5.1*.

(RCN 2, effective from 1 July 2008)

Table 11.1.5
Thickness and Bracket Standards for 760mm High Air Pipes

Nominal pipe size	Minimum fitted gross thickness, in mm	Maximum projected area of head, in cm^2	Height (1) of brackets, in mm
65A	6.0	-	480
80A	6.3	-	460
100A	7.0	-	380
125A	7.8	-	300
150A	8.5	-	300
175A	8.5	-	300
200A	8.5(2)	1900	300 (2)
250A	8.5(2)	2500	300 (2)
300A	8.5(2)	3200	300 (2)
350A	8.5(2)	3800	300 (2)
400A	8.5(2)	4500	300 (2)

Note
1. Brackets (see *1.3.3.2*) need not extend over the joint flange for the head.
2. Brackets are required where the gross thickness of the pipe section is less than 10.5mm, or where the tabulated projected head area is exceeded.

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1.3.4.2 The pressures acting on air pipes and their closing devices, P_{pipe}, are given by:

$$P_{pipe} = 0.5\rho_{sw} v_{sea}^2 C_1 C_2 C_3 \quad \text{kN/m}^2$$

Where:

ρ_{sw} density of sea water, 1.025 tonnes/m^3

v_{sea} velocity of water over the fore deck, 13.5 m/sec

C_1 shape coefficient:

0.5 for pipes

1.3 for pipe or ventilator heads in general

0.8 for pipe or ventilator heads of cylindrical form with its axis in the vertical direction

C_2 slamming coefficient, 3.2

C_3 protection coefficient:

0.7 for pipes and ventilator heads located immediately behind a breakwater or forecastle

1.0 elsewhere, including immediately behind a bulwark

(RCN 2, effective from 1 July 2008)

1.3.4.3 Forces acting in the horizontal direction on the pipe and its closing device may be calculated from the above pressure, using the largest projected area of each component.

1.3.5 Strength requirements for air pipes and their closing devices

(RCN 2, effective from 1 July 2008)

1.3.5.1 Bending moments and stresses in air pipes are to be calculated at critical positions:

(a) at penetration pieces

(b) at weld or flange connections

(c) at toes of supporting brackets.

Bending stresses in the net section are not to exceed $0.8\sigma_{yd}$, where σ_{yd} is the specified minimum yield stress or 0.2% proof stress of the steel at room temperature. Irrespective of corrosion protection, a corrosion addition to the net section of 2mm is then to be applied.

(RCN 2, effective from 1 July 2008)

1.3.6 Closing appliances for air pipes

1.3.6.1 All air pipes terminating on the weather deck are to be fitted with return bends (gooseneck), or other equivalent arrangement to prevent water from passing inboard.

1.3.6.2 A weathertight permanent means of closure is to be provided for the outlet. The closing device is to be of an automatic type, i.e. close automatically upon submergence (e.g. ball float or equivalent) for any one of the following cases:

(a) the outlet is submerged, with the ship at its summer load water line at an angle of 40 degrees, or the angle of down flooding if this is less than 40 degrees

(b) to comply with damage stability requirements.

1.3.6.3 Air pipes are not to be fitted with valves that may impair the venting function.

1.4 Deck Houses and Companionways

1.4.1 Applicability

1.4.1.1 The requirements of this section are applicable to steel deck houses and companionways, as defined in *1.4.3.1* and *1.4.3.2*.

1.4.1.2 Scantling requirements depend on the vertical location of the item relative to the waterline. This location is categorized in terms of “tiers”.

1.4.2 Materials

1.4.2.1 The scantlings in *1.4* apply to structures constructed of hull structural steel, in accordance with the requirements of *Section 6/1*. Scantlings of aluminium alloy deck houses will be considered by the individual Society, supported by the submission of a specification of the proposed alloys.

1.4.3 Definitions

1.4.3.1 A deck house is defined as a decked structure, above the strength deck, with the side plating being inboard of the shell plating by more than 4% of the ship's breadth, B.

1.4.3.2 A companionway is defined as a weathertight deck structure; protecting an access opening leading below the freeboard deck, or into a space within an enclosed superstructure.

1.4.3.3 A tier is defined as a measure of the extent of a deck house. A deck house tier consists of a deck and external bulkheads. In general, the first tier is the tier situated on the freeboard deck.

1.4.4 Structural continuity

1.4.4.1 In deck houses aft, the front bulkhead is to be in line with a transverse bulkhead in the hull below or is to be supported by a combination of partial transverse bulkheads, girders and pillars.

1.4.4.2 The aft end bulkhead is to be effectively supported.

1.4.4.3 At the corners of the deck house attachment at the strength deck, attention is to be given to the connection of the deck house to the deck and the arrangements to transmit load into the under-deck supporting structure.

1.4.4.4 As far as practicable, exposed sides and main longitudinal and transverse bulkheads are to be located above bulkheads and/or deep girder frames in the hull structure, and are to be in line in the various tiers of accommodation. Where such structural arrangement in line is not possible, there is to be other effective support.

1.4.4.5 Arrangements are to be made to minimize the effect of discontinuities in erections. All openings cut in the sides are to be substantially framed and have well-rounded corners. Continuous coamings or girders are to be fitted below and above doors and similar openings.

1.4.5 Deck plating

1.4.5.1 The gross thickness of the plating, $t_{dk\text{-}grs}$, is not to be less than:

$$t_{dk\text{-}grs} = 7.5\sqrt{\frac{k\,s}{s_{std}}}$$ mm, on first tier deck houses

$$t_{dk\text{-}grs} = 7.0\sqrt{\frac{k\,s}{s_{std}}}$$ mm, on second tier deck houses

$$t_{dk\text{-}grs} = 6.5\sqrt{\frac{k\,s}{s_{std}}}$$ mm, on third tier and above deck house

Where:

s spacing of stiffeners, in m

k	higher strength steel factor, as defined in *Section 6/1.1.4*
σ_{yd}	specified minimum yield stress of the material, in N/mm^2
s_{std}	standard reference spacing of longitudinals or beams, in m: $= 0.470 + 0.00167L_1$
L_1	rule length, as defined in *Section 4/1.1.1.1*, but is not to be taken greater than 250m

1.4.5.2 The plating thickness inside deck houses may be reduced by 10 percent provided that the reduced gross thickness, $t_{dh\text{-}grs}$, is not less than:

$$t_{dh\text{-}grs} = (5.8s + 1)\sqrt{k} \quad \text{mm, but is not to be less than 5.5mm}$$

Where:

s	spacing of stiffeners, in m
k	higher strength steel factor, as defined in *Section 6/1.1.4*
σ_{yd}	specified minimum yield stress of the material, in N/mm^2

1.4.6 Deck longitudinals and beams

1.4.6.1 For each longitudinal or beam, in association with the plating to which it is attached, the gross section modulus, $Z_{lng\text{-}grs}$, is not to be less than:

$$Z_{lng\text{-}grs} = 4.563s\,l_{bdg}^{\;2}h_{tier}k \quad \text{cm}^3$$

Where:

s	spacing of stiffeners, in m
l_{bdg}	effective bending span, as defined in *Section 4/2.1.1*, in m
B	as defined in *Section 4/1.1.3.1*
h_{tier}	load head in relation to the deck house tier, in m: 1.68 for poop and first tier above freeboard deck 1.30 for second tier above freeboard deck 0.91 for third and higher tiers above freeboard deck For decks with position second tier or higher above the freeboard deck, generally used only as weather covering, the value of h_{tier} may be reduced, but in no case is it to be less than 0.46
k	higher strength steel factor, as defined in *Section 6/1.1.4*
σ_{yd}	specified minimum yield stress of the material, in N/mm^2

1.4.7 Deck girders and transverses

1.4.7.1 Deck girders and transverses are to be arranged to support beams or deck longitudinals. Where arrangements of deck girders and transverses are such that these members act as a grillage structure, additional analysis may be carried out to consider grillage effects and justify that scantlings are equivalent to those required by *1.4.7.2* and *1.4.7.3*. In this analysis gross scantlings are to be used, basic geometry parameters are to be as indicated in *1.4.7.2*, the load is to be taken as the head required by *1.4.7.2* with a unit density of 0.715tonnes/m^3 and the permissible bending stress is to be taken as $0.67\sigma_{yd}$. For the determination of equivalent

scantlings to those required by *1.4.7.3*, equivalency is to be based on the deflection at girder/transverse intersection points and at midspan of the members, and the permissible deflection is to be taken as the deflections calculated for a simple beam meeting the requirements of *1.4.7.2* and with depth d_{grd} as required by *1.4.7.3*.

1.4.7.2 For each deck girder or transverse web, the gross section modulus, $Z_{t\text{-}grs}$, is not to be less than:

$$Z_{t\text{-}grs} = 4.74 b_{dk} l_{bdg}{}^2 h_{tier} k \quad \text{cm}^3$$

Where:

b_{dk}	mean breadth of the area of deck supported, in m
l_{bdg}	effective bending span, to be taken as the distance between centres of supporting pillars, or between pillars, tranverse members, girders and/or bulkheads supporting them, in m. Where an effective bracket is fitted at the bulkhead, the length l_{bdg} may be modified, see *Section 4/2.1.4*
h_{tier}	load head in relation to the deck house tier, in m: 1.68 for poop and first tier above freeboard deck 1.30 for second tier above freeboard deck 0.91 for third and higher tiers above freeboard deck For decks with position second tier or higher above the freeboard deck, generally used only as weather covering, the value of h_{tier} may be reduced, but in no case is it to be less than 0.46
k	higher strength steel factor, as defined in *Section 6/1.1.4*
σ_{yd}	specified minimum yield stress of the material, in N/mm^2

1.4.7.3 The depth of girders and transverse webs, d_{grd}, is not to be less than:

$$d_{grd} = 0.0583 l_{bdg} \quad \text{m}$$

Where:

l_{bdg}	effective bending span, to be taken as the distance between centres of supporting pillars, or between pillars, transverse members, girders and/or bulkheads supporting them, in m. Where an effective bracket is fitted at the bulkhead, the length l_{bdg} may be modified, see *Section 4/2.1.4*

Where girders and transverse webs intersect, consideration may be given to accept a lesser depth for the longer member, where the shorter member provides full support to the longer member.

1.4.7.4 The gross thickness of girders or transverse webs is not to be taken as less than 1mm per 100mm of depth, plus an additional 4mm. Where web shear strength and buckling capacity are demonstrated to be satisfactory, lesser thicknesses may be accepted. For shear strength analysis gross scantlings are to be used, basic geometry parameters are to be as indicated in *1.4.7.2*, the load is to be taken as the head required by *1.4.7.2* with a unit density of 0.715 tonnes/m^3 and the permissible shear stress is to be taken as $0.39\sigma_{yd}$. Bucking capacity is demonstrated as satisfactory when the depth to gross thickness ratio of the web is less than 75.

1.4.8 Pillars

1.4.8.1 The gross scantlings of pillars are to be such that the permissible load, determined in accordance with *1.4.8.2,* is greater than the design load, determined in accordance with *1.4.8.3*, considering the requirement of *1.4.8.4*.

1.4.8.2 The permissible loading on a pillar, W_{perm}, is given by:

$$W_{perm} = (f_{s1} - h_{pill}\, f_{s2}/r_{gyr\text{-}grs})A_{pill\text{-}grs} \quad \text{kN}$$

Where:

f_{s1} steel factor:

12.09	normal strength steel
13.59	HT27 strength steel
16.11	HT32 strength steel
17.12	HT34 strength steel
18.12	HT36 strength steel
20.14	HT40 strength steel

h_{pill} distance between the top of the pillar supporting deck or other structure to the underside of the supported beam or girder, in m

f_{s2} steel factor:

4.44	normal strength steel
5.57	HT27 strength steel
7.47	HT32 strength steel
8.24	HT34 strength steel
9.00	HT36 strength steel
10.52	HT40 strength steel

$r_{gyr\text{-}grs}$ radius of gyration for gross pillar section, in cm

$A_{pill\text{-}grs}$ gross cross sectional area of pillar, in cm^2

1.4.8.3 The design load for a specific pillar, W_{des}, is given by:

$$W_{des} = 7.04\, b_{dk}\, h_{tier}\, l_{dk} \quad \text{kN}$$

Where:

b_{dk} mean breadth of the area of deck supported, in m

h_{tier} load head in relation to the deck house tier, in m:

1.68	for poop and first tier above freeboard deck
1.30	for second tier above freeboard deck
0.91	for third and higher tiers above freeboard deck

For decks with position second tier or higher above the freeboard deck, generally used only as weather covering, the value of h_{tier} may be reduced, but in no case is it to be less than 0.46

l_{dk} mean length of the area of deck supported, in m

1.4.8.4 Where pillars are arranged in a vertical line, the design load on the pillar at each level is to be calculated by summing the design load for the deck directly above the pillar and one-half of the design load for each pillar above.

1.4.9 Exposed bulkheads

1.4.9.1 The scantlings of the exposed bulkheads of deck houses and companionways are to be in accordance with *1.4.10* to *1.4.13*. Increased scantlings may be required where the structure supports loads from deck equipment, fittings, etc.

1.4.9.2 Special consideration may be given to the bulkhead scantlings of deck houses which do not protect openings in the freeboard deck, superstructure deck or in the top of a lowest tier deck house. Special consideration may also be given to the bulkhead scantlings of deck houses which do not protect machinery casings, provided they do not contain accommodation or do not protect equipment essential to the operation of the vessel.

1.4.9.3 Long deck houses may need additional support in order to provide resistance to racking, see *1.4.13*.

1.4.10 Exposed bulkhead plating

1.4.10.1 The gross thickness of plating, $t_{blk\text{-}grs}$, is not to be less than that calculated from *1.4.10.2* and that given by:

$$t_{blk\text{-}grs} = 3s\sqrt{k\,h_{des}} \quad \text{mm}$$

Where:

s spacing of stiffeners, in m

k higher strength steel factor, as defined in *Section 6/1.1.4*

σ_{yd} specified minimum yield stress of the material, in N/mm^2

h_{des} design head, in m:

$C_4[(C_5 f) - z]c$

but is not to be taken less than given below for the specified location:

$2.5 + L_1/100$ unprotected front bulkheads on the lowest tier

$1.25 + L_2/200$ elsewhere

L_1 rule length, L, as defined in *Section 4/1.1.1.1*, but is not to be taken greater than 250m

L_2 rule length, L, as defined in *Section 4/1.1.1.1*, but is not to be taken greater than 300m

C_4 coefficient as given in *Table 11.1.6*

C_5 coefficient:

$$1.0 + \left[\frac{(x/L) - 0.45}{C_{b1} + 0.2}\right]^2 \qquad \text{where } x/L \le 0.45$$

$$1.0 + 1.5\left[\frac{(x/L) - 0.45}{C_{b1} + 0.2}\right]^2 \qquad \text{where } x/L > 0.45$$

C_{b1} block coefficient as defined in *Section 4/1.1.9.1*, but is not to be taken as less than 0.60 or greater than 0.80. For aft end

	bulkheads forward of amidships, C_{b1} may be taken as 0.80
x	distance between the A.P. and the bulkhead being considered, in m. Deck house side bulkheads are to be divided into equal parts not exceeding 0.15*L* in length, and x is to be measured from the A.P. to the centre of each part considered
L	rule length, as defined in *Section 4/1.1.1.1*
f	as defined in *Table 11.1.7*
z	vertical distance from the summer load waterline measured to the middle of the plate, in m
c	$0.3 + 0.7 b_{dh} / B_1$ but is not to be taken as less than 1.0 for exposed machinery casing bulkheads and in no case is b_{dh}/B_1 to be taken as less than 0.25
b_{dh}	breadth of deck house at the position being considered, in m
B_1	actual breadth of the vessel at the freeboard deck at the position being considered, in m

Table 11.1.6
Values of 'C_4'

Bulkhead location	Value of 'C_4'
Unprotected front, lowest tier	$2.0 + L_2/120$
Unprotected front, 2nd tier	$1.0 + L_2/120$
Unprotected front, 3rd tier and above	$0.5 + L_2/150$
Protected front, all tiers	$0.5 + L_2/150$
Sides, all tiers	$0.5 + L_2/150$
Aft ends, aft of amidships, all tiers	$0.7 + (L_2/1000) - 0.8x/L$
Aft ends, forward of amidships, all tiers	$0.5 + (L_2/1000) - 0.4x/L$

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Table 11.1.7
Values of 'f'

L, in m	f, in m
90	6.00
100	6.61
120	7.68
140	8.65
160	9.39
180	9.88
200	10.27
220	10.57
240	10.78
260	10.93
280	11.01
≥ 300	11.03

Note
1. This Table is based on the equations given in *Table 11.1.8*

Table 11.1.8
Origin of '*f*' Values

L, in m	*f*, in m
$L \leq 150$	$(L/10)(e^{-L/300}) - [1-(L/150)^2]$
$150 < L < 300$	$(L/10)(e^{-L/300})$
$L \geq 300$	11.03

1.4.10.2 The gross thickness for the lowest tier bulkheads, $t_{blk\text{-}tier\text{-}grs}$, is not to be less than:

$$t_{blk-tier-grs} = 5.0 + L_1/100 \quad \text{mm}$$

For other tiers, the gross thickness of bulkheads is not to be less than:

$$t_{blk\text{-}tier\text{-}grs} = 4.0 + L_1/100 \quad \text{mm, or 5.0mm, whichever is greater}$$

Where:

L_1 rule length, L, as defined in *Section 4/1.1.1.1*, but is not to be taken greater than 250m

1.4.11 Exposed bulkhead stiffeners

1.4.11.1 Each stiffener, in association with the plating to which it is attached, is to have a gross section modulus, $Z_{blk\text{-}grs}$, not less than:

$$Z_{blk\text{-}grs} = 3.5\, s\, h_{tween}{}^2 h_{des}\, k \quad \text{cm}^3$$

Where:

s spacing of stiffeners, in m

h_{tween} 'tween deck height, in m

h_{des} design head, as defined in *1.4.10.1*, with z taken as the vertical distance from the summer load waterline to midpoint of the stiffener span, in m

k higher strength steel factor, as defined in *Section 6/1.1.4*

σ_{yd} specified minimum yield stress of the material, in N/mm²

1.4.12 Stiffener end attachments for stiffeners on exposed bulkheads

1.4.12.1 Both ends of the webs of lowest tier bulkhead stiffeners are to be effectively attached. The scantlings of stiffeners having other types of end connection will be specially considered.

1.4.13 Web arrangements for webs on exposed bulkheads

1.4.13.1 In long deck houses with multiple tiers, web frames or partial bulkheads are to be fitted within the first tier, spaced a maximum of approximately 9m apart and arranged, where practicable, in line with watertight bulkheads below.

1.4.13.2 Webs are also to be arranged in way of large openings, boats davits and other points of high loading.

1.4.14 Closing arrangements for openings in deck houses and companionways

1.4.14.1 All openings in the bulkheads of deck houses and companionways, which give direct access to enclosed superstructures or to spaces below the freeboard, are to be

provided with efficient means of closing so that in any sea condition, water will not penetrate the vessel.

1.4.14.2 Doors of such openings are to be of steel or other equivalent material, permanently and strongly attached to the bulkhead. The doors are to be provided with gaskets and clamping devices, or other equivalent arrangements, which are to be permanently attached to the bulkhead or to the doors themselves. The doors are to be so arranged that they can be operated from both sides of the bulkhead. Doors complying with a recognized national or international standard will generally be accepted.

1.4.14.3 Access openings are to be framed and stiffened so that the whole structure is equivalent to the un-pierced bulkhead when closed.

1.4.14.4 Except as permitted by *1.4.14.5*, access doors, air inlets and openings to accommodation spaces, control stations and machinery spaces, are not to face the cargo tank region. They are to be located on the transverse bulkhead or on the side of the deck house at a distance of at least 0.04*L* and not less than 3m from the end of the deck house facing the cargo tank region. This distance need not exceed 5m.

1.4.14.5 Access doors in boundary bulkheads facing the cargo tank region, or within the 5m limits specified in *1.4.14.4*, leading to the main cargo control stations and to such service spaces used as provision rooms, store rooms and lockers, may be permitted, provided they do not give access directly or indirectly to any other space containing or providing for accommodation, control stations or service spaces such as galley, pantries or work shops, or similar spaces containing source of vapour ignition. The boundary of such a space is to be insulated to "A-60" class standard, with the exception of the boundary facing the cargo tank region.

1.4.15 Sills of access openings

1.4.15.1 The height of the sills of access openings, in the bulkheads of deck houses and companionways, which give direct access to enclosed superstructures or to spaces below the freeboard deck, is to be a minimum of 600mm in Position 1 and 380mm in Position 2, as defined in *Section 4/1.2*.

1.4.16 Access openings in machinery casings on Type 'A' freeboard tankers

1.4.16.1 In general, there are to be no openings giving direct access from the freeboard deck to the machinery space in exposed machinery casings.

1.4.16.2 A door complying with the requirements of *1.4.14.1* to *1.4.14.3* may be permitted in the exposed machinery casing provided that it leads to a space or passageway which is as strongly constructed as the casing, and is separated from the engine room by a second door complying with the requirements of *1.4.14.1* to *1.4.14.3*. The sill of the exterior door is not to be taken less than 600mm and the sill of the second door is not to be taken less than 230mm.

1.4.17 Windows and side scuttles

1.4.17.1 Side scuttles, in the external bulkheads of deck houses and weathertight doors, are to be of substantial construction in accordance with a recognised national or international standard.

1.4.17.2 Windows and side scuttles, fitted in the boundaries of deck houses protecting direct access into superstructures, or to spaces below the freeboard deck, are to be fitted with efficient hinged inside deadlights.

1.4.17.3 Windows and portlights facing the cargo tank region, and on the side of the superstructures or deck houses within the limits specified in *1.4.14.4* and *1.4.14.5*, shall be of a fixed (non-opening) type. Such windows and portlights, except wheelhouse windows, shall be constructed to "A-60" class standard.

1.5 Scuppers, Inlets and Discharges

1.5.1 Drains – enclosed spaces

1.5.1.1 Scuppers and discharges which drain spaces below the freeboard deck, or spaces within intact superstructures or deck houses on the freeboard deck, fitted with doors complying with the requirements of the *International Convention on Load Lines, Regulation 12*, may be led to the bilges in the case of scuppers, or to suitable sanitary tanks in the case of sanitary discharges. Alternatively, they may be led overboard, provided that:

(a) the freeboard is such that the deck edge is not immersed when the ship heels to five degrees either way, and

(b) each drain is fitted with means of preventing water from passing inboard, in accordance with *1.5.3*.

1.5.2 Drains – open spaces

1.5.2.1 Drains leading from superstructures or deck houses not fitted with doors complying with the requirements of *International Convention on Load Lines, Regulation 12* are to be led overboard.

1.5.3 Prevention of water passing inboard

1.5.3.1 Drains either from spaces below the freeboard deck or from within superstructures and deck houses on the freeboard deck, where permitted to be led overboard, see *1.5.1.1(a)*, are to be fitted with efficient and accessible means for preventing water from passing inboard, in accordance with *1.5.3.2* to *1.5.3.7*.

1.5.3.2 For drains which remain open during normal operation of the ship, such as sanitary discharges, means for preventing water passing inboard are to be in accordance with those given below for the area described. h_{disc} is the height from the summer load line to the inboard end of the discharge, in m:

(a) $h_{disc} \le 0.01L_L$:

- one automatic non-return valve with a positive means of closing it from a position above the freeboard deck
- alternatively, one automatic non-return valve and one positive closing valve controlled from above the freeboard deck may be accepted.

(b) $0.01L_L < h_{disc} \le 0.02L_L$:

- two automatic non-return valves, without positive means of closing, provided that the inboard valve is always accessible for examination under service conditions
- the inboard valve is to be located above the deepest salt water load line
- if this is not practicable, additional locally controlled positive closing may be provided outboard, or the outboard non-return valve may be provided with a

locally controlled positive closing feature, in which case the inboard valve need not be located above the deepest salt water load line.

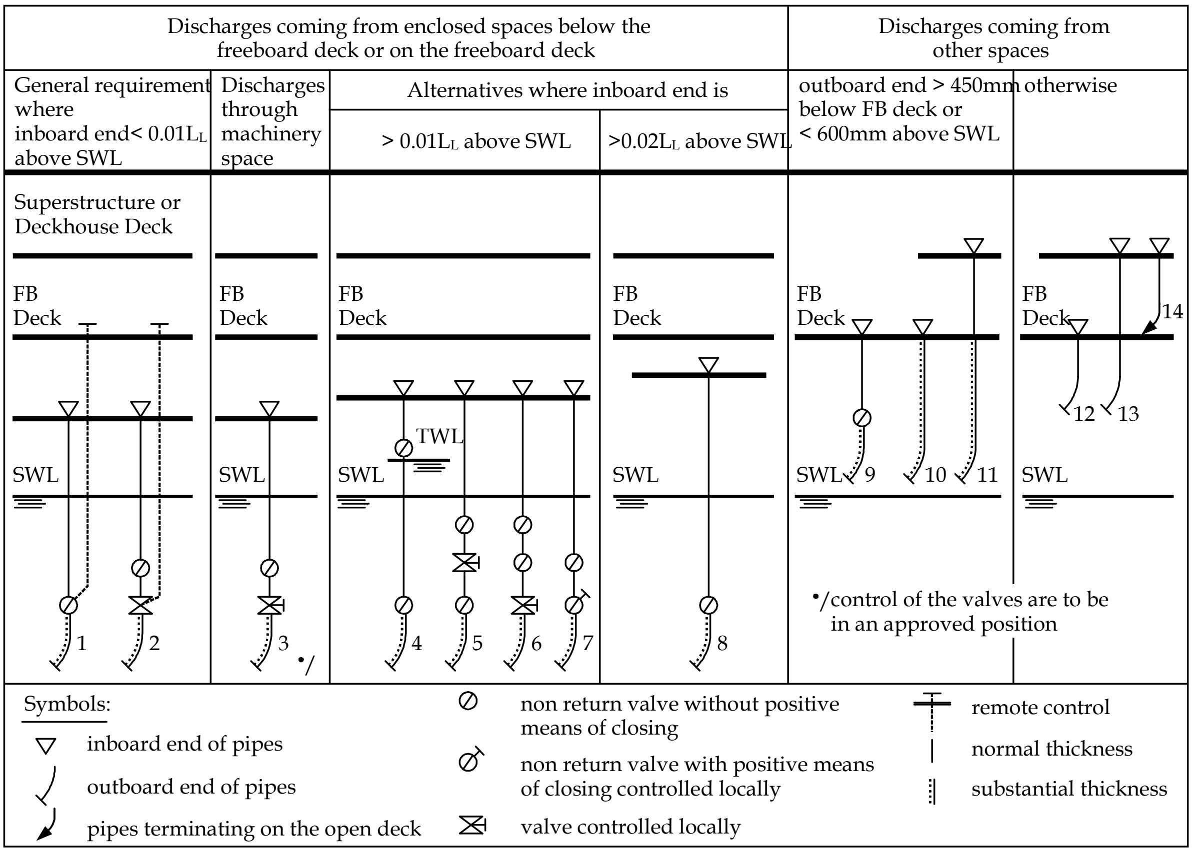
(c) $h_{disc} > 0.02L_L$:

- one single automatic non-return valve without positive means of closing.

1.5.3.3 For overboard discharges in way of machinery spaces, a locally operated positive closing valve at shell together with a non-return valve inboard, may be accepted in lieu of those required by *1.5.3.2*.

1.5.3.4 For acceptable arrangements for discharges and scuppers, see *Figure 11.1.3*.

Figure 11.1.3
Diagrammatic Arrangement of Discharge and Scupper Systems



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1.5.3.5 For drains which are closed at sea, such as gravity drains from topside ballast tanks, a single screw down valve operated from the deck may be accepted.

1.5.3.6 The means for operating the positive closing valve are to be readily accessible and provided with an indicator showing whether the valve is open or closed.

1.5.3.7 Drain pipes originating at any level and penetrating the shell either more than 450mm below the freeboard deck or less than 600mm above the summer load waterline are to be provided with a non-return valve at the shell. This valve, unless required by *1.5.3.2* through *1.5.3.4*, may be omitted if the pipe is of substantial thickness, in accordance with *1.5.7.3*.

1.5.4 Sea inlets

1.5.4.1 In manned machinery spaces, main and auxiliary sea inlets and discharges in connection with the operation of machinery may be controlled locally. The control is

to be readily accessible and provided with indicators showing whether the valves are open or closed.

1.5.5 Shell valves and fittings

1.5.5.1 For installation; the shell valves are to be mounted on the shell (or sea chest). However, where it is impracticable to do so, a distance piece, of substantial thickness in accordance with *1.5.7.3*, may be fitted. Shell outlets are to be so located as to prevent any discharge falling onto a lowered survival craft.

1.5.5.2 For material; all required shell valves and fittings are to be of steel, bronze or other approved ductile material. Valves of ordinary cast iron or similar material are not acceptable.

1.5.5.3 Material readily rendered ineffective by heat is not to be used for shell connection where the failure of the material in case of fire would give rise to danger of flooding.

1.5.6 Unattended machinery space

1.5.6.1 For unattended machinery space; the control of any valve serving a sea inlet, a discharge below the waterline, or a bilge injection system, is to be so sited as to allow adequate time to reach and operate the control, in case of ingress of water to the space with the ship in the fully loaded condition.

1.5.6.2 For application of *1.5.6.1* in an unattended machinery space; where it can be demonstrated by calculation that the damaged water line will not be above the tank top floor level after 10 minutes from the initiation of the uppermost bilge level alarm, the valve control may be from the tank top floor.

Guidance Note:

Various Flag Administrations have interpretations of this requirement. Where the ship is flagged by an Administration having an interpretation of this requirement, the interpretation of the Flag Administration shall take precedence or the requirements of *1.5.6.2*.

1.5.7 Pipes

1.5.7.1 All pipes from shell to the first valve are to be of steel or other equivalent material.

1.5.7.2 The gross wall thickness of steel piping inboard of the valve is not to be less than that given in *Table 11.1.9*, unless substantial thickness is required.

Table 11.1.9
Thickness of Normal Steel Piping

External diameter, in mm	Gross wall thickness, in mm
≤ 155	4.5
≥ 230	6.0

Note
1. Intermediate values are to be obtained by linear interpolation.

1.5.7.3 The gross wall thickness of steel piping, where required to be of substantial thickness, see *1.5.3.7* and *1.5.5.1*, is not to be less than given in *Table 11.1.10*.

Table 11.1.10
Thickness of Substantial Steel Piping

External diameter, in mm	Gross wall thickness, in mm
≤ 80	7.0
180	10.0
≥ 220	12.5

Note
1. Intermediate values are to be obtained by linear interpolation.

1.5.8 Rubbish chutes, offal and similar discharges

1.5.8.1 Rubbish chutes, offal, and similar discharges are to be constructed of mild steel piping or plating equal to the shell thickness. Other materials will be specially considered.

1.5.8.2 Openings are to be kept clear of the sheer strake and areas of high stress concentration.

1.5.8.3 Rubbish chute hoppers are to be provided that comprise a hinged weathertight cover at the inboard end with an interlock so that the discharge flap and hopper cover cannot be open at the same time.

1.5.8.4 The hopper cover is to be secured closed when not in use, and a suitable notice is to be displayed at the control position.

1.5.8.5 Where the inboard end of the hopper is less than $0.01L_L$, a positive closing valve is to be provided in addition to the cover and flap, in an easily accessible position above the deepest salt water load line.

1.5.8.6 The valve is to be controlled from a position adjacent to the hopper and provided with an open/shut indicator. The valve is to be kept closed when not in use, and a notice to that effect is to be displayed at the valve operating position.

2 CREW PROTECTION

2.1 Bulwarks and Guardrails

2.1.1 General

2.1.1.1 Bulwarks or guard rails are to be provided at the boundaries of exposed freeboard and superstructure decks, at the boundary of first tier deck houses and at the ends of superstructures.

2.1.1.2 Bulwarks, or guard rails, are to be a minimum of 1.0m in height, measured above sheathing, and are to be constructed as required in *2.1.2*. Where this height would interfere with the normal operation of the vessel, a lesser height may be approved. Where approval of a lower height is requested, justifying information is to be submitted.

2.1.1.3 Within 0.6L amidships, bulwarks are to be arranged to ensure that they are free from hull girder stresses.

2.1.1.4 Satisfactory means in the form of guard rails, life lines, gangways, under deck passages or an equivalent are to be provided for the protection of crew during passage from their quarters, the machinery space, and all other locations necessary for the crewing of the ship, see *2.3.1.1*.

2.1.2 Construction of bulwarks

2.1.2.1 The gross thickness of bulwark plating, at the boundaries of exposed freeboard and superstructure decks, is not to be less than that given in *Table 11.2.1*.

Table 11.2.1
Thickness of Bulwark Plates

Height of Bulwark	Gross Thickness
1.8m or more	As required for superstructure in the same position
1.0m	6.5mm
Intermediate height	To be determined by linear interpolation

2.1.2.2 Plate bulwarks are to be stiffened by a top rail. Plate bulwarks on the freeboard deck and forecastle deck are to be supported by stays having a spacing generally not greater than 2.0m.

2.1.2.3 The free edge of the stay is to be stiffened.

2.1.2.4 The gross section modulus of stays, $Z_{stay-grs}$, is not to be less than that given below. In the calculation of the section modulus, only the material connected to the deck is to be included. The bulb or flange of the stay may be taken into account where connected to the deck. Where, at the ends of the ship, the bulwark plating is connected to the sheer strake, a width of attached plating, not exceeding 600mm, may also be included.

$$Z_{stay-grs} = 77 h_{blwk}{}^2 s_{stay} \quad \text{cm}^3$$

Where:

h_{blwk} height of bulwark from the top of the deck plating to the top of the rail, in m

s_{stay} spacing of the stays, in m

2.1.2.5 Where mooring fittings subject the bulwark to large forces, the strength of the stays is to be suitably upgraded.

2.1.2.6 Bulwark stays are to be supported by, or are to be in line with, suitable under deck stiffening. The stiffening is to be connected by double continuous fillet welds in way of bulwark stay connections.

2.1.2.7 Where bulwarks are cut to form a gangway or other opening, stays of increased strength are to be fitted at the ends of openings.

2.1.2.8 Bulwarks are to be adequately strengthened and increased in thickness in way of mooring pipes.

2.1.2.9 Cuts in bulwarks for gangways or other openings are to be kept clear of breaks of superstructures.

2.1.2.10 Where bulwarks are fitted, freeing ports are to be provided as required in *2.1.5*. The freeing ports are to comply with the requirements of the individual Classification Society.

2.1.3 Construction of guard rails

2.1.3.1 Stanchions of guard rails required by *2.1.1.1* are to comply with the following requirements:

(a) fixed, removable or hinged stanchions are to be fitted approximately 1.5m apart

(b) at least every third stanchion is to be supported by a bracket or stay

(c) removable or hinged stanchions are to be capable of being locked in the upright position

(d) in the case of ships with rounded gunwales, the stanchions are to be placed on the flat of the deck

(e) in the case of ships with sheer strake, the stanchions are not to be attached to the sheer strake, upstand or a continuous gutter bar.

2.1.3.2 The size of openings, below the lowest course of rails and the deck or upstand, is to be a maximum of 230mm. The distance between other courses is not to be greater than 380mm.

2.1.3.3 Wire ropes may be accepted, in lieu of guard rails, only in special circumstances and then only in limited lengths. In such cases, they are to be made taut by means of turnbuckles.

2.1.3.4 Chains may be accepted, in lieu of guard rails, only where they are fitted between two fixed stanchions and/or bulwarks.

2.1.4 Additional requirements for bulwarks and guard rails related to spill containment

2.1.4.1 Generally, open guard rails are to be fitted on the upper deck. Plate bulwarks, with a 230mm high continuous opening, at the lower edge, may be accepted provided the arrangement allows for the acceptable handling of spillage on deck and minimises the possibility for accumulation of volatile gas.

2.1.4.2 Deck spills are to be prevented from spreading to the accommodation and service areas and from discharge into the sea by a permanent continuous coaming with a minimum height of 100mm surrounding the cargo deck. Along the sides at the aft end of the cargo deck, the coaming is to have a minimum height of 200mm extending a minimum of 4.5m forward from each corner. At the aft end of the cargo

deck, the coaming is to have a minimum height of 300mm and is to extend from ship-side to ship-side.

2.1.4.3 Where a continuous gutter bar deck coaming is fitted, it is to be constructed of the same material strength and grade as the deck plating to which it is attached.

2.1.4.4 Scupper plugs of mechanical type are to be provided. Means of draining or removing oil or oily water within the coaming are also to be provided.

2.1.5 Additional requirements for deeper loading

2.1.5.1 Ships with Type A or B-100 Freeboard (i.e. a freeboard less than that based on Type B-60) are to have open rails fitted for a minimum of half the length of the exposed parts of the weather deck. Alternatively, if a continuous bulwark is fitted, the minimum freeing area is to be at least 33% of the total area of the bulwark. The freeing area is to be located in the lower part of the bulwark.

2.1.5.2 Where superstructures are connected by trunks, open rails are to be fitted for the whole length of the exposed parts of the freeboard deck.

2.1.5.3 Ships with Type B-60 Freeboard (i.e. a freeboard less than that based on Type B but not less than Type B-60) are to have a minimum freeing area of at least 25% of the total area of the bulwark. The freeing area is to be located in the lower part of the bulwark.

2.2 Tank Access

2.2.1 Access to tanks in the cargo tank region

2.2.1.1 Access to tanks in the cargo tank region is to be in accordance with *Section 5/5*.

2.3 Bow Access

2.3.1 General

2.3.1.1 The ship is to be provided with means to enable the crew to gain safe access to the bow even in severe weather conditions, see *Table 11.2.2*.

Table 11.2.2
Acceptable Arrangements for Access

<table>
<tr><th rowspan="2">Locations of Access</th><th rowspan="2">Assigned Summer Freeboard</th><th colspan="4">Acceptable Arrangements According to Type of Freeboard Assigned (6)(7)(8)</th></tr>
<tr><th>Type A</th><th>Type B–100</th><th>Type B–60</th><th>Type B & B+</th></tr>
<tr><td rowspan="2">Access to Bow
Between poop and bow, or

Between a deck house containing living accommodation or navigation equipment, or both, and bow, or

In the case of a flush deck vessel, between crew accommodation and the forward end of vessel.</td><td>≤ (h_{FB} + h_{ss})</td><td colspan="4">a
e
f(1)
f(5)</td></tr>
<tr><td>> (h_{FB} + h_{ss})</td><td colspan="4">a
e
f(1)
f(2)</td></tr>
<tr><td rowspan="2">Access to Aft End
In the case of a flush deck vessel, between crew accommodation and the aft end of vessel.</td><td>≤ 3000mm</td><td>a
b
c(1)
e
f(1)</td><td>a
b
c(1)
c(2)
e
f(1)
f(2)</td><td>a
b
c(1)
c(2)
e
f(1)
f(2)</td><td rowspan="2">a
b
c(1)
c(2)
c(4)
d(1)
d(2)
d(3)
e
f(1)
f(2)
f(4)</td></tr>
<tr><td>> 3000mm</td><td>a
b
c(1)
d(1)
e
f(1)</td><td>a
b
c(1)
c(2)
d(1)
d(2)
e
f(1)
f(2)</td><td>a
b
c(1)
c(2)
c(4)
d(1)
d(2)
d(3)
e
f(1)
f(2)
f(4)</td></tr>
</table>

Where:

h_{ss} the standard height of a superstructure as defined in *ICLL Regulation 33*

h_{FB} freeboard from the summer load waterline amidships, in m, calculated as a Type A ship, regardless of the type of freeboard actually assigned

a a well lit and ventilated under deck passageway with a clear opening with a minimum width of 0.8m, and a minimum height of 2.0m, providing access to the locations under consideration and located as close as practicable to the freeboard deck

b a permanently constructed gangway fitted at or above the level of the superstructure deck, on or as near as practicable to the centreline of the vessel, providing a continuous platform of a non-slip surface at least 0.6m in width, with a foot-stop and guard rails extending on each side along its length. Guard rails are to be as required in *2.1.3*, except that stanchions are to be fitted with a maximum spacing of 1.5m

c a permanent walkway with a minimum width of 0.6m, fitted at the freeboard deck level, consisting of two rows of guard rails, the stanchions of which, are to have a maximum spacing of 3m. The number of courses of rails and their spacing are to be as given in *2.1.3*. On Type B freeboard ships, hatchway coamings with a height equal to or greater than 0.6m may be regarded as forming one side of the walkway provided that two rows of guard rails are fitted between the hatchways

Table 11.2.2 (Continued)
Acceptable Arrangements for Access

d	a rope lifeline with a minimum diameter of 10mm, supported by stanchions approximately 10m apart, or a single hand rail or wire rope attached to the hatch coamings, continued and adequately supported between hatchways
e	a permanently constructed gangway fitted at or above the level of the superstructure deck on, or as near as practicable, to the centreline of the vessel: • located so as not to hinder easy access across the working areas of the deck • providing a continuous platform with a minimum width of 1.0m • constructed of fire resistant and non-slip material • fitted with guard rails extending on each side throughout its length. Guard rails are to be as required in *2.1.3*, except that stanchions are to be fitted with a maximum spacing of 1.5m • provided with a foot stop on each side • having openings, with ladders to and from the deck, where appropriate. Openings are to be spaced a maximum of 40m apart • having shelters of substantial construction set in way of the gangway at intervals not exceeding 45m, if the length of the exposed deck to be traversed is greater than 70m. Every such shelter is to be capable of accommodating at least one person and be so constructed as to afford weather protection on the forward, port and starboard sides
f	a permanent and efficiently constructed walkway fitted at the freeboard deck level on, or as near as practicable, to the centreline of the vessel, having the same specifications as those defined for a permanent gangway in 'e' above, except for foot-stops. On Type B freeboard ships the hatch coamings may be accepted as forming one side of the walkway, provided that the combined height of the hatch coaming and hatch cover, in the closed condition, is not less than 1m, and that two rows of guard rails are fitted between the hatchways

Note

1. At or near the centreline of the vessel, or fitted on hatchways at or near the centreline of the vessel
2. Fitted on each side of the vessel
3. Fitted on one side of the vessel, provision being made for fitting on either side
4. Fitted on one side only
5. Fitted on each side of the hatchways as near to the centreline as far as practicable
6. In all cases where wire ropes are fitted, adequate devices are to be provided to enable the maintaining of their tautness
7. A means of passage over obstructions, if any, such as pipes or other fittings of a permanent nature is to be provided
8. Generally, the width of the gangway or walkway is not to exceed 1.5m.

Guidance Note

Deviations from some or all of these requirements may be allowed, subject to agreement on a case-by-case basis with the relevant Flag Administration.

3 SUPPORT STRUCTURE AND STRUCTURAL APPENDAGES

3.1 Support Structure for Deck Equipment

3.1.1 General

3.1.1.1 Information pertaining to the support structure of deck equipment and fittings, as listed in *3.1.2* to *3.1.7*, is to be submitted for approval.

3.1.1.2 This sub-section includes scantling requirements for the support structure and foundations of the following pieces of equipment and fittings:

(a) anchor windlasses

(b) anchoring chain stoppers

(c) mooring winches

(d) deck cranes, derricks and lifting masts

(e) emergency towing arrangements

(f) bollards and bitts, fairleads, stand rollers, chocks and capstans

(g) other deck equipment and fittings which are subject to specific approval

(h) miscellaneous deck fittings which are not subject to specific approval.

3.1.1.3 Where deck equipment is subject to multiple load cases, such as an operational load and a green seas load, the operational load and green seas load are be applied independently for the evaluation of strength of foundations and support structure.

3.1.2 Supporting structures for anchoring windlass and chain stopper

3.1.2.1 The windlass is to be efficiently bedded and secured to the deck. The deck thickness in way of the windlass and chain stopper is to be compatible with the deck attachment design.

3.1.2.2 In addition to complying with the requirements of *3.1.2.6*, the shipbuilder and the windlass manufacturer are to satisfy themselves that the foundation is suitable for the safe operation and maintenance of the windlass equipment.

3.1.2.3 The Breaking Strength is defined as the minimum breaking strength of the chain.

3.1.2.4 The following plans and information are to be submitted for approval:

(a) details of the supporting structure for the anchor windlass

(b) details of the windlass foundation design, including material specifications for holding down bolts and the connection of the foundation to the deck

(c) details of the chain stopper foundation design, including material specification and the connection of the foundation to the deck.

3.1.2.5 The following supporting information is also to be submitted:

(a) general arrangement drawing of anchoring equipment.

(b) design loads as specified in *3.1.2.8* and *3.1.2.9* and associated reaction forces applied to the foundation and supporting structure.

3.1.2.6 The scantlings of the support structure are to be dimensioned to ensure that for each of the load scenarios specified in *3.1.2.8* and *3.1.2.9*, the calculated stresses in the support structure does not exceed the permissible stress levels given in *3.1.2.15* to *3.1.2.18*.

3.1.2.7 These requirements are to be assessed using a simplified engineering analysis based on elastic beam theory, two-dimensional grillage or finite-element analysis using gross scantlings.

3.1.2.8 The following load cases are to be examined for the anchoring operation, as appropriate:

(a) windlass where chain stopper is provided: 45% of Breaking Strength

(b) windlass where chain stopper is not provided: 80% of Breaking Strength

(c) chain stopper: 80% of Breaking Strength

Breaking Strength is defined in 3*.1.2.3*.

3.1.2.9 The following forces are to be applied separately in the load cases that are to be examined for the design loads due to green seas in the forward 0.25*L*, see *Figure 11.3.1*:

$P_x = 200 A_x$ kN, acting normal to the shaft axis

$P_y = 150 A_y f$ kN, acting parallel to the shaft axis (inboard and outboard directions to be examined separately)

Where:

A_x projected frontal area, in m^2

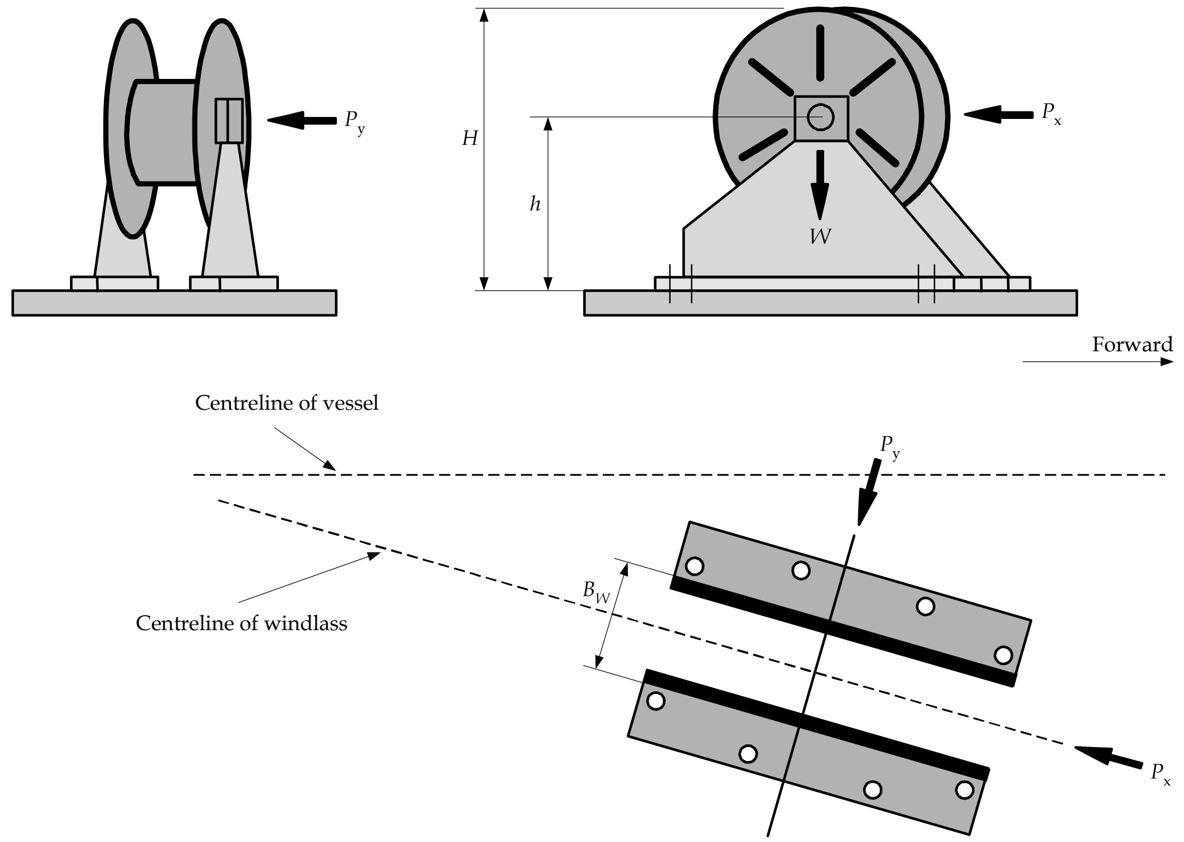
A_y projected side area, in m^2

f $= 1 + B_W/H$, but not to be taken greater than 2.5

B_W breadth of windlass measured parallel to the shaft axis, in m. See *Figure 11.3.1*

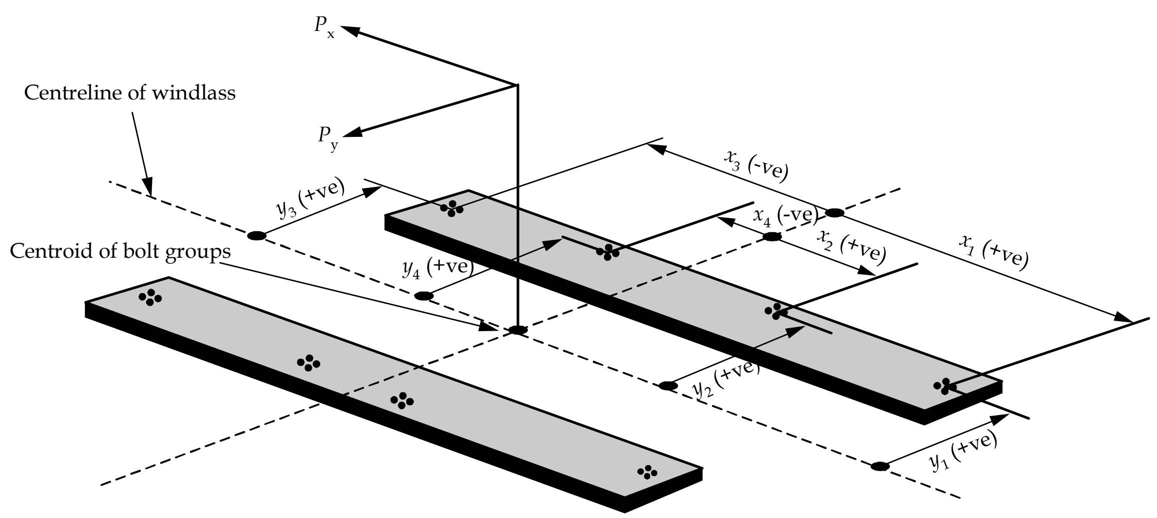
H overall height of windlass, in m, see *Figure 11.3.1*

Figure 11.3.1
Direction of Forces and Weight



3.1.2.10 Forces resulting from green sea design loads in the bolts, chocks and stoppers securing the windlass to the deck are to be calculated. The windlass is supported by a number of bolt groups, N, each containing one or more bolts. See *Figure 11.3.2*.

Figure 11.3.2
Bolting Arrangements and Sign Conventions



3.1.2.11 The axial forces, R_{xi} and R_{yi}, in bolt group (or bolt) i, positive in tension, are given by:

$$R_{xi} = P_x h x_i A_i / I_x$$

$$R_{yi} = P_y h y_i A_i / I_y$$

$$R_i = R_{xi} + R_{yi} - R_{si}$$

Where:

P_x	force acting normal to the shaft axis, in kN
P_y	force acting parallel to the shaft axis, either inboard or outboard, whichever gives the greater force in bolt group *i*, in kN
h	shaft centre height above the windlass mounting, in cm, see *Figure 11.3.1*
x_i, y_i	x and y coordinates of bolt group *i* from the centroid of all *N* bolt groups, in cm. Positive in the direction opposite to that of the applied force
A_i	cross sectional area of all bolts in group *i*, in cm^2
I_x	$= \Sigma A_i\, x_i^2$ for *N* bolt groups, in cm^4
I_y	$= \Sigma A_i\, y_i^2$ for *N* bolt groups, in cm^4
R_{si}	static reaction at bolt group *i*, due to the weight of windlass, in kN

3.1.2.12 The shear forces, F_{xi} and F_{yi}, applied to the bolt group *i*, and the resultant combined force F_i, are given by:

$$F_{xi} = (P_x - C_1 gm)/N$$

$$F_{yi} = (P_y - C_1 gm)/N$$

$$F_i = \sqrt{F_{xi}^{\,2} + F_{yi}^{\,2}}$$

Where:

C_1	coefficient of friction, 0.5
m	mass of windlass, in tonnes
g	acceleration due to gravity, 9.81m/s2
N	number of bolt groups

3.1.2.13 The resultant forces from the application of the loads specified in *3.1.2.8* and *3.1.2.9* are to be considered in the design of the supporting structure.

3.1.2.14 Where a separate foundation is provided for the windlass brake, the distribution of resultant forces is to be calculated on the assumption that the brake is applied for load cases *(a)* and *(b)* defined in *3.1.2.8*.

3.1.2.15 The stresses resulting from anchoring design loads induced in the supporting structure are not to be greater than the permissible values given below, based on the gross thickness of the structure:

Normal stress 1.00 σ_{yd}

Shear stress 0.58 σ_{yd}

Where:

σ_{yd}	specified minimum yield stress of the material, in N/mm^2

Normal stress is the sum of bending stress and axial stress with the corresponding shearing stress acting perpendicular to the normal stress.

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3.1.2.16 The tensile axial stresses resulting from green sea design loads in the individual bolts in each bolt group *i* are not to exceed 50% of the bolt proof strength under the above forces. The load is to be applied in the direction of the chain. Where fitted bolts are designed to support these shear forces in one or both directions, the von Mises equivalent stresses are not to exceed 50% of the bolt proof strength.

3.1.2.17 The horizontal forces resulting from the green sea design loads F_{xi} and F_{yi} may be reacted by shear chocks. Where pourable resins are incorporated in the holding down arrangements, due account is to be taken in the calculation.

3.1.2.18 The stresses resulting from green sea design loads induced in the supporting structure are not to be greater than the permissible values given below, based on the gross thickness of the structure:

Normal stress 1.00 σ_{yd}

Shear stress 0.58 σ_{yd}

Where:

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Normal stress is the sum of bending stress and axial stress with the corresponding shearing stress acting perpendicular to the normal stress.

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3.1.3 Supporting structure for mooring winches

3.1.3.1 Mooring winches are to be efficiently bedded and secured to the deck. The deck thickness in way of mooring winches is to be compatible with the deck attachment design.

3.1.3.2 In addition to complying with the requirements of *3.1.3.6*, the shipbuilder and mooring winch manufacturer are to satisfy themselves that the foundation is suitable for the safe operation and maintenance of the mooring winch equipment.

3.1.3.3 The Rated Pull is defined as the maximum load which the mooring winch is designed to exert during operation and is to be stated on the mooring winch foundation/support plan.

3.1.3.4 The Holding Load is defined as the maximum load which the mooring winch is designed to resist during operation and is to be taken as the design brake holding load or equivalent and is to be stated on the mooring winch foundation/support plan.

3.1.3.5 The following plans and information are to be submitted for approval:

(a) details of the supporting structure for mooring winches

(b) details of the mooring winch foundation design, including material specifications for hold down bolts and the connection of the foundation to the deck

(c) design loads as specified in *3.1.3.8* and *3.1.3.9* and associated reaction forces applied to the foundation and supporting structure.

3.1.3.6 The scantlings of the support structure are to be dimensioned to ensure that, for each of the load cases specified in *3.1.3.8* and *3.1.3.9*, the calculated stresses in the

support structure do not exceed the permissible stress levels specified in *3.1.3.13* and *3.1.3.14*, respectively.

3.1.3.7 These requirements are to be assessed using a simplified engineering analysis based on elastic beam theory, two-dimensional grillage or finite-element analysis using net scantlings.

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3.1.3.8 Each of the following load cases are to be examined for design loads due to mooring operation:

(a) mooring winch at maximum pull:	100% of the rated pull
(b) mooring winch with brake effective:	100% of the holding load
(c) line strength:	125% of the breaking strength of the mooring line (hawser) required by *Table 11.4.2* for the ship's corresponding equipment number

Rated pull and holding load are defined in *3.1.3.3* and *3.1.3.4*. The design load is to be applied through the mooring line according to the arrangement shown on the mooring arrangement plan.

3.1.3.9 For mooring winches situated within the forward 0.25*L*, the load cases for green seas are to be applied as indicated in *3.1.2.9*.

3.1.3.10 For mooring winches situated within the forward 0.25*L*, the resultant forces in the bolts obtained from green sea design loads are to be calculated in accordance with *3.1.2.10* to *3.1.2.12*.

3.1.3.11 The resultant forces from the application of the loads specified in *3.1.3.8* and *3.1.3.9* are to be considered in the design of the supporting structure.

3.1.3.12 Where a separate foundation is provided for the mooring winch brake, the distribution of resultant forces is to take account of the different load path. The brake is only to be considered in relation to the forces in *3.1.3.8*, load case *(b)*.

3.1.3.13 The stresses resulting from mooring operation design loads, induced in the supporting structure, are not to exceed those given in *3.1.2.15*.

3.1.3.14 For mooring winches situated within the forward 0.25*L*, the stresses resulting from green sea design loads, induced in the bolts and supporting structure, are not to exceed values indicated in *3.1.2.16* through *3.1.2.18*.

3.1.4 Supporting structure for cranes, derricks and lifting masts

3.1.4.1 Support structures of cranes, derricks and lifting masts with a Safe Working Load greater than 30kN, or a maximum overturning moment to the supporting structure greater than 100kNm, are to comply with the following requirements.

3.1.4.2 These requirements apply to the connection to the deck and the supporting structure of cranes, derricks and lifting masts. Where the crane, derrick or lifting mast is to be certified by the Classification Society, additional requirements may be applied by the individual Society.

3.1.4.3 These requirements do not cover the following items:

(a) supports of lifting appliances for personnel or passengers, see *3.1.7.5*

(b) the structure of the lifting appliance pedestals or post above the area of the deck connection

(c) holding down bolts and their arrangement, which are considered part of the lifting appliance.

3.1.4.4 The term, Lifting Appliance, is defined as a crane, derrick or lifting mast.

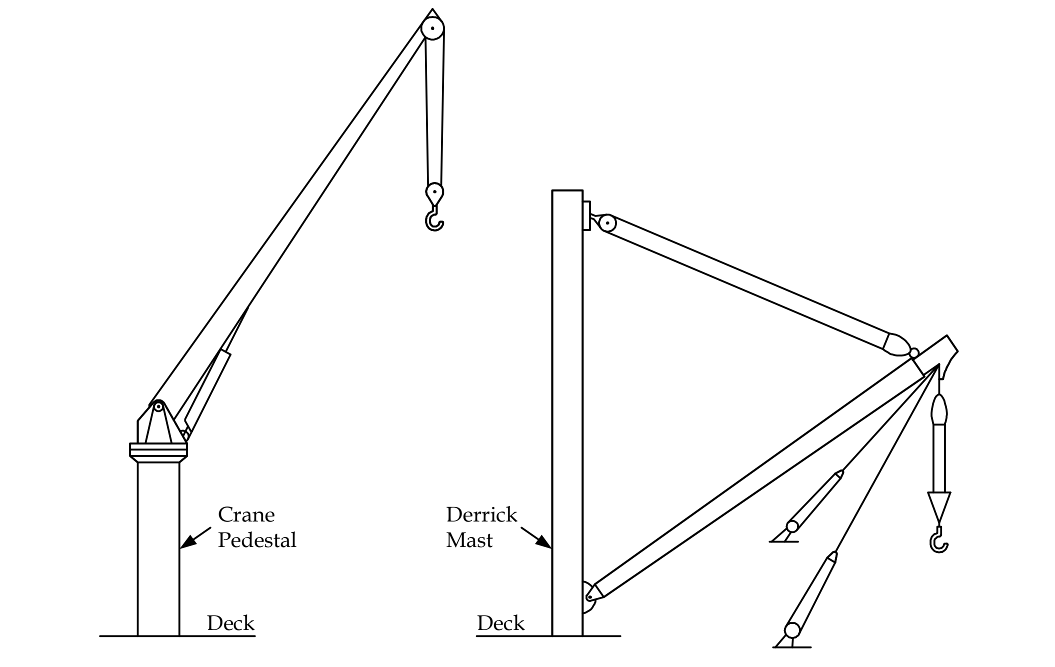
3.1.4.5 The Safe Working Load is defined as the maximum load which the lifting appliance is certified to lift at any specified outreach.

3.1.4.6 The Self Weight is the calculated gross self weight of the lifting appliance, including the weight of any lifting gear.

3.1.4.7 The Overturning Moment is the maximum bending moment, calculated at the connection of the lifting appliance to the ship structure, due to the lifting appliance operating at Safe Working Load, taking into account outreach and self weight.

3.1.4.8 The Crane Pedestal and Derrick Mast are as defined in *Figure 11.3.3*.

Figure 11.3.3
Crane Pedestal and Derrick Mast



3.1.4.9 The following plans and information are to be submitted for approval:

(a) details of the supporting structure of the lifting appliance, including its connection of the deck

(b) details of the Safe Working Load, self weight, vertical reaction forces and the maximum overturning moment in the supporting structure of the lifting appliance

(c) for offshore operation, the maximum sea state in which the lifting appliance is to be used.

3.1.4.10 The following supporting information is also to be submitted:

(a) a general arrangement drawing of the crane/derrick/lifting mast.

3.1.4.11 Deck plating and under deck structure is to provide adequate support for derrick masts against the calculated vertical loads and maximum overturning moment. Where the deck is penetrated, the deck plating is to be suitably strengthened.

3.1.4.12 Deck plating and under deck structure is to provide adequate support for crane pedestals against the calculated vertical loads and maximum overturning moment.

3.1.4.13 In general, structural continuity of the deck structure is to be maintained and deep under-deck members are to be provided to support the crane pedestal.

3.1.4.14 Depending on the arrangement of the deck connection in way of crane pedestals, the following additional requirements are to be complied with:

(a) where the pedestal is directly connected to the deck, without above deck brackets, adequate under deck structure directly in line with the crane pedestal is to be provided. Where the crane pedestal is attached to the deck without bracketing or where the crane pedestal is not continuous through the deck, welding to the deck of the crane pedestal and its under deck support structure is to be made by suitable full penetration welding. This could include a deep penetration welding procedure with a maximum root face of 3mm provided this results in full penetration and consequently enable ultrasonic lamination testing after welding has been completed. The design of the weld connection is to be adequate for the calculated stress in the welded connection, in accordance with *3.1.4.21*.

(b) where the pedestal is directly connected to the deck with brackets, under deck support structure is to be fitted to ensure a satisfactory transmission of the load, and to avoid structural hard spots. Above deck brackets may be fitted inside or outside of the pedestal and are to be aligned with deck girders and webs. The design is to avoid stress concentrations caused by an abrupt change of section. Brackets and other direct load carrying structure and under deck support structure are to be welded to the deck by suitable full penetration welding. This could include a deep penetration welding procedure with a maximum root face of 3mm provided this results in full penetration and consequently enables ultrasonic lamination testing after welding has been completed. The design of the connection is to be adequate for the calculated stress, in accordance with *3.1.4.21*.

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3.1.4.15 Deck plates are to be of a thickness and material strength compatible with the crane pedestal. Where necessary, a thicker insert plate is to be fitted. In no case are doublers to be used where structures are subject to tension.

3.1.4.16 The scantlings of the support structure are to be dimensioned to ensure that for the load cases specified in *3.1.4.18* and *3.1.4.19*, the calculated stresses in the support structure do not exceed those given in *3.1.4.21*.

3.1.4.17 These requirements are to be assessed using a simplified engineering analysis based on elastic beam theory, two-dimensional grillage or beam element finite-element analysis using gross scantlings.

3.1.4.18 For lifting appliances which are limited to use in harbour, the following load scenario is to be examined:

(a) 130% of the Safe Working Load added to the lifting appliances self weight.

3.1.4.19 For lifting appliances which may be used for offshore operations the following is to be submitted for approval purposes:

(a) the maximum sea state in which the lifting appliance is to be used

(b) the worst case vertical and horizontal accelerations

(c) the worst case wind loadings for the specified design sea state and wind environment.

The load scenario to be examined is to account for these environmental loads. As a minimum, the following load scenario is to be examined:

(a) 150% of the Safe Working Load added to the lifting appliances self weight.

When a crane cab is fitted above the slewing ring, the load scenario is to be specially considered.

3.1.4.20 The vertical reaction force and maximum overturning moment, corresponding to the design loads specified in *3.1.4.18* and *3.1.4.19*, are to be calculated and used in the assessment of the structure.

3.1.4.21 The stresses induced in the supporting structure are not to exceed the permissible values given below, based on the gross thickness of the structure:

Normal stress 0.67 σ_{yd}

Shear stress 0.39 σ_{yd}

Where:

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Normal stress is the sum of bending stress and axial stress with the corresponding shearing stress acting perpendicular to the normal stress.

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3.1.4.22 The capability of the supporting structure to resist buckling failure is also to be assured.

3.1.5 Supporting structures for components used in emergency towing arrangements on tankers

3.1.5.1 Tankers having a deadweight of greater than or equal to 20 000tonnes are to be fitted with an emergency towing arrangement at both ends, complying with *Maritime Safety Committee Resolution MSC 35(63)*.

3.1.5.2 The Safe Working Load of emergency towing arrangements is as specified in *IMO Resolution MSC 35(63)*, as follows:

(a) 1000kN for vessels having a deadweight greater than or equal to 20000tonnes, but less than 50 000tonnes

(b) 2000kN for vessels having a deadweight greater than or equal to 50000tonnes.

3.1.5.3 The following plans are to be submitted for approval:

(a) details of the supporting structure for the emergency towing arrangement, including the connection to the deck.

3.1.5.4 The following supporting information is also to be submitted:

(a) details of the emergency towing arrangement showing sufficient detail to enable the position and direction of load actions to be ascertained.

3.1.5.5 The deck in way of strong-points and fairleads is to have a minimum gross thickness of 15mm.

3.1.5.6 The structural arrangement is to provide continuity of strength.

3.1.5.7 The structural arrangement of the ship's structure in way of the emergency towing equipment is to be such that, abrupt changes of shape or section are to be avoided in

order to minimise stress concentrations. Sharp corners and notches are to be avoided, especially in high stress areas.

3.1.5.8 The scantlings of the support structure are to be dimensioned to ensure that for the load cases specified in *3.1.5.10* and *3.1.5.11*, the calculated stresses in the support structure do not exceed the permissible stress levels specified in *3.1.5.12*.

3.1.5.9 These requirements are to be assessed using a simplified engineering analysis based on elastic beam theory, two-dimensional grillage or finite-element analysis using gross scantlings.

3.1.5.10 The design load for the connection of the strong-point and fittings to the deck and its supporting structure is to be taken as twice the Safe Working Load.

3.1.5.11 The assessment of the structure is to consider lines of action of the applied design load, taking into account the particular arrangements proposed. See *IMO MSC 35(63)*.

3.1.5.12 For the design load specified in *3.1.5.10* and *3.1.5.11* the stresses induced in the supporting structure and welds, in way of strong-points and fairleads, are not to exceed the permissible values given below based on the gross thickness of the structure:

Normal stress 1.00 σ_{yd}

Shear stress 0.58 σ_{yd}

Where:

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Normal stress is the sum of bending stress and axial stress with the corresponding shearing stress acting perpendicular to the normal stress.

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3.1.5.13 The capability of the structure to resist buckling failure is also to be assured.

3.1.6 Supporting structure for bollards and bitts, fairleads, stand rollers, chocks and capstans

3.1.6.1 In general, shipboard fittings (bollards and bitts, fairleads, stand rollers and chocks) and capstans used for mooring, and towing (other than as specified in *3.1.5*) of the vessel are to be fitted to the deck or bulwark structures using a purpose designed base or attachment.

3.1.6.2 The attachment of shipboard fittings to sheer strakes or sheer strake upstands is to be avoided, as required by *Sections 8/2.2.5.2* and *Section 8/2.2.5.3*.

3.1.6.3 Where fairleads are fitted in bulwarks and the imposed loads from mooring or towing lines are high, the thickness of bulwarks may need to be increased. See also *2.1.2*.

3.1.6.4 The following plans are to be submitted for approval:

(a) details of the supporting structure for the shipboard fitting and capstan arrangements, including the connection of shipboard fittings and their seats to the deck.

3.1.6.5 The following supporting information is also to be submitted:

(a) details of the shipboard fittings and capstans including the Safe Working Load of shipboard fittings and arrangements showing sufficient detail to enable the position and direction of load actions to be ascertained.

3.1.6.6 The structural arrangement is to provide continuity of strength.

3.1.6.7 The structural arrangement of the ship's structure in way of the shipboard fittings and their seats and in way of capstans is to be such that, abrupt changes of shape or section are to be avoided in order to minimise stress concentrations. Sharp corners and notches are to be avoided, especially in high stress areas.

3.1.6.8 The scantlings of the support structure are to be dimensioned to ensure that for the loads specified in *3.1.6.10, 3.1.6.11* and *3.1.6.12*, the calculated stresses in the support structure do not exceed the permissible stress levels specified in *3.1.6.13*.

3.1.6.9 These requirements are to be assessed using a simplified engineering analysis based on elastic beam theory, two-dimensional grillage or finite-element analysis using net scantlings. The required gross thickness is obtained by adding the relevant full corrosion addition specified in *Section 6/3* to the required net thickness.

3.1.6.10 The design load for the connection of shipboard fittings and their seats to the deck and its supporting structure is to be based on the line load as the greater of the following requirements, as applicable for the particular fitting and its intended use:

(a) in the case of normal towing in harbour or manoeuvring operations, 125% of the maximum towline load as indicated on the towing and mooring arrangement plan, or

(b) in the case of towing service other than that experienced in harbour or manoeuvring operations, such as escort service, the nominal breaking strength of towline according to *Table 11.4.2* for the ship's corresponding equipment number, or

(c) in the case of mooring operations 125% of the nominal breaking strength of the mooring line (hawser) or towline according to *Table 11.4.2* for the ship's corresponding equipment number.

3.1.6.11 The design load for the supporting structure for capstans is to be based the following:

(a) 125% of the maximum hauling in force.

3.1.6.12 The assessment of the structure is to consider lines of action of the applied design load, taking into account the particular arrangements proposed, however, the total load applied for towing and mooring scenarios described in *3.1.6.10* need not be more than twice the design load on the mooring line or towline. The acting point for the force on the shipboard fittings is to be taken as the attachment point of the mooring line or towline, or at a change in its direction.

3.1.6.13 For the design load specified in *3.1.6.10, 3.1.6.11* and *3.1.6.12* the stresses induced in the supporting structure and welds are not to exceed the permissible values given below based on the net thickness of the structure. The required gross thickness is obtained by adding the relevant full corrosion addition specified in *Section 6/3* to the required net thickness.

Normal stress $1.00\ \sigma_{yd}$

Shear stress $0.60\ \sigma_{yd}$

Where:

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Normal stress is the sum of bending stress and axial stress with the corresponding shearing stress acting perpendicular to the normal stress.

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3.1.6.14 The capability of the structure to resist buckling failure is also to be assured.

3.1.6.15 The following requirements on Safe Working Load apply for a single post basis (no more than one turn of one cable).

(a) The Safe Working Load used for normal towing operations (e.g., harbour/manoeuvring is not to exceed 80% of the design load per *3.1.6.10(a)* and the Safe Working Load used for other towing operations (e.g., escort) is not to exceed the design load per *3.1.6.10(b)*. For deck fittings used for both normal and other towing operations, the greater of the design loads of *3.1.6.10(a)* and *3.1.6.10(b)* is to be used.

(b) The Safe Working Load for mooring operations is not to exceed 80% of the design load per *3.1.6.10(c)*.

(c) The Safe Working Load of each deck fitting is to be marked (by weld bead or equivalent) on the deck fittings used for towing and/or mooring.

(d) The towing and mooring arrangements plan mentioned in 3.1.6.16 is to define the method of use of towing lines and/or mooring lines.

3.1.6.16 The Safe Working Load for the intended use for each deck fitting is to be noted in the towing and mooring arrangements plan available on board for the guidance of the Master. Information provided on the plan is to include in respect of each deck fitting:

(a) Location on the ship;

(b) Fitting type;

(c) SWL;

(d) Purpose (mooring/harbour towing/escort towing); and

(e) Manner of applying towing or mooring line load including limiting fleet angles.

This information is to be incorporated into the pilot card in order to provide the pilot proper information on harbour/escorting operations.

3.1.7 Supporting structures for other deck equipment or fittings which are subject to specific approval

3.1.7.1 The following requirements relate to other items of deck equipment which are not covered by *3.1.2* to *3.1.6*. The scantlings and arrangements of support structure for such items are to be in accordance with the following requirements and the additional requirements of the individual Classification Society.

3.1.7.2 The support structure of items not mentioned in this sub-section will be independently considered by the individual Classification Society.

3.1.7.3 The following details are to be submitted for approval. They may be indicated separately or may be included on the main structural drawings:

(a) plans showing the supporting structure for deck equipment/fittings

(b) details of the loads imposed on the structure by the deck equipment/fittings.

3.1.7.4 The support structure is to be arranged in order to resist both in-plane and out-of-plane loads acting on the deck structure.

3.1.7.5 Support for lifting appliances for personnel is to be provided as follows:

(a) in general, lifesaving appliances (lifeboats, life-rafts and rescue boats) are to be stowed on a purpose built cradle, seat or deployment appliance. The design load imposed on the ship structure is to be established by the supplier of the lifesaving appliance

(b) the support structure is to be adequate for the design loads. Local stiffening and a local increase in plating thickness is to be provided. Deep supporting members may be required. Additional National and International Regulations are to be applied, where applicable

(c) support structure for crew lifts is to be provided in way of the anchor points of lift operating equipment

(d) support structure for boarding (accommodation) ladders is to be provided in way of the anchor points of accommodation ladders.

3.1.7.6 Support for mast structures fitted with navigation aids is to be provided as follows:

(a) adequate primary support members for the mast are to be arranged in the form of bulkheads, deep beams or girders. Such members are to be arranged below or close to the mast structure

(b) in order to transmit the loads from the mast structure to the primary support members, under-deck stiffening members are to be arranged below the mast structure forming the attachment of the mast to the deck

(c) the deck thickness may be required to be increased to provide an adequate thickness for the weld attachments.

3.1.7.7 Supporting structure for breakwaters is to be designed to withstand the same design load as the breakwater itself. It is to be suitable for transmitting the loads from the breakwater into the primary supporting members of the ship. Efficient under-deck stiffening is to be provided in way of the breakwater structure that forms the deck connection.

3.1.8 Support and attachment of miscellaneous deck fittings which are not subject to specific approval

3.1.8.1 The following general requirements are to be considered in the design of the support and attachment of miscellaneous fittings which impose relatively small loads on the ship's structure and are not subject to specific approval. The arrangements of such details do not require the approval of plans by the Classification Society.

3.1.8.2 Support positions are to be arranged so that the attachment to the ship structure is clear of deck openings and stress concentrations, such as the toes of end brackets. Design of supports is to be such that the attachment to the deck minimises the creation of hard points.

3.1.8.3 A cargo manifold support is a self-contained, fabricated assembly designed to support the main pipework used for loading and unloading the ship. The design of the cargo manifold support is to be such as to distribute the loads imposed on the pipework during loading and unloading into the ship structure. To achieve this, the connection of the cargo manifold support to the deck is normally to be arranged to align with stiffening members of the main hull structure. Where this is impracticable, additional stiffening is to be fitted in order to avoid the creation of hard points. Attention is to be paid to the detail design of the structure forming the deck attachment in order to minimise the effects of change of section.

3.2 Docking

3.2.1 Docking arrangements

3.2.1.1 The drydocking arrangement itself is not covered explicitly in these Rules.

3.2.1.2 The structure of bottom girders is to be sufficiently stiffened to withstand the forces imposed by drydocking the ship.

3.2.1.3 For ships of unusual form, or where the Owner of the vessel has specific requirements for docking strength, the builder may need to carry out additional calculations. Such calculations are outside of the scope of Classification, but may be reviewed upon request.

3.2.2 Docking plan

3.2.2.1 It is recommended that consideration be given to providing a docking plan for a vessel. The docking plan is to indicate any and all assumptions made during the design, including but not limited to, the arrangement of docking blocks, the maximum permissible loading during docking and the corresponding load at each block.

3.2.2.2 The docking plan does not require approval by the Society as a condition of Classification.

Guidance Note:

1. It is recommended that bottom plugs are not fitted in way of the keel plate.

3.3 Bilge Keels

3.3.1 Construction and materials

3.3.1.1 The bilge keel is to be of the same material tensile properties as the bilge strake to which it is attached.

3.3.1.2 Bilge keels of a different design, from that shown in *Figure 11.3.4*, will be specially considered.

3.3.1.3 A plan of all bilge keels is to be submitted for the approval of the material strength and grades, welded connections and detail design.

3.3.1.4 The design of single web bilge keels is to ensure that failure to the web occurs before failure of the ground bar. In general, this may be achieved by ensuring the web thickness of the bilge keel does not exceed that of the ground bar.

3.3.2 Ground bars

3.3.2.1 Bilge keels, where fitted, are to be attached to the shell by a ground bar, or doubler, as shown in *Figures 11.3.4* and *11.3.5*. In general, the ground bar is to be continuous.

3.3.2.2 The gross thickness of the ground bar is not to be less than the gross thickness of the bilge strake or 14mm, whichever is the lesser.

3.3.2.3 The ground bar is to be of the same material strength as the bilge strake to which it is attached and constructed of the steel grade given in *Section 6/1.2, Tables 6.1.2* and *6.1.3* for bilge strakes.

3.3.3 End details

3.3.3.1 The ends of the bilge keel are to be suitably tapered and are to terminate on an internal stiffening member. Typical arrangements complying with the requirements of this subsection are shown in *Figure 11.3.5*. Alternative end arrangements will be accepted, provided that they are considered equivalent.

3.3.3.2 The ground bar and bilge keel ends are to be tapered or rounded. Where the ends are tapered, the tapers are to be gradual with a minimum ratio of 3:1. See *Figures*

11.3.5(a), *11.3.5(b)*, *11.3.5(d)* and *11.3.5(e)*. Where the ends are rounded, details are to be as shown in *Figure 11.3.5(c)*. Cut outs on the bilge keel web, within zone 'A', see *Figures 11.3.5(b)* and *11.3.5(e)*, are not permitted.

3.3.3.3 The end of the bilge keel web is to be not less than 50mm and not greater than 100mm from the end of the ground bar. See *Figures 11.3.5(a)* and *11.3.5(d)*.

3.3.3.4 An internal transverse support member is to be positioned between the end of the bilge keel web and the halfway point between the end of the bilge keel web and the end of the ground bar. See *Figures 11.3.5(a), 11.3.5(b)* and *11.3.5(c)*.

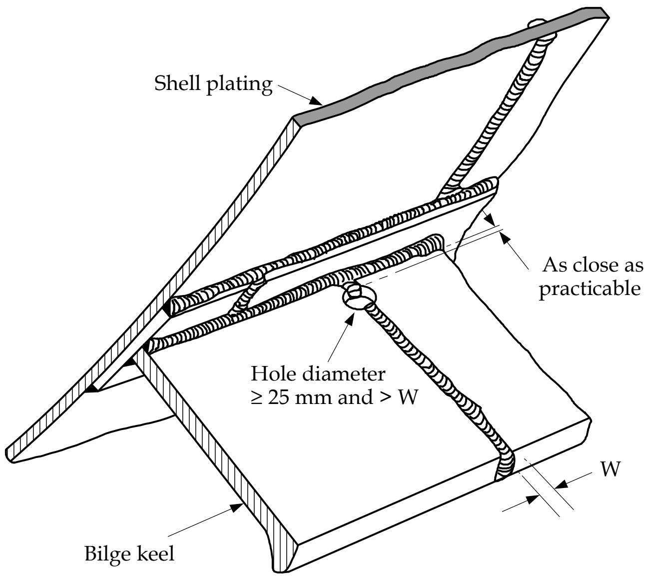
3.3.3.5 Where an internal longitudinal stiffener is fitted in line with the bilge keel web, the longitudinal stiffener is to extend to at least the nearest transverse member forward and aft of zone 'A'. See *Figures 11.3.5(b)* and *11.3.5(e)*. In this case, the requirement in *3.3.3.4* relating to the internal transverse support does not apply.

3.3.4 Welding

3.3.4.1 The ground bar is to be connected to the shell with a continuous fillet weld, and the bilge keel to the ground bar with a light continuous fillet weld, in accordance with *Table 11.3.1*.

3.3.4.2 Butt welds, in the bilge keel and ground bar, are to be well clear of each other and of butts in the shell plating. In general, shell butts are to be flush in way of the ground bar and ground bar butts are to be flush in way of the bilge keel. Direct connection between ground bar butt welds and shell plating, and between bilge keel butt welds and ground bar is to be avoided.

Figure 11.3.4
Bilge Keel Construction



3.3.4.3 In general, scallops and cut-outs are not to be used. Crack arresting holes are to be drilled in the bilge keel butt welds as close as practicable to the ground bar. The diameter of hole is to be greater than the width of the butt weld and is to be a minimum of 25mm in diameter, as illustrated in *Figure 11.3.4*. Where the butt weld has been subject to non-destructive examination, the crack arresting hole may be omitted.

3.3.4.4 Welds at the end of the ground bar and shell plating, and at the end of the bilge keel web and ground bar connection, within Zone 'B', see *Figures 11.3.5(a)* and *11.3.5(d)* are to have a throat thickness as given in *Table 11.3.1* for "At ends". The toes of these welds are to be ground to blend them smoothly with the base materials.

Figure 11.3.5 (a) – (c)
Bilge Keel End Design

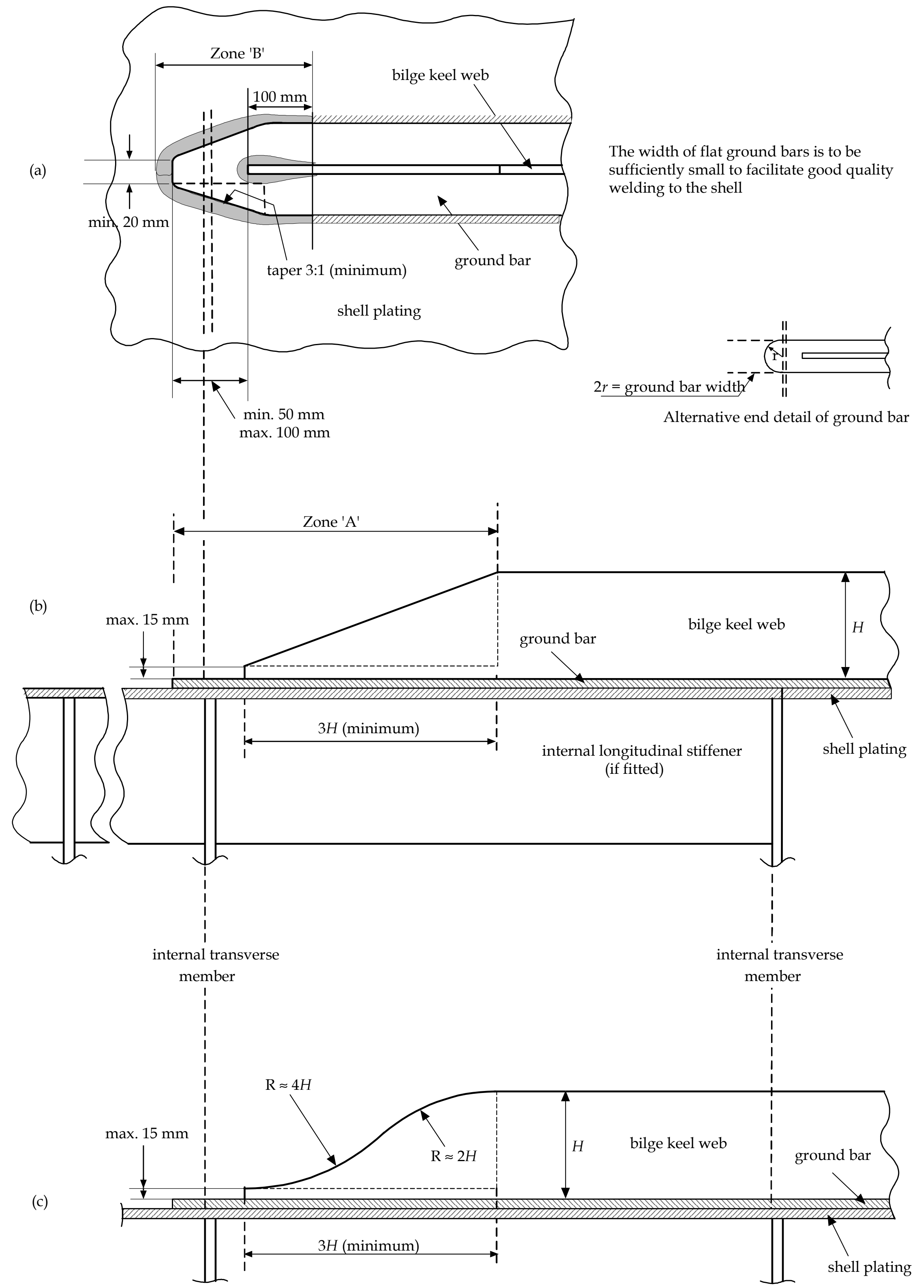


Figure 11.3.5 (d) – (e)
Bilge Keel End Design

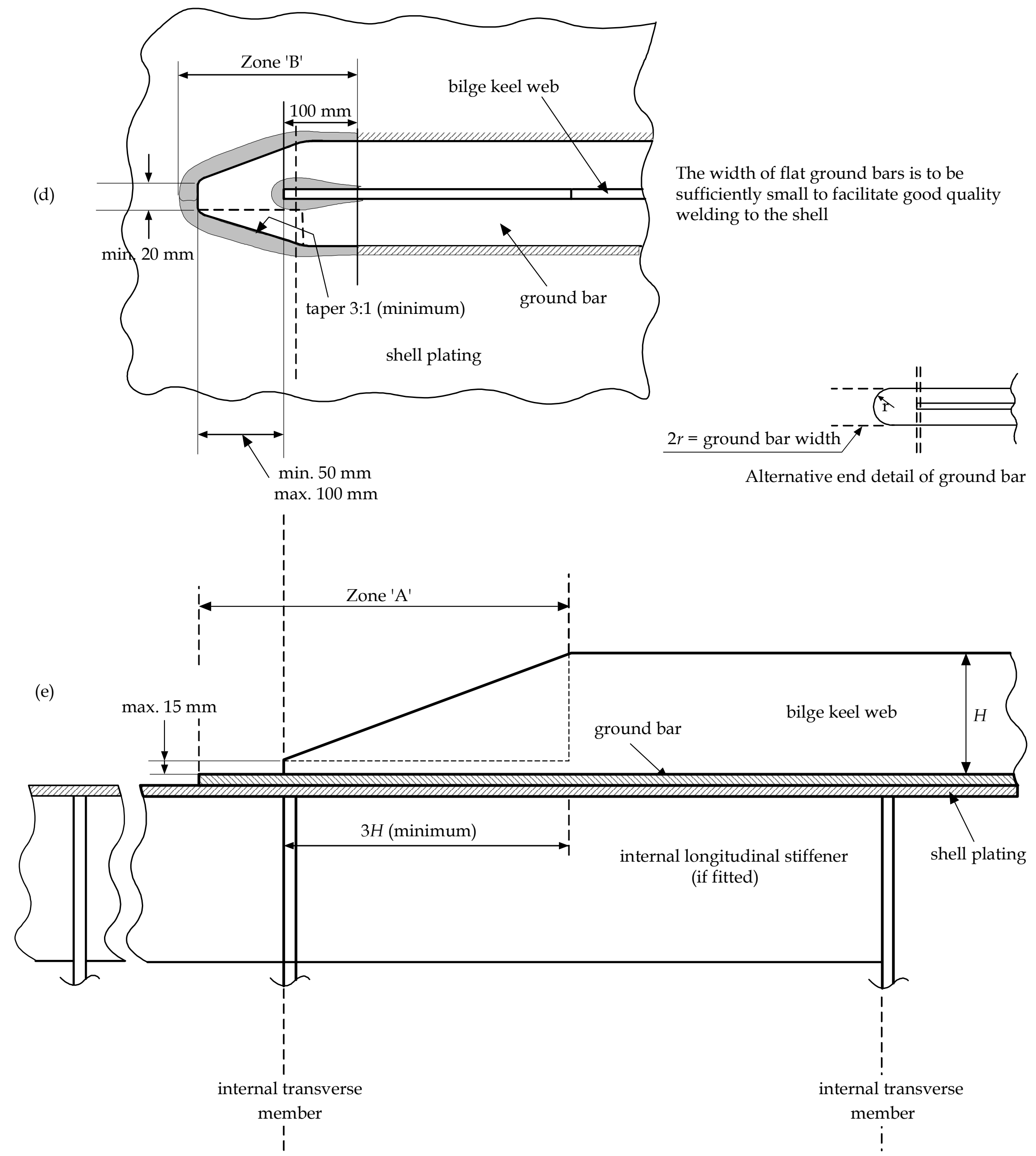


Table 11.3.1
Welding Requirements for End Connections of Bilge Keels

Structural items being joined	Throat thickness, in mm	
	At ends	Elsewhere
Ground bar to shell	0.44 t_{grs}	0.34 t_{grs}
Bilge keel web to ground bar	0.34 t_{grs}	0.21 t_{grs}
Where: t_{grs} gross thickness of the item being attached, in mm		

4 EQUIPMENT

4.1 Equipment Number Calculation

4.1.1 Requirements

4.1.1.1 Anchors and chains are to be in accordance with *Table 11.4.1* and the quantity, mass and sizes of these are to be determined by the equipment number (EN), given by:

$$EN = \Delta^{2/3} + 2Bh_{dk} + 0.1A$$

Where:

Δ	moulded displacement, in tonnes, as defined in *Section 4/1.1.7.1*
B	moulded breadth, in m, as defined in *Section 4/1.1.3.1*
h_{dk}	$h_{FB} + h_1 + h_2 + h_3 + \ldots$, as shown in *Figure 11.4.1*. In the calculation of h, sheer, camber and trim may be neglected
h_{FB}	freeboard from the summer load waterline amidships, in m
$h_1, h_2, h_3 \ldots h_n$	height on the centreline of each tier of houses having a breadth greater than $B/4$, in m
A	profile area of the hull, superstructure and houses above the summer load waterline which are within the length L, in m^2. Superstructures or deck houses having a breadth equal to or less than $B/4$ at any point may be excluded. With regard to determining A, when a screen or bulwark is more than 1.5m high, the area shown in *Figure 11.4.2* as A_2 is to be included in A
L	rule length, as defined in *Section 4/1.1.1.1*

Notes

(a) Screens or bulwarks 1.5 m or more in height are to be regarded as parts of houses when determining h and A.

(b) If a house having a breadth greater than B/4 is above a house with a breadth of B/4 or less then the wide house is to be included but the narrow house ignored.

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Figure 11.4.1
Effective Heights of Deck Houses

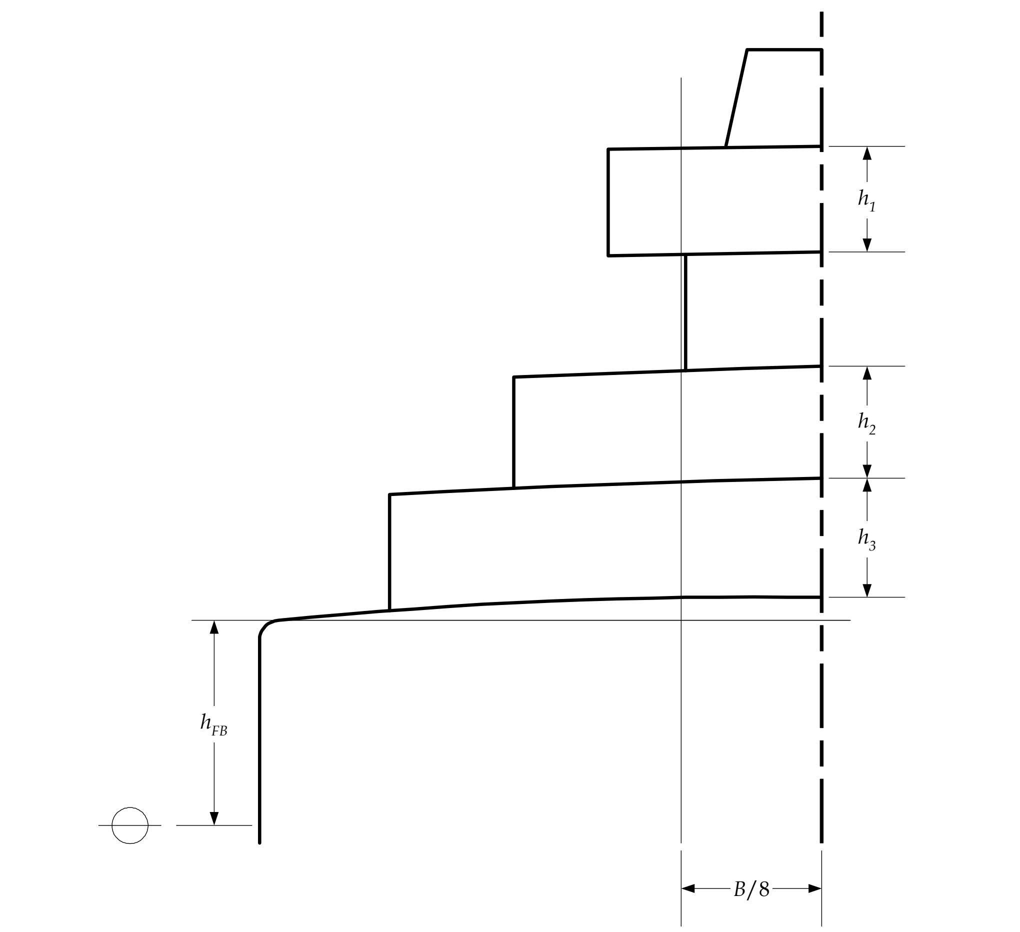
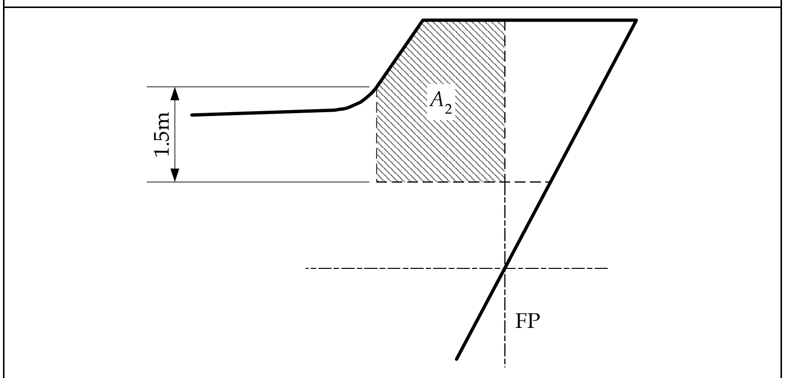


Figure 11.4.2
Profile Areas of Screens and Bulwarks



4.2 Anchors and Mooring Equipment

4.2.1 General

4.2.1.1 The following anchoring equipment specification is intended for temporary mooring of a vessel within a harbour or sheltered area when the vessel is awaiting berth, tide, etc.

4.2.2 Limitations

4.2.2.1 The equipment specified is not intended to be adequate to hold a ship off fully exposed coasts in rough weather or to stop a ship that is moving or drifting. In such a condition, the loads on the anchoring equipment increase to such a degree that its components may be damaged or lost.

4.2.2.2 The anchoring equipment specified is intended to hold a ship in good holding ground in conditions such as to avoid dragging of the anchor. In poor holding ground, the ability of the anchors to hold the ship will be significantly reduced.

4.2.3 Assumptions

4.2.3.1 The Equipment Number (*EN*) formula for the required anchoring equipment is based on an assumed current speed of 2.5m/s, wind speed of 25m/s and a scope of chain cable between 6 and 10. The scope of chain cable is defined as the ratio between the length of chain paid out and the waters depth.

4.2.3.2 It is assumed that under normal circumstances a ship will use only one bow anchor and chain cable at a time.

4.2.4 Documentation

4.2.4.1 The following plans and particulars are to be submitted for approval:

(a) equipment number calculations

(b) list of equipment including type of anchor, grade of anchor chain, type and breaking load of steel and fibre ropes

(c) anchor design, if different from standard or previously approved anchor types, including material specification

(d) windlass design; including material specifications for cable lifters, shafts, couplings and brakes

(e) chain stopper design and material specification

(f) emergency towing, towing and mooring arrangement plans and applicable Safe Working Load data, and other information related to emergency towing and mooring arrangements that will be available onboard the ship for the guidance of the Master.

4.2.5 Anchors

4.2.5.1 Two bower anchors are to be connected to chain cable and stowed in position ready for use.

4.2.5.2 A third anchor is recommended to be provided as a spare bower anchor and is listed for guidance only; it is not required as a condition of classification.

4.2.5.3 Anchors are to be of an approved design. The design of anchor heads is to be such as to minimize stress concentrations. In particular, the radii, on all parts of cast anchor heads are to be as large as possible, especially where there is considerable change of section.

4.2.5.4 The mass per anchor of bower anchors given in *Table 11.4.1* is for anchors of equal mass. The mass of individual anchors may vary 7% above or below the tabulated value, provided that the combined mass of all anchors is not less than that required for anchors of equal mass.

4.2.6 Ordinary anchors

4.2.6.1 Anchors are to be of the stockless type. The mass of the head of a stockless anchor, including pins and fittings, is not to be less than 60% of the total mass of the anchor.

4.2.7 High holding power anchors

4.2.7.1 Where agreed by the Owner, consideration will be given to the use of special types of anchors. Where these are of a proven increased holding ability, consideration may also be given to some reduction in the basic requirement of anchor mass, up to a maximum of 25 percent from the mass specified in *Table 11.4.1*.

4.2.7.2 An anchor for which approval is sought as a high holding power (HHP) anchor is to be tested at sea to show that it has a holding power of twice that approved for a standard stockless anchor of the same mass.

4.2.7.3 If approval is sought for a range of sizes then at least two are to be tested. The smaller of the two anchors is to have a mass not less than one-tenth of that of the larger anchor. The larger of the two anchors tested is to have a mass not less than one-tenth of that of the largest anchor for which approval is sought.

4.2.7.4 Each test is to comprise a comparison between at least two anchors, one ordinary stockless bower anchor and one HHP anchor. The masses of the anchors are to be approximately equal.

4.2.7.5 The tests are to be conducted on at least three different types of bottom, which may be soft mud or silt, sand or gravel, and hard clay or similarly compacted material.

4.2.7.6 The tests are generally to be carried out by means of a tug. The pull is to be measured by a dynamometer or determined from recently verified data of the tug's bollard pull as a function of propeller rpm.

4.2.7.7 The diameter of the chain cables connected to the anchors is to be as required for the relevant Equipment Number. During the test, the length of the chain cable on each anchor is to be sufficient to obtain an approximately horizontal pull on the anchor. Generally, a horizontal distance between anchor and tug equal to 10 times the water depth will be sufficient.

4.2.7.8 High holding power anchors are to be of a design that will ensure that the anchors will take effective hold of the sea bed without undue delay and will remain stable, for holding forces up to those required by *4.2.7.2*, irrespective of the angle or position at which they first settle on the sea bed when dropped from a normal type of hawse pipe. A demonstration of these abilities may be required.

4.2.7.9 The design approval of high holding power anchors may be given as a general/type approval, and listed in a published document by the Society.

4.2.8 Chain cables

4.2.8.1 The total length of chain required to be carried onboard, as given in *Table 11.4.1*, is to be divided approximately equally between the two bower anchors.

4.2.8.2 Where the Owner requires equipment for anchoring at depths greater than 82.5m, it is the Owner's responsibility to specify the appropriate total length of the chain cable required. In such a case, consideration can be given to dividing the chain cable into two unequal lengths.

4.2.8.3 Chain cables which are intended to form part of the equipment are not to be used as check chains when the vessel is launched.

4.2.9 Chain lockers

4.2.9.1 The chain locker is to have adequate capacity and be of a suitable form to provide for the proper stowage of the chain cable, allowing an easy direct lead for the cable into the chain pipes when the cable is fully stowed. Port and starboard cables are to have separate spaces.

4.2.9.2 The chain locker boundaries and access openings are to be watertight. Provisions are to be made to minimize the probability of the chain locker being flooded in bad weather. Adequate drainage facilities for the chain locker are to be provided.

4.2.9.3 Chain or spurling pipes are to be of suitable size and provided with chafing lips.

4.2.9.4 Chain lockers fitted aft the collision bulkhead are to be watertight and the space is to be efficiently drained.

4.2.10 Securing and emergency release of chain cable

4.2.10.1 Provisions are to be made for securing the inboard ends of the chain to the structure. This attachment is to be able to withstand a force of not less than 15% or more than 30% of the minimum breaking strength of the as fitted chain cable. The structure to which it is attached is to be adequate for this load.

4.2.10.2 The fastening of the chain to the ship is to be arranged in such a way that in case of an emergency, when the anchor and chain have to be sacrificed, the chain can be readily released from an accessible position outside the chain locker. The proposed arrangement for slipping the chain cable must be made as watertight as possible.

4.2.11 Chain stoppers

4.2.11.1 Means are to be provided to secure each chain cable once it is paid out. This is normally achieved by means of chain stoppers.

4.2.11.2 Securing arrangements of chain stoppers are to be capable of withstanding a load equal to 80% of the breaking load of the chain cable as required by *4.2.8*, without undergoing permanent deformation.

4.2.12 Tests

4.2.12.1 All anchors and chain cables are to be tested at establishments and on machines recognised by the Society, under the supervision of Surveyors or other Representatives of the Society and in accordance with the relevant requirements for materials of the individual Classification Society.

4.2.12.2 Test certificates showing particulars of weights of anchors, or size and weight of cable and of the test loads applied are to be available. These certificates are to be examined by the Surveyor when the anchors and cables are placed onboard the ship.

4.2.12.3 Steel wire and fibre ropes are to be tested in accordance with the relevant requirements for materials of the individual Classification Society.

4.2.13 Mooring lines and towlines

4.2.13.1 Except as indicated in *4.3*, mooring lines and towlines are not required as a condition of Classification. The hawsers and towlines listed in *Table 11.4.2* are intended as a guide. Where the tabular breaking strength is greater than 490kN, the breaking strength and the number of individual hawsers given in the Table may be modified, provided that their product is not less than that of the breaking strength and the number of hawsers given in the Table.

4.2.14 Increased number or strength of mooring lines

4.2.14.1 On a ship regularly using exposed berths, it is recommended that the total strength of mooring lines is twice that indicated in *4.2.13.1*.

4.2.14.2 Attention is also drawn to the Oil Companies International Marine Forum document, *Mooring Equipment Guidelines*, for guidance on mooring of tankers at exposed locations.

4.2.15 Alternative mooring arrangement

4.2.15.1 For ease of handling, fibre ropes should not to be less than 20mm in diameter.

4.2.15.2 All ropes having breaking strengths greater than 736kN and used in normal mooring operations should be handled by, and stored on, suitably designed winches. Alternative methods of storing are to give due consideration to the difficulties experienced in manually handling ropes having breaking strengths in excess of 490kN. In such cases, the breaking strength and the number of individual hawsers given in *Table 11.4.2* may be modified, but their product is not to be less than that of the breaking strength and the number of hawsers given in the Table. However, the number of mooring lines is not be less than six, and no line should have a breaking strength less than 490kN.

4.2.16 Securing mooring lines

4.2.16.1 Means should be provided to enable mooring lines to be adequately secured onboard ship. It is recommended that the total number of suitably placed bollards on either side of the ship and/or the total brake holding power of mooring winches is to be capable of holding not less than 1.5 times the sum of the maximum breaking strengths of the mooring lines.

4.2.17 Bollards and bitts, fairleads, stand rollers and chocks

4.2.17.1 The strength of shipboard fittings used for normal and/or emergency operations at bow, sides and stern are to comply with the requirements of *4.2.17.2* and *4.2.17.3*. The requirements for the support structure of these shipboard fittings are specified in *3.1.6*.

4.2.17.2 Shipboard fittings are to be designed and constructed in accordance with recognized standards (e.g. ISO3913 Shipbuilding Welded Steel Bollards). The design load used to assess shipboard fittings and their attachments to the hull are to be in accordance with *3.1.6*.

4.2.17.3 The following requirements on Safe Working Load (SWL) apply to shipboard fittings used for mooring and/or emergency towing:

(a) the SWL is not to exceed 80% of the design load specified in *3.1.6.10(a)* and *3.1.6.10(c)* or 100% of the design load specified in *3.1.6.10(b)*, as applicable

(b) the SWL of each fitting is to be marked by weld bead or equivalent

(c) the SWL with its intended use, i.e., mooring, towing or emergency towing operations or some combination thereof, for each fitting is to be indicated in the towing/emergency towing and mooring arrangement plans available onboard the ship for the guidance of the Master. The arrangement plans or information is to include information on each fitting detailing location on the ship, fitting type, Safe Working Load, purpose, method of applying load and limiting fleet angle, and it is to explicitly prohibit the use of mooring and/or towing lines outside of their intended function and/or different characteristics

(d) the requirements of this paragraph apply for a single post basis (no more than one turn of one cable).

4.2.18 Mooring winches

4.2.18.1 Mooring winch design and capacity are not subject to approval by the Society as a condition of Classification. Mooring winch plans and information are to be submitted for approval of the supporting structure in way of the winch and for the connection of the mooring winch to its foundation and the connection of the foundation to the deck, as required by *3.1.3*.

Guidance Note:
Mooring winches should be fitted with drum brakes, the strength of which is to be sufficient to prevent unreeling of the mooring line when the rope tension is equal to 80 percent of that for a rope with breaking strength equal to the greater of the maximum breaking strength of the rope specified on the mooring arrangement plan or that according to *Table 11.4.2* for the ship's corresponding equipment number, as fitted on the first layer on the winch drum.

4.2.19 Windlass

4.2.19.1 A windlass of sufficient power and suitable for the size of chain is to be fitted to the ship in accordance with the requirements of the Classification Society. Where an Owner requires equipment significantly in excess of Rule requirements, it is the Owner's responsibility to specify increased windlass power.

4.2.19.2 The windlass is to be capable of heaving in either cable.

4.2.19.3 The design of the windlass is to be such that access to the chain pipe is adequate to permit the fitting of a cover or seal of sufficient strength over the sperling pipe.

Special consideration will be given to the acceptance of equivalent arrangements that minimize the probability of the chain locker or forecastle being flooded in bad weather.

4.2.20 Anchor windlass trial

4.2.20.1 Each windlass is to be tested under working conditions after installation onboard to demonstrate satisfactory operation. Each unit is to be independently tested for the following:

(a) braking

(b) clutch functioning

(c) lowering and hoisting of chain cable and anchor

(d) proper riding of the chain over the chain lifter

(e) proper transit of the chain through the hawse pipe and the chain pipe

(f) effecting proper stowage of the chain and the anchor.

4.2.20.2 During trials onboard ship, the windlass is to be shown to:

(a) for all specified design anchorage depths, raise the anchor from a depth of 82.5m to a depth of 27.5m at a mean speed of 9m/min

(b) for specified design anchorage depths greater than 82.5m, in addition to (a), raise the anchor from the specified design anchorage depth to a depth of 82.5m at a mean speed of 3m/min.

Where the depth of the water in the trial area is inadequate, suitable equivalent simulating conditions will be considered as an alternative.

4.2.21 Stowage and deployment arrangements for anchors

4.2.21.1 Arrangements are to be provided to ensure the simple deployment, recovery and stowage of anchors. Such arrangements generally consist of a hawse pipe and anchor housing which may be in the form of a fabricated anchor box or pocket.

4.2.21.2 Where hawse pipes are not fitted, alternative arrangements will be specially considered.

4.2.22 Dimensions and scantlings of hawse pipes and anchor pockets

4.2.22.1 Hawse pipes are to be of a suitable size and configuration to ensure adequate clearance and an easy lead of the chain cable from the chain stopper through the ship's side.

4.2.22.2 Hawse pipes are to be of sufficient strength.

4.2.22.3 Anchor pockets are to be of substantial thickness and of a suitable size and form to house the anchors efficiently, preventing, as much as practicable, slackening of the cable or movements of the anchor, caused by wave action.

4.2.22.4 Hawse pipes and anchor pockets are to have full-rounded flanges or rubbing bars in order to minimize the nip on the cables and to minimize the probability of cable links being subjected to high bending stresses. The radius of curvature is to be such that at least three links of chain will bear simultaneously on the rounded parts of the upper and lower ends of the hawse pipes in those areas where the chain cable is supported during paying out and hoisting and when the vessel is at anchor.

4.2.23 Hull reinforcement

4.2.23.1 Hawse pipes are to be securely attached to thick, doubling or insert plates, by continuous welds.

4.2.23.2 Framing in way of hawse pipes or anchor pockets is to be reinforced as necessary to ensure a rigid fastening to the hull.

4.2.23.3 On ships provided with a bulbous bow, where it is not possible to obtain a suitable clearance between shell plating and the anchors during anchor handling, local reinforcements of the bulbous bow are to be provided in the form of increased shell plate thickness.

4.2.24 Testing

4.2.24.1 The anchors are to be shipped and unshipped so that the Surveyor is satisfied that there is no risk of the anchor jamming in the hawse pipe.

4.2.24.2 During the windlass trials at sea, the Surveyor is to be satisfied that upon release of the brake, the anchor immediately starts falling by its own weight.

4.2.24.3 When in position, hawse pipes and anchor pockets are to be thoroughly tested for watertightness by means of a hose in which the water pressure is in accordance with the requirements given in *Sub-section 5*.

Table 11.4.1
Equipment – Bower Anchors and Chain Cables

Equipment Number		Stockless bower anchors		Chain cable stud link bower chain diameter			
greater than or equal to	less than	Number of anchors	Mass per anchor, in kg	Length, in m	Normal strength steel (Grade 1), in mm	Higher strength steel (Grade 2), in mm	Extra higher strength steel (Grade 3), in mm
150	175	2	480	275	22	19	
175	205	2	570	302.5	24	20.5	
205	240	2	660	302.5	26	22	20.5
240	280	2	780	330	28	24	22
280	320	2	900	357.5	30	26	24
320	360	2	1020	357.5	32	28	24
360	400	2	1140	385	34	30	26
400	450	2	1290	385	36	32	28
450	500	2	1440	412.5	38	34	30
500	550	2	1590	412.5	40	34	30
550	600	2	1740	440	42	36	32
600	660	2	1920	440	44	38	34
660	720	2	2100	440	46	40	36
720	780	2	2280	467.5	48	42	36
780	840	2	2460	467.5	50	44	38
840	910	2	2640	467.5	52	46	40
910	980	2	2850	495	54	48	42
980	1060	2	3060	495	56	50	44
1060	1140	2	3300	495	58	50	46
1140	1220	2	3540	522.5	60	52	46
1220	1300	2	3780	522.5	62	54	48
1300	1390	2	4050	522.5	64	56	50
1390	1480	2	4320	550	66	58	50
1480	1570	2	4590	550	68	60	52
1570	1670	2	4890	550	70	62	54
1670	1790	2	5250	577.5	73	64	56
1790	1930	2	5610	577.5	76	66	58
1930	2080	2	6000	577.5	78	68	60
2080	2230	2	6450	605	81	70	62
2230	2380	2	6900	605	84	73	64
2380	2530	2	7350	605	87	76	66
2530	2700	2	7800	632.5	90	78	68
2700	2870	2	8300	632.5	92	81	70
2870	3040	2	8700	632.5	95	84	73
3040	3210	2	9300	660	97	84	76

Table 11.4.1 (Continued)
Equipment – Bower Anchors and Chain Cables

Equipment Number		Stockless bower anchors		Chain cable stud link bower chain diameter			
greater than or equal to	less than	Number of anchors	Mass per anchor, in kg	Length, in m	Normal strength steel (Grade 1), in mm	Higher strength steel (Grade 2), in mm	Extra higher strength steel (Grade 3), in mm
3210	3400	2	9900	660	100	87	78
3400	3600	2	10500	660	102	90	78
3600	3800	2	11100	687.5	105	92	81
3800	4000	2	11700	687.5	107	95	84
4000	4200	2	12300	687.5	111	97	87
4200	4400	2	12900	715	114	100	87
4400	4600	2	13500	715	117	102	90
4600	4800	2	14100	715	120	105	92
4800	5000	2	14700	742.5	122	107	95
5000	5200	2	15400	742.5	124	111	97
5200	5500	2	16100	742.5	127	111	97
5500	5800	2	16900	742.5	130	114	100
5800	6100	2	17800	742.5	132	117	102
6100	6500	2	18800	742.5	*	120	107
6500	6900	2	20000	770	*	124	111
6900	7400	2	21500	770	*	127	114
7400	7900	2	23000	770	*	132	117
7900	8400	2	24500	770	*	137	122
8400	8900	2	26000	770	*	142	127
8900	9400	2	27500	770	*	147	132
9400	10000	2	29000	770	*	152	132
10000	10700	2	31000	770	*	*	137
10700	11500	2	33000	770	*	*	142
11500	12400	2	35500	770	*	*	147
12400	13400	2	38500	770	*	*	152
13400	14600	2	42000	770	*	*	157
14600	16000	2	46000	770	*	*	162

Note

1. Spare anchors are not included in the number of required anchors.
2. '*' chain grade not to be used at this diameter.

Table 11.4.2
Equipment - Towline and Hawsers

Equipment Number		Towline wire or rope		Hawsers		
greater than or equal to	less than	Length, in m	Breaking strength, in kN	Number	Length of each, in m	Breaking strength, in kN
150	175	180	98.0	3	120	54.0
175	205	180	112.0	3	120	59.0
205	240	180	129.0	4	120	64.0
240	280	180	150.0	4	120	69.0
280	320	180	174.0	4	140	74.0
320	360	180	207.0	4	140	78.0
360	400	180	224.0	4	140	88.0
400	450	180	250.0	4	140	98.0
450	500	180	277.0	4	140	108.0
500	550	190	306.0	4	160	123.0
550	600	190	338.0	4	160	132.0
600	660	190	371.0	4	160	147.0
660	720	190	406.0	4	160	157.0
720	780	190	441.0	4	170	172.0
780	840	190	480.0	4	170	186.0
840	910	190	518.0	4	170	201.0
910	980	190	559.0	4	170	216.0
980	1060	200	603.0	4	180	230.0
1060	1140	200	647.0	4	180	250.0
1140	1220	200	691.0	4	180	270.0
1220	1300	200	738.0	4	180	284.0
1300	1390	200	786.0	4	180	309.0
1390	1480	200	836.0	4	180	324.0
1480	1570	220	888.0	5	190	324.0
1570	1670	220	941.0	5	190	333.0
1670	1790	220	1024.0	5	190	353.0
1790	1930	220	1109.0	5	190	378.0
1930	2080	220	1168.0	5	190	402.0
2080	2230	240	1259.0	5	200	422.0
2230	2380	240	1356.0	5	200	451.0
2380	2530	240	1453.0	5	200	480.0
2530	2700	260	1471.0	6	200	480.0
2700	2870	260	1471.0	6	200	490.0
2870	3040	260	1471.0	6	200	500.0
3040	3210	280	1471.0	6	200	520.0
3210	3400	280	1471.0	6	200	554.0
3400	3600	280	1471.0	6	200	588.0
3600	3800	300	1471.0	6	200	618.0
3800	4000	300	1471.0	6	200	647.0
4000	4200	300	1471.0	7	200	647.0
4200	4400	300	1471.0	7	200	657.0
4400	4600	300	1471.0	7	200	667.0
4600	4800	300	1471.0	7	200	677.0
4800	5000	300	1471.0	7	200	686.0

Table 11.4.2 (Continued)
Equipment - Towline and Hawsers

Equipment Number		Towline wire or rope		Hawsers		
greater than or equal to	less than	Length, in m	Breaking strength, in kN	Number	Length of each, in m	Breaking Strength, in kN
5000	5200	300	1471.0	8	200	686.0
5200	5500	300	1471.0	8	200	696.0
5500	5800	300	1471.0	8	200	706.0
5800	6100	300	1471.0	8	200	706.0
6100	6500	300	1471.0	9	200	716.0
6500	6900	300	1471.0	9	200	726.0
6900	7400	300	1471.0	10	200	726.0
7400	7900	300	1471.0	11	200	726.0
7900	8400	300	1471.0	11	200	735.0
8400	8900	300	1471.0	12	200	735.0
8900	9400	300	1471.0	13	200	735.0
9400	10000	300	1471.0	14	200	735.0
10000	10700	-	-	15	200	735.0
10700	11500	-	-	16	200	735.0
11500	12400	-	-	17	200	735.0
12400	13400	-	-	18	200	735.0
13400	14600	-	-	19	200	735.0
14600	16000	-	-	21	200	735.0

4.3 Emergency Towing

4.3.1 General requirements

4.3.1.1 Emergency towing arrangements are to be fitted at both the bow and stern of every tanker with a deadweight of 20000 tonnes or more, as required by the *International Convention for the Safety of Life at Sea, 1974, as amended (Regulation II-1/3-4)*.

4.3.1.2 The design and construction of the towing arrangements is to be approved by the applicable Flag Administration, based on *IMO MSC.35(63), Guidelines for Emergency Towing Arrangements on Tankers*. See also *3.1.5* for requirements relating to the support structure of emergency towing equipment.

5 TESTING PROCEDURES

5.1 Tank Testing

5.1.1 Application

5.1.1.1 The following tanks and boundaries are to be tested in accordance with the requirements given in *5.1.3* to *5.1.9*, as follows:

(a) gravity tanks, excluding independent tanks of less than 5m^3 in capacity, for their structural adequacy and tightness

(b) watertight boundaries, other than tank boundaries, for watertightness

(c) weathertight boundaries for weathertightness.

5.1.2 Definitions

5.1.2.1 Watertight means capable of preventing the passage of water through the structure under a head of water for which the surrounding structure is designed.

5.1.2.2 Weathertight means that in any sea conditions water will not penetrate into the ship.

5.1.2.3 Structural Testing is a hydrostatic test carried out in order to demonstrate structural adequacy of the design. Where severe practical limitations prevail and hydrostatic testing is not feasible, hydropneumatic testing may be carried out instead.

5.1.2.4 Leak Testing is an air or other medium test, carried out in order to demonstrate the tightness of the structure.

5.1.2.5 Hose Testing is carried out by a jet of water in order to demonstrate the tightness of the structure items which are not subjected to hydrostatic or leak testing, and to other components which contribute to the watertight or weathertight integrity of the hull.

5.1.2.6 Hydropneumatic Testing is a combination of hydrostatic and air testing, undertaken by filling the tank with water and applying an additional air pressure. It is carried out in order to demonstrate the tightness of the tanks and the structural adequacy of the design as an alternative to a hydrostatic test.

5.1.2.7 Hydrostatic Testing is a test to verify the structural adequacy of the design and the tightness of the tank's structure by means of water pressure, produced by filling water to the level given in *Table 11.5.1*. Hydrostatic testing is the normal means for structural testing, with exception, where severe practical limitations prevent it or where air testing is permitted.

5.1.2.8 Shop Primer is a thin coating applied after surface preparation and prior to fabrication as a protection against corrosion during fabrication.

5.1.2.9 Protective Coating is the coating system applied to protect the structure from corrosion. This excludes the shop primer.

5.1.3 Test procedures

5.1.3.1 Tests are to be carried out in the presence of, and to the satisfaction of the Surveyor. The construction is to be at a stage sufficiently close to completion, after all attachments, outfittings or penetrations, which may affect the strength or tightness of the structure, have been completed, such that the strength and tightness are not subsequently impaired, and before any ceiling and cement work is applied over joints.

5.1.3.2 Specific test requirements are given in *Table 11.5.1*.

5.1.3.3 For the timing of the application of coating in relation to testing, see *5.1.8*.

5.1.4 Structural testing

5.1.4.1 Where structural testing is specified by *Table 11.5.1*, hydrostatic testing will be acceptable, except where practical limitations prevent it or where leak testing is permitted by *Note 1* to *Table 11.5.1*. Hydropneumatic testing may be approved in lieu of hydrostatic testing.

5.1.4.2 Hydrostatic testing is to consist of a head of water to the level specified in *Table 11.5.1*.

5.1.4.3 Hydropneumatic testing, where approved, is to simulate the actual loading as far as practicable in relation to the combined water level and air pressure. The requirements and recommendations in *5.1.5* relative to air pressure will also apply.

5.1.4.4 Structural testing may be carried out afloat where testing using water is undesirable in dry dock or on the building berth. When structural testing is carried out afloat it is to be performed by filling each tank and cofferdam separately to the test head given in *Table 11.5.1*.

5.1.4.5 With about half the number of tanks full, the bottom and lower side shell in the empty tanks is to be examined and the remainder of the lower side shell is to be examined when the water has been transferred to the remaining tanks.

5.1.4.6 Tank boundaries are to be tested from at least from one side. Tanks to be tested for structural adequacy (see *Note 1* to *Table 11.5.1*) are to be selected so that all representative structural members are tested for the expected tension and compression.

5.1.5 Leak testing

5.1.5.1 All boundary welds, erection joints, and penetrations including pipe connections, except welds made by automatic processes are to be examined in accordance with the approved procedure and under a pressure of at least 0.15bar with a leak indicating solution (e.g. soapy water solution). Pressures greater than 0.20bar are not recommended.

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5.1.5.2 It is recommended that the air pressure in the tank be raised to and maintained at 0.20bar for approximately one hour, with a minimum number of personnel around the tank, before being lowered to the test pressure.

5.1.5.3 A U-tube filled with water up to a height corresponding to the required test pressure is to be fitted for verification and to avoid over pressure. The cross sectional area of the U-tube is to be not less than that of the pipe supplying the air. In addition to the U-tube, a master gauge or other approved means is to be provided to verify the pressure.

5.1.5.4 Other effective methods of leak testing, including compressed air fillet weld testing or vacuum testing may be considered upon submission of full particulars.

5.1.6 Hose testing

5.1.6.1 Hose testing is applied to structures not subjected to structural or air testing but that are required to be watertight or weathertight as specified in *Table 11.5.1*.

5.1.6.2 Hose testing is to be carried out with a pressure in the hose of at least 2.0 bar for the duration of the test. The nozzle is to have minimum inside diameter of 12mm and is to be directed at the joint being tested from a distance not exceeding 1.5m.

5.1.6.3 Leak testing or structural testing may be accepted in lieu of hose testing.

5.1.7 Other methods of testing

5.1.7.1 Other methods of testing may be considered upon submission of the full particulars.

5.1.8 Application of coating – protective coating

5.1.8.1 Final coating may be applied prior to the hydrostatic testing provided that leak testing is carried out before the application of the final coating.

5.1.8.2 The cause of any discolouration or disturbance of the coating is to be ascertained, and any deficiencies repaired.

5.1.8.3 For all manual or semi-automatic erection welds, and all fillet weld tank boundary connections, including penetrations, final coating is to be applied after leak testing has taken place. For other welds, the final coating may be applied prior to leak testing, provided the Surveyor, after careful examination prior to the application of coating, is satisfied with the weld. The Surveyor may require leak testing to be carried out prior to final coating of automatic erection welds and manual or automatic pre-erection welds, taking account of the quality control procedure of the shipyard.

5.1.8.4 Final coating is to be applied after all required hose testing is completed.

5.1.9 Temporary coating

5.1.9.1 Temporary coatings which may conceal defects or leaks are to be applied as specified for protective coating, see *5.1.8*. This requirement does not apply to shop primer applied before fabrication.

5.1.9.2 Silicate based shop primer may be applied to welds before leak testing. The layer of the primer is to be applied with a maximum thickness of 50 microns. Other primers of uncertain chemical composition are to be applied with a maximum thickness of 30 microns.

Table 11.5.1
Testing Requirements for Tanks and Boundaries

	Structures to be tested	Type of testing	Hydrostatic testing head or pressure	Remarks
1	Double Bottom Tanks	Structural(1)	The greater of - to the top of overflow, or - to the bulkhead deck	Tank boundaries tested from at least one side
2	Double Side Tanks	Structural(1)	The greater of - to the top of overflow, or - to 2.4m above top of tank(2)	Tank boundaries tested from at least one side
3	Cargo Tanks Fuel Oil Bunkers	Structural(1) Structural(1)	The greatest of - to the top of overflow, - to 2.4m above top of tank(2), or - to the top of tank(2) plus setting of any pressure relief valve	Tank boundaries tested from at least one side
4	Cofferdams	Structural(3)	The greater of - to the top of overflow, or - to 2.4m above top of cofferdam	
5a	Peak Tanks	Structural	The greater of - to the top of overflow, or - to 2.4m above top of tank(2)	Aft peak tank test to be carried out after installation of stern tube.
5b	Fore Peak not used as a tank	Refer to *SOLAS II.1 Reg.14*		
5c	Aft Peak not used as a tank	Leak		
6	Watertight Bulkheads in way of dry space	Hose(4)		Including steps and recesses
7	Watertight Doors below freeboard or bulkhead deck	Hose		For testing before installation(5)
8	(void)			
9	Watertight hatch covers of tanks on combination carriers	Structural testing	The greater of: - to 2.4m above the top of hatch cover, or - setting pressure of the pressure relief valve	At least every second hatch cover is to be tested
10	Weathertight Hatch Covers, Doors and other Closing Appliances	Hose(4)		
11	Shell plating in way of pump room	Visual examination		To be carefully examined with the vessel afloat

RCN 2 to July 2008 version (effective from 1 July 2010)
RCN 1 to July 2010 version (effective from 1 July 2012)

Table 11.5.1 (Continued)
Testing Requirements for Tanks and Boundaries

	Structures to be tested	Type of testing	Hydrostatic testing head or pressure	Remarks
12	Chain Locker (aft Collision Bulkhead)	Structural	To the top of chain locker spurling pipe	
13	Independent Tanks	Structural	The greater of - to the top of overflow, or - to 0.9 m above top of tank	
14	Ballast Ducts	Structural	Ballast pump maximum pressure or setting of any relief valve for the ballast duct if that is less	
15	Hawse Pipes	Hose		

Note

1. Leak or hydropneumatic testing may be accepted under the conditions specified in *5.1.5*, provided that at least one tank for each type is structurally tested, and selected in connection with the approval of the design. In general, the structural testing need not be repeated for subsequent vessels of a series of identical new buildings unless the Surveyor deems the repetition necessary. The structural testing of cargo space boundaries and tanks for segregated cargoes or pollutants on subsequent vessels of a series of identical new buildings are to be in accordance with the requirements of the individual Classification Society.
2. Top of tank is defined as the deck forming the top of the tank excluding hatchways.
3. Leak testing in accordance with *5.1.5* may be accepted, except that hydropneumatic testing may be required in consideration of the construction techniques and welding procedures employed.
4. Where hose testing is impractical due to the stage of outfitting (machinery, cables, switchboard, insulation etc.), it may be replaced at the individual Society's discretion, by a careful visual examination of all the crossings and welded joints. A dye penetrant test, leak test or ultrasonic leak test may be required.
5. Before installation (i.e. normally at manufacture) the watertight access doors or hatches are to be hydrostatically tested with a head of water equivalent to the bulkhead deck at centre, from the side which is most prone to leakage. The acceptance criteria are as follows:
    - no leakage for doors or hatches with gaskets
    - a maximum water leakage of one litre per minute for doors or hatches with metallic sealing.
6. If leak or hydropneumatic testing is carried out, arrangements are to be made to ensure that no pressure in excess of 0.30 bar is applied.

SECTION 12

SHIP IN OPERATION RENEWAL CRITERIA

1 ALLOWABLE THICKNESS DIMINUTION FOR HULL STRUCTURE

1.1 General

1.1.1 Applicability

1.1.1.1 The purpose of this Section is to provide criteria for the allowable thickness diminution of the ships' hull structure.

1.1.1.2 The criteria apply only to ships in operation that are designed and built in accordance with these Rules.

1.1.1.3 Thickness measurements are to be used to assess the ships' structure against the specified renewal criteria.

1.1.2 Wastage allowance concept

1.1.2.1 Wastage allowance is comprised of two aspects; local wastage allowance and overall hull girder wastage allowance. Local wastage allowance is defined in *1.4* and the overall hull girder wastage allowance is defined in *1.5*.

1.1.2.2 Assessment against both local and overall hull girder wastage criteria is required during the operational life of the vessel.

1.1.2.3 Steel renewal is required if either the local or overall hull girder wastage allowance is exceeded.

1.1.2.4 The newbuilding requirements within these Rules incorporate corrosion additions, see *Section 6/3*, and consider all relevant loads and failure modes (e.g. yielding, buckling, and fatigue). No further assessment of the scantlings against the requirements within these Rules is required during the operational life of the ship provided that the thickness of any structural member remains greater than the renewal thickness specified herein.

1.1.3 Requirements for documentation

1.1.3.1 The plans to be supplied onboard the ship, see *Section 3/2.2.3*, are to include both the as-built and renewal thickness as defined in *1.4.2*. Any owner's extra thickness is also to be clearly indicated on the drawings.

1.1.3.2 The "as-built" Midship Section plan provided by the builder and carried on board the ship is to include a table showing the minimum allowable hull girder sectional properties, as defined in *1.5*, for the mid-tank transverse section in all cargo tanks.

1.2 Assessment of Thickness Measurements

1.2.1 General

1.2.1.1 The minimum survey requirements for the maintenance of class of double hull oil tankers are defined in *IACS Unified Requirement Z10.4*.

1.2.1.2 Thickness measurements are to be conducted in accordance with the requirements of the individual Classification Society and *IACS Unified Requirement Z10.4*.

1.2.2 Assessment of local wastage

1.2.2.1 Thickness measurements are to be taken to confirm that the measured thickness is not less than the renewal thickness for general corrosion and local pitting/edge corrosion as defined in *1.4.2* and *1.6* respectively. See also *1.3*.

1.2.2.2 When a survey identifies that steel renewal is required or structural defects are present which, in the opinion of the Surveyor, will impair the ships' fitness for continued service, remedial measures are to be implemented before the ship continues in service.

1.2.2.3 Re-examination and additional thickness measurements at Annual and Intermediate Surveys are required where the measured thickness, t_m, is less than the allowable thickness at annual survey, t_{annual}, defined as:

$$t_{annual} = t_{as-built} - t_{own} - t_{was} \quad \text{mm}$$

Where:

$t_{as\text{-}.built}$ as built thickness, in mm

t_{was} wastage allowance, as defined in *1.4.2.2*

t_{own} owner/builder specified additional wastage allowance, if applicable, in mm

1.2.2.4 Where re-examination and additional thickness measurements are required by *1.2.2.3* then additional measurements are to be carried out in accordance with *Table 12.1.1* to determine the full extent of the corrosion pattern.

Table 12.1.1
Additional Thickness Measurement in way of Structure Identified with $t_m < t_{annual}$

Structural member	Extent of measurement	Pattern of measurement
Plating	Suspect areas and adjacent plates	5 point pattern over 1m^2
Stiffeners	Suspect areas	3 measurements in line across web 3 measurements in line across flange

1.2.2.5 At each Special Survey, thickness measurements are to be taken in way of critical areas, as considered necessary by the Surveyor. Critical areas are to include locations throughout the ship with corrosion levels that are likely to contravene *1.2.2.3* and/or are considered prone to rapid wastage.

1.2.3 Assessment of overall hull girder wastage

1.2.3.1 The hull girder sectional properties of the ship are to be calculated for the cross-sections as specified in *IACS Unified Requirement Z10.4*, based on the thicknesses given by the thickness measurements, to confirm that the resulting hull girder sectional properties are not less than the minimum allowable defined in *1.5.2*. The actual sectional properties calculated based on measured thicknesses and in accordance with *IACS Unified Requirement Z10.4*, are to be submitted to the Classification Society.

1.3 Categories of Corrosion

1.3.1 General corrosion

1.3.1.1 General corrosion is defined as areas where general uniform reduction of material thickness is found over an extensive area.

1.3.1.2 Renewal criteria for general corrosion are given in *1.4*.

1.3.2 Pitting corrosion

1.3.2.1 Pitting corrosion is defined as scattered corrosion spots/areas with local material reductions which are greater than the general corrosion in the surrounding area.

1.3.2.2 The pitting intensity is defined in *Figure 12.1.1*.

1.3.2.3 Renewal criteria for pitting corrosion are given in *1.6.2*.

1.3.3 Edge corrosion

1.3.3.1 Edge corrosion is defined as local corrosion at the free edges of plates, stiffeners, primary support members and around openings. An example of edge corrosion is shown in *Figure 12.1.2*.

1.3.3.2 Renewal criteria for edge corrosion are given in *1.6.3*.

1.3.4 Groove corrosion

1.3.4.1 Groove corrosion is typically local material loss adjacent to weld joints along abutting stiffeners and at stiffener or plate butts or seams. An example of groove corrosion is shown in *Figure 12.1.3*.

1.3.4.2 Renewal criteria for groove corrosion are given in *1.6.4*.

Figure 12.1.1
Pitting Intensity Diagrams

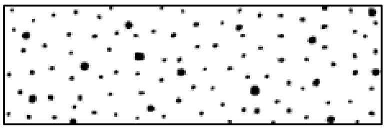
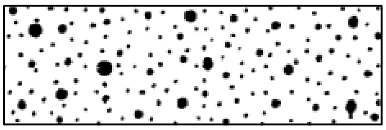
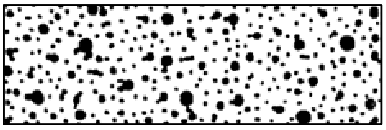
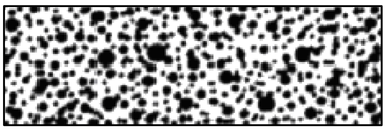
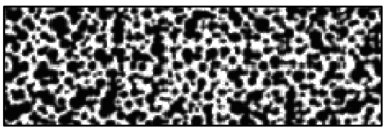
5% Scattered	
10% Scattered	
20% Scattered	
30% Scattered	
50% Scattered	

Figure 12.1.2
Edge Corrosion

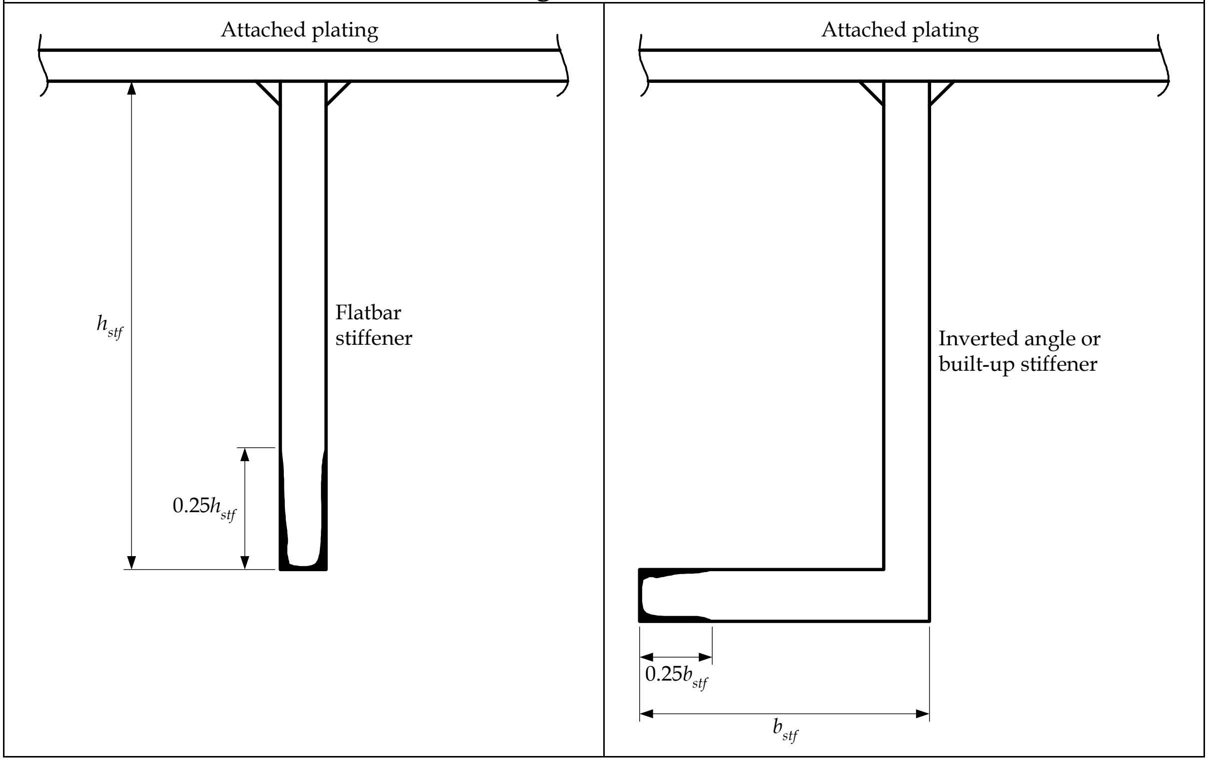
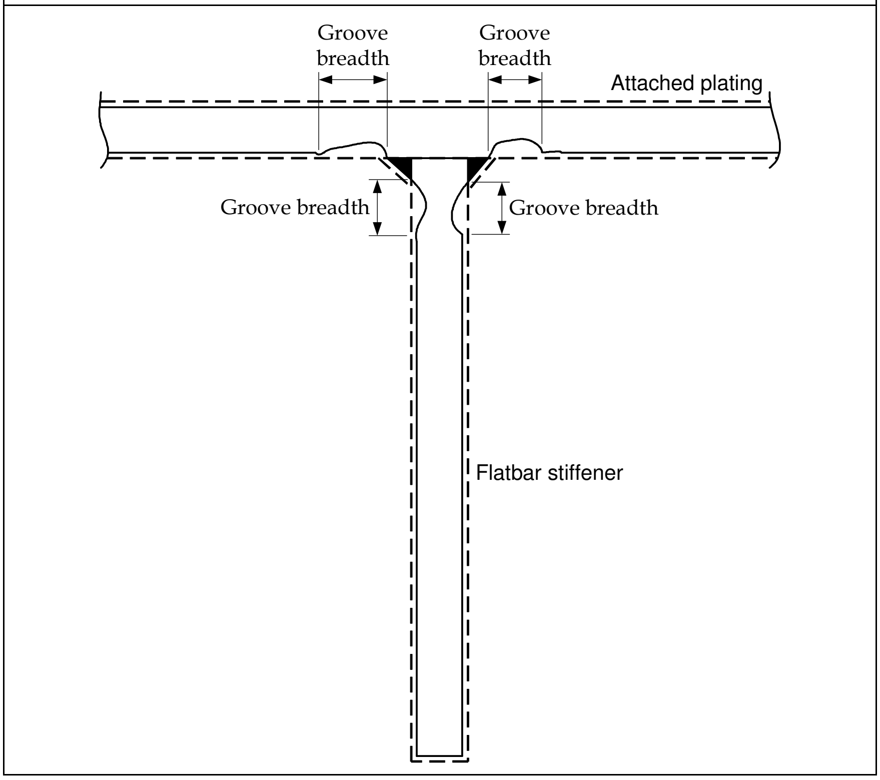


Figure 12.1.3
Groove Corrosion



1.4 Renewal Criteria of Local Structure for General Corrosion

1.4.1 Application

1.4.1.1 The renewal criteria in *1.4.2* generally apply to areas of structural members with general corrosion.

1.4.2 Renewal criteria

1.4.2.1 Steel renewal is required if the measured thickness, t_{tm}, is less than the renewal thickness, t_{ren}, defined as:

$$t_{ren} = t_{as-built} - t_{was} - t_{own} - t_{corr-2.5} \quad \text{mm}$$

Where:

$t_{as-.built}$ as built thickness, in mm

t_{was} wastage allowance, as defined in *1.4.2.2*

t_{own} owner/builder specified additional wastage allowance, if applicable, in mm

$t_{corr-2.5}$ 0.5mm, wastage allowance in reserve for corrosion occurring in the two and a half years between Intermediate and Special surveys

1.4.2.2 The wastage allowance, t_{was}, is given by:

$$t_{was} = t_{was-1} + t_{was-2} \quad \text{mm} \quad \text{and rounded up to the nearest 0.5mm}$$

Where:

t_{was} total wastage allowance of the considered structural member, in mm

t_{was-1} wastage allowance for side one of the structural member considering the contents of the compartment to which it is exposed, in mm, as given *Table 12.1.2*

t_{was-2} wastage allowance for side two of the structural member considering the contents of the compartment to which it is exposed, in mm, as given *Table 12.1.2*

1.4.2.3 In no case is the wastage allowance, t_{was}, to be less than 1.5mm, except in way of internals of dry spaces and pump room where 1.0mm is applicable.

1.4.2.4 Wastage allowances for compartments not listed in *Table 12.1.2* will be subject to special consideration.

1.4.2.5 Areas which need to be renewed based on the renewal criteria in *1.4.2.1* are, in general, to be repaired with inserted material which is to have the same or greater grade/strength as the original and to have a thickness, t_{repair}, not less than:

$$t_{repair} = t_{as-built} - t_{own} \quad \text{mm}$$

Where:

$t_{as-built}$ as built thickness, in mm

t_{own} owner/builder specified additional wastage allowance, if applicable, in mm

Table 12.1.2
Local Wastage Allowance for One Side of Structural Elements

Compartment Type	Structural Member		Ship in Operation Component Wastage Allowance, t_{was-1} or t_{was-2} (mm)
Ballast water tank and chain locker	Face plate of PSM	Within 3m below top of tank (1)	2.0
		Elsewhere	1.5
	Other members(3)	Within 3m below top of tank (1)	1.7
		Elsewhere	1.2
Cargo oil tank	Face plate of PSM	Within 3m below top of tank (1)	1.7
		Elsewhere	1.4
	Inner-bottom plating/bottom of tank		2.1
	Other members	Within 3m below top of tank (1)	1.7
		Elsewhere	1.0
Exposed to atmosphere	Weather deck plating		1.7
	Other members		1.0
Exposed to sea water	Shell plating(2)		1.0
Fuel and lube oil tank (4)	Top of tank and attached internal stiffeners		1.0
	Elsewhere		0.7
Fresh water tank	Top of tank and attached internal stiffeners		1.0
	Elsewhere		0.7
Void spaces	Spaces not normally accessed, e.g. access only via bolted manhole openings, pipe tunnels, etc.		0.7
Dry spaces	Internals of deckhouses, machinery spaces, pump room, store rooms, steering gear space, etc.		0.5

Notes
1. Only applicable to cargo and ballast tanks with weather deck as the tank top.
2. 0.5mm to be added for side plating in the quay contact region as defined in *Section 8/Figure 8.2.2.*
3. 0.5mm to be added to the plate surface exposed to ballast for plate boundary between water ballast and heated cargo oil tanks. 0.3mm to be added to each surfaces of the web and face plate of a stiffener in a ballast tank and attached to the boundary between water ballast and heated cargo oil tanks. Heated cargo oil tanks are defined as tank arranged with any form of heating capability (most common type is heating coils).
4. 0.7mm to be added for plate boundary between water ballast and heated fuel oil tanks

(RCN 1, effective from 1 April 2007)

1.5 Renewal Criteria of Hull Girder Sectional Properties for General Corrosion

1.5.1 General

1.5.1.1 The following actual hull girder sectional properties are required to be verified, see *1.5.2-3*:

(a) vertical hull girder moment of inertia, about the horizontal axis, I_v

(b) hull girder section modulus about the horizontal axis - at deck-at-side, Z_{v-dk}

(c) hull girder section modulus about the horizontal axis - at keel, Z_{v-kl}

(d) hull girder section modulus about the vertical axis - at side, Z_{h-side}

(e) hull girder vertical shear area, A_{v-shr}

1.5.2 Renewal criteria

1.5.2.1 Steel renewal is required if the actual hull girder sectional properties, $I_{v\text{-}tm}$, $Z_{v\text{-}tm\text{-}dk}$, $Z_{v\text{-}tm\text{-}kl}$, $Z_{h\text{-}tm\text{-}side}$, $A_{v\text{-}tm\text{-}shr}$, calculated using the actual thickness measurements are less than the minimum allowable hull girder sectional properties defined in accordance with *1.5.3*.

1.5.2.2 The actual hull girder sectional properties listed in *1.5.2.1* are to be calculated in accordance with *Section 4/2.6*, using the measured thicknesses.

1.5.2.3 If steel renewal is required due to reduced hull girder sectional properties this is to be done by replacing local corroded structural elements. Any combination of structural elements may be replaced provided that the resulting hull girder sectional properties satisfy *1.5.2.1*. Local structural elements being renewed are to be replaced in accordance with the requirements of *1.4.2.3*.

1.5.3 Calculation of the minimum allowable hull girder sectional properties

1.5.3.1 The minimum allowable hull girder sectional properties listed in *1.5.1.1* are to be calculated in accordance with *Section 4/2.6*, using the thicknesses defined in *1.5.3.2*.

1.5.3.2 The minimum allowable hull girder sectional properties in the corroded condition are calculated using the same corrosion thickness reductions that are used during the newbuilding stage, thus linking the newbuilding and ship in operation criteria. Therefore the calculation of the minimum allowable hull girder sectional properties is to be based on a member thickness, t, given by:

$$t = t_{as-built} - 0.5t_{corr} - t_{own} \quad \text{mm}$$

Where:

$t_{as\text{-}built}$ as built thickness, in mm

t_{corr} corrosion addition, as defined in *Section 6/3.2*

t_{own} owner/builder specified additional wastage allowance, if applicable, in mm

1.6 Allowable Material Diminution for Pitting, Grooving and Edge Corrosion

1.6.1 General

1.6.1.1 Steel renewal for pitting, grooving and edge corrosion is required if the measured thickness is less than the criteria defined in *1.6.2*, *1.6.3* and *1.6.4* respectively.

1.6.2 Pitting

1.6.2.1 For plates with pitting intensity less than 20%, see *Figure 12.1.1*, the measured thickness, t_{tm}, of any individual measurement is to meet the lesser of the following criteria:

$$t_{tm} \geq 0.7\left(t_{as-built} - t_{own}\right) \quad \text{mm}$$

$$t_{tm} \geq t_{ren} - 1 \quad \text{mm}$$

Where:

$t_{as\text{-}built}$ as built thickness of the member, in mm

t_{own} owner/builder specified additional wastage allowance, if applicable, in mm

t_{ren} renewal criteria for general corrosion as defined in *1.4.2.1*

1.6.2.2 The average thickness across any cross section in the plating is not to be less than the renewal criteria for general corrosion given in *1.4.2.1*.

1.6.3 Edge corrosion

1.6.3.1 Provided that the overall corroded height of the edge corrosion of the flange, or web in the case of flat bar stiffeners, is less than 25%, see *Figure 12.1.2*, of the stiffener flange breadth or web height, as applicable, the measured thickness, t_{tm}, is to meet the lesser of the following criteria:

$$t_{tm} \geq 0.7(t_{as-built} - t_{own}) \quad \text{mm}$$

$$t_{tm} \geq t_{ren} - 1 \quad \text{mm}$$

Where:

$t_{as-built}$ as built thickness of the member, in mm

t_{own} owner/builder specified additional wastage allowance, if applicable, in mm

t_{ren} renewal criteria for general corrosion as defined in *1.4.2.1*

1.6.3.2 The average measured thickness across the breadth or height of the stiffener is not to be less than that defined in *1.4.2*.

1.6.3.3 Plate edges at openings for manholes, lightening holes etc. may be below the minimum thickness given in *1.4.2* provided that:

(a) the maximum extent of the reduced plate thickness, below the minimum given in *1.4.2*, from the opening edge is not more than 20% of the smallest dimension of the opening and does not exceed 100mm

(b) rough or uneven edges may be cropped-back provided that the maximum dimension of the opening is not increased by more than 10%.

1.6.4 Grooving

1.6.4.1 Where the groove breadth is a maximum of 15% of the web height, but not more than 30mm, see *Figure 12.1.3*, the measured thickness, t_{tm}, in the grooved area is to meet the lesser of the following criteria:

$$t_{tm} \geq 0.75(t_{as-built} - t_{own}) \quad \text{mm}$$

$$t_{tm} \geq t_{ren} - 0.5 \quad \text{mm}$$

but is not to be less than

$$t_{tm} = 6 \quad \text{mm}$$

Where:

$t_{as-built}$ as built thickness of the member, in mm

t_{own} owner/builder specified additional wastage allowance, if applicable, in mm

t_{ren} renewal criteria for general corrosion as defined in *1.4.2.1*

1.6.4.2 Members with areas of grooving greater than those in *1.6.4.1* are to be assessed based on the criteria for general corrosion as defined in *1.4.2* using the average measured thickness across the plating/stiffener.

APPENDIX A

HULL GIRDER ULTIMATE STRENGTH

1 GENERAL

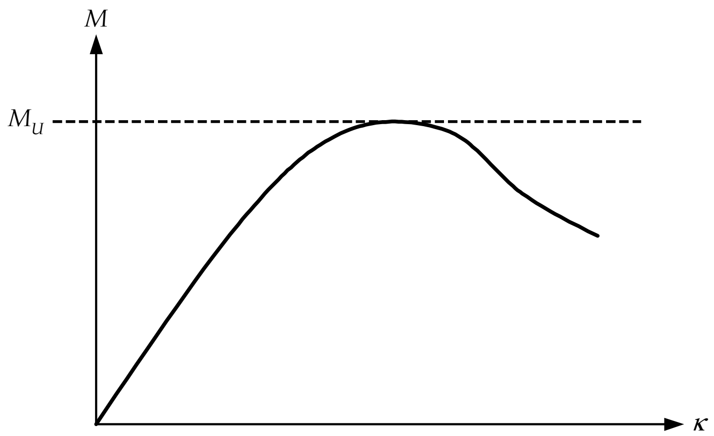
1.1 Definitions

1.1.1 Hull girder bending moment capacity

1.1.1.1 The hull girder ultimate bending moment capacity, M_U, is defined as the maximum bending capacity of the hull girder beyond which the hull will collapse. Hull girder failure is controlled by buckling, ultimate strength and yielding of longitudinal structural elements.

1.1.1.2 The sagging hull girder ultimate capacity of a hull girder section, is defined as the maximum value on the static non-linear bending moment-curvature relationship M-κ, see *Figure A.1.1*. The curve represents the progressive collapse behaviour of hull girder under vertical bending.

Figure A.1.1
Bending Moment - Curvature Curve M-κ



1.1.1.3 The curvature of the critical inter-frame section, κ, is defined as:

$$\kappa = \frac{\theta}{l}$$

Where:

θ the relative angle rotation of the two neighbouring cross-sections at transverse frame positions

l the transverse frame spacing, i.e. span of longitudinals

1.2 Application

1.2.1 General

1.2.1.1 The sagging hull girder ultimate bending capacity is to be assessed by the single step method in *2.1* or the incremental-iterative method in *2.2*. This is only applicable to longitudinally framed double hull tankers in the sagging bending condition.

1.2.1.2 The magnitudes of the partial safety factors in *Section 9/1.4* have been calibrated for this single step method in *2.1* and are also appropriate for the incremental iterative method in *2.2*.

1.3 Assumptions

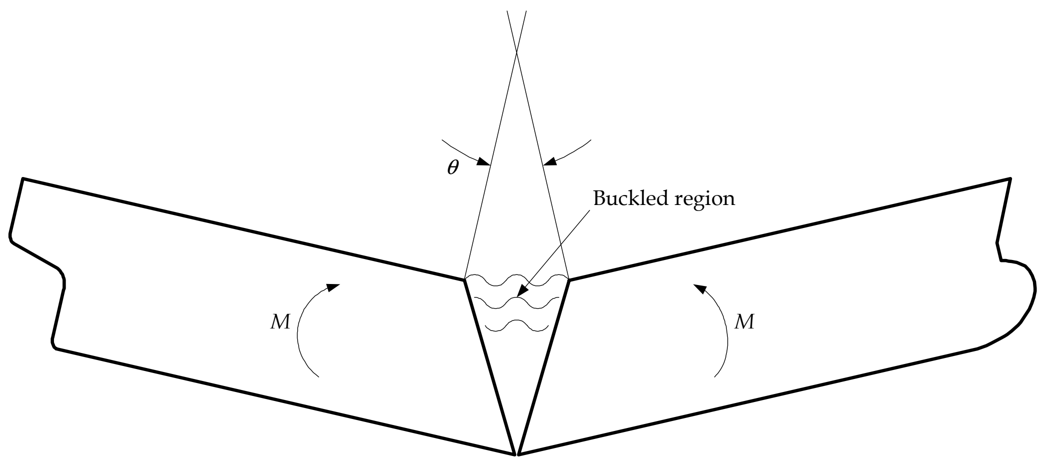
1.3.1 General

1.3.1.1 The method for calculating the ultimate hull girder capacity is to identify the critical failure modes of all main longitudinal structural elements. For tankers, in sagging, the critical mode is generally inter-frame buckling of deck structures, as shown in *Figure A.1.2*.

1.3.1.2 Structures compressed beyond their buckling limit have reduced load carrying capacity. All relevant failure modes for individual structural elements, such as: plate buckling, torsional stiffener buckling, stiffener web buckling, lateral or global stiffener buckling; and their interactions, are to be considered in order to identify the weakest inter-frame failure mode.

1.3.1.3 For tankers in the sagging condition, only vertical bending is considered. The effects of shear force, torsional loading, horizontal bending moment and lateral pressure are neglected.

Figure A.1.2
Ship in Extreme Sagging Inter-Frame Buckling Failure



1.4 Alternative Methods

1.4.1 General

1.4.1.1 Principles for alternative methods for the calculation of the hull girder ultimate bending capacity; e.g. incremental-iterative procedure that may differ from the one defined in *2.2*, and non-linear finite element analysis, are given in *Sub-Section 3*.

1.4.1.2 Application of alternative methods is to be agreed with the individual Classification Society prior to commencement. Documentation of the analysis methodology and detailed comparison of its results with those of the individual Classification Societies' procedures are to be submitted for review and acceptance. The use of such methods may require the partial safety factors in *Section 9/1.4* to be re-calibrated.

2 CALCULATION OF HULL GIRDER ULTIMATE CAPACITY

2.1 Single Step Ultimate Capacity Method

2.1.1 Procedure

2.1.1.1 The single step procedure for calculation of the sagging hull girder ultimate bending capacity is a simplified method based on a reduced hull girder bending stiffness accounting for buckling of the deck, see *Figure A.2.1*. The hull girder ultimate bending moment capacity, M_U, is to be taken as:

$$M_U = Z_{red}\sigma_{yd} \cdot 10^3 \quad \text{kNm}$$

Where:

Z_{red} reduced section modulus of deck (to the mean deck height)

$$= \frac{I_{red}}{z_{dk-mean} - z_{NA-red}} \quad \text{m}^3$$

I_{red} reduced hull girder moment of inertia, in m^4. The inertia is to be calculated in accordance with *Section 4/2.6.1.1*, using:

- a hull girder net thickness of t_{net50} for all longitudinally effective members
- the effective net area after buckling of each stiffened panel of the deck, A_{eff}

A_{eff} effective net area after buckling of the stiffened deck panel. The effective area is the proportion of stiffened deck panel that is effectively able to be stressed to yield:

$$= \frac{\sigma_U}{\sigma_{yd}} A_{net50} \quad \text{m}^2$$

Note

The effective area of deck girders is to be taken as the net area of the girders using a thickness of t_{net50}.

A_{net50} net area of the stiffened deck panel, in m^2

σ_U buckling capacity of stiffened deck panel, in N/mm^2. To be calculated for each stiffened panel using:

- the advanced buckling analysis method, see *Section 10/4* and *Appendix D*
- the net thickness t_{net50}

σ_{yd} specified minimum yield stress of the material, in N/mm^2, that is used to determine the hull girder section modulus. In the case of the stiffener and plate having different specified minimum yield stress, σ_{yd}, is to be taken as the lesser of the two.
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$z_{dk-mean}$ vertical distance to the mean deck height, taken as the mean of the deck at side and the deck at centre line, measured from the baseline, in m

z_{NA-red} vertical distance to the neutral axis of the reduced section measured from the baseline, in m

2.1.1.2 It is to be shown that the ultimate bending moment capacity, M_U, does not give stresses exceeding the specified minimum yield stress of the material, σ_{yd}, in the bottom shell plating. Therefore the ultimate hull girder bending moment capacity, M_U, is not to be greater than:

$$M_U = \sigma_{yd} \frac{I_{red}}{z_{NA-red}} \cdot 10^3 \quad \text{kNm}$$

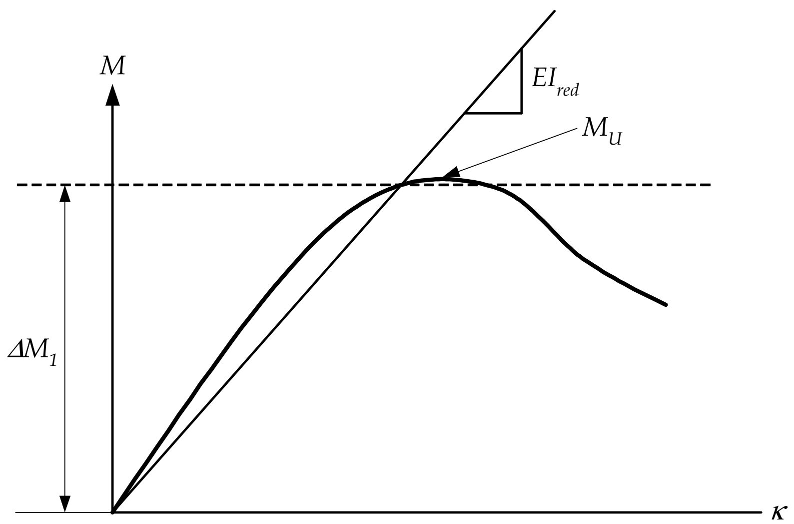
Where:

σ_{yd} specified yield stress of material, in N/mm²

I_{red} reduced hull girder moment of inertia, as defined in *2.1.1.1*

z_{NA-red} vertical distance to the neutral axis of the reduced section measured from the baseline, in m

Figure A.2.1
Moment – Curvature of Hull Girder Single Step Procedure



2.1.2 Assumption

2.1.2.1 The assumption behind this procedure is that the ultimate sagging capacity of tankers is the point at which the ultimate capacity of the stiffened deck panels is reached. If the structural configuration is such that this assumption is not valid, then an alternative method to derive the ultimate capacity is to be used.

2.2 Simplified Method Based on an Incremental-iterative Approach

2.2.1 Procedure

2.2.1.1 In this approach, the ultimate hull girder bending moment capacity M_U is defined as the peak value of the curve with vertical bending moment M versus the curvature κ of the ship cross section as shown in *Figure A.1.1*.

2.2.1.2 The curve M-κ is obtained by means of an incremental-iterative approach; the steps involved in the procedure are given in *2.2.1.7* and illustrated in the flow chart in *Figure A.2.2*.

2.2.1.3 The bending moment M_i which acts on the hull girder transverse section due to the imposed curvature κ_i is calculated for each step of the incremental procedure. This imposed curvature corresponds to an angle of rotation of the hull girder transverse section about its effective horizontal neutral axis, which induces an axial strain ε in each hull structural element. In the sagging condition, the structural elements below the neutral axis are lengthened, whilst elements above the neutral axis are shortened.

2.2.1.4 The stress σ induced in each structural element by the strain ε is obtained from the stress-strain curve σ-ε of the element, which takes into account the behaviour of the structural element in the non-linear elasto-plastic domain.

2.2.1.5 The force in each structural element is obtained from its area times the stress and these force are summated to derive the total axial force on the transverse section. Note the element area is taken as the total net area of the structural element. This total force may not be zero as the effective neutral axis may have moved due to the non linear response. Hence it is necessary to adjust the neutral axis position, recalculate the element strains, forces and total sectional force and iterate until the total force is zero.

2.2.1.6 Once the position of the new neutral axis is known, then the correct stress distribution in the structural elements is obtained. The bending moment M_i about the new neutral axis due to the imposed curvature κ_i is then obtained by summating the moment contribution given by the force in each structural element.

2.2.1.7 The main steps of the incremental-iterative approach are summarised as follows (see also *Figure A.2.2*):

Step 1 Divide the hull girder transverse section into structural elements, ie longitudinal stiffened panels (one stiffener per element), hard corners and transversely stiffened panels, see *2.2.2.2*.

Step 2 Derive the stress-strain curves (or so called load-end shortening curves) for all structural elements, see *2.3*.

Step 3 Derive the expected maximum required curvature κ_F, see *2.2.1.8*. The curvature step size $\Delta\kappa$ is to be taken as $\kappa_F/300$. The curvature for the first step, κ_1 is to be taken as $\Delta\kappa$.

Derive the neutral axis z_{NA-i} for the first incremental step (i=1) with the value of the elastic hull girder section modulus, $z_{v-net50}$, see *Section 4/2.6.1*

Step 4 For each element (index j), calculate the strain $\varepsilon_{ij} = \kappa_i \ (z_j - z_{NA-i})$ corresponding to κ_i, the corresponding stress σ_j, see *2.2.1.9*, and hence the force in the element $\sigma_j A_j$.

Step 5 Determine the new neutral axis position z_{NA-i} by checking the longitudinal force equilibrium over the whole transverse section. Hence adjust z_{NA_i} until

$F_i = 0.1\Sigma A_j \sigma_j$ kN = 0

Note σ_j is positive for elements under compression and negative for elements under tension. Repeat from step 4 until equilibrium is satisfied. Equilibrium is satisfied when the change in neutral axis position is less than 0.0001m.

Step 6 Calculate the corresponding moment by summating the force contributions of all elements as follows:

$$M_i = 0.1\sum \left|\sigma_j A_j \left(z_j - z_{NA-i}\right)\right| \quad \text{kNm}$$

Step 7 Increase the curvature by $\Delta\kappa$, use the current neutral axis position as the initial value for the next curvature increment and repeat from step 4 until the maximum required curvature is reached. The ultimate capacity is the peak value M_u from the M-κ curve. If the peak does not occur in the curve, then κ_F is to be increased until the peak is reached

2.2.1.8 The expected maximum required curvature, κ_F, in m^{-1}, for the sagging condition is to be taken as:

$$\kappa_F = 3\frac{M_{yd}}{EI_{v-net50}}10^{-3} \text{ m}^{-1}$$

Where:

M_{yd} vertical bending moment given by a linear elastic bending stress of yield in the deck or keel. To be taken as the greater of :

$Z_{v-net50-dk}\ \sigma_{yd}\ 10^3$ kNm

$Z_{v-net50-kl}\ \sigma_{yd}\ 10^3$ kNm

$Z_{v-net50-dk}$
$Z_{v-net50-kl}$ section modulus at deck or bottom, in m^3, see *Section 8/1.2.2.3* and *1.2.2.4*,

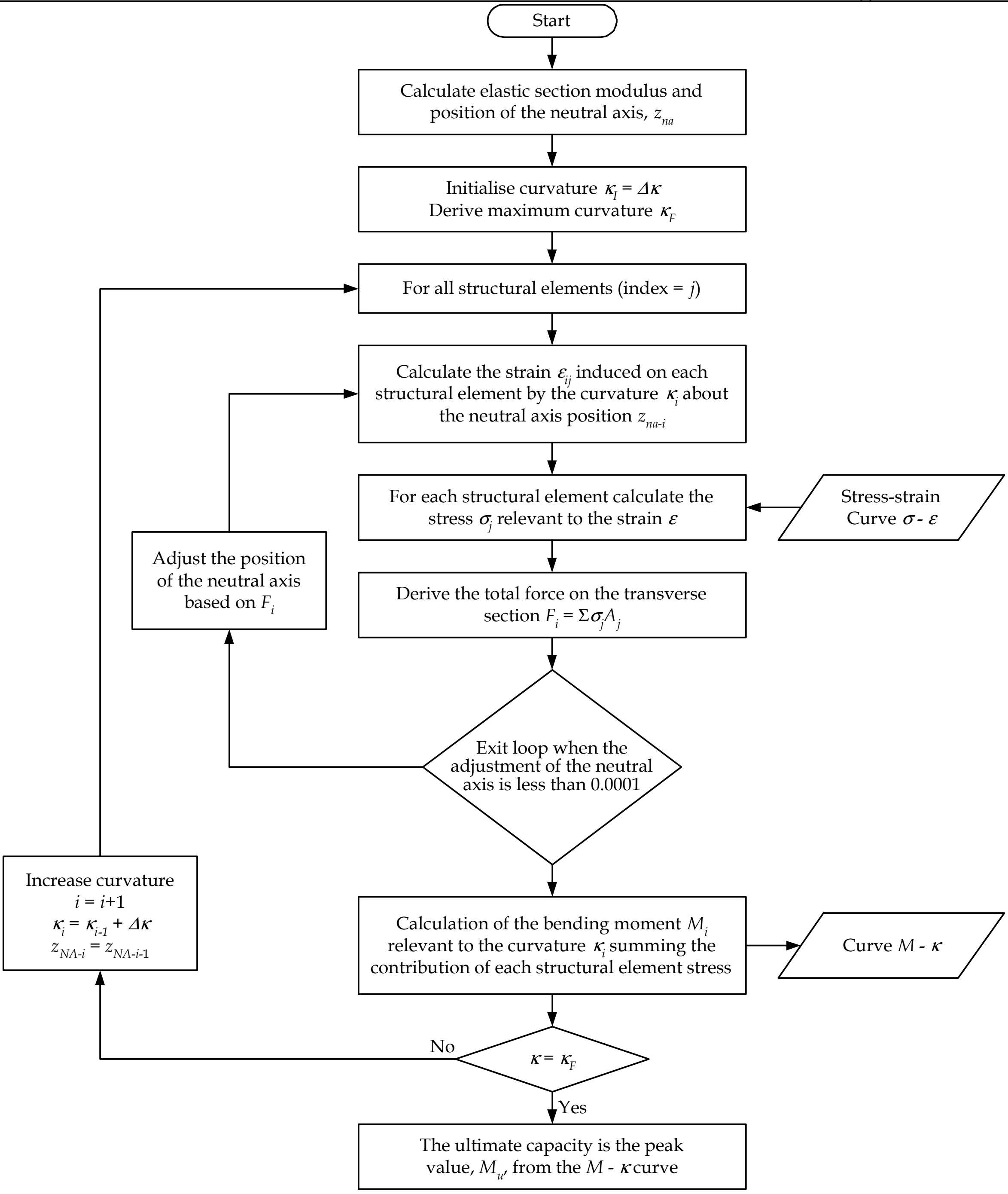
E modulus of elasticity, 2.06×10^5 N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

$I_{v-net50}$ hull girder moment of inertia, in m^4, see *Section 8/1.2.1.1*

2.2.1.9 For each structural element, the stress σ_j corresponding to the element strain ε_{ij} is to be taken as the minimum stress value from all applicable stress-strain curves σ-ε for that element.

Figure A.2.2
Flow Chart of the Procedure for the Evaluation of the Curve M-χ



2.2.2 Assumptions and modelling of the hull girder cross-section

2.2.2.1 In applying the procedure described in *2.2.1*, the following assumptions are to be made:

(a) The ultimate strength is calculated at a hull girder transverse section between two adjacent transverse webs.

(b) The hull girder transverse section remains plane during each curvature increment.

(c) The material properties of steel are assumed to be elastic, perfectly plastic.

(d) The hull girder transverse section can be divided into a set of elements which act independently of each other.

2.2.2.2 The elements making up the hull girder transverse section are:

(a) longitudinal stiffeners with attached plating, the structural behaviour is given in *2.3.1*

(b) transversely stiffened plate panels, the structural behaviour is given in *2.3.1*

(c) hard corners, as defined in *2.2.2.3*, the structural behaviour is given in *2.3.2*

2.2.2.3 The following structural areas are to be defined as hard corners:

(a) the plating area adjacent to intersecting plates

(b) the plating area adjacent to knuckles in the plating with an angle greater than 30 degrees.

(c) plating comprising rounded gunwales

An illustration of hard corner definition for girders on longitudinal bulkheads is given in *Figure A.2.3*. The hard corner size is defined in *2.2.2.4*.

2.2.2.4 The size and modelling of hard corner elements is to be as follows:

(a) it is to be assumed that the hard corner extends up to $s/2$ from the plate intersection for longitudinally stiffened plate, where s is the stiffener spacing

(b) it is to be assumed that the hard corner extends up to $20t_{grs}$ from the plate intersection for transversely stiffened plates, where t_{grs} is the gross plate thickness.

Note

(a) For transversely stiffened plate, the effective breadth of plate for the load shortening portion of the stress-strain curve is to be taken as the full plate breadth, i.e. to the intersection of other plates – not from the end of the hard corner if any. The area on which the value of σ_{CR5} defined in 2.3.8.1 applies is to be taken as the breadth between the hard corners, i.e. excluding the end of the hard corner if any.

(b) For longitudinally stiffened plate, the effective breadth of attached plate is equal to the mean spacing of the ordinary stiffener when the panels on both sides of the stiffener are longitudinally stiffened, or equal to the breadth of the longitudinally stiffened panel when the panel on one side of the stiffener is longitudinally stiffened and the other panel is of the transversely stiffened.

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2.2.2.5 Where the plate members are stiffened by non-continuous longitudinal stiffeners, the non-continuous stiffeners are considered only as dividing a plate into various elementary plate panels.

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2.2.2.6 Openings are to be considered in accordance with Section 4/2.6.3.

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2.2.2.7 Where attached plating is made of steels having different thicknesses and/or yield stresses, an average thickness and/or average yield stress obtained by the following formula are to be used for the calculation:

(a) $$t = \frac{t_1 s_1 + t_2 s_2}{s}$$

(b) $$\sigma_{ydp} = \frac{\sigma_{ydp1} t_1 s_1 + \sigma_{ydp2} t_2 s_2}{ts}$$

Where: t_1, s_1, t_2, s_2, σ_{ydp1}, σ_{ydp2}, s, see Figure A.2.4.

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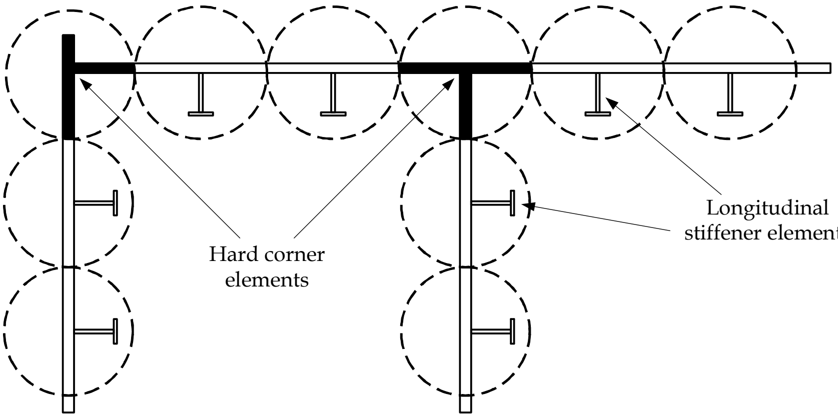
Figure A.2.3
Example of Defining Structural Elements

a) Example showing side shell, inner hull and deck



b) Example showing girder on longitudinal bulkhead

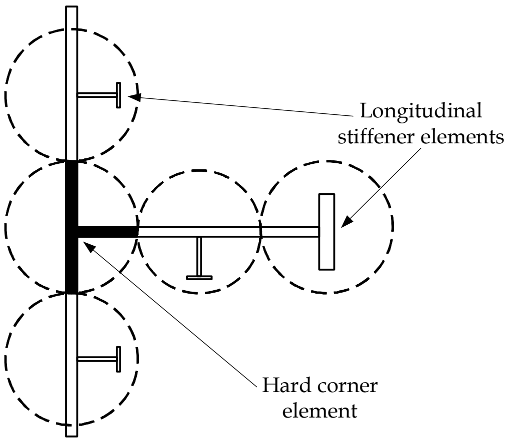
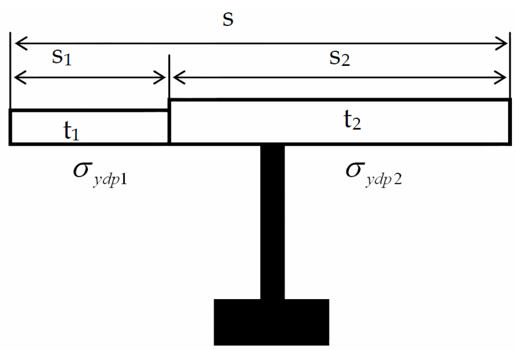


Figure A.2.4
Definitions



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2.3 Stress-strain Curves σ-ε (or Load-end Shortening Curves)

2.3.1 Plate panels and stiffeners

2.3.1.1 Plate panels and stiffeners are assumed to fail according to one of the modes of failure specified in *Table A.2.1*. The relevant stress-strain curve σ-ε is to be obtained for lengthening and shortening strains according to *Table A.2.1*.

2.3.1.2 Where the plate members are stiffened by non-continuous longitudinal stiffeners, the stress of the element is to be obtained in accordance with 2.3.3 to 2.3.7, taking into account the non-continuous longitudinal stiffener. In calculating the total forces for checking the hull girder ultimate strength, the area of non-continuous longitudinal stiffener is to be assumed as zero.

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2.3.1.3 Where openings are provided in the plate panel, the considered area of the element is to be obtained by deducting the opening area from the plating in calculating the total force for checking the hull girder ultimate strength. Openings are to be considered in accordance with Section 4/2.6.3.

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2.3.2 Hard corners

2.3.2.1 Hard corners are sturdier elements which are assumed to buckle and fail in an elastic, perfectly plastic manner. The relevant stress strain curve σ-ε is to be obtained for lengthened and shortened hard corners according to *2.3.3*.

Table A.2.1
Modes of Failure of Plate Panels and Stiffeners

Element	Mode of failure	Stress-strain curve σ-ε defined in
Lengthened transversely framed plate panels or stiffeners	Elastic, perfectly plastic failure	See *2.3.3*
Shortened stiffeners	Beam column buckling Torsional buckling Web local buckling of flanged profiles Web local buckling of flat bars	See *2.3.4* See *2.3.5* See *2.3.6* See *2.3.7*
Shortened transversely framed plate panels	Plate buckling	See *2.3.8*

2.3.3 Elasto-plastic failure of structural elements

2.3.3.1 The equation describing the stress-strain curve σ-ε or the elasto-plastic failure of structural elements is to be obtained from the following formula, valid for both positive (compression or shortening) of hard corners and negative (tension or lengthening) strains of all elements (see *Figure A.2.5*):

$$\sigma = \Phi \sigma_{ydA}$$

Where:

Φ edge function:

$\Phi = -1$ for $\varepsilon < -1$

$\Phi = \varepsilon$ for $-1 < \varepsilon < 1$

$\Phi = 1$ for $\varepsilon > 1$

ε relative strain:

$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_{yd}}$$

ε_E element strain

ε_{yd} strain corresponding to yield stress in the element:

$$\varepsilon_{yd} = \frac{\sigma_{ydA}}{E}$$

σ_{ydA} equivalent minimum yield stress of the considered element, in N/mm^2

$$\sigma_{ydA} = \frac{\sigma_{ydp} A_{p-net50} + \sigma_{yds} A_{s-net50}}{A_{p-net50} + A_{s-net50}}$$

σ_{ydp} specified minimum yield stress of the material of the plate, in N/mm^2

σ_{yds} specified minimum yield stress of the material of the stiffener, in N/mm^2

$A_{p-net50}$ net sectional area of attached plating, in cm^2

$A_{s-net50}$ net sectional area of the stiffener without attached plating, in cm^2

Note

The signs of the stresses and strains in this Appendix are opposite to those in the rest of the Rules

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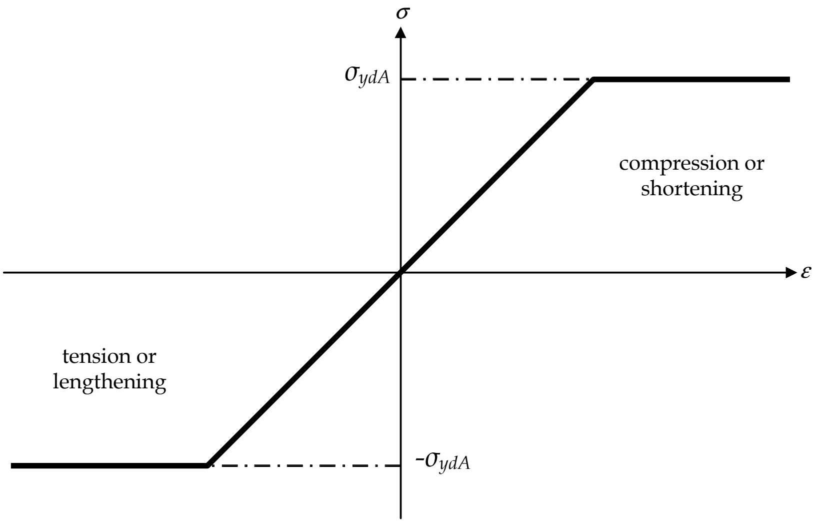
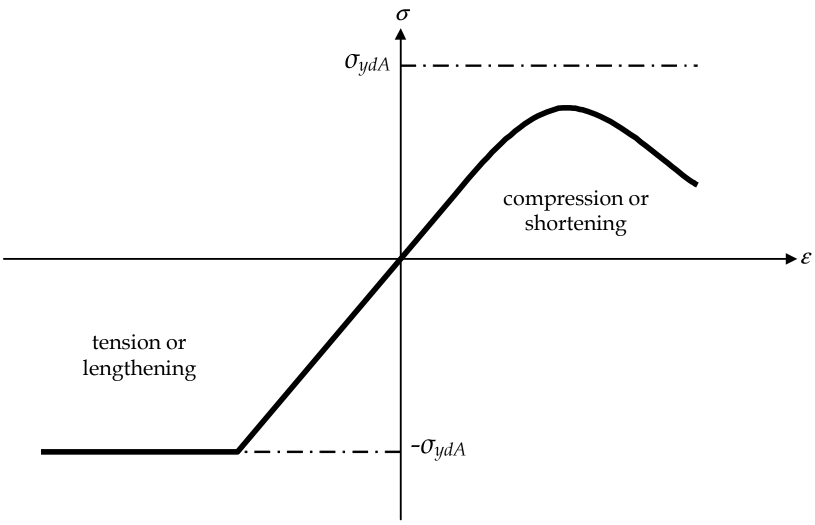
Figure A.2.5
Example of Stress Strain Curves σ-ε

a) Stress strain curve σ-ε for elastic, perfectly plastic failure of a hard corner



b) Typical stress strain curve σ-ε for elasto-plastic failure of a stiffener



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2.3.4 Beam column buckling

2.3.4.1 The equation describing the shortening portion of the stress strain curve σ_{CR1}-ε for the beam column buckling of stiffeners is to be obtained from the following formula:

$$\sigma_{CR1} = \Phi \sigma_{C1} \left(\frac{A_{s-net50} + 10^{-2} b_{eff-p} t_{net50}}{A_{s-net50} + 10^{-2} s t_{net50}} \right) \quad \text{N/mm}^2$$

Where:

Φ edge function defined in *2.3.3.1*

$A_{s-net50}$ net area of the stiffener, in cm², without attached plating

σ_{C1} critical stress, in N/mm²:

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon} \quad for \quad \sigma_{E1} \le \frac{\sigma_{ydB}}{2}\varepsilon$$

$$\sigma_{C1} = \sigma_{ydB}\left(1 - \frac{\sigma_{ydB}\varepsilon}{4\sigma_{E1}}\right) \quad for \quad \sigma_{E1} > \frac{\sigma_{ydB}}{2}\varepsilon$$

ε relative strain defined in *2.3.3.1*

σ_{E1} Euler column buckling stress, in N/mm²:

$$\sigma_{E1} = \pi^2 E \frac{I_{E-net50}}{A_{E-net50} l_{stf}^2} 10^{-4}$$

E modulus of elasticity, 2.06 x 10⁵ N/mm²

$I_{E-net50}$ net moment of inertia of stiffeners, in cm⁴, with attached plating of width b_{eff-s}

b_{eff-s} effective width, in mm, of the attached plating for the stiffener:

$$b_{eff-s} = \frac{s}{\beta_p} \quad \text{for} \quad \beta_p > 1.0$$

$$b_{eff-s} = s \quad \text{for} \quad \beta_p \le 1.0$$

β_p $= \frac{s}{t_{net50}}\sqrt{\frac{\varepsilon\sigma_{ydp}}{E}}$

s plate breadth, in mm, taken as the spacing between the stiffeners, as defined in *Section 4/2.2.1*

t_{net50} net thickness of attached plating, in mm

$A_{E-net50}$ net area, in cm², of stiffeners with attached plating of width b_{eff-p}

l_{stf} span of stiffener, in m, equal to spacing between primary support members

b_{eff-p} effective width, in mm, of the plating:

$$b_{eff-p} = \left(\frac{2.25}{\beta_p} - \frac{1.25}{\beta_p^2}\right)s \quad \text{for} \quad \beta_p > 1.25$$

$$b_{eff-p} = s \quad \text{for} \quad \beta_p \le 1.25$$

σ_{ydB} equivalent minimum yield stress of the considered element, in N/mm²

$$\sigma_{ydB} = \frac{\sigma_{ydp} A_{pE-net50} l_{pE} + \sigma_{yds} A_{s-net50} l_{sE}}{A_{pE-net50} l_{pE} + A_{s-net50} l_{sE}}$$

$A_{pE-net50}$ effective area, in cm²

$$A_{pE-net50} = 10^{-2} b_{eff-s} t_{net50}$$

σ_{ydp} specified minimum yield stress of the material of the plate, in N/mm²

σ_{yds} specified minimum yield stress of the material of the stiffener, in N/mm²

l_{pE} distance, in mm, measured from the neutral axis of the stiffener with attached plate of width, b_{eff-s}, to the bottom of the attached

plate

l_{sE} distance, in mm, measured from the neutral axis of the stiffener with attached plate of width, b_{eff-s}, to the top of the stiffener

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2.3.5 Torsional buckling of stiffeners

2.3.5.1 The equation describing the shortening portion of the stress-strain curve σ_{CR2}-ε for the lateral-flexural buckling of stiffeners is to be obtained according to the following formula:

$$\sigma_{CR2} = \Phi \frac{A_{s-net50}\sigma_{C2} + 10^{-2} st_{net50}\sigma_{CP}}{A_{s-net50} + 10^{-2} st_{net50}} \quad \text{N/mm}^2$$

Where:

Φ edge function defined in *2.3.3.1*

$A_{s-net50}$ net area of the stiffener, in cm², without attached plating

σ_{C2} critical stress, in N/mm²:

$$\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon} \qquad for \quad \sigma_{E2} \le \frac{\sigma_{yds}}{2}\varepsilon$$

$$\sigma_{C2} = \sigma_{yds}\left(1 - \frac{\sigma_{yds}\varepsilon}{4\sigma_{E2}}\right) \qquad for \quad \sigma_{E2} > \frac{\sigma_{yds}}{2}\varepsilon$$

σ_{E2} Euler torsional buckling stress, in N/mm²

$\sigma_{E2} = \sigma_{ET}$

σ_{ET} reference stress for torsional buckling, in N/mm², defined in *Section 10/3.3.3.1*, calculated based on gross thickness minus the corrosion addition $0.5t_{corr}$.

ε relative strain defined in *2.3.3.1*

s plate breadth, in mm, taken as the spacing between the stiffeners, as defined in *Section 4/2.2.1*

t_{net50} net thickness of attached plating, in mm

σ_{CP} ultimate strength of the attached plating for the stiffener, in N/mm²:

$$\sigma_{CP} = \left(\frac{2.25}{\beta_p} - \frac{1.25}{\beta_p^2}\right)\sigma_{ydp} \qquad \text{for} \quad \beta_p > 1.25$$

$$\sigma_{CP} = \sigma_{ydp} \qquad \text{for} \quad \beta_p \le 1.25$$

β_p coefficient defined in *2.3.4*

σ_{ydp} specified minimum yield stress of the material of the plate, in N/mm²

σ_{yds} specified minimum yield stress of the material of the stiffener, in N/mm²

(RCN 2, effective from 1 July 2008)

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2.3.6 Web local buckling of stiffeners with flanged profiles

2.3.6.1 The equation describing the shortening portion of the stress strain curve σ_{CR3}-ε for the web local buckling of flanged stiffeners is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi \frac{b_{eff-p} t_{net50} \sigma_{ydp} + \left(d_{w-eff} t_{w-net50} + b_f t_{f-net50}\right) \sigma_{yds}}{s t_{net50} + d_w t_{w-net50} + b_f t_{f-net50}} \quad \text{N/mm}^2$$

Where:

Φ edge function defined in *2.3.3.1*

b_{eff-p} effective width, in mm, of the plating, defined in *2.3.4*

t_{net50} net thickness of plate, in mm

d_w depth of the web, in mm

$t_{w-net50}$ net thickness of web, in mm

b_f breadth of the flange, in mm

$t_{f-net50}$ net thickness of flange, in mm

s plate breadth, in mm, taken as the spacing between the stiffeners, as defined in *Section 4/2.2.1*

d_{w-eff} effective depth of the web, in mm:

$$d_{w-eff} = \left(\frac{2.25}{\beta_w} - \frac{1.25}{\beta_w^2}\right) d_w \quad \text{for} \quad \beta_w > 1.25$$

$$d_{w-eff} = d_w \quad \text{for} \quad \beta_w \le 1.25$$

β_w $\dfrac{d_w}{t_{w-net50}} \sqrt{\dfrac{\varepsilon \sigma_{yds}}{E}}$

ε relative strain defined in *2.3.3.1*

E modulus of elasticity, 2.06×10^5 N/mm²

σ_{ydp} specified minimum yield stress of the material of the plate, in N/mm²

σ_{yds} specified minimum yield stress of the material of the stiffener, in N/mm²

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2.3.7 Web local buckling of flat bar stiffeners

2.3.7.1 The equation describing the shortening portion of the stress-strain curve σ_{CR4}-ε for the web local buckling of flat bar stiffeners is to be obtained from the following formula:

$$\sigma_{CR4} = \Phi\left(\frac{s t_{net50} \sigma_{CP} + 10^{-2} A_{s-net50} \sigma_{C4}}{s t_{net50} + 10^{-2} A_{s-net50}}\right)$$

Where:

Φ edge function defined in *2.3.3.1*

σ_{CP} ultimate strength of the attached plating, in N/mm², defined in *2.3.5*

σ_{C4} critical stress, in N/mm²:

$$\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon} \qquad for \quad \sigma_{E4} \le \frac{\sigma_{yds}}{2}\varepsilon$$

$$\sigma_{C4} = \sigma_{yds}\left(1 - \frac{\sigma_{yds}\varepsilon}{4\sigma_{E4}}\right) \qquad for \quad \sigma_{E4} > \frac{\sigma_{yds}}{2}\varepsilon$$

σ_{E4} Euler buckling stress, in N/mm²:

$$\sigma_{E4} = 160000\left(\frac{t_{w-net50}}{d_w}\right)^2$$

ε relative strain defined in *2.3.3.1*.

$A_{s\text{-}net50}$ net area of stiffener, in cm², *see* 2.3.5.1

$t_{w\text{-}net50}$ net thickness of web, in mm

d_w depth of the web, in mm

s plate breadth, in mm, taken as the spacing between the stiffeners, as defined in *Section 4/2.2.1*

t_{net50} net thickness of attached plating, in mm

σ_{yds} specified minimum yield stress of the material of the stiffener, in N/mm²

(RCN 2, effective from 1 July 2008)

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2.3.8 Buckling of transversely stiffened plate panels

2.3.8.1 The equation describing the shortening portion of the stress-strain curve σ_{CR5}-ε for the buckling of transversely stiffened panels is to be obtained from the following formula:

$$\sigma_{CR5} = \min\begin{cases} \Phi\sigma_{ydp}\left[\dfrac{s}{1000l_{stf}}\left(\dfrac{2.25}{\beta_p} - \dfrac{1.25}{\beta_p^2}\right) + 0.1\left(1 - \dfrac{s}{1000l_{stf}}\right)\left(1 + \dfrac{1}{\beta_p^2}\right)^2\right] \\ \sigma_{ydp}\Phi \end{cases} \quad \text{N/mm}^2$$

Where:

β_p coefficient defined in *2.3.4.1*

Φ edge function defined in *2.3.3.1*

s plate breadth, in mm, taken as the spacing between the stiffeners, as defined in *Section 4/2.2.1*

l_{stf} stiffener span, in m, equal to spacing between primary support members

σ_{ydp} specified minimum yield stress of the material of the plate, in N/mm²

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3 ALTERNATIVE METHODS

3.1 General

3.1.1 Considerations for alternative models

3.1.1.1 The bending moment-curvature relationship, M-κ, may be established by alternative methods. Such models are to consider all the relevant effects important to the non-linear response with due considerations of:

(a) non-linear geometrical behaviour

(b) inelastic material behaviour

(c) geometrical imperfections and residual stresses (geometrical out-of flatness of plate and stiffeners)

(d) simultaneously acting loads:

- bi-axial compression
- bi-axial tension
- shear and lateral pressure

(e) boundary conditions

(f) interactions between buckling modes

(g) interactions between structural elements such as plates, stiffeners, girders etc.

(h) post-buckling capacity.

3.2 Methods

3.2.1 Incremental-iterative procedure

3.2.1.1 The most generally used method to assess the hull girder ultimate moment capacity is to derive the non-linear moment-curvature relationship, M-κ, by incrementally increasing the bending curvature, κ, of the hull section between two adjacent transverse frames and then identifying the maximum moment along this curve as the ultimate bending capacity, M_U.

3.2.1.2 The M-κ curve is to be based on the axial non-linear P-ε (load/strain) load-shortening curves for individual structural component in the cross-section. The P-ε curves shall consider all relevant structural effects as listed in *3.1.1.1*.

3.2.2 Non-linear finite element analysis

3.2.2.1 Advanced non-linear finite element analyses models may be used for the assessment of the hull girder ultimate capacity. Such models are to consider the relevant effects important to the non-linear responses with due consideration of the items listed in *3.1.1.1*.

3.2.2.2 Particular attention is to be given to modelling the shape and size of geometrical imperfections. It is to be ensured that the shape and size of geometrical imperfections trigger the most critical failure modes.

APPENDIX B

STRUCTURAL STRENGTH ASSESSMENT

1 GENERAL

1.1 Application

1.1.1 General

1.1.1.1 In accordance with *Section 9/2.1*, a finite element (FE) assessment is to be carried out to verify the strength of the hull structure.

1.1.1.2 The structural assessment is to be carried out in accordance with the requirements given in this Appendix. The structural assessment is to verify that the acceptance criteria specified are complied with.

1.1.1.3 The requirements in this Appendix apply to the assessment of longitudinal hull girder structural members, primary supporting structural members and transverse bulkheads of the tanks in the midship cargo region and, in addition, the assessment of strengthening of longitudinal hull girder shear structural members, as defined in *Section 9/2.2.1.1* and *Section 4/Table 4.1.1*, in way of transverse bulkheads for hull girder vertical shear loads in the forward and aft cargo regions. The strength assessment of longitudinal hull girder shear structural members given in this Appendix is not applicable for forward transverse collision bulkhead, engine room transverse bulkhead and slop tank transverse bulkheads.

1.1.1.4 For the purpose of the FE structural assessment the cargo tank regions are as defined in *Figure B1.1*.

1.1.1.5 Cargo tank structural strength analysis, in accordance with *Appendix B/2*, for the assessment of scantlings of longitudinal hull girder structural members, primary supporting structural members and transverse bulkheads in tanks within the midship cargo region, is mandatory. The assessment is to be based on the maximum permissible still water (load combination S) and combined permissible still water and wave hull girder vertical shear forces (load combination S+D) between and including the forward bulkhead of the aft most cargo tank and 0.65*L* from AP, but not including the engine room and slop tank transverse bulkheads, *see Figure B.1.1(a)*.

1.1.1.6 The assessment of longitudinal hull girder shear structural members in the forward cargo region, in accordance with *Appendix B/2*, is mandatory. The strengthening of these structural members in way of transverse bulkheads in the tanks of the forward cargo region may be based on the maximum permissible still water (load combination S) and combined permissible still water and wave hull girder vertical shear forces (load combination S+D) at the bulkhead positions forward of 0.65*L* from AP, but not including the forward collision bulkhead, *see Figure B.1.1(b).*

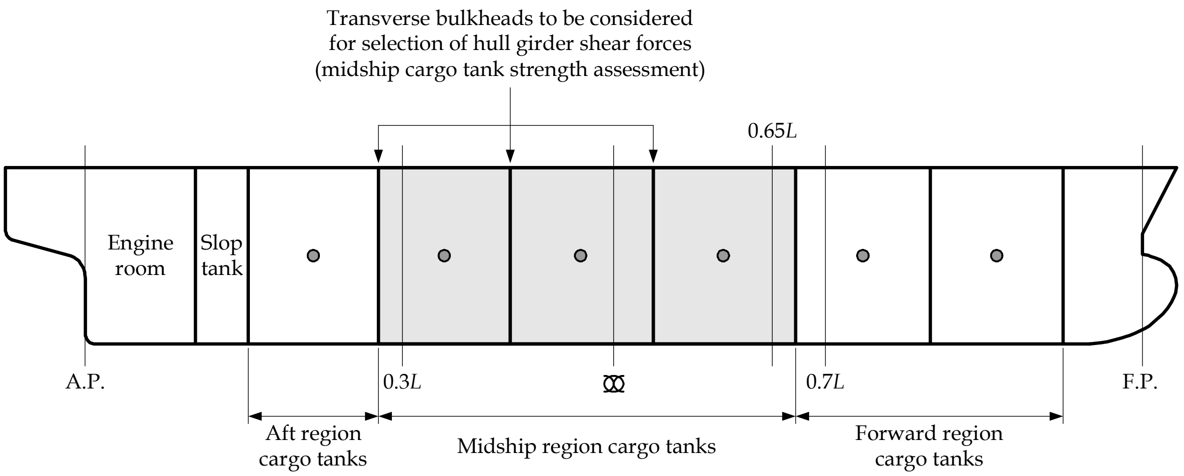
1.1.1.7 Strengthening of longitudinal hull girder shear structural members in way of transverse bulkheads of the tanks in the midship cargo region and the aft cargo region, in accordance with *Appendix B/2*, may be based on the scantling result obtained from the midship cargo tank analysis as described in *1.1.1.5*.

1.1.1.8 Alternatively, optional assessment may be carried out to determine the strengthening requirement of longitudinal hull girder shear structural members in way of individual transverse bulkheads based on the permissible still water (load combination S) and combined permissible still water and wave hull girder vertical shear forces (load combination S+D) at the transverse bulkhead position under consideration, *see Figure B.1.1(b).*

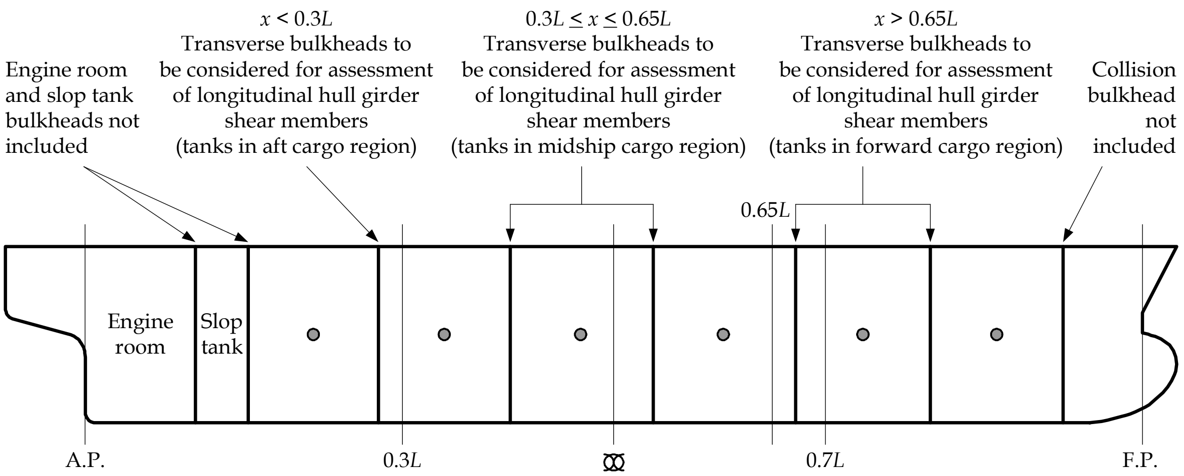
1.1.1.9 Fine mesh finite element analysis, in accordance with *Appendix B/3*, and the finite element based fatigue assessment of lower hopper knuckle joint, in accordance with *Appendix B/4*, are mandatory for the midship cargo region.

Figure B.1.1
Definition of Cargo Tank Regions for FE Structural Assessment

(a) Midship cargo tank strength assessment



(b) Assessment of longitudinal hull girder shear structural members



Note

1. Tanks in the forward cargo region are defined as tanks with their longitudinal centre of gravity position forward of $0.7L$ from A.P.
2. Tanks in the midship cargo region are defined as tanks with their longitudinal centre of gravity position at or forward of $0.3L$ from AP and at or aft of $0.7L$ from A.P.
3. Tanks in the aft cargo region are defined as tanks with their longitudinal centre of gravity position aft of $0.3L$ from A.P.

1.2 Symbols, Units and Definitions

1.2.1 General

1.2.1.1 The symbols and definitions, applicable to this section, are given in *Section 4/1*, *Section 7* and as follows:

a_v	vertical acceleration, taken at centre of gravity of tank
a_t	transverse acceleration, taken at centre of gravity of tank
a_{lng}	longitudinal acceleration, taken at centre of gravity of tank
E	Modulus of Elasticity of steel, $2.06\text{x}10^5$ N/mm^2
M_{wv}	vertical wave bending moment for a dynamic load case
M_{sw}	vertical still water bending moment for a finite element loading pattern
M_h	horizontal wave bending moment for a dynamic load case
Q_{wv}	vertical wave shear force for a dynamic load case
Q_{sw}	vertical still water shear force for a finite element loading pattern
T_{LC}	draught at the loading condition being considered
T_{sc}	scantling draught, as defined in *Section 4/1.1.5.5*
T_{bal-em}	emergency draught of ship
t_{grs}	proposed new building gross thickness excluding Owner's extras, see *Section 2/6.3.4*
t_{corr}	corrosion addition, as defined in *Section 6/3.2*
σ_{yd}	specified minimum yield stress of the material, N/mm^2
σ_{vm}	von Mises stress $= \sqrt{\sigma_x{}^2 + \sigma_y{}^2 - \sigma_x\sigma_y + 3\tau_{xy}{}^2}$
σ_x	axial stress in element x direction
σ_y	axial stress in element y direction
τ_{xy}	element shear stress in x-y plane
δ_x	displacement in x direction, in accordance with the coordinate system defined in *Section 4/1.4*
δ_y	displacement in y direction, in accordance with the coordinate system defined in *Section 4/1.4*
δ_z	displacement in z direction, in accordance with the coordinate system defined in *Section 4/1.4*
θ_x	rotation about x axis, in accordance with the coordinate system defined in *Section 4/1.4*
θ_y	rotation about y axis, in accordance with the coordinate system defined in *Section 4/1.4*
θ_z	rotation about z axis, in accordance with the coordinate system defined in *Section 4/1.4*

1.2.1.2 The nomenclature of structural components is defined in *Section 4/1.5*.

1.2.1.3 Consistent co-ordinate and unit systems are to be used throughout all parts of the structural analysis. However, in calculations using Rule Formulae, the units and co-ordinate system as specified are to be used. Where output values from Rule formulae are in a different unit and/or co-ordinate system as used in the structural analysis, the output values are to be converted to the appropriate unit and co-ordinate system.

1.2.2 Finite element types

1.2.2.1 The structural assessment is to be based on linear finite element analysis of three dimensional structural models. The general types of finite elements to be used in the finite element analysis are given in *Table B.1.1*.

1.2.2.2 Two node line elements and three or four node plate/shell elements are considered sufficient for the representation of the hull structure. The mesh requirements given in this Appendix are based on the assumption that these elements are used in the finite element models. However, higher order elements may also be used.

Table B.1.1
Types of Finite Element

Rod (or truss) element	Line element with axial stiffness only and constant cross-sectional area along the length of the element
Beam element	Line element with axial, torsional and bi-directional shear and bending stiffness and with constant properties along the length of the element
Membrane (or plane-stress) plate element	Plate element with bi-axial and in-plane plate element stiffness with constant thickness
Shell (or bending plate) element	Plate element with in-plane stiffness and out-of-plane bending stiffness with constant thickness

1.2.2.3 For the cargo tank and fine mesh strength analyses as specified in *Appendix B/2* and *B/3,* the assessment against stress acceptance criteria is to be based on membrane (or in-plane) stresses of plate elements. For the fatigue assessment as specified in *Appendix B/4*, the calculation of dynamic stress range for the determination of fatigue life is to be based on surface stresses of plate elements.

2 CARGO TANK STRUCTURAL STRENGTH ANALYSIS

2.1 Assessment

2.1.1 General

2.1.1.1 For tankers of conventional arrangements, the finite element strength assessment of the hull girder and primary supporting structural members is to be in accordance with the requirements in this section.

2.2 Structural Modelling

2.2.1 General

2.2.1.1 The longitudinal extent of the midship cargo tank finite element (FE) model is to cover three cargo tank lengths about midships. Where the tanks in the midship cargo region are of different lengths, the middle tank of the finite element model is to represent the cargo tank of the greatest length. The finite element model may be prismatic. The transverse bulkheads at the ends of the model are to be represented. Where corrugated transverse bulkheads are fitted, the model is to include the extent of the bulkhead stool structure forward and aft of the tanks at the model ends. The length of the model extending beyond the end transverse bulkheads is to be kept equal, at both ends. The web frames at the ends of the model are to be modelled. Typical finite element models representing the midship cargo tank region of different tanker configurations are shown in *Figure B.2.1*.

2.2.1.2 The assessment of longitudinal hull girder shear structural members, as defined in *Section 9/2.2.1.1* and *Section 4/Table 4.1.1*, against hull girder vertical shear loads in the forward and aft cargo regions may be based on the midship cargo tank finite element model with modification of plate and stiffener properties where appropriate. Where a separate cargo tank finite element model is used for the assessment of shear strength, the model is to cover three tank lengths.

2.2.1.3 Both port and starboard sides of the ship are to be modelled. The full depth of the ship is to be modelled.

2.2.1.4 All main longitudinal and transverse structural elements are to be modelled. These include inner and outer shell, double bottom floor and girder system, transverse and vertical web frames, stringers and transverse and longitudinal bulkhead structures. All plates and stiffeners on the structure, including web stiffeners, are to be modelled, see *2.2.1.11*.

2.2.1.5 The reduced thickness used in the FE model of the cargo tanks, applicable to all plating and stiffener's web and flanges is to be calculated as follows:

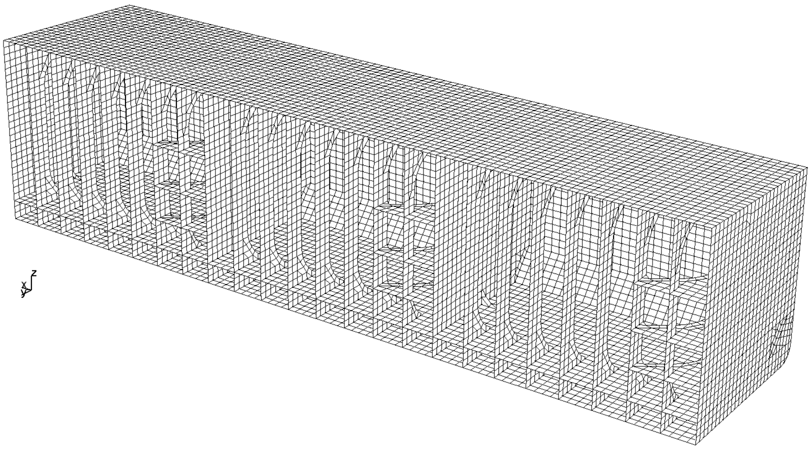
$$t_{FEM-net50} = t_{grs} - 0.5\, t_{corr}$$

Where:

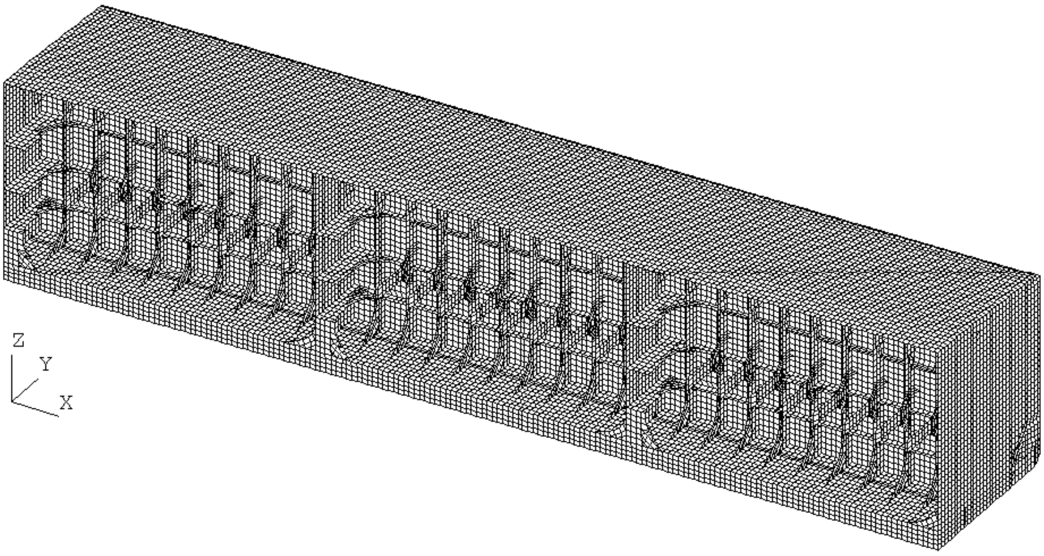
t_{grs} gross thickness, as defined in *1.2*

t_{corr} corrosion addition, as defined in *Section 6/3.2*

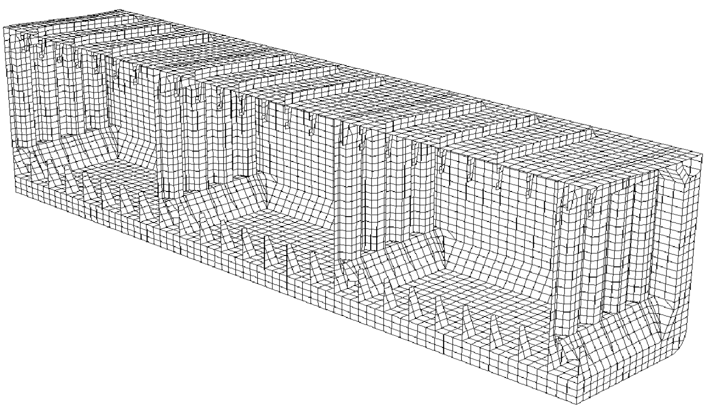
Figure B.2.1
Typical 3-Tank FE Models Representing Midship Cargo Tank Region of Tankers



Typical Cargo Tank Model of an AfraMax Oil Tanker (shows only starboard side of the full breadth model)



Typical Cargo Tank Model of a VLCC (shows only port side of the full breadth model)



Typical Cargo Tank Model of a Product Tanker (shows only port side of the full breadth model)

2.2.1.6 The plate element mesh is to follow the stiffening system as far as practicable, hence representing the actual plate panels between stiffeners. In general, the plate element mesh is to satisfy the following requirements:

(a) one element between every longitudinal stiffener, see *Figure B.2.2*.
Longitudinally, the element length is not to be greater than 2 longitudinal spaces

(b) one element between every vertical stiffener on transverse bulkheads, see *Figure B.2.3*

(c) one element between every web stiffener on transverse and vertical web frames, cross ties and stringers, see *Figure B.2.2* and *Figure B.2.4*

(d) at least three elements over the depth of double bottom girders and floors, transverse web frames, vertical web frames and horizontal stringers on transverse bulkheads. For cross ties, deck transverse and horizontal stringers on transverse wash bulkheads and longitudinal bulkheads with a smaller web depth, representation using two elements over the depth is acceptable provided that there is at least one element between every web stiffener. The mesh size of adjacent structure is to be adjusted to suit

(e) the mesh on the hopper tank web frame shall be fine enough to represent the shape of the web ring opening, see *Figure B.2.2*

(f) the curvature of the free edge on large brackets of primary support members is to be modelled accurately to avoid unrealistic high stress due to geometry discontinuities. In general, a mesh size equal to the stiffener spacing is acceptable. The bracket toe may be terminated at the nearest nodal point provided that the modelled length of the bracket arm does not exceed the actual bracket arm length. The bracket flange is not to be connected to the plating, see *Figure B.2.5*. The modelling of the tapering part of the flange is to be in accordance with *2.2.1.14*. An acceptable mesh is shown in *Figure B.2.5.* A finer mesh is to be used for the determination of detailed stress at the bracket toe, see *Appendix B/3*.

2.2.1.7 Corrugated bulkheads and bulkhead stools are to be modelled using shell plate elements, see *Figure B.2.6.* Diaphragms in the stools and internal longitudinal and vertical stiffeners on the stool plating are to be included in the model. Modelling is to be carried out as follows:

(a) the shell element mesh on the flange and web of the corrugation is in general to follow the stiffener spacing inside the bulkhead stool

(b) where difficulty occurs in matching the mesh on the corrugations directly with the mesh on the stool, it is acceptable to adjust the mesh on the stools in way of the corrugations in order that the corrugation bulkhead will retain its original geometrical shape. However, if the shape of the corrugation is adjusted in order to simplify the modelling procedure, this effect is to be taken into account in evaluation of stresses as described in *2.7.2.6.*

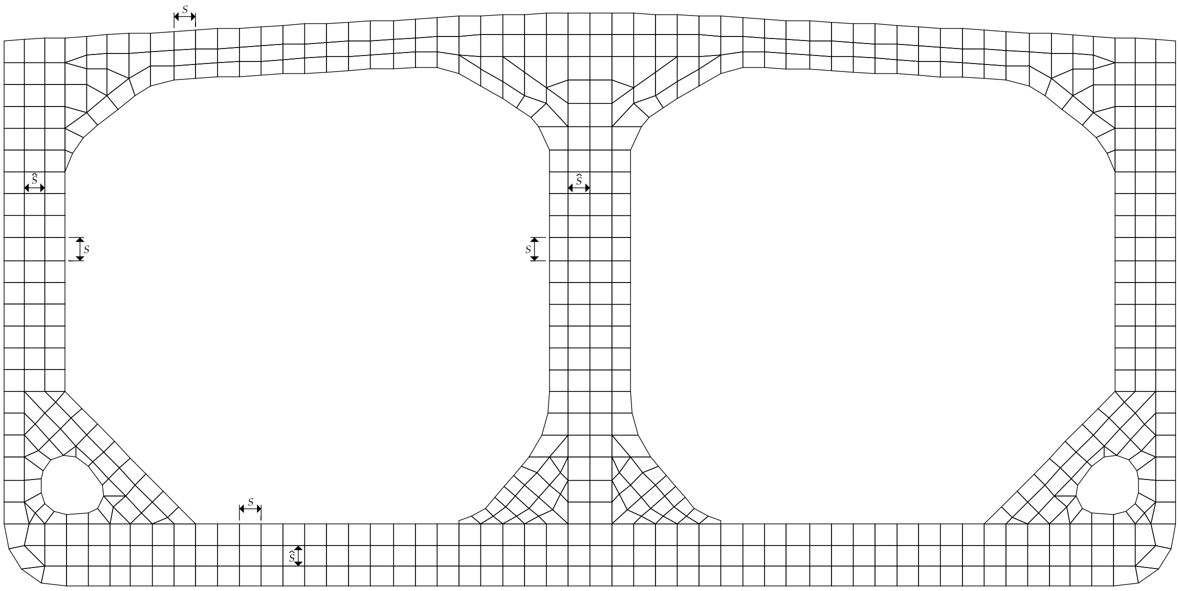
(c) for a corrugated bulkhead without an upper stool and/or lower stool, it may be necessary to adjust the geometry in order to simplify the modelling. The adjustment is to be made such that the shape and position of the corrugations and primary support members are retained. Hence, the adjustment is to be made on stiffeners and plate seams if necessary.

2.2.1.8 The aspect ratio of the plate elements is in general not to exceed three. The use of triangular plate elements is to be kept to a minimum. Where possible, the aspect ratio of plate elements in areas where there are likely to be high stresses or a high stress gradient is to be kept close to one and the use of triangular elements is to be avoided.

2.2.1.9 Typical mesh arrangements of the cargo tank structure are shown in *Figure B.2.7*.

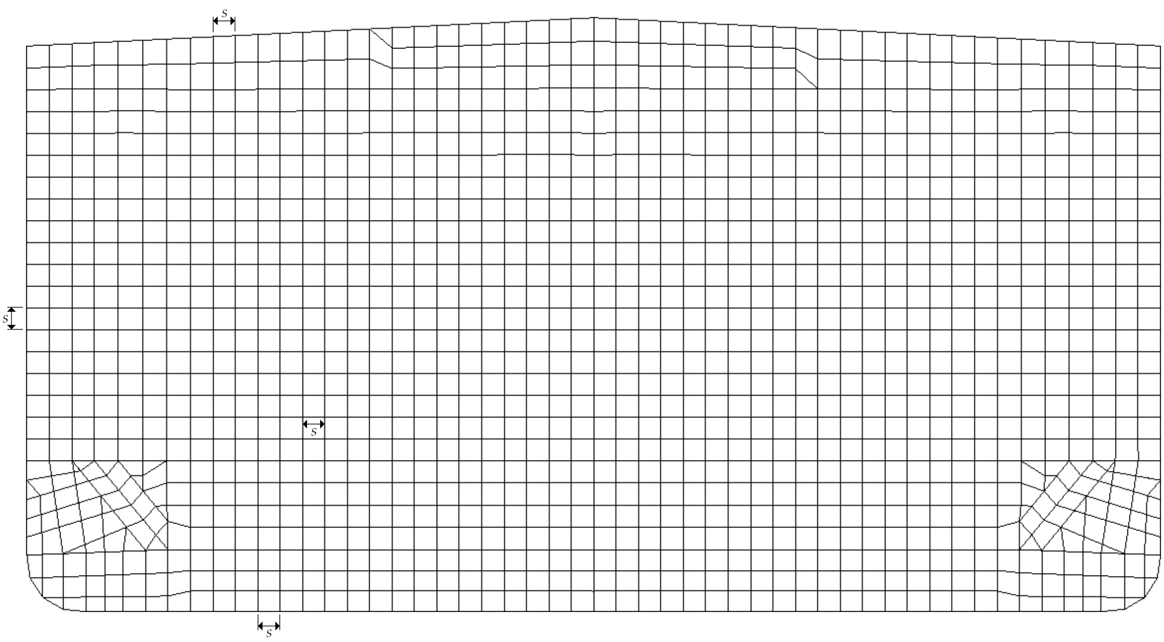
2.2.1.10 Shell elements, in association with beam elements, are to be used to represent stiffened panels in areas under lateral pressure. Shell elements are to be used to represent unstiffened panels in areas under lateral pressure. Membrane and rod elements may be used to represent non-tight structure under no pressure loads.

Figure B.2.2
Typical Finite Element Mesh on Web Frame



S = stiffener spacing

Figure B.2.3
Typical Finite Element Mesh on Transverse Bulkhead



S = stiffener spacing

Figure B.2.4
Typical Finite Element Mesh on Horizontal Transverse Stringer on Transverse Bulkhead

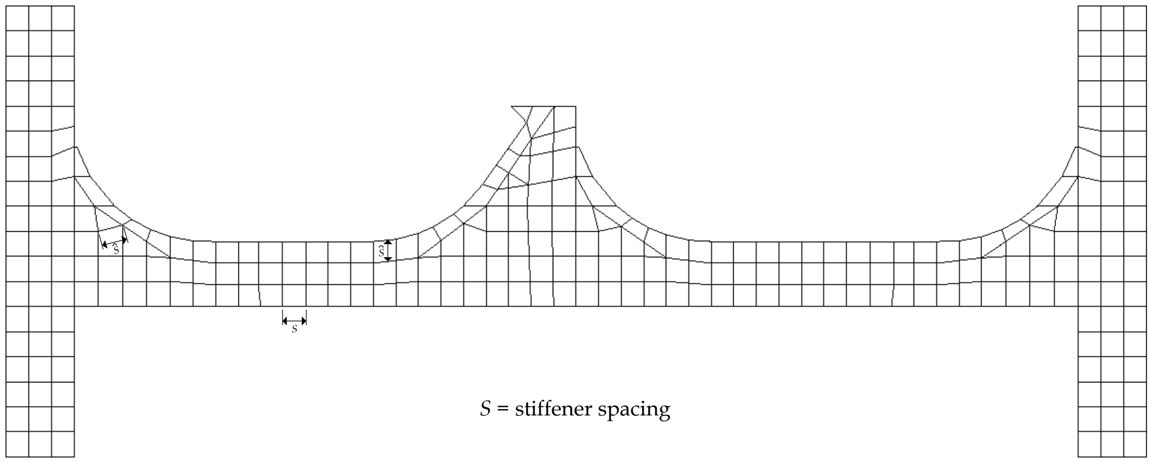


Figure B.2.5
Typical Finite Element Mesh on Transverse Web Frame Main Bracket

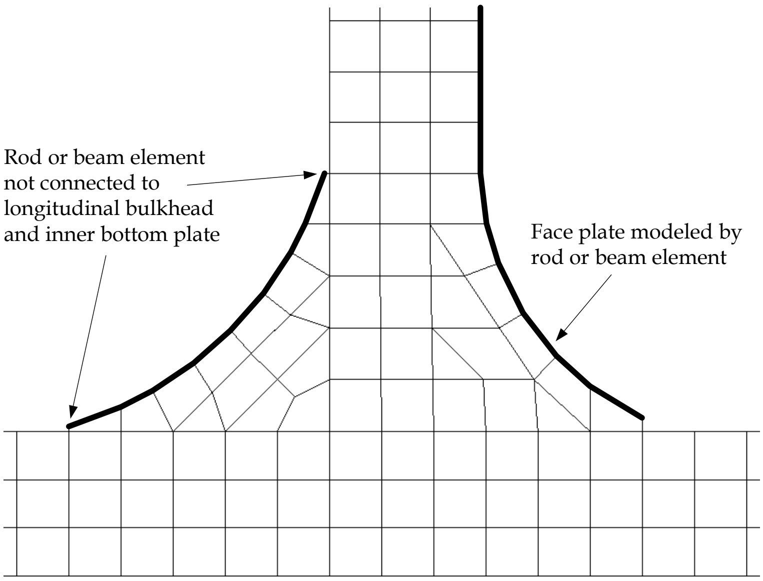


Figure B.2.6
Typical Finite Element Mesh on Transverse Corrugated Bulkhead Structure

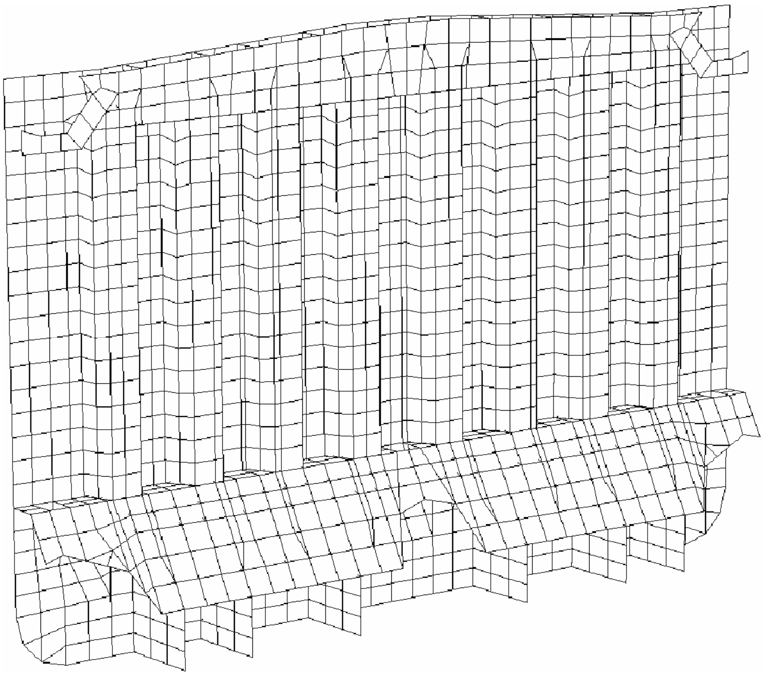
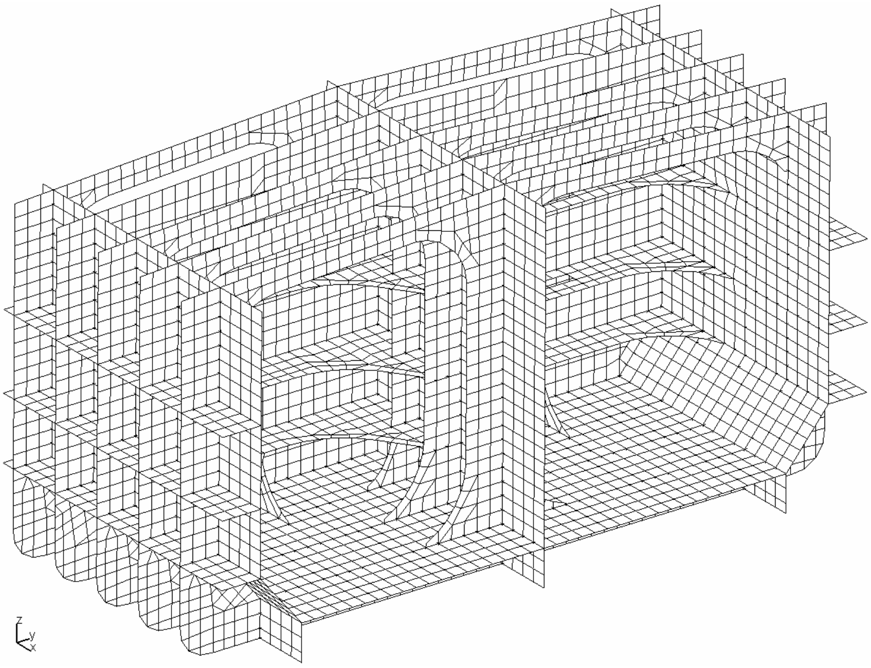
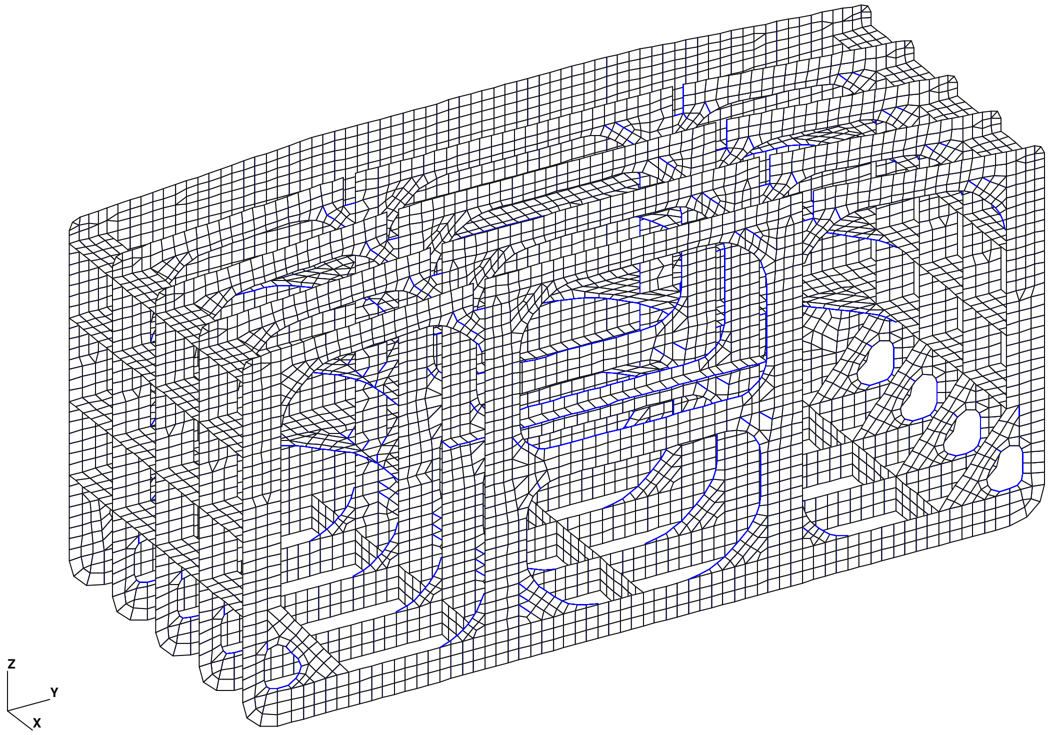


Figure B.2.7
Typical Finite Element Mesh Arrangements of Cargo Tank Structure

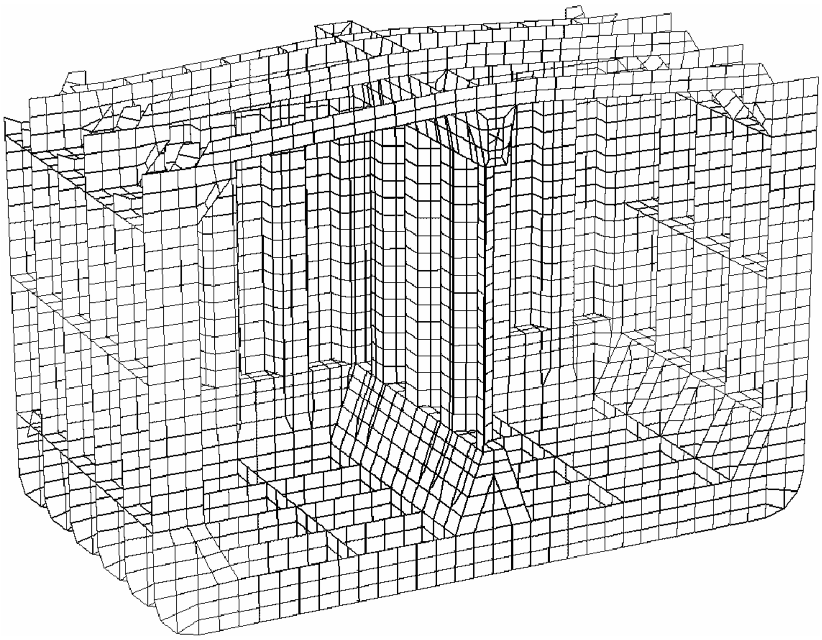


Aframax Oil Tanker

Figure B.2.7 (Continued)
Typical Finite Element Mesh Arrangements of Cargo Tank Structure



VLCC



Product tanker

2.2.1.11 All local stiffeners are to be modelled. These stiffeners may be modelled using line elements positioned in the plane of the plating. Beam elements are to be used in areas under the action of lateral loads whilst rod (truss) elements may be used to represent local stiffeners on internal structural members under no lateral loads. The line elements are to have the following properties:

(a) for beam elements, out of plane bending properties are to represent the inertia of the combined plating and stiffener. The width of the attached plate is to be

taken as ½ + ½ stiffener spacing on each side of the stiffener. The eccentricity of the neutral axis is not required to be modelled.

(b) for beam and rod elements, other sectional properties are to be based on a cross sectional area representing the stiffener area, excluding the area of the attached plating.

2.2.1.12 The effective cross sectional area of non-continuous stiffeners is to be calculated in accordance with *Table B.2.1*.

Table B.2.1
Effective Cross Sectional Area of Stiffener Line Elements

Structure represented by line element	Effective area A_e	
Stiffener within a distance $2d_w$ from a sniped (non-continuous) end	All sections	A_e=25%$A_{n\text{-}net50}$
Stiffener outside a distance $2d_w$ from a sniped (non-continuous) end	All sections	A_e=100%$A_{n\text{-}net50}$

Where:
$A_{n\text{-}net50}$ average cross sectional area over length of line element
d_w depth of stiffener web, excluding attached plate

2.2.1.13 Web stiffeners on primary support members are to be modelled. Where these stiffeners are not in line with the primary FE mesh, it is sufficient to place the line element along the nearby nodal points provided that the adjusted distance does not exceed 0.2 times the stiffener spacing under consideration. The stresses and buckling utilisation factors obtained need not be corrected for the adjustment. Buckling stiffeners on large brackets, deck transverses and stringers parallel to the flange are to be modelled. These stiffeners may be modelled using rod elements.

2.2.1.14 Face plates of primary support members and brackets may be modelled using rod elements. The effective cross sectional area at the curved part of the face plate is to be calculated in accordance with *Section 4/2.3.4*. The cross sectional area of a rod element representing the tapering part of the face plate is to be based on the average cross sectional area of the face plate in way of the element length.

2.2.1.15 Methods of representing openings in webs of primary support members are to be in accordance with *Table B.2.2*. Cut-outs for local stiffeners, scallops, drain and air holes need not be represented.

Table B.2.2
Representation of Openings in Primary Support Member Webs

$h_o/h < 0.35$ and $g_o < 1.2$	Openings do not need to be modelled
$0.5 > h_o/h \geq 0.35$ and $g_o < 1.2$	The plate modelled with mean thickness $t_{1\text{-}net50}$
$h_o/h < 0.5$ and $2 > g_o \geq 1.2$	The plate modelled with mean thickness $t_{2\text{-}net50}$
$h_o/h \geq 0.5$ or $g_o \geq 2.0$	The geometry of the opening is to be modelled

Where:

g_o $= 1 + \dfrac{l_o^2}{2.6(h - h_o)^2}$

$t_{1\text{-}net50}$ $= \dfrac{h - h_o}{h} t_{w-net50}$

$t_{2\text{-}net50}$ $= \dfrac{h - h_o}{h g_o} t_{w-net50}$

$t_{w\text{-}net50}$ net web thickness

l_o length of opening parallel to primary support member web direction, see *Figure B.2.8*

h_o height of opening parallel to depth of web, see *Figure B.2.8*

h height of web of primary support member in way of opening, see *Figure B.2.8*

t_{corr} corrosion addition, as defined in *Section 6/3.2*

Note

1. For sequential openings where the distance, d_o, between openings is less than $0.25h$, the length l_o is to be taken as the length across openings as shown in *Figure B.2.9*.
2. The same unit is to be used for l_o, h_o and h.

Figure B.2.8
Openings in Web

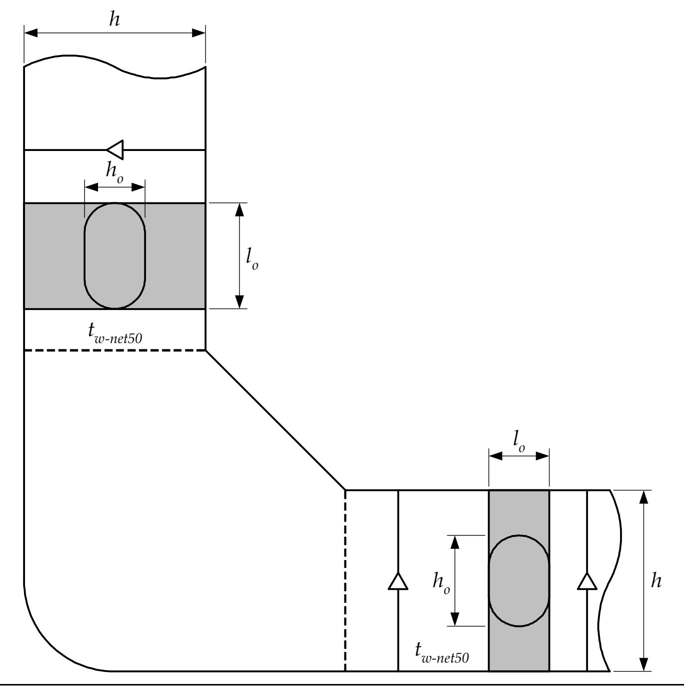
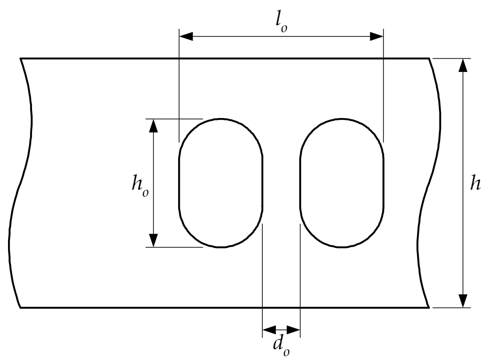


Figure B.2.9
Length l_o for Sequential Openings with $d_o < h/4$



2.3 Loading Conditions

2.3.1 Finite element load cases

2.3.1.1 The standard design load combinations to be used in the structural analysis are given in *Tables B.2.3* and *B.2.4* for tankers with two oil-tight longitudinal bulkheads and one centreline oil-tight longitudinal bulkhead respectively.

2.3.1.2 For S+D design load combinations (seagoing load cases) the number of dynamic load cases required to be investigated for each loading pattern is indicated by the dynamic load case numbers specified for each loading pattern in *Tables B.2.3* and *B.2.4*. Each S+D design load combination consists of two parts:

(a) static loads, as described by the loading pattern, ship draught, hull girder still water bending moment and shear force specified, and

(b) dynamic loads defined in *Section 7/Table 7.6.2* for the dynamic load case number specified.

2.3.1.3 For tankers with two oil-tight longitudinal bulkheads and a cross tie arrangement in the centre cargo tanks, loading patterns A7 and A12 in *Table B.2.3* are to be examined for the possibility that unequal filling levels in transversely paired wing cargo tanks would result in a more onerous stress response. Loading pattern A7 is required to be analysed only if such a non-symmetric seagoing loading condition is included in the ship loading manual. Loading patterns A7 and A12 need not be examined for tankers without a cross tie arrangement in the centre cargo tanks.

2.3.1.4 For tankers with two oil-tight longitudinal bulkheads, seagoing loading pattern A3 and harbour loading pattern A13, with all cargo tanks abreast empty, are to be analysed with a ship draught of $0.55T_{sc}$ and $0.65T_{sc}$ respectively. If conditions in the ship loading manual specify greater draughts for loading pattern A3 or A13, then the maximum specified draught in the ship's loading manual for the loading pattern is to be used.

2.3.1.5 For tankers with two oil-tight longitudinal bulkheads, seagoing loading pattern A5 and harbour loading pattern A11, with all cargo tanks abreast fully loaded, are to be analysed with a ship draught of $0.8T_{sc}$ and $0.7T_{sc}$ respectively. If conditions in the ship loading manual specify lesser draughts for loading pattern A5 or A11, then the minimum specified draught in the ship's loading manual for the loading pattern is to be used.

2.3.1.6 For loading patterns A1, A2, B1, B2 and B3, with cargo tank(s) empty, a minimum ship draught of $0.9T_{sc}$ is to be used in the analysis. If conditions in the ship loading

manual specify greater draughts for loading patterns with empty cargo tank(s), then the maximum specified draught for the actual condition is to be used.

2.3.1.7 Where a ballast condition is specified in the ship loading manual with ballast water filled in one or more cargo tanks, loading patterns A8 and B7 in *Tables B.2.3* and *B.2.4* are to be examined. If this loading is un-symmetrical then additional strength assessment is to be carried out according to the requirements of the individual Classification Society.

RCN 2 to July 2008 version (effective from 1 July 2010)

Table B.2.3
FE Load Cases for Tankers with Two Oil-tight Longitudinal Bulkheads

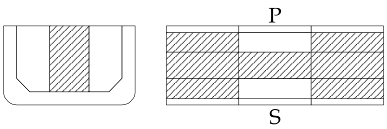
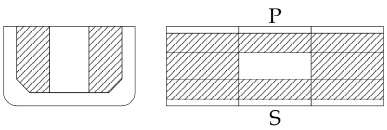
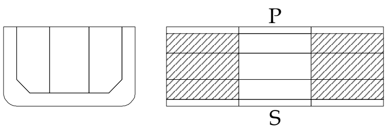
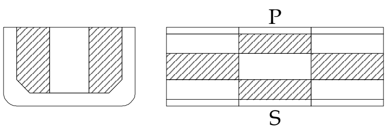
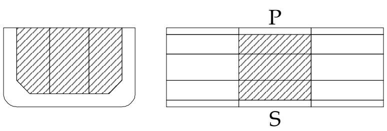
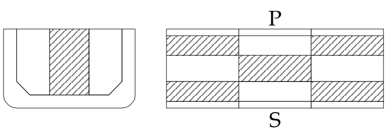
Loading Pattern	Figure	Still Water Loads: Draught	Still Water Loads: % of Perm. SWBM(2)	Still Water Loads: % of Perm. SWSF(2)	Dynamic load cases: Strength assessment (1a) Midship region	Dynamic load cases: Strength assessment against hull girder shear loads (1b) Forward region	Dynamic load cases: Strength assessment against hull girder shear loads (1b) Midship and aft regions
Design load combination S + D (Sea-going load cases)							
A1		0.9 T_{sc}	100% (sag)	See note 3	1	\	\
			100% (hog)	100% (-ve fwd) See note 4	2, 5a	\	\
A2		0.9 T_{sc}	100% (sag)	See note 3	1	\	\
			100% (hog)	100% (-ve fwd) See note 4	2, 5a	\	\
A3		0.55 T_{sc} see note 6	100% (hog)	100% (-ve fwd) See note 5	2	4	2
				100% (-ve fwd) See note 4	5a	\	\
A4		0.6 T_{sc}	100% (sag)	100% (+ve fwd) See note 4	1, 5a	\	\
A5		0.8 T_{sc} See note 7	100% (sag)	100% (+ve fwd) See note 5	1	3	1
				100% (+ve fwd) See note 4	5a	\	\
A6		0.6 T_{sc}	100% (hog)	100% (-ve fwd) See note 4	5a	\	\

Table B.2.3 (Continued)
FE Load Cases for Tankers with Two Oil-tight Longitudinal Bulkheads

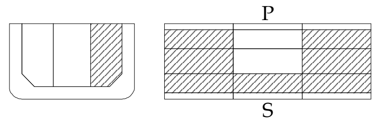
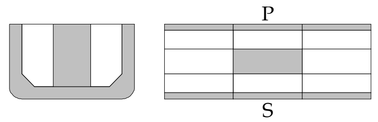
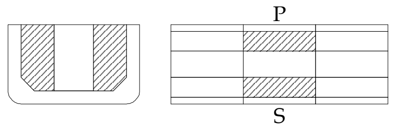
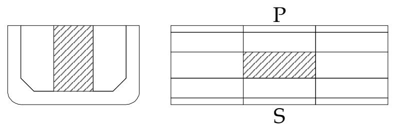
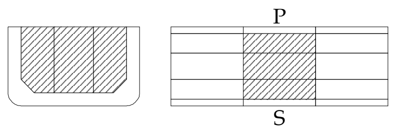
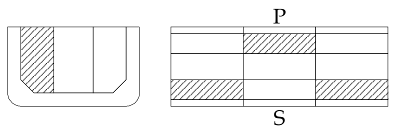
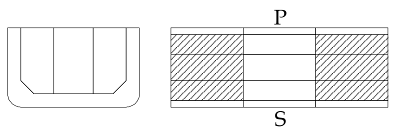
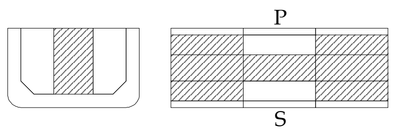
Loading Pattern	Figure	Still Water Loads			Dynamic load cases		
		Draught	Perm. SWBM(2)	Perm. SWSF(2)	Strength assessment (1a)	Strength assessment against hull girder shear loads (1b)	
					Midship region	Forward region	Midship and aft regions
A7 (8)		T_{LC}	100% (hog)	100% (-ve fwd) See note 4	5a	\	\
A8(9)		T_{bal-em}	100% (sag)	100% (+ve fwd) See note 4	1	\	\
Design load combination S (Harbour and tank testing load cases)							
A9(13)		¼T_{sc}	100% (sag)	100% (+ve fwd) See note 4	Only applicable to strength assessment of midship region (see note 1(a))		
A10(13)		¼T_{sc}	100% (sag)	100% (+ve fwd) See note 4	Only applicable to strength assessment of midship region (see note 1(a))		
A11(12,13)		0.7 T_{sc} see note 12	100% (sag)	100% (+ve fwd) See note 5	Applicable to strength assessment of midship region (see 1(a)) and strength assessment against hull girder shear loads (see 1(b))		
A12(10,13)		1/3T_{sc}	See note 10	See note 10	Only applicable to strength assessment of midship region (see note 1(a))		
A13(11,13)		0.65 T_{sc} see note 11	100% (Hog)	100% (-ve fwd) See note 5	Applicable to strength assessment of midship region (see 1(a)) and strength assessment against hull girder shear loads (see 1(b))		
A14(13)		T_{sc}	100% (Hog)	100% (-ve fwd) See note 4	Only applicable to strength assessment of midship region (see note 1(a))		

Table B.2.3 (Continued)
FE Load Cases for Tankers with Two Oil-tight Longitudinal Bulkheads

Note

1.
   (a) For the assessment of scantlings of longitudinal hull girder structural members, primary supporting structural members and transverse bulkheads within midship cargo region, *see 1.1.1.5*.
   (b) For the assessment of strengthening of longitudinal hull girder shear structural members in way of transverse bulkheads for hull girder vertical shear loads, see *1.1.1.6*, *1.1.1.7* and *1.1.1.8*.
2. The selection of permissible SWBM and SWSF for the assessment of different cargo regions of the ship is to be in accordance with *Table B.2.6*. The percentage of the permissible SWBM and SWSF to be applied are to be in accordance with this table.
3. The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.
4. The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used. Where this shear force exceeds the target SWSF (design load combination S) or target combined SWSF and VWSF, calculated in accordance with *2.4.5.2,* (design load combination S+D) as specified in the table, correction vertical loads are to be applied to adjust the shear force down to the required value.
5. Correction vertical loads are to be applied to adjust the shear force to the required value specified.
6. For loading pattern A3, with all cargo tanks abreast empty in sea-going condition, a draught of $0.55T_{sc}$ is to be used in the analysis. Where such conditions are specified in the ship's loading manual with a draught greater than $0.55T_{sc}$, the maximum specified draught for those loading conditions is to be used in the FE analysis.
7. For loading pattern A5, with all cargo tanks abreast fully loaded in sea-going condition, a draught of $0.8T_{sc}$ is to be used in the analysis. Where such conditions are specified in the ship's loading manual with a draught lesser than $0.8T_{sc}$, the minimum specified draught for those loading conditions is to be used in the FE analysis.
8. Loading pattern A7 is only required to be analysed for tankers with a cross tie arrangement in the centre cargo tanks if the ship's loading manual includes a non-symmetrical loading condition with only one of the wing tanks filled. The actual draught from the loading manual for the condition is to be used in the analysis, see *Table B.2.5*.
9. Ballast loading pattern A8 with ballast filled in one or more cargo tanks (i.e. gale ballast/emergency ballast conditions etc.) is only required to be analysed if the condition is specified in the ship's loading manual. The actual loading pattern and draught from the loading manual for the condition is to be used in the analysis, see *Table B.2.5*.
10. Loading patterns A12 is only required for tankers with a cross tie arrangement in the centre cargo tanks. The actual shear force and bending moment that results from the application of local loads to the FE model are to be used. Adjusting vertical loads and bending moments are not applied.
11. For loading pattern A13, with all cargo tanks abreast empty in harbour condition, a draught of $0.65T_{sc}$ is to be used in the analysis. Where such conditions are specified in the ship's loading manual with a draught greater than $0.65T_{sc}$, the maximum specified draught for those loading conditions is to be used in the FE analysis.
12. For loading pattern A11, with all cargo tanks abreast fully loaded in harbour condition, a draught of $0.7T_{sc}$ is to be used in the analysis. Where such conditions are specified in the ship's loading manual with a draught less than $0.7T_{sc}$, the minimum specified draught for those loading conditions is to be used in the FE analysis.
13. No dynamic loads are to be applied to Design Load Combination S (harbour and tank testing load cases).

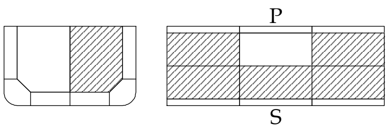
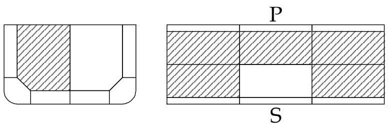
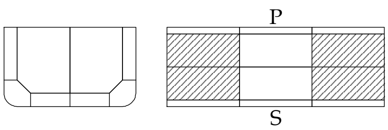
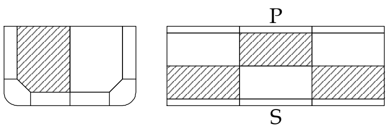
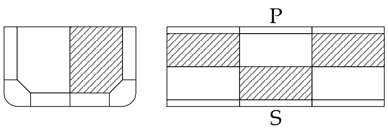
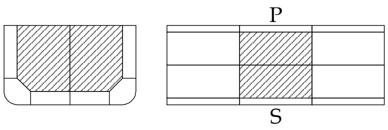
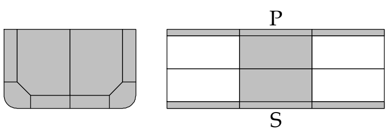
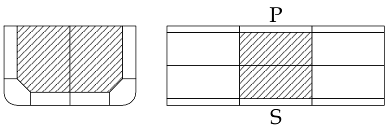
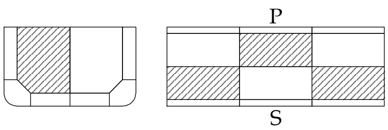
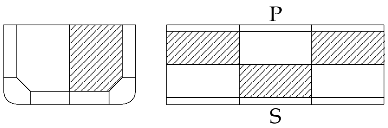
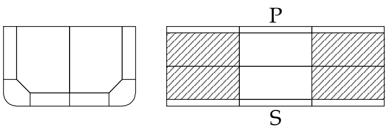
<table>
<tr><th colspan="8">Table B.2.4
Load Cases for Tankers with One Centreline Oil-tight Longitudinal Bulkhead</th></tr>
<tr><th rowspan="3">Loading Pattern</th><th rowspan="3">Figure</th><th colspan="3">Still Water Loads</th><th colspan="3">Dynamic load cases</th></tr>
<tr><th rowspan="2">Draught</th><th rowspan="2">% of Perm. SWBM(2)</th><th rowspan="2">% of Perm. SWSF(2)</th><th>Strength assessment (1a)</th><th colspan="2">Strength assessment against hull girder shear loads (1b)</th></tr>
<tr><th>Midship region</th><th>Forward region</th><th>Midship and aft regions</th></tr>
<tr><td colspan="8">Design load combination S + D (Sea-going load cases)</td></tr>
<tr><td rowspan="2">B1</td><td rowspan="2"></td><td rowspan="2">0.9 T_{sc}</td><td>100% (sag)</td><td>See note 3</td><td>1</td><td>\</td><td>\</td></tr>
<tr><td>100% (hog)</td><td>100% (-ve fwd) See note 4</td><td>2, 5a</td><td>\</td><td>\</td></tr>
<tr><td rowspan="2">B2 (6)</td><td rowspan="2"></td><td rowspan="2">0.9 T_{sc}</td><td>100% (sag)</td><td>See note 3</td><td>1</td><td>\</td><td>\</td></tr>
<tr><td>100% (hog)</td><td>100% (-ve fwd) See note 4</td><td>2, 5b</td><td>\</td><td>\</td></tr>
<tr><td rowspan="2">B3</td><td rowspan="2"></td><td rowspan="2">0.9 T_{sc}</td><td rowspan="2">100% (hog)</td><td>100% (-ve fwd) See note 5</td><td>2</td><td>4</td><td>2</td></tr>
<tr><td>100% (-ve fwd) See note 4</td><td>5a, 5b, 6a, 6b</td><td>\</td><td>\</td></tr>
<tr><td>B4</td><td></td><td>0.6 T_{sc}</td><td>100% (sag)</td><td>75% (+ve fwd) See note 4</td><td>1, 5a</td><td>\</td><td>\</td></tr>
<tr><td>B5 (6)</td><td></td><td>0.6 T_{sc}</td><td>100% (sag)</td><td>75% (+ve fwd) See note 4</td><td>1, 5b</td><td>\</td><td>\</td></tr>
<tr><td rowspan="2">B6</td><td rowspan="2"></td><td rowspan="2">0.6 T_{sc}</td><td rowspan="2">100% (sag)</td><td>100% (+ve fwd) See note 5</td><td>1</td><td>3</td><td>1</td></tr>
<tr><td>100% (+ve fwd) See note 4</td><td>5a, 5b</td><td>\</td><td>\</td></tr>
<tr><td>B7 (7)</td><td></td><td>T_{bal-em}</td><td>100% (sag)</td><td>100% (+ve fwd) See note 4</td><td>1</td><td>\</td><td>\</td></tr>
<tr><td colspan="8">Design load combination S (Harbour and tank testing load cases)</td></tr>
<tr><td>B8 (8)</td><td></td><td>1/3T_{sc}</td><td>100% (sag)</td><td>100% (+ve fwd) See note 5</td><td colspan="3">Applicable to strength assessment of midship region (see 1(a)) and strength assessment against hull girder shear loads (see 1(b))</td></tr>
<tr><td>B9 (8)</td><td></td><td>1/3T_{sc}</td><td>100% (sag)</td><td>75% (+ve fwd) See note 4</td><td colspan="3">Only applicable to strength assessment of midship region (see note 1(a))</td></tr>
</table>

Table B.2.4 (Continued)
Load Cases for Tankers with One Centreline Oil-tight Longitudinal Bulkhead

Loading Pattern	**Figure**	**Still Water Loads**			**Dynamic load cases**		
		Draught	Perm. SWBM(2)	Perm. SWSF(2)	Strength assessment (1a)	Strength assessment against hull girder shear loads (1b)	
					Midship region	Forward region	Midship and aft regions
B10 (6, 8)		$1/3T_{sc}$	100% (sag)	75% (+ve fwd) See note 4	Only applicable to strength assessment of midship region (see note 1(a))		
B11(8)		T_{sc}	100% (Hog)	100% (-ve fwd) See note 5	Applicable to strength assessment of midship region (see 1(a)) and strength assessment against hull girder shear loads (see 1(b))		

Note

1.
   (a) For the assessment of scantlings of longitudinal hull girder structural members, primary supporting structural members and transverse bulkheads within midship region, see *1.1.1.5*.
   (b) For the assessment of strengthening of longitudinal hull girder shear structural members in way of transverse bulkheads for hull girder vertical shear loads, see *1.1.1.6*, *1.1.1.7* and *1.1.1.8*.
2. The selection of permissible SWBM and SWSF for the assessment of different cargo regions of the ship is to be in accordance with *Table B.2.6*. The percentage of the permissible SWBM and SWSF to be applied are to be accordance with this table.
3. The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.
4. The actual shear force that results from the application of static and dynamic local loads are to be used. Where this shear force exceeds the target SWSF (design load combination S) or target combined SWSF and VWSF, calculated in accordance with *2.4.5.2*, (design load combination S+D) as specified in the table, correction vertical loads are to be applied to adjust the shear force down to the required value.
5. Correction vertical loads are to be applied to adjust the shear force to the required value specified.
6. Load cases B2, B5 and B10 are only required if the structure is not symmetrical about the ship's centreline.
7. Ballast loading pattern B7 with ballast filled in cargo tanks (i.e. gale ballast/emergency ballast conditions etc.) is only required to be analysed if the condition is specified in the ship's loading manual. The actual loading pattern and draught from the loading manual for the condition is to be used in the analysis, see *Table B.2.5*. If the actual loading pattern is different from load case B7 then:
   (a) An operational restriction corresponding to the analysed condition is to be added in the Loading Manual.
   (b) 100% of the permissible SWBM is to be applied when analyzing loading pattern with ballast in cargo tanks.
8. No dynamic loads are to be applied to Design Load Combination S (harbour and tank testing load cases).

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2.3.2 Dynamic load cases

2.3.2.1 The dynamic load cases to be used for the finite element analysis are specified in *Section 7/6.4.*

2.4 Application of Loads

2.4.1 General

2.4.1.1 The application of loads to the finite element model is to be in accordance with *Section 7/6* and the requirements specified in *B/2.4*.

2.4.1.2 The load parameters and locations to be used for the calculation of the applied loads and accelerations are to be in accordance with *Table B.2.5* and *Table B.2.6*.

2.4.1.3 Constant pressure load, evaluated at the element's centroid, may be applied to a finite plate element. Alternately, a linear pressure distribution between the element's nodal points can be applied.

Table B.2.5
Parameters for Calculation of Loads and Accelerations

Parameter	**Standard Conditions**			**Optional Conditions**	
	Draught T_{sc}	Draught $0.9T_{sc}$	Draught $0.6T_{sc}$	Loaded conditions: A3 (draught > $0.6T_{sc}$) and A7	Gale/emergency ballast conditions: A8 and B7
L	Rule Length			Rule Length	
C_b	block coefficient, as defined in *Section 4/1.1.1.1*			block coefficient, as defined in *Section 4/1.1.1.1*	
Ship speed	0.0			0.0	
Roll response					
GM	$0.12B$	$0.12B$	$0.24B$	Corrected GM in the ship's loading manual for the loaded or gale/emergency ballast pattern under consideration, see Note 1	
$r_{roll\text{-}gyr}$	$0.35B$	$0.35B$	$0.4B$	See Note 2	
Pitch response, longitudinal and transverse accelerations, horizontal wave bending moment and sea pressures					
Ship draught	T_{sc}	$0.9T_{sc}$	$0.6T_{sc}$	Maximum mean draught in the loading manual for the loading pattern under consideration	Minimum mean draught in the loading manual for the loading pattern under consideration

<u>Note</u>

1. Where GM for optional loaded or gale/emergency ballast conditions is not given in the ship's loading manual, GM is to be determined in accordance with *Section 7/3.1.3.2.*
2. Where $r_{roll\text{-}gyr}$ for optional loaded or gale/emergency ballast conditions is not given in the ship's loading manual, $r_{roll\text{-}gyr}$ is to be determined in accordance with *Section 7/3.1.3.3.*
3. A gale/emergency ballast condition is defined as a ballast condition with one or more cargo tanks filled with ballast.

Table B.2.6
Locations for the Determination of Loads and Accelerations

	Strength assessment (1a)	Strength assessment against hull girder shear loads (1b)		
	Midship cargo region	**Forward cargo region**	**Midship cargo region**	**Aft cargo region**
Design load combinations S + D (Sea-going load cases)				
Dynamic wave pressure and green sea load	Transverse section at 0.5*L* from AP	Transverse section at 0.75*L* from AP	Transverse section at 0.5*L* from AP	Transverse section at 0.25*L* from AP
Acceleration a_v, a_t, a_{lng}	at CG position of midship tanks (i.e. 0.5*L* from AP is within the tank boundary)	at CG position of forward tanks (i.e. 0.75*L* from AP is within the tank boundary)	at CG position of midship tanks (i.e. 0.5*L* from AP is within the tank boundary)	at CG position of aft tanks (i.e. 0.25*L* from AP is within the tank boundary)
VWBM and SWBM (SWBM is to be based on sea-going permissible values, as defined in *Section 7/2.1.1* and *2.1.2*)	at 0.5*L* from AP	at 0.75*L* from AP	at 0.5*L* from AP	at 0.25*L* from AP
HWBM	at 0.5*L* from AP	\	\	\
VWSF and SWSF (SWSF is to be based on sea-going permissible values, as defined in *Section 7/2.1.3* and *2.1.4*)	at the transverse bulkhead with maximum combined seagoing permissible SWSF and VWSF in the region (see *1.1.1.5*)	at the transverse bulkhead with maximum combined seagoing permissible SWSF and VWSF in the region (see *1.1.1.6*) or at individual bulkhead position (see *1.1.1.8*)	based on midship cargo tank strength assessment (see *1.1.1.7*) or seagoing permissible SWSF and VWSF at individual transverse bulkhead position (see *1.1.1.8*)	
Design load combination S (Harbour and tank testing load cases)				
SWBM (SWBM is to be based on harbour permissible values, as defined in *Section 7/2.1.1* and *2.1.2*)	at 0.5*L* from AP	at 0.75*L* from AP	at 0.5*L* from AP	at 0.25*L* from AP
SWSF (SWSF is to be based on harbour permissible values, as defined in *Section 7/2.1.3* and *2.1.4*)	maximum harbour permissible SWSF in the region (see *1.1.1.5*)	maximum harbour permissible SWSF in the region (see *1.1.1.6*) or at individual bulkhead position (see *1.1.1.8*)	based on midship cargo tank strength assessment (see *1.1.1.7*) or harbour permissible SWSF at individual transverse bulkhead position (see *1.1.1.8*)	

Note

1. The following assessments are to be carried out:
   (a) for the assessment of scantlings of longitudinal hull girder structural members, primary supporting structural members and transverse bulkheads in tanks within midship cargo region, see *1.1.1.5*
   (b) for the assessment of strengthening of longitudinal hull girder shear structural members in way of individual transverse bulkheads for hull girder shear loads, see *1.1.1.6, 1.1.1.7* and *1.1.1.8*.
2. For each FE load case, accelerations are to be calculated at the centre of gravity position of the ballast and/or cargo in accordance with this table. The acceleration calculated for each reference tank is to be applied to the 3 corresponding cargo or ballast tanks along the length of the FE model.
3. Longitudinal distances used in the calculation of loads refer to distance measured forward from the A.P., as defined in *Section 4/1.1.12*
4. Dynamic wave pressure calculated at the specified section is to be applied to the full length of the FE model
5. Dynamic load combination factors applied to dynamic loads for design load combination S + D (sea-going load cases) as defined in *Section 7/6.4.*
6. The SWBM and SWSF to be applied are to be in accordance with *Tables B.2.3* and *B.2.4*.

2.4.2 Structural weight, cargo and ballast density

2.4.2.1 The design cargo density is to be taken as 1.025 tonnes/m³, see *2.4.7.2*.

2.4.2.2 The density of sea water is to be taken as 1.025 tonnes/m³.

2.4.2.3 The weight of the structure is to be included in the FE analysis. The density of steel is to be taken as 7.85 tonnes/m³.

2.4.3 Static sea pressure

2.4.3.1 The static sea pressure applied to a plate element due to draught immersion is to be calculated in accordance with *Section 7/2.2.2*.

2.4.3.2 The still water draught to be considered for each finite element load case is to be in accordance with *Tables B.2.3* and *B.2.4*. A constant draught is to be applied over the full length of the cargo tank FE model.

2.4.3.3 The static sea pressure due to immersed draught for the ship in an upright condition is to be applied for all finite element load cases. The static sea pressure change due to rolling of the ship is included in the dynamic wave pressure formulation.

2.4.4 Dynamic wave pressure

2.4.4.1 The dynamic wave pressure distribution is to be determined at a transverse section of the hull at the longitudinal position as defined in *TableB.2.6*. The dynamic wave pressure distribution is to be calculated in accordance with *Section 7/6.3.5*. This pressure distribution is to be applied over the full length of the FE model.

2.4.4.2 The pressure distribution due to green sea load on the weather deck is to be calculated in accordance with *Section 7/6.3.6* at the longitudinal position as defined in *Table B.2.6*. This pressure distribution is to be applied to the weather deck over the full length of the FE model.

2.4.5 Hull girder vertical bending moment and vertical shear force

2.4.5.1 The hull girder vertical bending moment is to reach the following required value, $M_{v\text{-}targ}$, at a section within the length of the middle tank of the three tanks FE model:

$$M_{v-targ} = M_{sw} + M_{wv}$$

Where:

M_{sw} is the still water bending moment to be applied to the FE load case, as specified in *Tables B.2.3* and *B.2.4*.

M_{wv} is the vertical wave bending moment for the dynamic load case under consideration, calculated in accordance with *Section 7/6.3.2*

2.4.5.2 Hull girder vertical shear force is to reach the following required Q_{targ} value at the forward transverse bulkhead position of the middle tank:

$$Q_{targ} = Q_{sw} + Q_{wv}$$

Where:

Q_{sw} is the vertical still water shear force to be applied to the FE load case, as specified *in Tables B.2.3* and *B.2.4.*

Q_{wv} is the vertical wave shear force for the dynamic load case under consideration, calculated in accordance with *Section 7/6.3.4.*

2.4.5.3 The required hull girder vertical bending moment and shear force are to be achieved in the same load case where required by *Tables B.2.3* and *B.2.4*. The procedure to apply the required shear force and bending moment distributions is described in *2.5*.

2.4.6 Hull girder horizontal wave bending moment

2.4.6.1 Hull girder horizontal wave bending moment at a section within the length of the middle tank of the three tanks FE model is to reach the value required by the dynamic load case under consideration, calculated in accordance with *Section 7/6.3.3*.

2.4.6.2 The procedure to adjust the required hull girder horizontal bending moment is described in *2.5*.

2.4.7 Pressure in cargo and ballast tanks

2.4.7.1 The total tank pressure, P_{in}, to be applied at the boundary of a cargo or ballast tank in the finite element analysis is to include the static and dynamic components specified in *Section* 7/*Table 7.6.1* and *Table B.2.6.*.

2.4.7.2 For the seagoing load cases (design combination S + D) the cargo tank pressure is to be taken as:

$$P_{in} = f_{density}(P_{in-tk} + P_{in-dyn}) \quad \text{kN/m}^2$$

where:

$f_{density}$ factor for joint probability of occurrence of cargo density and maximum sea state in 25 years design life

$= \rho_{max-LM} / \rho_{allowable}$

ρ_{max-LM} maximum cargo density associated with a full tank from any loading condition in the ship's loading manual. ρ_{max-LM} is not to be taken as less than 0.9 tonnes/m^3 for cargo loaded conditions and 1.025 tonnes/m^3 for the optional emergency ballast condition (i.e. A8 and B7 in *Tables B.2.3* and *B.2.4* respectively)

$\rho_{allowable}$ design cargo density associated with a full tank to be taken as 1.025 tonnes/m^3 unless a higher density is specified by the builder, see *Section 2/3.1.8.1*

P_{in-tk} static tank pressure as given in *Section 7/2.2.3.1*, in kN/m^2, and with density of fluid in tank equal to the design cargo density, $\rho_{allowable}$

P_{in-dyn} simultaneously acting dynamic pressure given in *Section 7/6.3.7.1* , in kN/m^2, with simplification given in *2.4.7.3* and with density of fluid in tank equal to the design cargo density, $\rho_{allowable}$

2.4.7.3 The envelope vertical acceleration, a_v, at the centre of gravity of tanks is calculated in accordance with *Section 7/3.3.3* with the following simplifications:

(a) for head sea conditions, a_{roll-z} is taken as 0

(b) for beam sea conditions, $a_{pitch-z}$ is taken as 0.

2.4.7.4 The vertical, transverse and longitudinal accelerations are to be calculated at the centre of gravity of the abreast tanks at the longitudinal position as specified in

Table B.2.6. These accelerations are to be applied to all corresponding tanks along the length of the three-tank FE model.

2.4.7.5 The dynamic tank pressure is to be calculated in accordance with *Section 7/6.3.7.1*, also see *Table B.2.6*.

2.4.7.6 For ballast tanks which utilise ballast water exchange by flow-through method, the following are to be considered when calculating tank pressure for seagoing load cases (design combination S + D) as required by *Section 7/Table 7.6.1*:

- Maximum vertical height of the air pipe or overflow pipe, i.e. h_{air} as defined in *Section 7/2.2.3.2* and *Figure 7.2.3*, of all ballast tanks in the cargo region is to be used in the calculation of the dynamic tank pressure due to vertical acceleration (see *Section 7/6.3.7.1*).
- Maximum value of h_{air} and P_{drop}, as defined in *Section 7/2.2.3.3*, of all ballast tanks in the cargo region are to be used to calculate the static tank pressure.

2.4.7.7 The following are to be considered when calculating the static tank pressure in cargo tanks for harbour/tank testing load cases (design combination S) as required by *Section 7/Table 7.6.1*:

- Maximum h_{air}, as defined in *Section 7/2.2.3.2* and *Figure 7.2.3*, of all cargo tanks in the cargo region are to be considered in the calculation of $P_{in\text{-}test}$, see *Section 7/2.2.3.5*.

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2.4.7.8 Where the length of the model is extended beyond the end transverse bulkheads, see *2.2.1.1*, tank pressure is only to be applied to the complete tanks within the model length.

2.4.7.9 Maximum setting of pressure relief valve, P_{valve}, as defined in Section 7/2.2.3.5 are to be considered in design combination S and S+D as required by Section 7/Table 7.6.1.
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2.5 Procedure to Adjust Hull Girder Shear Forces and Bending Moments

2.5.1 General

2.5.1.1 The procedure described in this section is to be applied to adjust the hull girder horizontal bending moment, vertical shear force and vertical bending moment distributions on the three cargo tanks FE model to achieve the required values.

2.5.1.2 Vertical distributed loads are applied to each frame position, together with a vertical bending moment applied to the model ends to produce the required value of vertical shear force at both the forward and aft bulkhead of the middle tank of the FE model, and the required value of vertical bending moment at a section within the length of the middle tank of the FE model. The required values are specified in *2.4.5*.
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2.5.1.3 A horizontal bending moment is applied to the ends of the model to produce the required target value of horizontal bending moment at a section within the length of the middle tank of the FE model. The required values are specified in *2.4.6*.

2.5.2 Shear force and bending moment due to local loads

2.5.2.1 The vertical shear forces generated by the local loads are to be calculated at the transverse bulkhead positions of the middle tank of the FE model. The maximum absolute shear force at the bulkhead position of the middle tank of the FE model is

to be used to obtain the required adjustment in shear forces at the transverse bulkhead, see 2.5.3. The vertical bending moment distribution generated by the local loads is to be calculated along the length of the middle tank of the three cargo tank FE model. The FE model can be used to calculate the shear forces and bending moments. Alternatively, a simple beam model representing the length of the 3-tank FE model with simply supported ends may be used to determine the shear force and bending moment values.

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2.5.2.2 For beam and oblique sea conditions, the horizontal bending moment distribution due to dynamic sea pressure and dynamic tank pressure is to be calculated along the length of the middle tank of the FE model.

2.5.2.3 The following local loads are to be applied for the calculation of hull girder shear forces and bending moments:

(a) ship structural weight distribution over the length of the 3-tank model (static loads). Where a simple beam model is used, the weight of the structure of each tank can be distributed evenly over the length of the cargo tank. The structural weight is to be calculated based on a thickness deduction of $0.5t_{corr}$, as used in the construction of the cargo tank FE model, see *2.2.1.5.*

(b) weight of cargo and ballast (static loads)

(c) static sea pressure, dynamic wave pressure and, where applicable, green sea load. For the Design Load Combination S (harbour/tank testing load cases), only static sea pressure needs to be applied

(d) dynamic tank pressure load for Design Load Combination S+D (seagoing load cases).

2.5.3 Procedure to adjust vertical shear force distribution

2.5.3.1 The required adjustment in shear forces at the transverse bulkhead positions (ΔQ_{aft} and ΔQ_{fwd} as shown in *Figure B.2.10*) are to be generated by applying vertical load at the frame positions as shown in *Figure B.2.11*. It is to be noted that vertical correction loads are not to be applied to any transverse tight bulkheads, any frames forward of the forward tank and any frames aft of the aft tank of the FE model. The sum of the total vertical correction loads applied is equal to zero.

2.5.3.2 The required adjustment in shear forces at the aft and forward transverse bulkheads of the middle tank of the FE model in order to generate the required shear forces at the bulkheads are given by:

$$\Delta Q_{aft} = - Q_{targ} - Q_{aft}$$

$$\Delta Q_{fwd} = Q_{targ} - Q_{fwd}$$

Where:

ΔQ_{aft} required adjustment in shear force at aft bulkhead of middle tank based on the maximum absolute shear force at the bulkhead

ΔQ_{fwd} required adjustment in shear force at fore bulkhead of the middle tank based on the maximum absolute shear force at the bulkhead

Q_{targ} required shear force value to be achieved at forward bulkhead of middle tank, see *2.4.5.*

Q_{aft} shear force due to local loads at aft bulkhead of middle tank,

see *2.5.2*

Q_{fwd} shear force due to local loads at fore bulkhead of middle tank, see *2.5.2*

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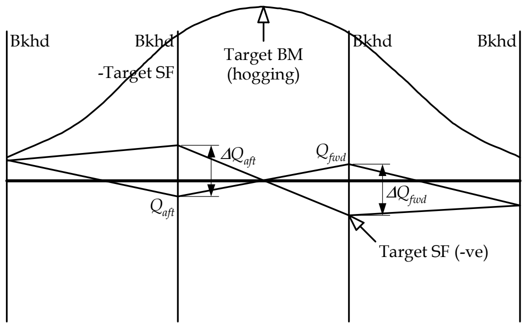
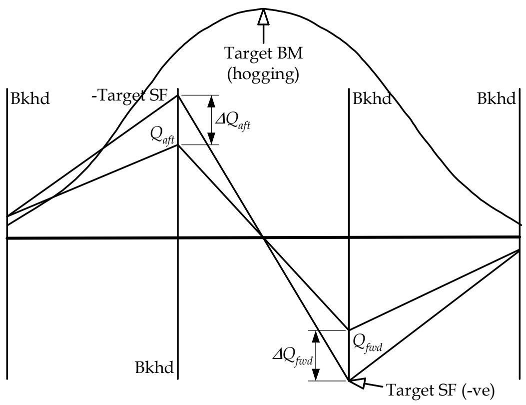
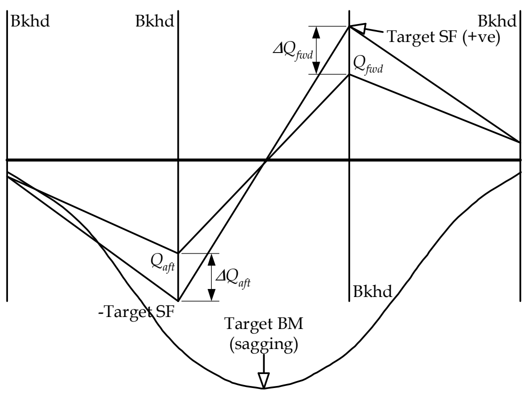
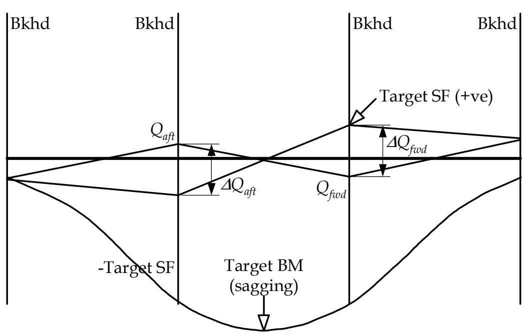
Figure B.2.10
Position of Target Shear Force and Required Shear Force Adjustment at Transverse Bulkhead Positions

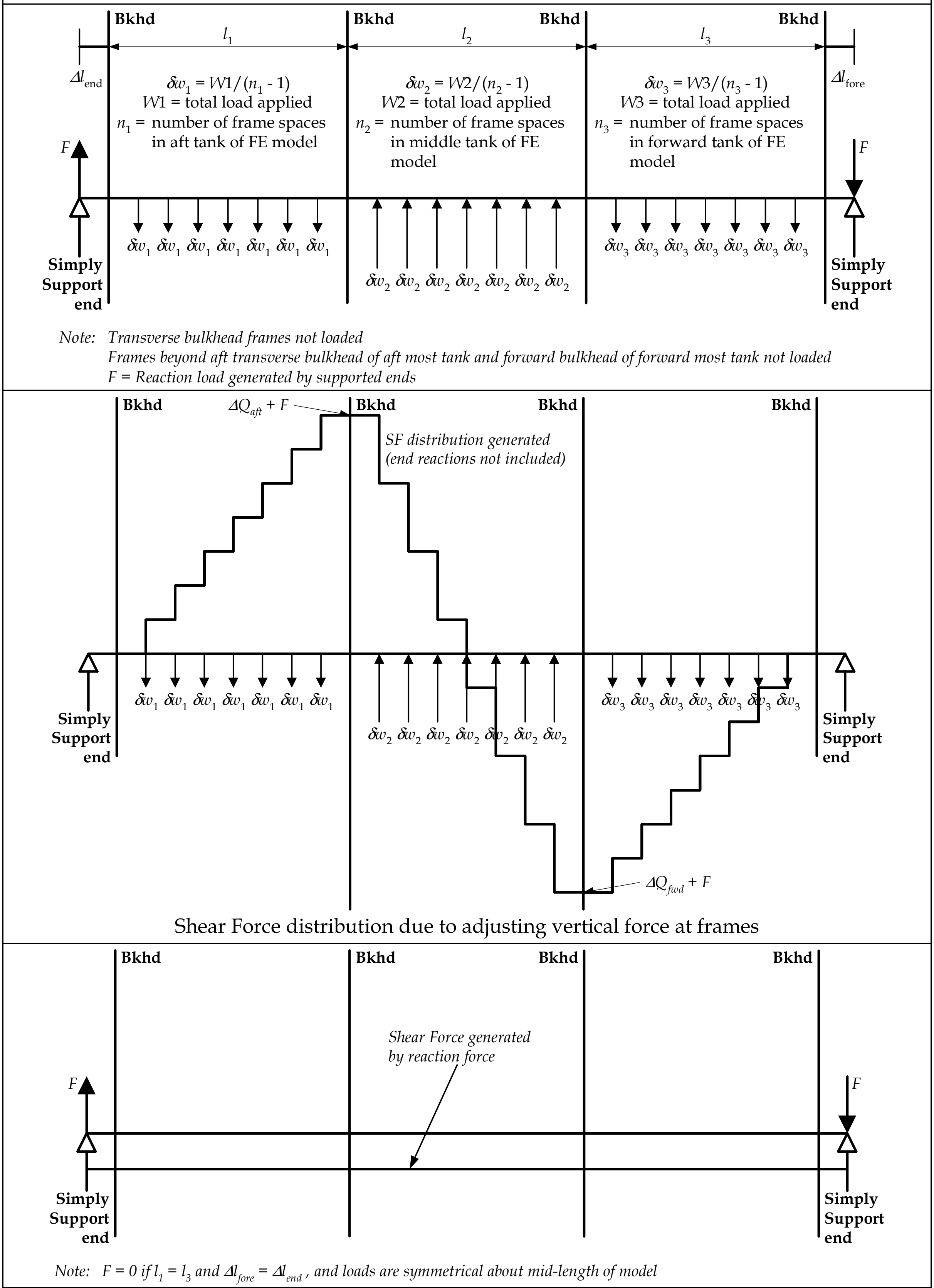
Condition	Target			Aft Bkhd		Fore Bkhd	
	BM	SF	Bkhd pos	SF	ΔQ_{aft}	SF	ΔQ_{fwd}
	Hog	-ve	Fore	$-Q_{targ}$	$-Q_{targ} - Q_{aft}$	Q_{targ} (-ve)	$Q_{targ} - Q_{fwd}$
	Hog	-ve	Fore	$-Q_{targ}$	$-Q_{targ} - Q_{aft}$	Q_{targ} (-ve)	$Q_{targ} - Q_{fwd}$
	Sag	+ve	Fore	$-Q_{targ}$	$-Q_{targ} - Q_{aft}$	Q_{targ} (+ve)	$Q_{targ} - Q_{fwd}$
	Sag	+ve	Fore	$-Q_{targ}$	$-Q_{targ} - Q_{aft}$	Q_{targ} (+ve)	$Q_{targ} - Q_{fwd}$

Note

For definition of symbols, see *2.5.3.2*.

Figure B.2.11

Distribution of Adjusting Vertical Force at Frames and Resulting Shear Force Distributions



Note

For definition of symbols, see *Table B.2.7*.

2.5.3.3 The value of the vertical loads to be applied to each frame to generate the increase in shear force at the bulkheads may be calculated using a simple beam model. For the case where an uniform frame spacing is used within each tank, the amount of vertical force to be distributed at each frame may be calculated in accordance with *Table B.2.7*. The length and frame spacing of individual cargo tanks may be different.

Table B.2.7
Formulae for Calculation of Vertical Loads for Adjusting Vertical Shear Forces

$$\delta w_1 = \frac{\Delta Q_{aft}(2l - l_2 - l_3) + \Delta Q_{fwd}(l_2 + l_3)}{(n_1 - 1)(2l - l_1 - 2l_2 - l_3)} \qquad F = 0.5\left(\frac{W1(l_2 + l_1) - W3(l_2 + l_3)}{l}\right)$$

$$\delta w_2 = \frac{(W1 + W3)}{(n_2 - 1)} = \frac{(\Delta Q_{aft} - \Delta Q_{fwd})}{(n_2 - 1)}$$

$$\delta w_3 = \frac{-\Delta Q_{fwd}(2l - l_1 - l_2) - \Delta Q_{aft}(l_1 + l_2)}{(n_3 - 1)(2l - l_1 - 2l_2 - l_3)}$$

Where:

l_1	length of aft cargo tank of model
l_2	length of middle cargo tank of model
l_3	length of forward cargo tank of model
ΔQ_{aft}	required adjustment in shear force at aft bulkhead of middle tank, see *Figure B.2.10*
ΔQ_{fwd}	required adjustment in shear force at fore bulkhead of middle tank, see *Figure B.2.10*
F	end reactions due to application of vertical loads to frames, see *2.5.3*
$W1$	total evenly distributed vertical load applied to aft tank of FE model, $(n_1 - 1)\,\delta w_1$
$W2$	total evenly distributed vertical load applied to middle tank of FE model, $(n_2 - 1)\,\delta w_2$
$W3$	total evenly distributed vertical load applied to forward tank of FE model, $(n_3 - 1)\,\delta w_3$
n_1	number of frame spaces in aft cargo tank of FE model
n_2	number of frame spaces in middle cargo tank of FE model
n_3	number of frame spaces in forward cargo tank of FE model
δw_1	distributed load at frame in aft cargo tank of FE model
δw_2	distributed load at frame in middle cargo tank of FE model
δw_3	distributed load at frame in forward cargo tank of FE model
Δl_{end}	distance between end bulkhead of aft cargo tank to aft end of FE model
Δl_{fore}	distance between fore bulkhead of forward cargo tank to forward end of FE model
l	total length of FE model (beam) including portions beyond end bulkheads: $= l_1 + l_2 + l_3 + \Delta l_{end} + \Delta l_{fore}$

Notes

1. Positive direction of loads, shear forces and adjusting vertical forces in the formulae is in accordance with *Figures B.2.10* and *B.2.11*.
2. $W1 + W3 = W2$
3. Note that the above formulae are only applicable if an uniform frame spacing is used within each tank, see *2.5.3.3*. The length and frame spacing of individual cargo tanks may be different.

2.5.3.4 The amount of adjusting load to be applied to the structural parts of each transverse frame section to generate the vertical load, δw_i, is to be in accordance with *Figure B.2.12*. This load is to be distributed at the finite element grid points of the structural parts. Where 4-node or 3-node finite plate elements are used, the load to be applied at each grid point of a plate element is given by:

$$F_{i-grid} = \frac{\sum_{1}^{n} 0.5\, A_{i-elem-net50}}{A_{s-net50}} F_s$$

Where:

F_{i-grid} load to be applied to the i^{th} FE grid point on the individual structural member under consideration, i.e. side shell, longitudinal bulkheads and bottom girders, inner hull longitudinal bulkheads, hopper plates, upper slope plates of inner hull and outboard girders as defined in *Figure B.2.12*

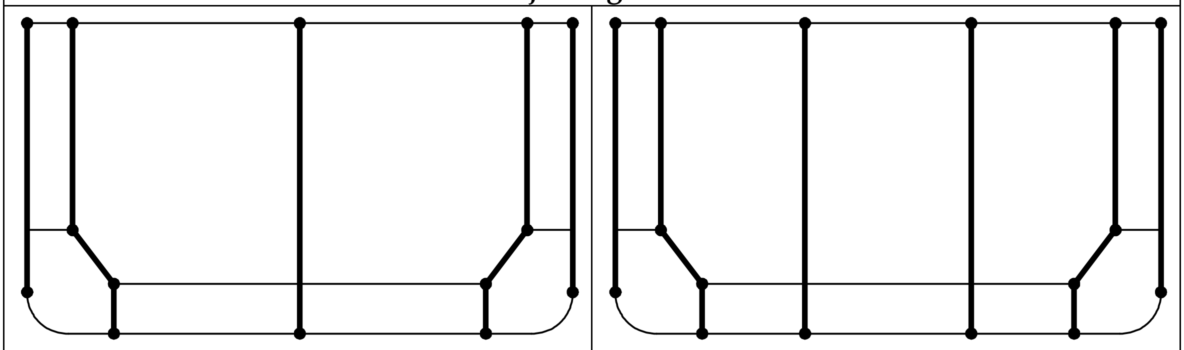
$A_{i-elem-net50}$ sectional area of each plate element in the individual structural member under consideration (see *Figure B.2.12)*, which is connected to the i^{th} grid point

n number of plate elements connected to the i^{th} grid point

F_s total load applied to individual structural member under consideration, as specified in *Figure B.2.12*

$A_{s-net50}$ plate sectional area of the individual structural member under consideration, i.e. side shell, longitudinal bulkheads, bottom girders, inner hull longitudinal bulkheads, hopper plates, upper slope plates of inner hull and outboard girders as defined in *Figure B.2.12*

Figure B.2.12
Distribution of Adjusting Load on a Transverse Section



Structural member	**Applied load F_s**
Side Shell	$f \cdot \delta w_i$
Longitudinal bulkhead including bottom girder beneath	$f \cdot \delta w_i$
Inner hull longitudinal bulkhead (vertical part)	$f \cdot \delta w_i \cdot \frac{A_{Ih-net50}}{A_{2-net50}}$
Hopper plate	$f \cdot \delta w_i \cdot \frac{A_{Hp-net50}}{A_{2-net50}}$
Upper slope plating of inner hull	$f \cdot \delta w_i \cdot \frac{A_{Usp-net50}}{A_{2-net50}}$
Outboard girder	$f \cdot \delta w_i \cdot \frac{A_{Og-net50}}{A_{2-net50}}$

Figure B.2.12 (Continued)
Distribution of Adjusting Load on a Transverse Section

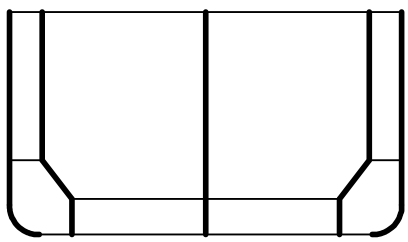
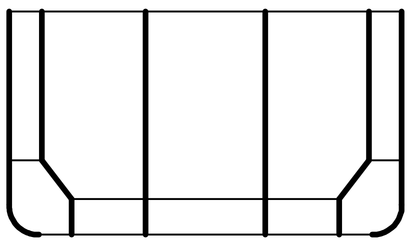
Where

$\delta w_{i,}$	vertical load to be applied to each transverse frame section, see *2.5.3.3* and *Table B.2.7*
f	shear force distribution factor of structural part calculated at the mid-tank position in accordance with *Table B.2.8*
$A_{Ih\text{-}net50}$	plate sectional area of individual inner hull longitudinal bulkhead
$A_{Hp\text{-}net50}$	plate sectional area of individual hopper plate
$A_{Usp\text{-}net50}$	Plate sectional area of individual upper slope plate of inner hull
$A_{Og\text{-}net50}$	plate sectional area of individual outboard girder
$A_{2\text{-}net50}$	plate sectional area calculated in accordance with *Table B.2.8*

<u>Note</u>

1. Adjusting load is to be applied in plane to the hopper slope plate and upper slope plate of inner hull.
2. Adjusting load given is to be applied to individual structural member.

Table B.2.8
Shear Force Distribution Factors

	Side Shell	$f = 0.055 + 0.097\dfrac{A_{1-net50}}{A_{2-net50}} + 0.020\dfrac{A_{2-net50}}{A_{3-net50}}$
	Inner hull	$f = 0.193 - 0.059\dfrac{A_{1-net50}}{A_{2-net50}} + 0.058\dfrac{A_{2-net50}}{A_{3-net50}}$
	CL longitudinal bulkhead	$f = 0.504 - 0.076\dfrac{A_{1-net50}}{A_{2-net50}} - 0.156\dfrac{A_{2-net50}}{A_{3-net50}}$
	Side Shell	$f = 0.028 + 0.087\dfrac{A_{1-net50}}{A_{2-net50}} + 0.023\dfrac{A_{2-net50}}{A_{3-net50}}$
	Inner hull	$f = 0.119 - 0.038\dfrac{A_{1-net50}}{A_{2-net50}} + 0.072\dfrac{A_{2-net50}}{A_{3-net50}}$
	Longitudinal bulkhead	$f = 0.353 - 0.049\dfrac{A_{1-net50}}{A_{2-net50}} - 0.095\dfrac{A_{2-net50}}{A_{3-net50}}$

Where:

$A_{1\text{-}net50}$	plate sectional area of individual side shell (i.e. on one side), including bilge
$A_{2\text{-}net50}$	plate sectional area of individual inner hull longitudinal bulkhead (i.e. on one side), including hopper slope plate, double bottom side girder in way and, where fitted, upper slope plating of inner hull.
$A_{3\text{-}net50}$	plate sectional area of individual longitudinal bulkhead, including double bottom girder in way

<u>Note</u>

1. Where part of the structural member is not vertical, the area is to be calculated using the projected area in the vertical direction.
2. All plate areas are to be calculated based on the modelled thickness of the cargo tank FE model, see *2.2.1.5*.
3. For corrugated longitudinal bulkheads, the corrugation thickness for the calculation of shear force distribution factor, *f*, is to be corrected according to *Section 4/2.6.4*.

2.5.4 Procedure to adjust vertical and horizontal bending moments

2.5.4.1 An additional vertical bending moment is to be applied at both ends of the cargo tank finite element model to generate the required vertical bending moment in the middle tank of the model. This end vertical bending moment can be calculated as follows:

$$M_{v-end} = M_{v-targ} - M_{v-peak}$$

Where:

M_{v-end}	additional vertical bending moment to be applied at both ends of finite element model
M_{v-targ}	required hogging (positive) or sagging (negative) vertical bending moment, as specified in *2.4.5*
M_{v-peak}	maximum or minimum bending moment within the length of the middle tank due to the local loads described in *2.5.2.3* and the additional vertical loads applied to generate the required shear force, see *2.5.3*. M_{v-peak} is to be taken as the maximum bending moment if M_{v-targ} is hogging (positive) and as the minimum bending moment if M_{v-targ} is sagging (negative). M_{v-peak} can be obtained from FE analysis. Alternatively, M_{v-peak} may be calculated as follows based on a simply supported beam model: $M_{v-peak} = Max\{M_o + xF + M_{lineload}\}$
M_o	vertical bending moment at position x, due to the local loads described in *2.5.2.3*.
$M_{lineload}$	vertical bending moment at position x, due to application of vertical line loads at frames to generate required shear force, see *2.5.3*
F	reaction force at ends due to application of vertical loads to frames, see *2.5.3*
x	longitudinal position of frame in way of the middle tank of FE model from end, see *2.5.4.2*

2.5.4.2 For beam and oblique sea load cases, an additional horizontal bending moment is to be applied at the ends of the cargo tank FE model to generate the required horizontal bending moment at a section within the length of the middle tank of the model. The additional horizontal bending moment can be calculated as follows:

$$M_{h-end} = M_{h-targ} - M_{h-peak}$$

Where:

M_{h-end}	additional horizontal bending moment to be applied to ends of FE model
M_{h-targ}	required positive or negative horizontal bending moment, see *2.4.6*
M_{h-peak}	maximum or minimum horizontal bending moment within the length of the middle tank due to the local loads described in *2.5.2.3*. M_{h-peak} is to be taken as the maximum horizontal bending moment if M_{h-targ} is positive (starboard side in tension) and as the minimum horizontal bending moment if M_{h-targ} is negative (port side in tension).

2.5.4.3 The vertical and horizontal bending moments should be calculated over the length of the middle tank of the FE model to identify the position and value of each maximum/minimum bending moment as specified in *2.5.4.1* and *2.5.4.2*.

2.5.4.4 The additional vertical bending moment, $M_{v\text{-}end}$, and horizontal bending moment, $M_{h\text{-}end}$, are to be applied to both ends of the cargo tank model. The bending moments may be applied by either of the methods described in *2.5.4.5* and *2.5.4.6*.

2.5.4.5 The vertical and horizontal bending moments may be applied at the model ends by distributing axial nodal forces to all longitudinal elements according to the simple beam theory as follows:

$$(F_x)_i = \frac{M_{v-end}}{I_{y-net50}} \frac{A_{i-net50}}{n_i} z_i \qquad \text{for vertical bending moment}$$

$$(F_x)_i = \frac{M_{h-end}}{I_{z-net50}} \frac{A_{i-net50}}{n_i} y_i \qquad \text{for horizontal bending moment}$$

Where:

$M_{v\text{-}end}$	vertical bending moment to be applied to the ends of the model
$M_{h\text{-}end}$	horizontal bending moment to be applied to the ends of the model
$(F_x)_i$	axis force applied to a node of the ith element
$I_{y\text{-}net50}$	hull girder vertical moment of inertial of the end section about its horizontal neutral axis
$I_{z\text{-}net50}$	hull girder horizontal moment of inertial of the end section about its vertical neutral axis (normally centreline)
z_i	vertical distance from the neutral axis to the centre of the cross sectional area of the i^{th} element
y_i	horizontal distance from the neutral axis to the centre of the cross sectional area of the i^{th} element
$A_{i\text{-}net50}$	cross sectional area of the i^{th} element
n_i	number of nodal points of i^{th} element on the cross section, n_i = 2 for 4-node plate element

2.5.4.6 The vertical and horizontal bending moments may alternatively be applied to an independent grid point at the intersection of the vertical neutral axis (normally centreline) and the horizontal neutral axis, see *Figure B.2.13*. All nodal points of the longitudinal elements on the end section are to be rigidly linked to the independent point in θ_y (for vertical bending), θ_z (for horizontal bending) and δ_x. This independent point is not to be connected to the model except by the rigid link. The rigid links are to maintain the end plane of the model in keeping plane under the action of the applied bending moment, which is equivalent to imposing a prescribed displacement to the nodal points in accordance with the simple beam theory.

2.6 Boundary Conditions

2.6.1 General

2.6.1.1 All boundary conditions described in this section are in accordance with the global co-ordinate system defined in *Section 4/1.4.* The boundary conditions to be applied at the ends of the cargo tank FE model are given in *Table B.2.9*. The analysis may be carried out by applying all loads to the model as a complete load case or by combining the stress responses resulting from several separate sub-cases.

2.6.1.2 Ground spring elements, i.e. spring elements with one end constrained in all 6 degrees of freedom, with stiffness in global y degree of freedom are to be applied to the grid points along deck, inner bottom and bottom shell as shown in *Figure B.2.13.*

2.6.1.3 Ground spring elements with stiffness in global z degree of freedom are to be applied to the grid points along the vertical part of the side shells, inner hull longitudinal bulkheads and oil-tight longitudinal bulkheads as shown in *Figure B.2.13*.

Figure B.2.13
Spring Constraints at Model Ends

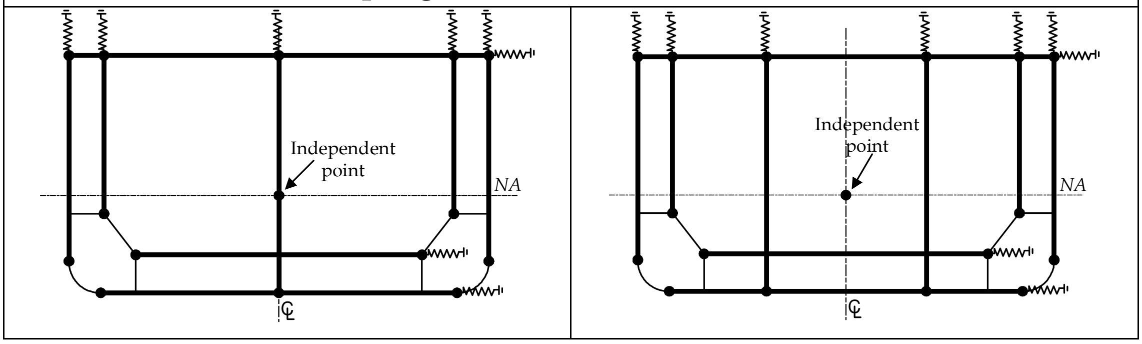


Table B.2.9
Boundary Constraints at Model Ends

Location	Translation			Rotation		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Aft End						
Aft end (all longitudinal elements)	***RL***	-	-	-	***RL***	***RL***
Independent Point aft end, see *Figure B.2.13*	Fix	-	-	-	$M_{v\text{-}end}$	$M_{h\text{-}end}$
Deck, inner bottom and outer shell	-	Springs	-	-	-	-
Side, inner skin and longitudinal bulkheads	-	-	Springs	-	-	-
Fore End						
Fore end (all longitudinal elements)	***RL***	-	-	-	***RL***	***RL***
Independent point fore end, see *Figure B.2.13*	-	-	-	-	$M_{v\text{-}end}$	$M_{h\text{-}end}$
Deck, inner bottom and outer shell	-	Springs	-	-	-	-
Side, inner skin and longitudinal bulkheads	-	-	Springs	-	-	-

Where:

- no constraint applied (free)

RL nodal points of all longitudinal elements rigidly linked to independent point at neutral axis on centreline

Note

1. All translation and rotation displacements are in accordance with the global coordinate system defined in *Section 4/1.4*.
2. Where $M_{h\text{-}end}$ is not applied, the independent points at the fore and aft ends are to be free in θ_z.
3. Where $M_{v\text{-}end}$ is not applied, the independent points at the fore and aft ends are to be free in θ_y.
4. Where no bending moment is applied, the independent points at the fore and aft ends are to be free in θ_y and θ_z.
5. Where bending moment is applied as nodal forces, the independent points at the fore and aft ends are to be free in the corresponding degree of freedom of rotations (i.e. θ_y and/or θ_z).

2.6.2 Calculation of spring stiffness

2.6.2.1 The stiffness, *c*, of individual spring elements for each structural member, to be applied at each end of the cargo tank model, is given by:

$$c = \left(\frac{E}{1+\nu}\right)\frac{A_{s-net50}}{l_{tk}\ n} = 0.77\ \frac{A_{s-net50}E}{l_{tk}\ n} \quad \text{N/mm}$$

Where:

$A_{s\text{-}net50}$ shearing area of the individual structural member under consideration, i.e. plating of deck, inner bottom, bottom shell, side shell, inner hull longitudinal bulkheads or oil-tight longitudinal bulkhead. $A_{s\text{-}net50}$ is to be calculated based on the thickness of the cargo tank finite element model for areas indicated in *Table B.2.10* for the appropriate structural member under consideration, in mm^2

ν Poisson's ratio of the material

l_{tk} length of cargo tank, between bulkheads of the middle tank of the FE model, in mm^2

E Modulus of Elasticity, in N/mm^2

n number of nodal points to which the spring elements are applied to the structural member under consideration

Table B.2.10
Shear Areas to be Considered for the Calculation of Spring Stiffness

Vertical springs

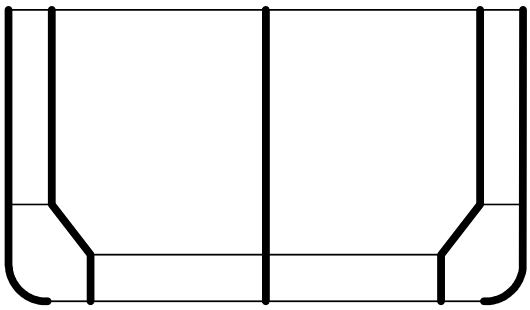
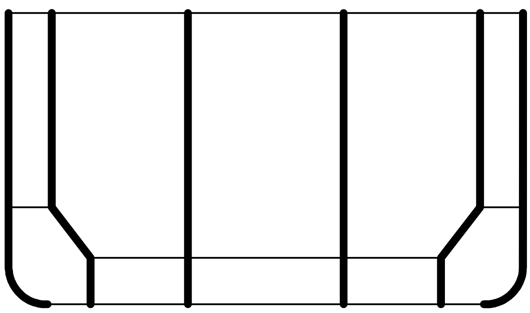
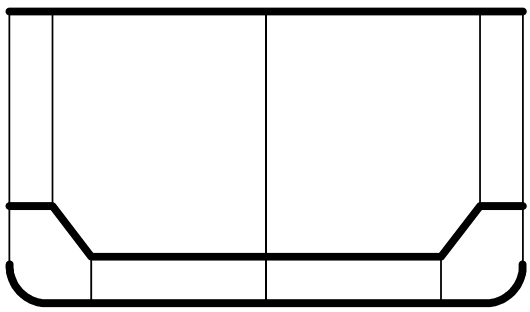
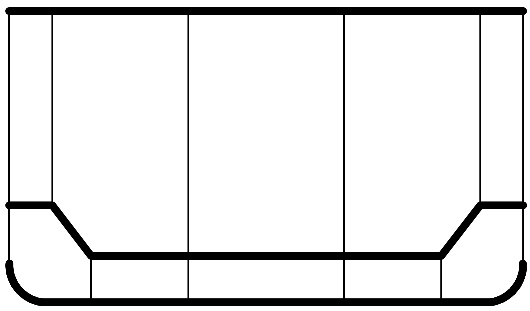
	Side	Area of side shell plating, including bilge
	Inner hull longitudinal bulkheads	Area of inner skin plating, including hopper slope plate and double bottom side girder in way
	Longitudinal bulkheads	Area of longitudinal bulkhead plating, including double bottom girder in way
	<u>Note</u> Where part of the structural member is not vertical, the area is to be calculated using the projected area in the vertical direction.	

Table B.2.10 (Continued)
Shear Areas to be Considered for the Calculation of Spring Stiffness

Horizontal springs	
	Deck — Area of deck plating Inner bottom — Area of inner bottom plating, including hopper slope plate and horizontal stringer in way Bottom shell — Area of bottom shell plating, including bilge
	<u>Note</u> Where part of the structural member is not horizontal the area is to be calculated using the projected area in the horizontal direction.

2.6.2.2 For vertical corrugated longitudinal bulkheads, the corrugation thickness for the calculation of spring stiffness, c, shall be calculated according to *Section 4/2.6.4*.

2.6.2.3 Alternatively, rod elements may be used instead of spring elements, the equivalent cross section area of the rod is $(c{\cdot}l)/E$, where l is the length of the rod. One end of the rod is to be constrained in all 6 degrees of freedom.

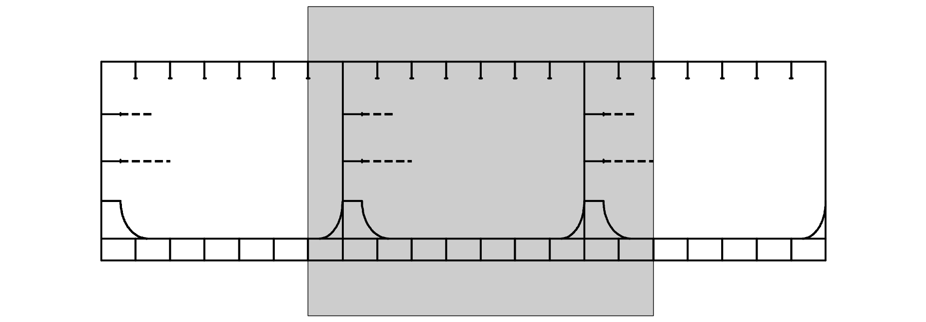
2.7 Result Evaluation

2.7.1 General

2.7.1.1 Verification of result against acceptance criteria is to be carried out for structural members within longitudinal extent shown in *Figure B.2.14*, which includes the middle tanks of the three cargo tanks FE model and the region forward and aft of the middle tanks up to the extent of the transverse bulkhead stringer and buttress structure. For the strength assessment of tanks in the midship cargo region, stress level and buckling capability of longitudinal hull girder structural members, primary supporting structural members and transverse bulkheads are to be verified. For the assessment of required strengthening in way of transverse bulkheads against hull girder shear load, stress level and buckling capability of inner hull longitudinal bulkheads including upper sloped plate where fitted, side shell, hopper, bottom girders and longitudinal bulkheads are to be verified.

2.7.1.2 Assessment of results is to be carried out for the standard load cases specified in *2.3.1*, and any other load cases specially considered as required by *Section 9/2.2.3*.

Figure B.2.14
Extent of FE Model for Verification against Acceptance Criteria



2.7.2 Stress assessment

2.7.2.1 Stresses are not to exceed the permissible values given in *Section 9/2.2.5*.

2.7.2.2 The maximum permissible stresses are based on the mesh sizes and element types described in *2.2*.

2.7.2.3 The von Mises stress, σ_{vm}, is to be calculated based on the membrane direct and shear stresses of the plate element. Where shell elements are used, the stresses are to be evaluated at the mid plane of the element. Where plate elements are used, the stresses are to be evaluated at the element centroid.

2.7.2.4 Except as indicated in *2.7.2.5*, the element shear stress in way of openings in webs is to be corrected for loss in shear area in accordance with the following formula. The corrected element shear stress is to be used to calculate the von Mises stress of the element for verification against the acceptance criteria.

$$\tau_{cor} = \frac{h \; t_{mod-net50}}{A_{s-net50}} \tau_{elem}$$

Where:

τ_{cor} corrected element shear stress

h height of web of girder in way of opening, see *Figure B.2.8*. Where the geometry of the opening is modelled, h is to be taken as the net height with the height of the modelled opening deducted.

$t_{mod-net50}$ modelled web thickness in way of opening, see *Table B.2.2*.

$A_{s-net50}$ actual effective shear area of web, including area lost due to slots for stiffeners, calculated in accordance with *Section 4/2.5*. The thickness of the web is to be based on net thickness obtained by deducting $0.5t_{corr}$ from the gross thickness

τ_{elem} element shear stress before correction

2.7.2.5 Correction of element shear stress due to presence of openings is not required provided that:

(a) all slots for local support stiffeners are fitted with lugs or collar plates;

(b) the difference between the modelled shear area of the plate and the actual effective shear area, $A_{s-net50}$ calculated in accordance with *Section 4/2.5.1*, is less than 20% of the modelled shear area, and

(c) the yield utilisation factor is less than 80% of the permissible yield utilisation factor given in *Section 9/Table 9.2.1*.

2.7.2.6 Where the corrugation is not modelled with its exact geometric shape, the corrected axial stress in the flange of the corrugation, $\sigma_{fl\text{-}act}$, is to be taken as the greater of:

$$\sigma_{fl-act} = \sigma_{fl-FEM} \frac{Z_{corr-FEM-net50}}{Z_{corr-act-net50}} \frac{l_{corr-act}}{l_{corr-FEM}}$$

$$\sigma_{fl-act} = \sigma_{fl-FEM}$$

Where:

$\sigma_{fl\text{-}FEM}$ axial stress obtained from the finite element analysis, see *Figure B.2.15*

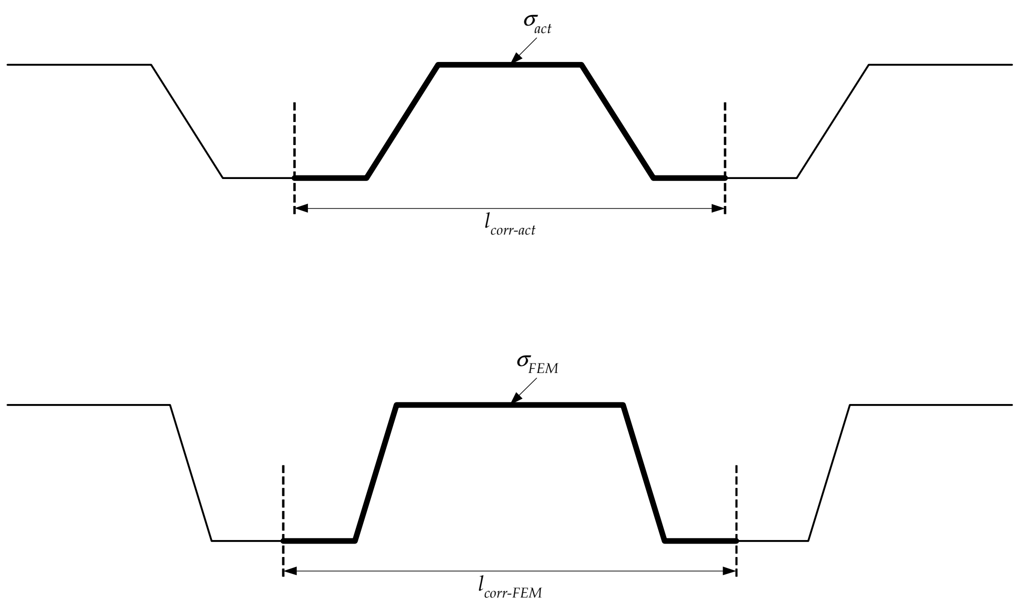
$Z_{corr\text{-}FEM\text{-}net50}$ is the section modulus of the modelled corrugation calculated in accordance with *Figure B.2.15*

$Z_{corr\text{-}act\text{-}net50}$ is the section modulus of the actual corrugation calculated in accordance with *Figure B.2.15*

$l_{corr\text{-}act}$ length of corrugation section, as given in *Figure B.2.15*

$l_{corr\text{-}FEM}$ length of corrugation section, as given in *Figure B.2.15*

Figure B.2.15
Axial Bending Stress in Flange Corrugation



<u>Note</u>
$l_{corr\text{-}act}$ = length of corrugation section, for the calculation of $Z_{corr\text{-}act\text{-}net50}$
$l_{corr\text{-}FEM}$ = length of corrugation section, for the calculation of $Z_{corr\text{-}FEM\text{-}net50}$

2.7.3 Buckling assessment

2.7.3.1 Buckling capability is to be assessed for the plating and stiffened panels of longitudinal hull girder structural members, primary support members and transverse bulkheads, including deck, double side, side, bottom, double bottom, hopper, transverse and vertical web frames, stringers, transverse and longitudinal bulkhead structures. Buckling capability of curved panels (e.g. bilge), face plate of

primary support members and tripping brackets is not assessed based on stress result obtained by the finite element analysis.

2.7.3.2 The utilisation factor against buckling for all plates and stiffened panels is not to exceed the permissible values given in *Section 9/2.2.5*. The method for carrying out buckling assessment of plates and stiffened panels is described in *Appendix D/5.*

2.7.3.3 The buckling assessment is to be based on the stresses obtained from the finite element analysis in conjunction with buckling capacity model based on net thickness obtained by deducting the full corrosion addition, t_{corr}, and any Owner's extras from the proposed thickness. This thickness deduction applies to all plating, stiffener webs and face plates.

2.7.3.4 The buckling assessment is to be based on membrane stress evaluated at the centroid of the plate elements. Where shell elements are used, stresses at the mid plane of the element are to be used for the buckling assessment.

2.7.3.5 The combined interaction of bi-axial compressive stresses, shear stress and lateral pressure loads are to be considered in the buckling calculation. Where a stress correction is to be applied to the finite element stresses as required by *2.7.2*, the buckling assessment is to be based on the corrected stresses.

2.7.3.6 For tankers with a cross tie arrangement, the pillar buckling capability of the cross tie structure is to be assessed based on the buckling formulae given in *Section 10/3.5.1*. The average axial compressive stress at the mid span of the cross tie in the ship's transverse direction, weighted by cross section area, is to be used for the buckling assessment.

2.7.3.7 In the absence of a suitable advanced buckling method described in *Appendix D/5* for the modelling of bulkhead corrugation, assessment of local buckling of unit corrugation flanges is to be in accordance with *Section 10/3.5.2* and criteria given in *Section 9/2.2.5*. The assessment is to be based only on uni-axial stress (membrane stress evaluated at element centroid) parallel to the corrugation knuckles. Averaged stress between elements is not to be used. For the part of the corrugated plate flange from the lower bulkhead stool top to a level of $s/2$ above, where s is the breadth of the flange, the stress used for the buckling assessment needs not be taken as greater than the value obtained at $s/2$ above the bulkhead stool top. The stress value at $s/2$ may be obtained by interpolation if the stress value cannot be obtained directly from a plate element.

2.7.3.8 In the absence of a suitable advanced buckling assessment method described in *Appendix D/5* for the modelling of panel with opening, local buckling of web plates of primary support members in way of openings is to be assessed in accordance with *Section 10/3.4* based on acceptance criteria on buckling utilisation factor given in *Section 9/2.2.5*. The assessment is to be based on FE membrane stress evaluated at the centroid of plate elements. Stresses in the area of the web required for buckling assessment are to be obtained as averaged stresses of the plate elements within the required area. Stress obtained from either the cargo tank analysis or local fine mesh analysis may be used for the assessment. Where the effect of opening is not taken into account in the cargo tank analysis, the stresses obtained from the finite element analysis are to be corrected in accordance with *2.7.2.4* and *2.7.2.5*.

3 LOCAL FINE MESH STRUCTURAL STRENGTH ANALYSIS

3.1 General

3.1.1 Application

3.1.1.1 For tankers of conventional arrangements, finite element fine mesh analysis of structural details is to be in accordance with the requirements given in this section.

3.1.1.2 Additional requirements of fine mesh analysis are to be in accordance with *Section 9/2.3.1.3* and *Section 9/2.3.1.4*.

3.1.2 Transverse web frame and wash bulkhead

3.1.2.1 Upper hopper knuckle connections as indicated in *Figure B.3.1* are to be evaluated by fine mesh analysis on a typical transverse web frame in the middle tank of the cargo tank model. Main bracket toes and openings as indicated in *Figure B.3.1* are to be evaluated by fine mesh analysis if the screening criteria given in *3.1.6* are not complied with.

3.1.2.2 Where a wash bulkhead is fitted, main bracket toes and openings of the transverse and vertical webs as indicated in *Figure B.3.1* are to be evaluated by fine mesh analysis if the screening criteria given in *3.1.6* are not complied with.

3.1.2.3 The web frame which indicates highest von Mises stresses in way of each structural detail from the cargo tank analysis is to be selected for the fine mesh analysis.

Figure B.3.1
Areas Requiring Consideration for Fine Mesh Analysis on a Typical Transverse Web Frame, Wash Bulkhead and Web Frame adjacent to Transverse Bulkhead

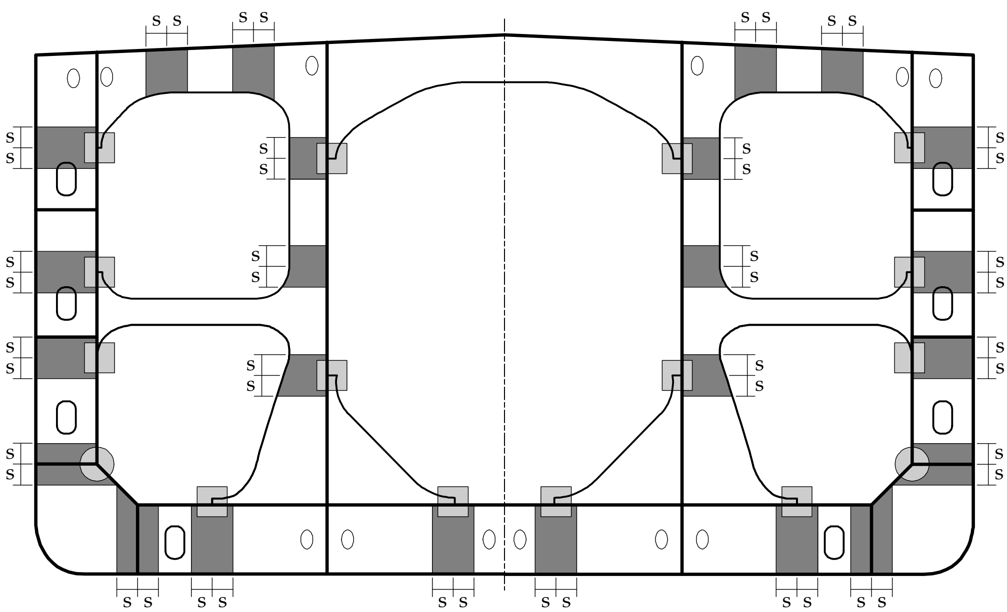
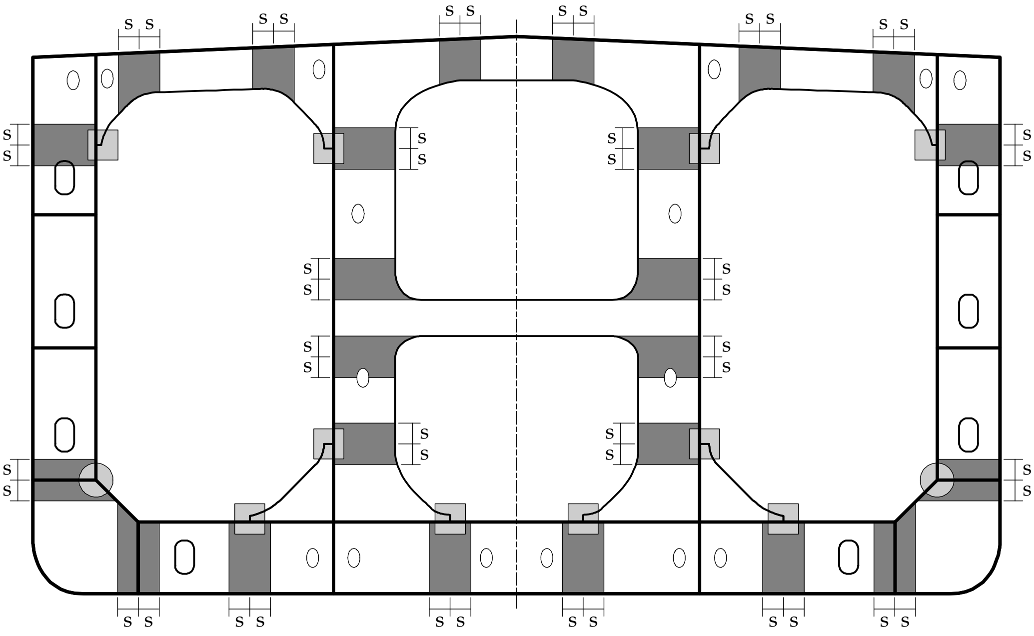


Figure B.3.1 (Continued)
Areas Requiring Consideration for Fine Mesh Analysis on a Typical Transverse Web Frame, Wash Bulkhead and Web Frame adjacent to Transverse Bulkhead



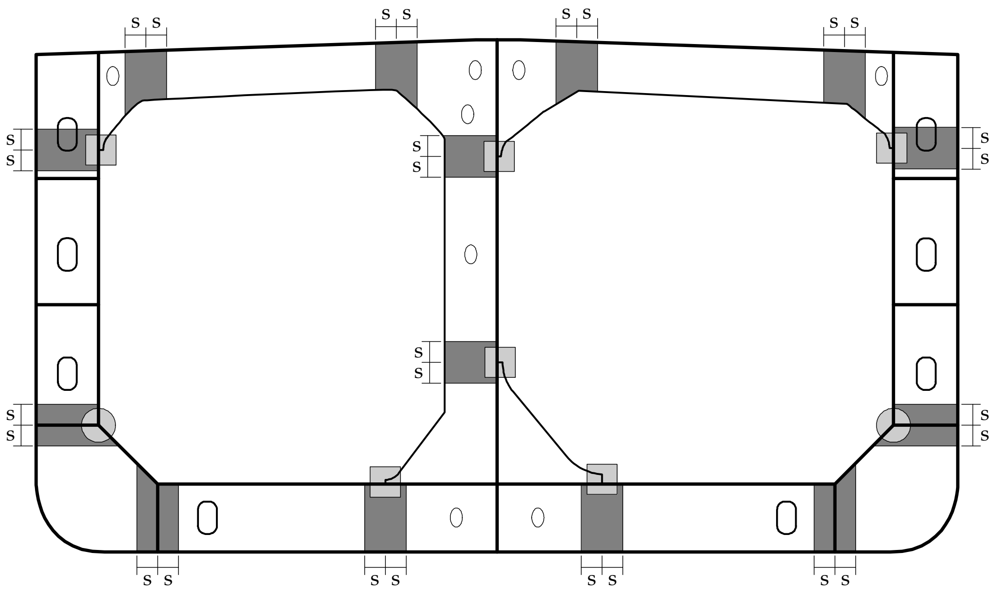
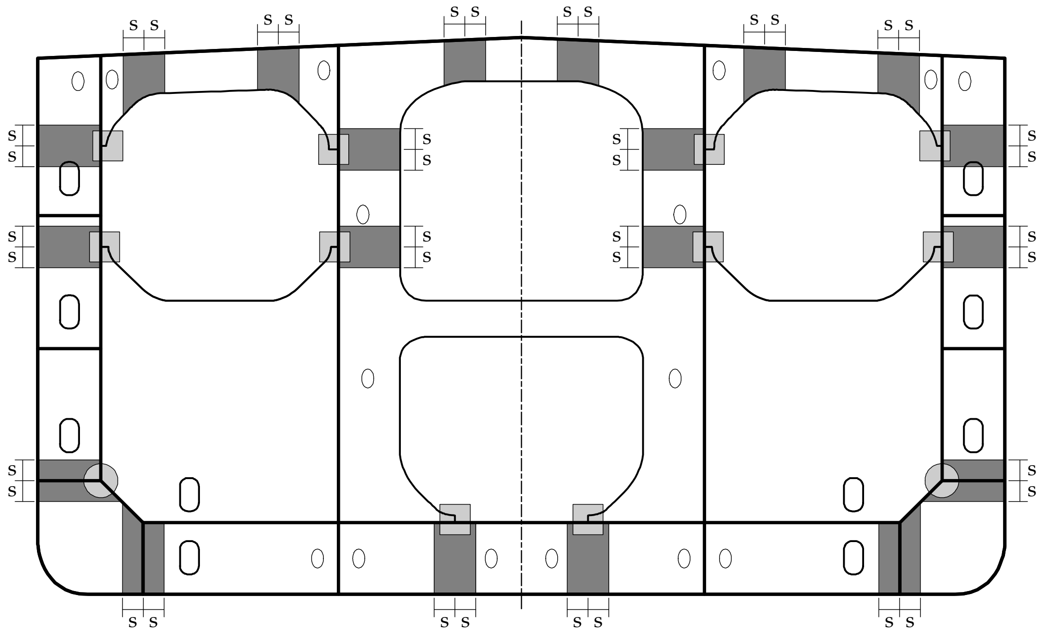


Figure B.3.1 (Continued)
Areas Requiring Consideration for Fine Mesh Analysis on a Typical Transverse Web Frame, Wash Bulkhead and Web Frame adjacent to Transverse Bulkhead



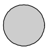
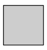
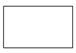
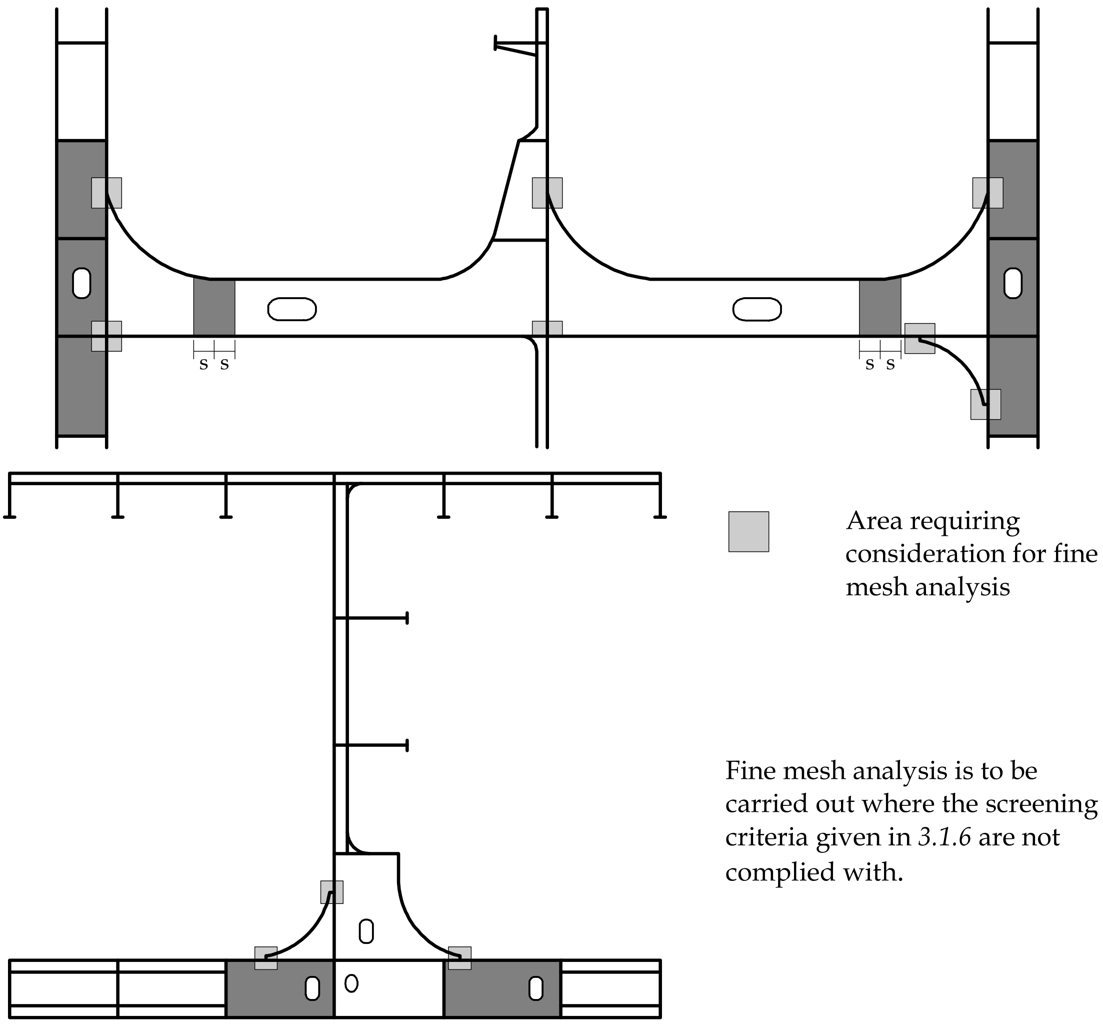
	Upper hopper knuckle	Fine mesh analysis of upper hopper knuckle is required for cargo tank typical web frame, see *3.1.2*. Fine mesh analysis is not required for upper hopper knuckles on web frame adjacent to transverse bulkhead.
	Bracket toes	Fine mesh analysis is to be carried out where the screening criteria given in *3.1.6* are not complied with
	Openings (shaded regions)	Fine mesh analysis is to be carried out for all openings in shaded regions where the screening criteria given in *3.1.6* are not complied with
	Openings (un-shaded regions)	Fine mesh analysis or evaluation based on screening criteria given in *3.1.6* is not required for openings in un-shaded regions if: • $h_o/h < 0.35$ and $g_o < 1.2$, and, • each end of the opening forms a semi circle arc (i.e. radius of opening equal to $b/2$). where h_o, h and g_o are defined in *Table B.2.2* and b is the smallest of the length and breadth of the opening. Other openings in the un-shaded regions are subjected to fine mesh analysis where the screening criteria given in *3.1.6* are not complied with.

Figure B.3.2
Areas Requiring Consideration for Fine Mesh Analysis on Horizontal Stringer and Transverse Bulkhead to Double Bottom Connections



Bracket toes and heels	Fine mesh analysis is to be carried out where the screening criteria given in *3.1.6* are not complied with
Openings (shaded regions)	Fine mesh analysis is to be carried out for all openings in shaded regions where the screening criteria given in *3.1.6* are not complied with
Openings (un-shaded regions)	Fine mesh analysis or evaluation based on screening criteria given in *3.1.6* is not required for openings in un-shaded regions if: • $h_o/h < 0.35$ and $g_o < 1.2$, and, • each end of the opening forms a semi circle arc (i.e. radius of opening equal to $b/2$). where h_o, h and g_o are defined in *Table B.2.22* and b is the smallest of the length and breadth of the opening. Other openings in the un-shaded regions are subjected to fine mesh analysis where the screening criteria given in *3.1.6* are not complied with.

3.1.3 Transverse bulkhead stringers, buttress and adjacent web frame

3.1.3.1 Fine mesh analysis is to be carried out for the following locations where the screening criteria given in *3.1.6* are not complied with:

(a) main bracket toes, heels and openings on horizontal stringers of a transverse bulkhead specified in *Figure B.3.2*. The stringers of the forward and aft transverse bulkheads of the middle tank of the FE model which indicate highest

von Mises stresses in way of the structural details from the cargo tank analysis is to be selected for the fine mesh analysis.

(b) main bracket toes and openings on transverse bulkhead to double bottom connection or buttress structure specified in *Figure B.3.2*. The double bottom connection/buttress structure in way of the forward and aft transverse bulkheads of the middle tank of the FE model which indicates highest von Mises stresses in way of the structural details from the cargo tank analysis is to be selected for the fine mesh analysis.

(c) main bracket toes and openings specified in *Figure B.3.1* on a web frame adjacent to the transverse bulkhead. Both web frames in way of the horizontal stringers of the forward and aft transverse bulkheads of the middle tank of the cargo tank FE model are to be considered. The web frame which indicates highest von Mises stresses in way of the structural details from the cargo tank analysis is to be selected for the fine mesh analysis.

3.1.3.2 Where the stress level at the heel connection of the transverse bulkhead horizontal stringer to the side horizontal girder exceeds the permissible criteria, it is recommended that a backing bracket be fitted in accordance with *Appendix C/2.5* to reduce the stresses.

3.1.4 Deck, double bottom longitudinal and adjoining transverse bulkhead vertical stiffeners

3.1.4.1 End connections and attached web stiffeners of the following structural members are to be assessed:

(a) at least one pair of inner and outer bottom longitudinal stiffeners and adjoining vertical stiffener of transverse bulkhead

(b) at least one longitudinal stiffener on deck and adjoining vertical stiffener of transverse bulkhead

3.1.4.2 The selection of the longitudinal and vertical stiffeners to be analysed is to be based on the maximum relative deflection between supports, e.g. between floor and transverse bulkhead. Where there is a significant variation in end connection arrangement and scantlings between stiffeners, analysis of additional stiffeners may be required. *Figure B.3.3* shows the areas that require fine mesh analysis in way of deck, inner bottom and bottom longitudinal and transverse bulkhead vertical stiffeners.

3.1.5 Corrugated bulkheads

3.1.5.1 Where no shedder plate or shedder plate without a gusset plate is fitted to a corrugated transverse or longitudinal corrugated bulkhead, connection of corrugation and below supporting structure to lower stool shelf plate, as shown in *Figure B.3.4,* is to be evaluated by fine mesh analysis. Where no lower stool is fitted, connection of corrugation and below supporting structure to inner bottom plate is to be evaluated by fine mesh analysis.

3.1.5.2 Where shedder plate with a gusset plate is fitted to a corrugated transverse or longitudinal corrugated bulkhead, connection of the corrugation at the upper corner of the gusset plate is to be evaluated by fine mesh analysis.

3.1.5.3 The selection of the location of the corrugation unit for fine mesh analysis is to be based on the stress result from the cargo tank analysis. The location with the highest von Mises stress in way of the corrugation connection is to be selected for the analysis.

3.1.5.4 Where transverse and longitudinal corrugated bulkheads are of different arrangements or scantlings, the fine mesh analysis is to be carried out for both bulkheads.

3.1.5.5 Where the stress level at the connection of corrugation to the lower stool exceeds the permissible criteria, it is recommended that shedder plate and gusset plate be fitted in accordance with *Appendix C/2.5* to reduce the stresses. See *Section 8/2.5.7.9* for required arrangement of supporting structure for corrugated bulkhead without a lower stool.

Figure B.3.3
Areas Requiring Fine Mesh Analysis on Deck, Inner and Outer Bottom Longitudinals

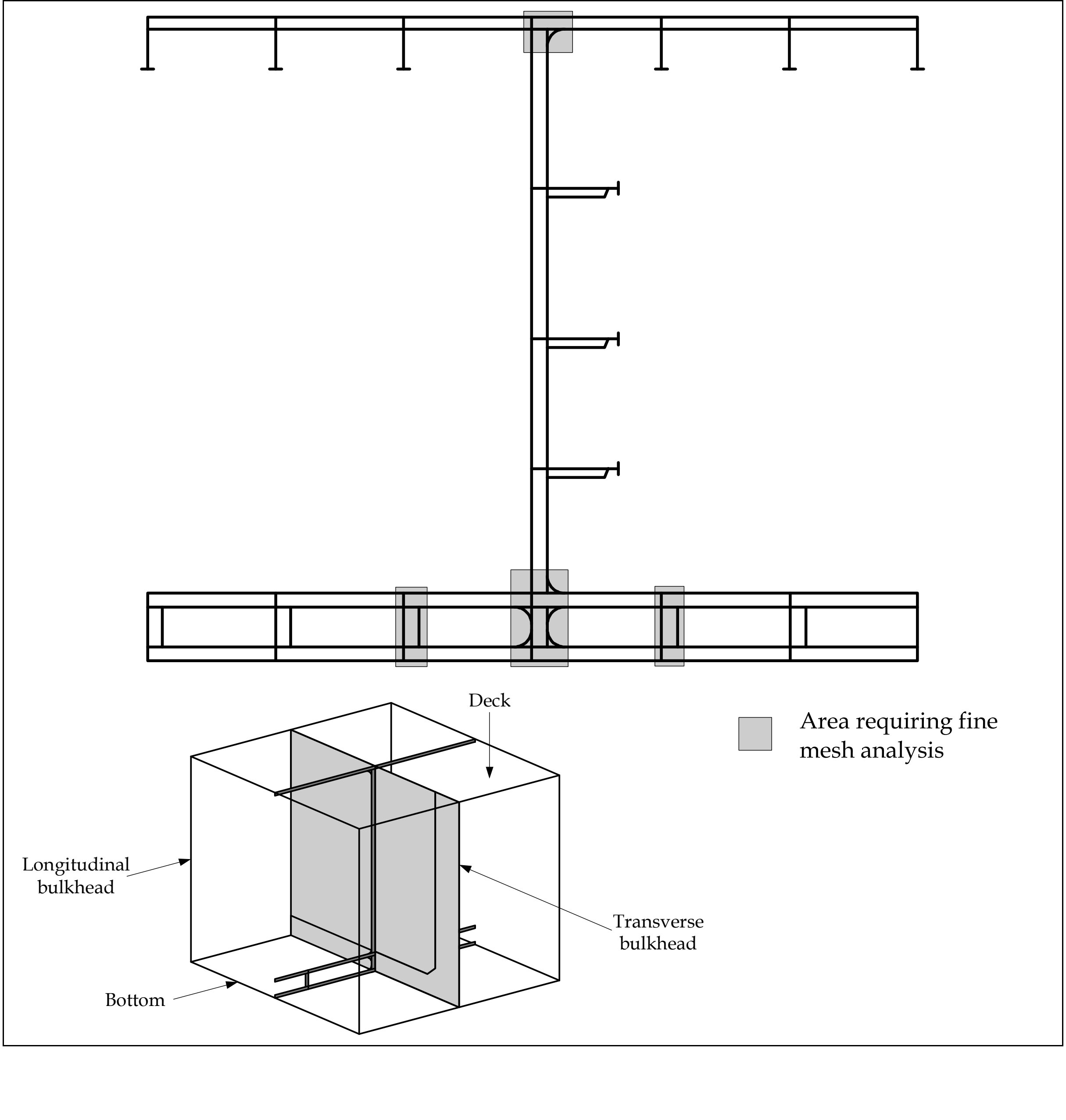
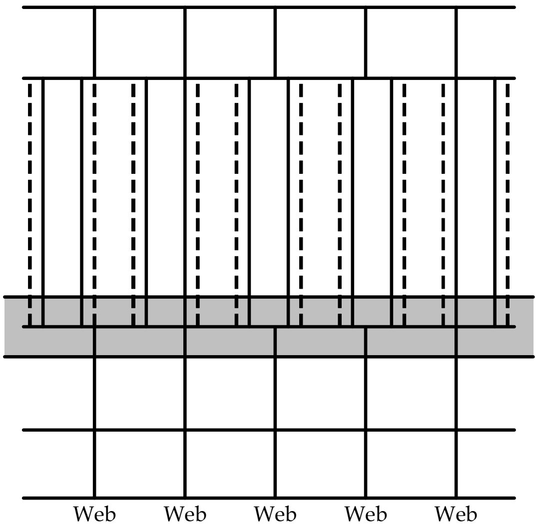


Figure B.3.4
Areas Requiring Fine Mesh Analysis at Connections of Corrugated Bulkhead to Bottom Stool



Note

Exact location of corrugation unit to be examined using fine mesh analysis is to be selected based on stress result from cargo tank analysis.

3.1.6 Screening criteria for Fine Mesh Analysis

3.1.6.1 The criteria given in this section are intended to identify areas that require to be investigated by means of fine mesh finite element analysis. These criteria apply to openings, bracket toes and heels of transverse web frames, vertical and transverse webs of wash bulkheads, horizontal stringers of transverse bulkhead and adjoining side horizontal girders, buttress and bottom girders.

3.1.6.2 Where the criteria given in this section for the structural detail are complied with, fine mesh finite element analysis of the structural detail may be waived with the exception of *3.1.6.3.* The compliance with these criteria is to be verified for all finite element load cases.

3.1.6.3 Large openings, for which their geometry is required to be represented in the cargo tank FE model in accordance with *Table B.2.*2, are to be investigated by fine mesh analysis.

Table B.3.1
Fine Mesh Analysis Screening Criteria for Openings in Primary Support Members

A fine mesh finite element analysis is to be carried out where:

$\lambda_y > 1.7$ (load combination S + D)

$\lambda_y > 1.36$ (load combination S)

Where:

λ_y	yield utilisation factor	
	$= 0.85 C_h \left(\lvert \sigma_x + \sigma_y \rvert + \left(2 + \left(\frac{l_0}{2r} \right)^{0.74} + \left(\frac{h_0}{2r} \right)^{0.74} \right) \lvert \tau_{xy} \rvert \right) \frac{k}{235}$	
C_h	$= 1.0 - 0.23 \left(\frac{h_0}{h} \right) + 2.12 \left(\frac{h_0}{h} \right)^2$	for openings in vertical web and horizontal girder of wing ballast tank, double bottom floor and girder and horizontal stringer of transverse bulkhead
	= 1.0	for opening in web of main bracket and buttress (see figures below)
r	radius of opening, in mm	
h_0	height of opening parallel to depth of web, in mm	
l_0	length of opening parallel to girder web direction, in mm	
h	height of web of girder in way of opening, in mm	
σ_x	axial stress in element x direction determined from cargo tank FE analysis according to the coordinate system shown, in N/mm^2	
σ_y	axial stress in element y direction determined from cargo tank FE analysis according to the coordinate system shown, in N/mm^2	
τ_{xy}	element shear stress determined from cargo tank FE analysis, in N/mm^2, (2)	
k	higher strength steel factor, as defined in *Section 6/1.1.4* but not to be taken as less than 0.78 for load combination S + D	

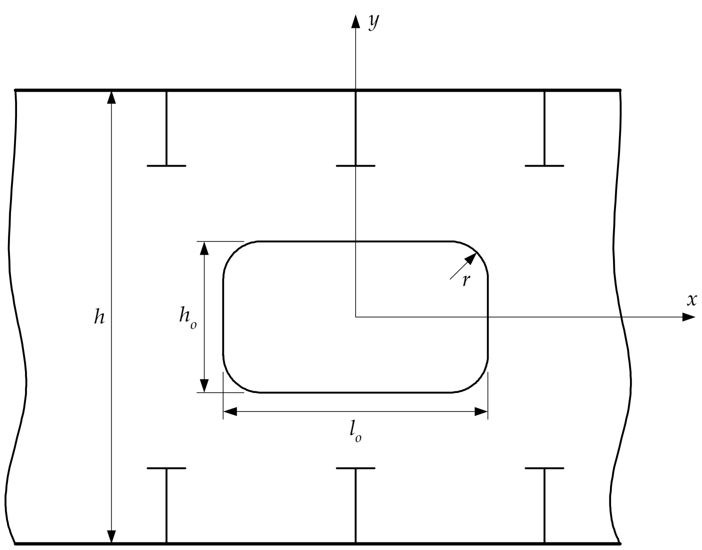
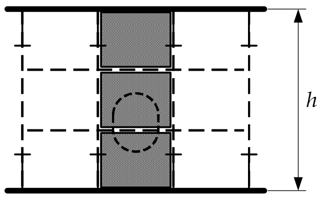
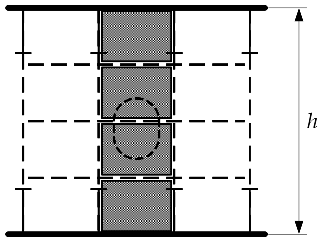
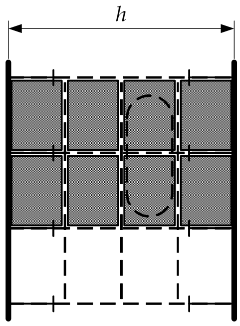
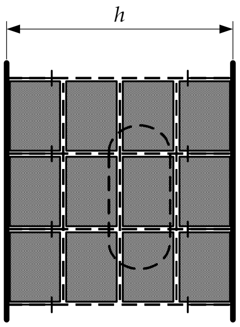


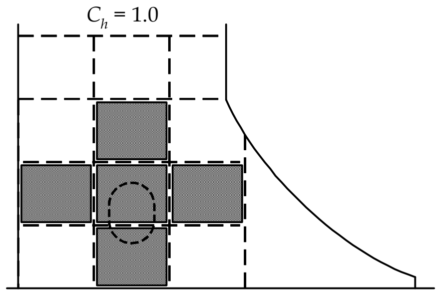
Table B.3.1 (Continued)
Fine Mesh Analysis Screening Criteria for Openings in Primary Support Members











Individual element in web to be verified against criteria

Notes

1. For opening where the modelled shear area in way of the opening is different from the actual net shear area the element shear stress is to be adjusted using the formula given in *B.2.7.2.4* prior to the evaluation of yield utilisation factor for verification against the screening criteria.
2. Where the geometry of the opening is required to be modelled in accordance with *Table B.2.2*, fine mesh FE analysis is to be carried out to determine the stress level. The screening criteria given in this table are not applicable.
3. Screening criteria is only valid if the cargo tank finite element analysis and the derivation of element stresses is carried out in accordance with *B/2*.

RCN 2 to July 2008 version (effective from 1 July 2010)

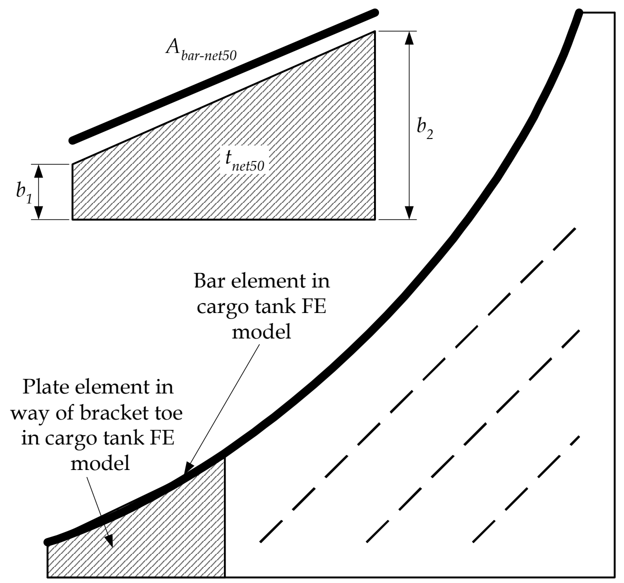
Table B.3.2
Fine Mesh Analysis Screening Criteria for Bracket Toes of Primary Support Members

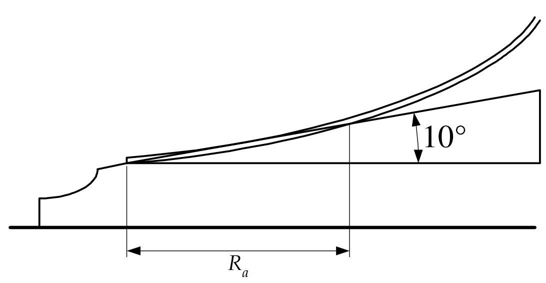
A fine mesh finite element analysis is to be carried out where:

$\lambda_y > 1.5$　(load combination S + D)
$\lambda_y > 1.2$　(load combination S)

Where:

λ_y	yield utilisation factor $= C_a\left(0.75\left(\frac{b_2}{b_1}\right)^{0.5}\lvert\sigma_{vm}\rvert + 0.55\left(\frac{A_{bar-net50}}{b_1 t_{net50}}\right)^{0.5}\lvert\sigma_{bar}\rvert\right)\frac{k}{235}$
C_a	$= 1.0 - 0.2\left(\frac{R_a}{1400}\right)^2$
b_1, b_2	height of plate element in way of bracket toe in cargo tank FE model, in mm
$A_{bar-net50}$	sectional area of bar element in cargo tank FE model representing the face plate of bracket, in mm^2
σ_{bar}	bar element axial stress determined from cargo tank FE analysis, in N/mm^2
σ_{vm}	von Mises stress of plate element in way of bracket toe determined from cargo tank FE analysis, in N/mm^2
t_{net50}	thickness of plate element in way of bracket toe, in mm
R_a	leg length distance in mm, not to be taken as greater than 1400mm
k	higher strength steel factor, as defined in *Section 6/1.1.4,* but not to be taken as less than 0.78 for load combination S + D





Note

1. Screening criteria is only valid if the cargo tank finite element analysis and the derivation of element stresses is carried out in accordance with *B/2*.

Table B.3.3
Fine Mesh Analysis Screening Criteria for Heels of Transverse Bulkhead Horizontal Stringers

A fine mesh finite element analysis is to be carried out where:

$\lambda_y > 1.5$ (load combination S + D)
$\lambda_y > 1.2$ (load combination S)

Where:

λ_y yield utilisation factor

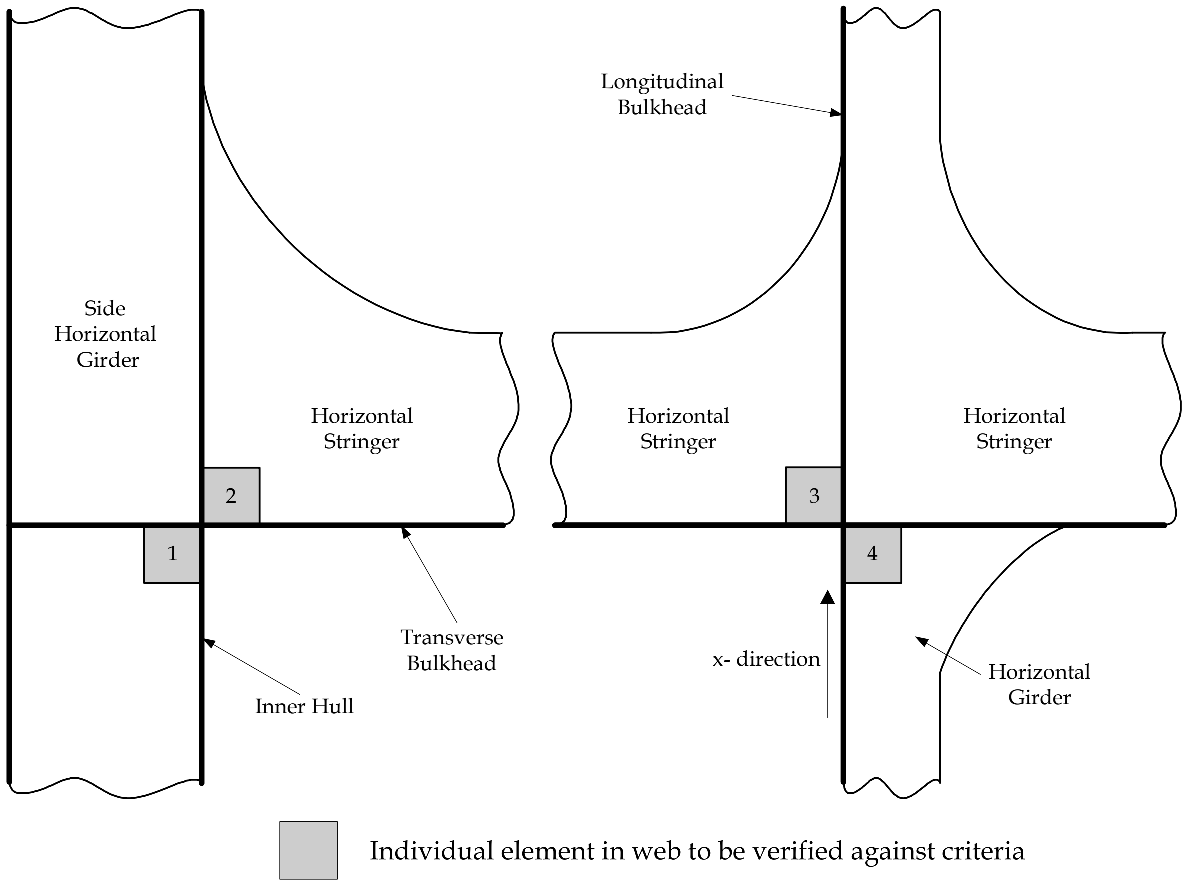
$= 3.0\left|\sigma_{vm}\right|\dfrac{k}{235}$ for heels at side horizontal girder and transverse bulkhead horizontal stringer, i.e. locations 1, 2 and 3 in figures.

$= 5.2\left|\sigma_{x}\right|\dfrac{k}{235}$ for heel at longitudinal bulkhead horizontal stringer, i.e. location 4.

σ_x axial stress in element x direction determined from cargo tank FE analysis in accordance with the coordinate system shown, in N/mm²

σ_{vm} von Mises stress of plate element in way of heel determined from cargo tank FE analysis, in N/mm²

k higher strength steel factor, as defined in *Section 6/1.1.4*, but not to be taken as less than 0.78 for load combination S + D



Note

1. Screening criteria is only valid if the cargo tank finite element analysis and the derivation of element stresses is carried out in accordance with *B/2*.

3.2 Structural Modelling

3.2.1 General

3.2.1.1 Evaluation of detailed stresses requires the use of refined finite element mesh in way of areas of high stress. This fine mesh analysis can be carried out by means of separate local finite element model with fine mesh zones in conjunction with the boundary conditions obtained from the cargo tank model. Alternatively, fine mesh zones incorporated into the cargo tank model may be used.

3.2.1.2 The extent of the local finite element model is to be such that the calculated stresses at the areas of interest are not significantly affected by the imposed boundary conditions and application of loads. The boundary of the fine mesh model is to coincide with primary support members, such as girders, stringers and floors, in the cargo tank model.

3.2.1.3 The mesh size in the fine mesh zones is not to be greater than 50mm x 50mm. In general, the extent of the fine mesh zone is not to be less than 10 elements in all directions from the area under investigation.

3.2.1.4 All plating within the fine mesh zone is to be represented by shell elements. A smooth transition of mesh density is to be maintained. The aspect ratio of elements within the fine mesh zone is to be kept as close to 1 as possible. Variation of mesh density within the fine mesh zone and the use of triangular elements are to be avoided. In all cases, the elements are to have an aspect ratio not exceeding 3. Distorted elements, with element corner angle less than 60° or greater than 120°, are to be avoided. Stiffeners inside the fine mesh zone are to be modelled using shell elements. Stiffeners outside the fine mesh zones may be modelled using beam elements.

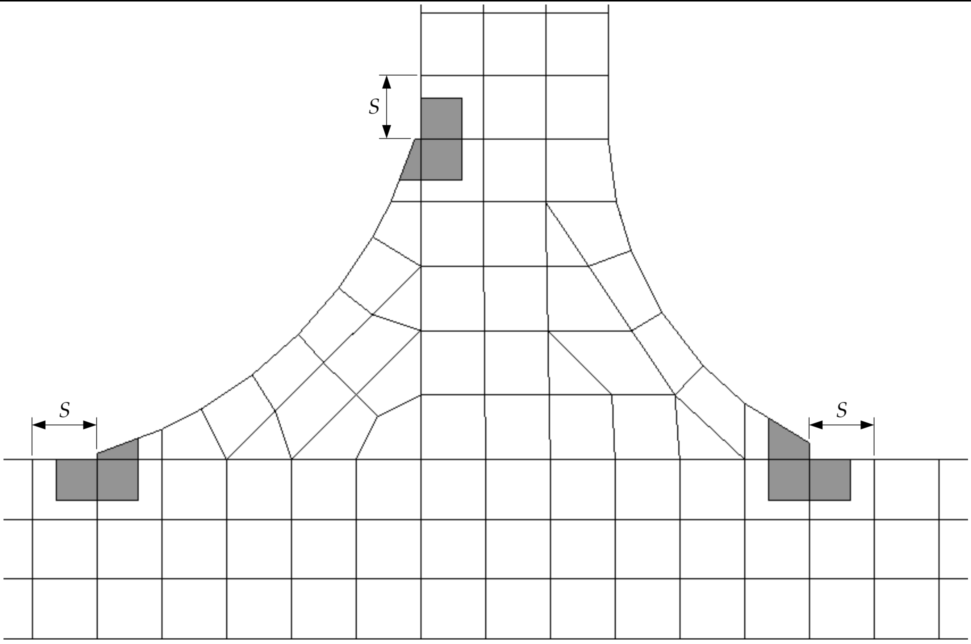
3.2.1.5 The element inside the fine mesh zone is to be modelled based on the net thickness, obtained by deducting the full corrosion addition, t_{corr}, from the gross thickness. The structure outside the fine mesh zone is to be modelled based on the net thickness obtained by deducting half the corrosion addition, $0.5t_{corr}$, from the gross thickness, as specified in *2.2.1.5*, for use in the cargo tank FE analysis.

3.2.1.6 Where fine mesh analysis is required for main bracket end connections, the fine mesh zone is to be extended at least 10 elements in all directions from the area of interest, see *Figure B.3.5*. The modelling scantlings in the fine mesh zone are to be in accordance with *3.2.1.5*.

3.2.1.7 Where fine mesh analysis is required for an opening, the first two layers of elements around the opening are to be modelled with mesh size not greater than 50mm x 50mm, based on the net thickness with deduction of full corrosion addition, t_{corr},. The elements outside the first two layers are to be based on the net thickness with a deduction of corrosion addition, $0.5t_{corr}$, see *3.2.1.5*. A smooth transition from the fine mesh to the coarser mesh is to be maintained. Edge stiffeners which are welded directly to the edge of an opening are to be modelled with plate elements. Web stiffeners close to an opening may be modelled using rod or beam elements located at a distance of at least 50mm from the edge of the opening. Typical fine mesh zone around an opening is shown in *Figure B.3.6*.

3.2.1.8 Face plates of openings, primary support members and associated brackets are to be modelled with at least three elements across their width.

Figure B.3.5
Fine Mesh Zone Around Bracket Toes



Fine mesh zone
Element size ≤ 50mm x 50mm
Extent - at least 10 elements in all directions
Face plate modelled by plate elements

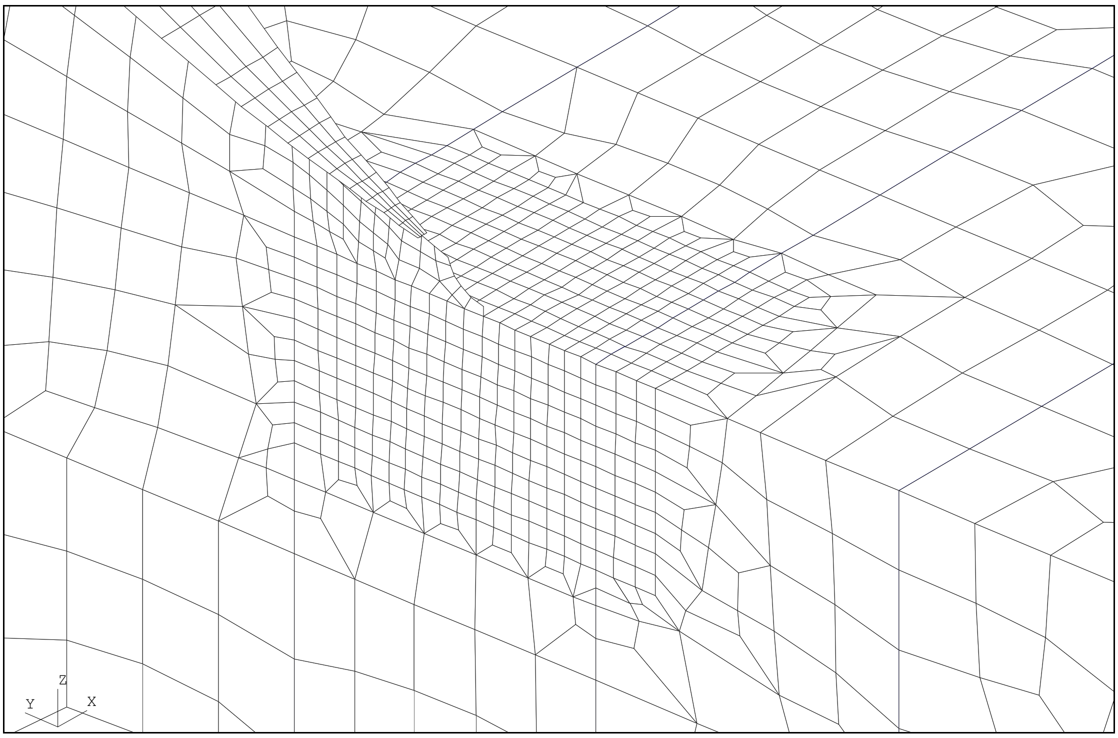
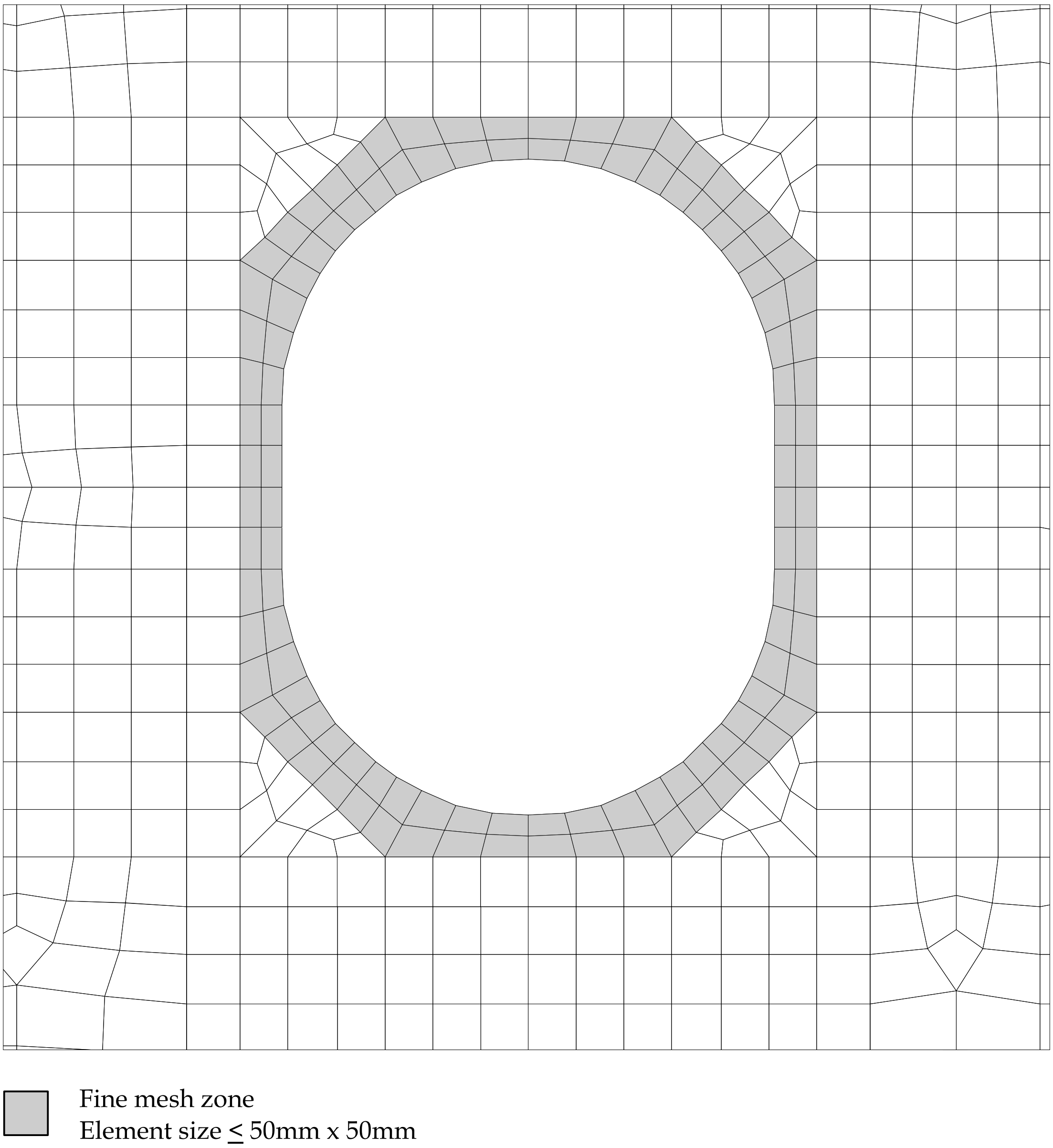


Figure B.3.6
Fine Mesh Zone Around an Opening



3.2.2 Transverse web frames

3.2.2.1 In addition to the requirements of *3.2.1*, the modelling requirements in this sub-section are applicable to the analysis of typical transverse web frame.

3.2.2.2 Where a FE sub model is used, the model is to have an extent of at least 1 + 1 web frame spaces, i.e. one web frame space extending either side of the transverse web frame under investigation. The transverse web frames forward and aft of the web frame under investigation need not be included in the sub model.

3.2.2.3 The full depth and full breadth of the ship shall be modelled, see *Figure B.3.7*.

3.2.2.4 *Figure B.3.8* shows a close up view of the finite element mesh at the lower part of the vertical web and backing brackets.

Figure B.3.7
Extent of Sub-Model for Fine Mesh Analysis of Web Frame Bracket Connections and Openings

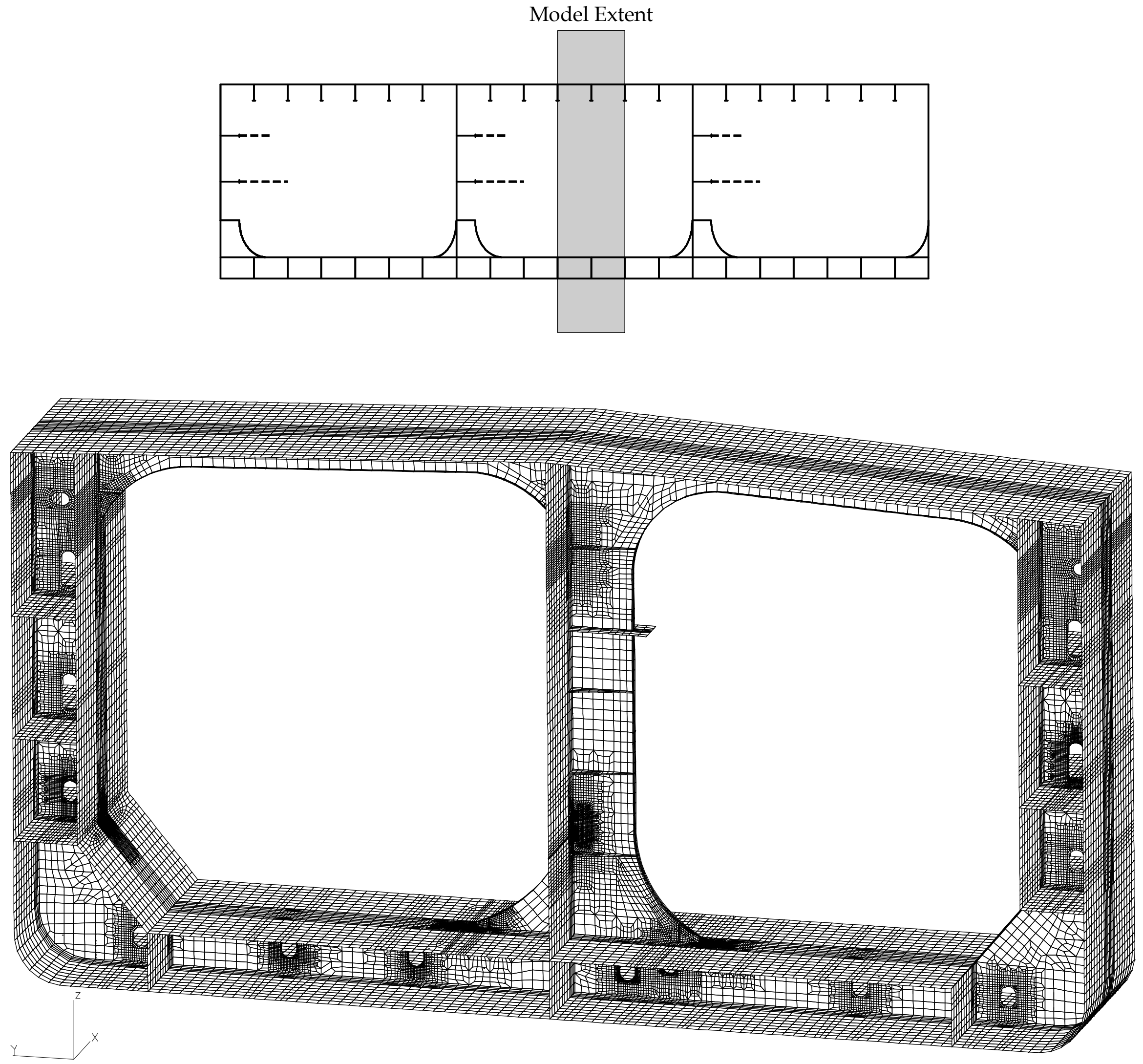
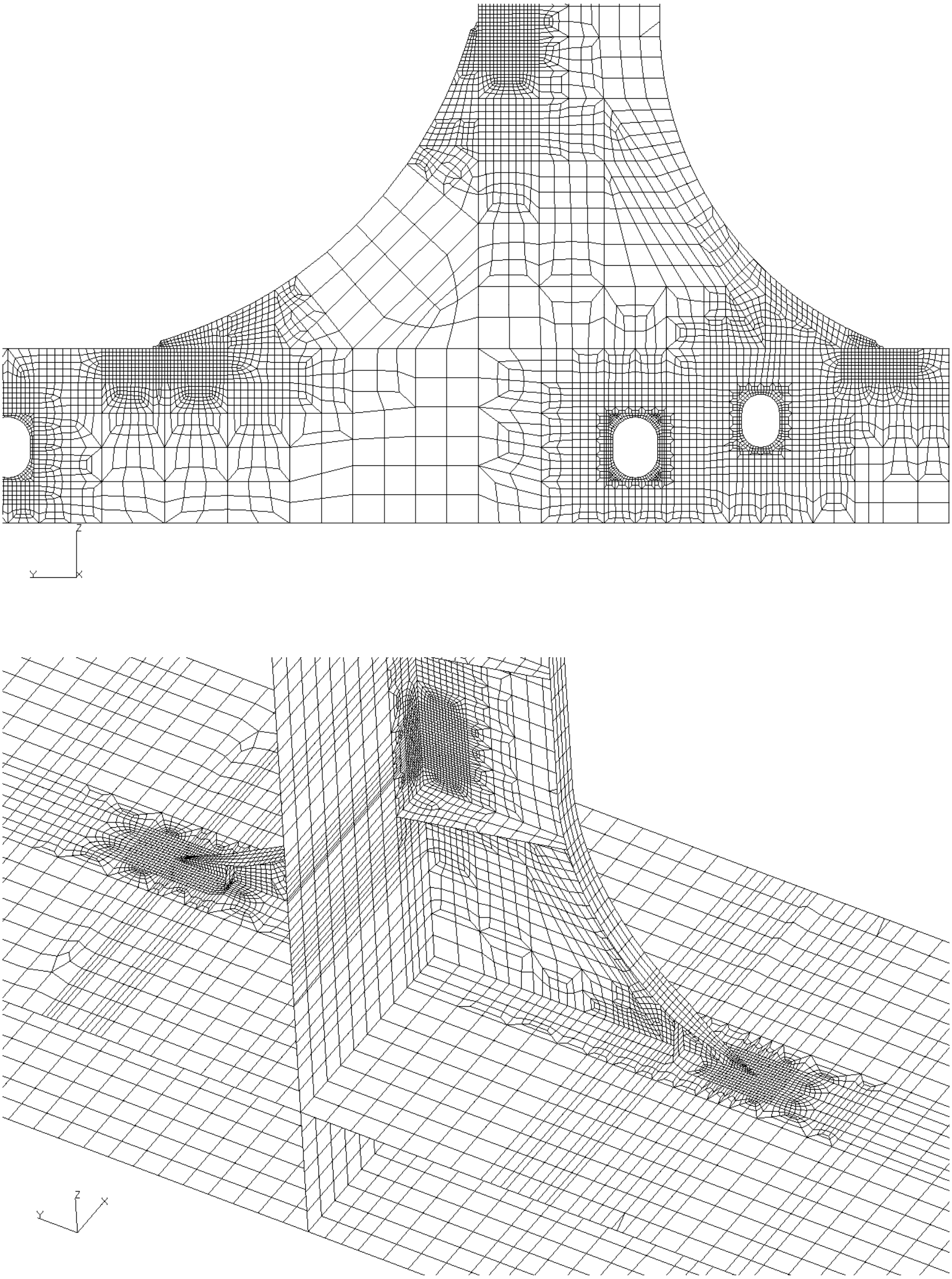


Figure B.3.8
Close-up View of Finite Element Mesh at the Lower Part of a Vertical Web Frame and Backing Brackets



3.2.3 Transverse bulkhead stringers, buttress and adjacent web frame

3.2.3.1 In addition to *3.2.1*, the modelling requirements in this sub-section are applicable to the analysis of transverse bulkhead and adjacent web frame as described in *3.1.3*.

3.2.3.2 Due to the structural interaction between the transverse bulkhead, horizontal stringers, web frames, deck and bottom, it is recommended that the FE sub-model represents a full section of the hull. Longitudinally, the ends of the model should at least be extended one web frame space beyond the areas that require investigation, see *Figure B.3.9*. The full breadth and depth of the ship should be modelled.

3.2.3.3 Alternatively, it is acceptable to use a number of sub-models, as shown in *Figure B.3.10,* to analyse different parts of the structure. For the analysis of the transverse bulkhead horizontal stringers the full breadth of the ship should be modelled. For the analysis of buttress structure, the sub-model width should be at least 4 + 4 longitudinal spaces, i.e. four longitudinal spaces at each side of the buttress.

3.2.3.4 *Figure B.3.11* shows the finite element mesh on a transverse bulkhead horizontal stringer. *Figure B.3.12* shows the sub-model for the analysis of buttress connections to transverse bulkhead and double bottom structure, and openings.

Figure B.3.9
Extent of Sub-Model for Fine Mesh Analysis of Transverse Bulkhead and Adjacent Structure

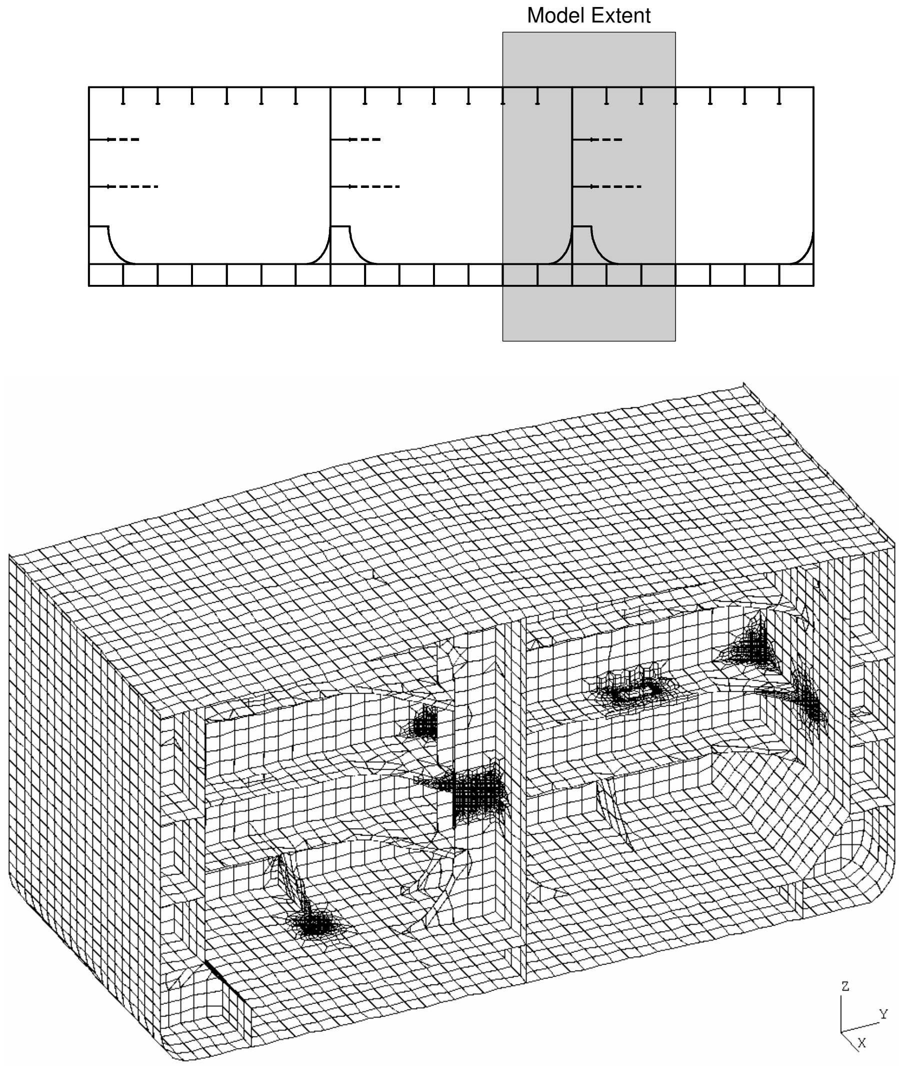


Figure B.3.10
Analysis of Transverse Bulkhead Structure Using Sub-Models

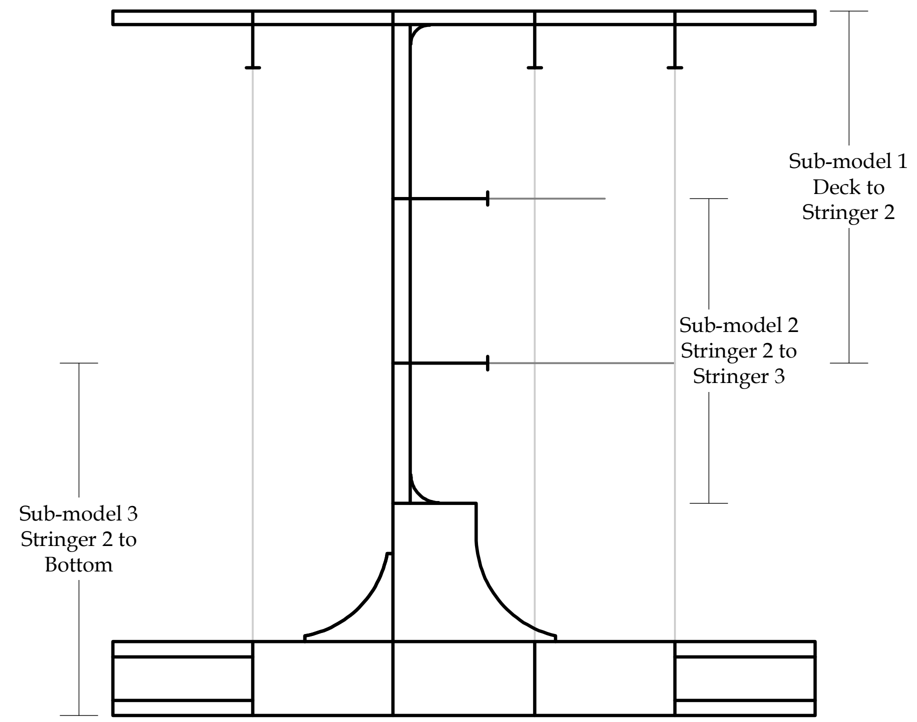


Figure B.3.11
Finite Element Mesh on Transverse Bulkhead Horizontal Stringer
(figure shows port side of model)

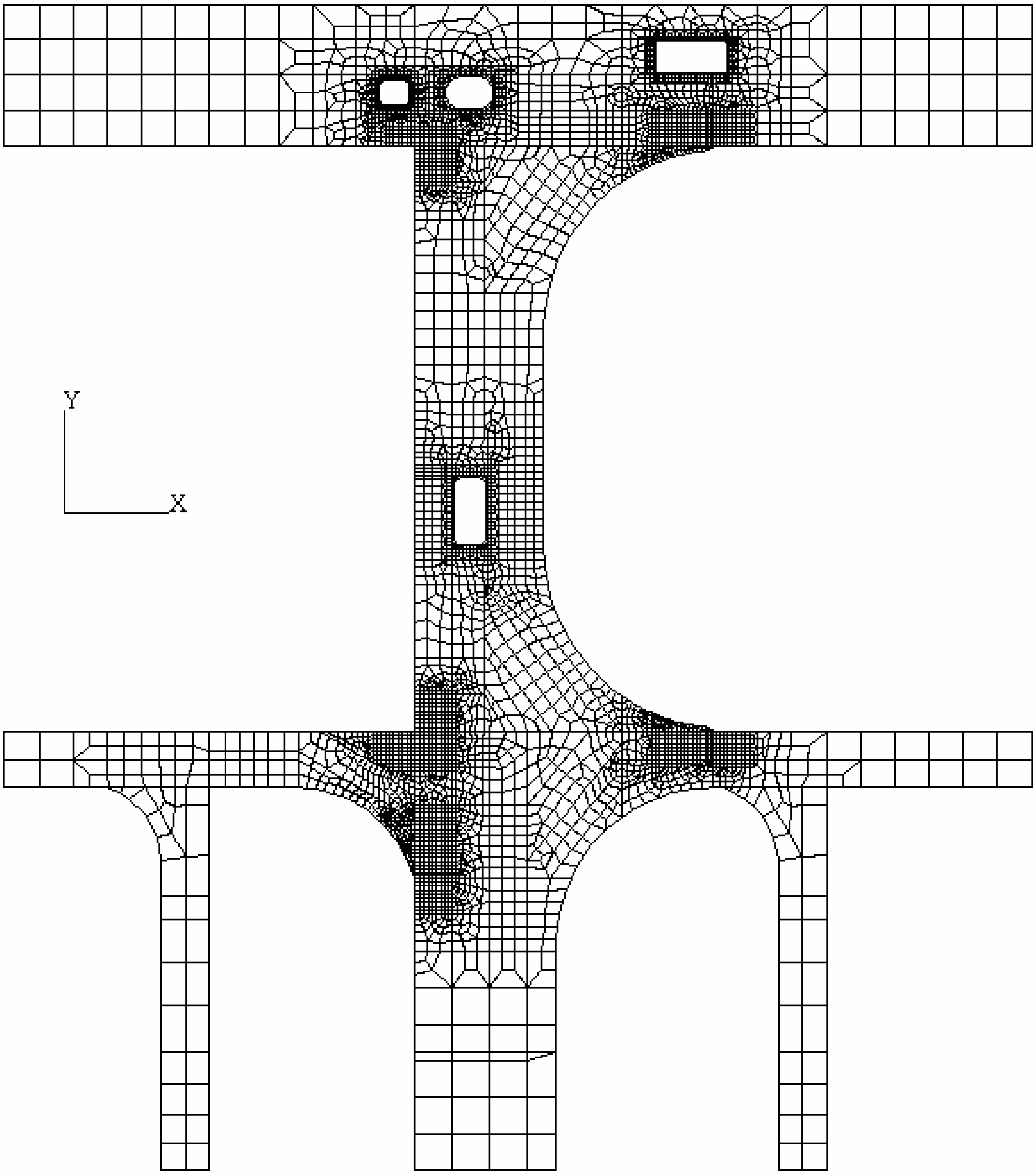
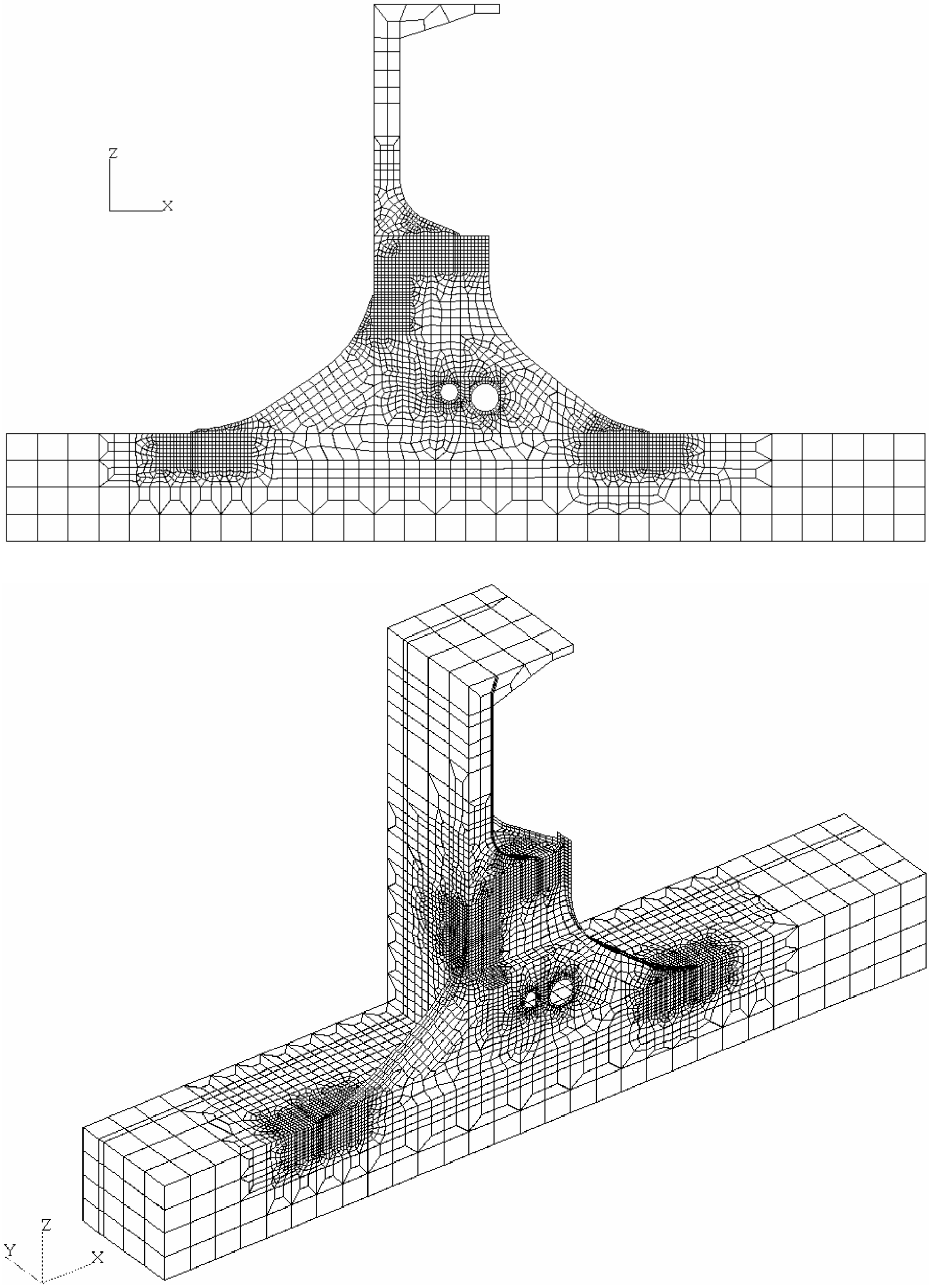


Figure B.3.12
Sub-Model for the Analysis of Buttress Connections to Bulkhead and Double Bottom Structure (figure shows port half of model)



3.2.4 Deck, double bottom longitudinal and adjoining transverse bulkhead vertical stiffeners

3.2.4.1 The modelling requirements in this sub-section are applicable specifically to the analysis of longitudinal and vertical stiffener end connections and attached web stiffeners as described in *3.1.4.*

3.2.4.2 Where a local FE model is used, each end of the model is to be extended longitudinally at least two web frame spaces from the areas under investigation. The model width is to be at least 2 + 2 longitudinal spaces. *Figure B.3.13* shows the longitudinal extent of the sub-model for the analysis of deck and double bottom longitudinal stiffeners and adjoining transverse bulkhead vertical stiffener.

3.2.4.3 The prescribed displacements or forces obtained from the cargo tank FE model should be applied to all boundary nodes which coincide with the cargo tank model.

3.2.4.4 The longitudinal and vertical stiffeners under investigation, including web, faceplate, attached plating (within ½ + ½ longitudinal spaces) and associated brackets are to be modelled based on the gross thickness with deduction of the full corrosion addition t_{corr}. Other areas are to be based on gross thickness with deduction of half corrosion addition, $0.5t_{corr}$.

3.2.4.5 The web of the longitudinal stiffeners should be represented by at least 3 shell elements across its depth. Similar size elements should be used to represent the plating of the bottom shell and inner bottom. The face plate of the longitudinal stiffeners and brackets should be modelled with at least three elements across its width.

3.2.4.6 The mesh size and extent of the fine mesh zone is to be in accordance with *3.2.1.3*, see also *Figure B.3.13*.

Figure B.3.13
Sub-Model for Fine Mesh Analysis of End Connections and Web Stiffeners of Deck and Double Bottom Longitudinals

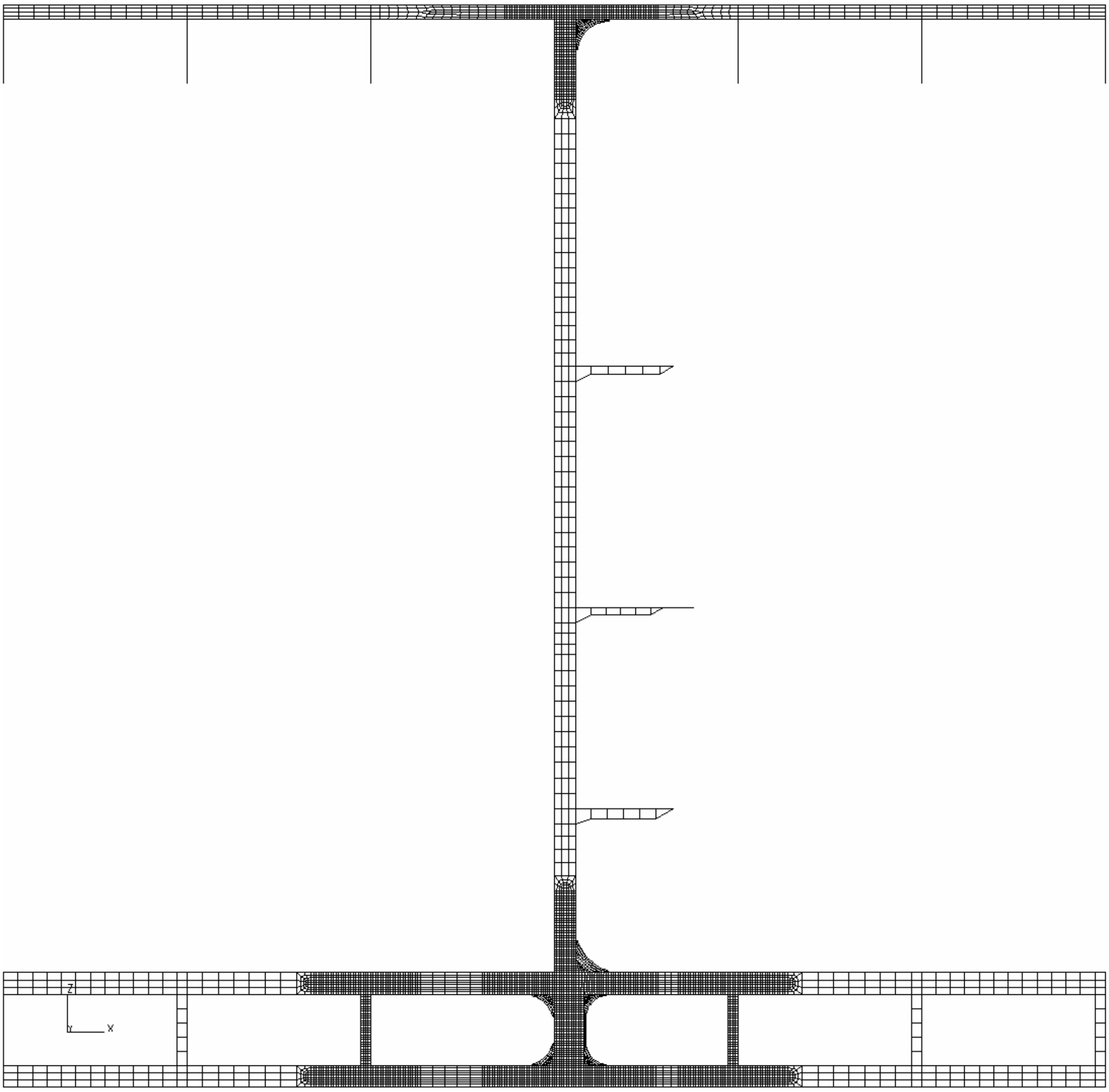
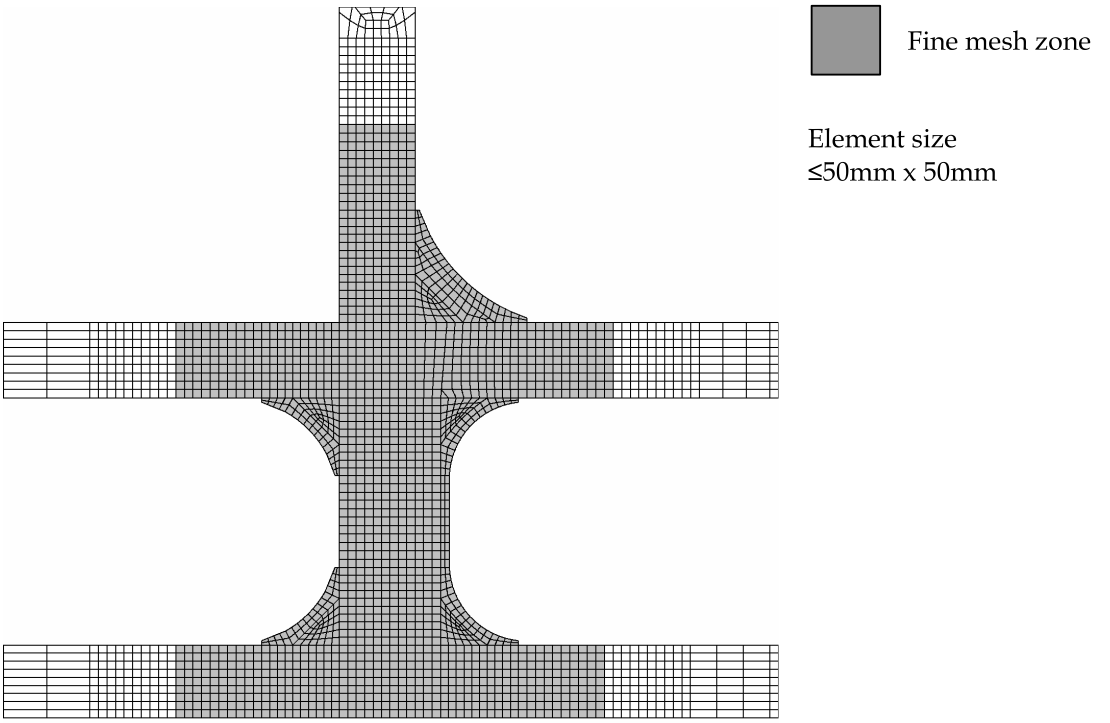
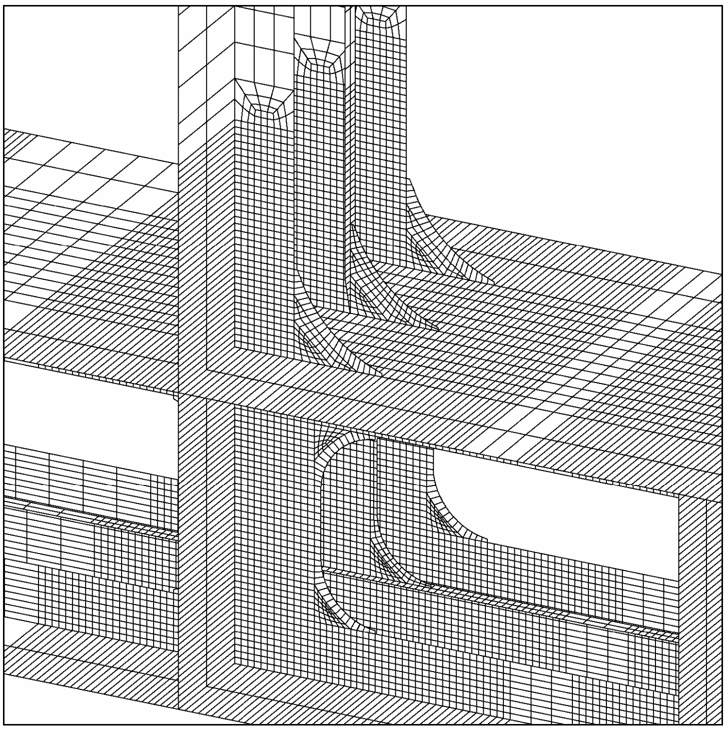


Figure B.3.13 (Continued)
Sub-Model for Fine Mesh Analysis of End Connections and Web Stiffeners of Deck and Double Bottom Longitudinals





3.2.5 Corrugated bulkheads

3.2.5.1 In addition to *3.2.1*, the modelling requirements in this sub-section are applicable to the analysis of connections of corrugated bulkheads to lower bulkhead stools as described in *3.1.5*.

3.2.5.2 The minimum extent of the sub-model is as follows, see also *Figure B.3.14*:

(a) vertically, from the bottom of the bottom bulkhead stool to a level at least 2m above the connection of the corrugation to the upper part of the bulkhead stool. The upper boundary of the sub-model should be coincident with the horizontal mesh line of the cargo tank FE model

(b) for transverse corrugated bulkheads, the sub-model is to be extended transversely to the nearest diaphragm web in the lower stool on each side of the fine mesh zone (i.e. the sub-model covers two bulkhead stool transverse web spaces). The end diaphragms need not be modelled

(c) for longitudinal corrugated bulkheads, the sub-model is to be extended to the nearest web frame on each side of the fine mesh zone (i.e. the sub-model covers two frame spaces). The end web frames need not be modelled

(d) where the area under investigation is located close to the intersection of transverse and longitudinal corrugated bulkheads, the sub-model should cover the structure between the diaphragms (in transverse direction) and web frames (in longitudinal direction) closest to the detail, whichever relevant. In addition the sub-model is to be extended at least one diaphragm/web frame outside the intersection of the stools.

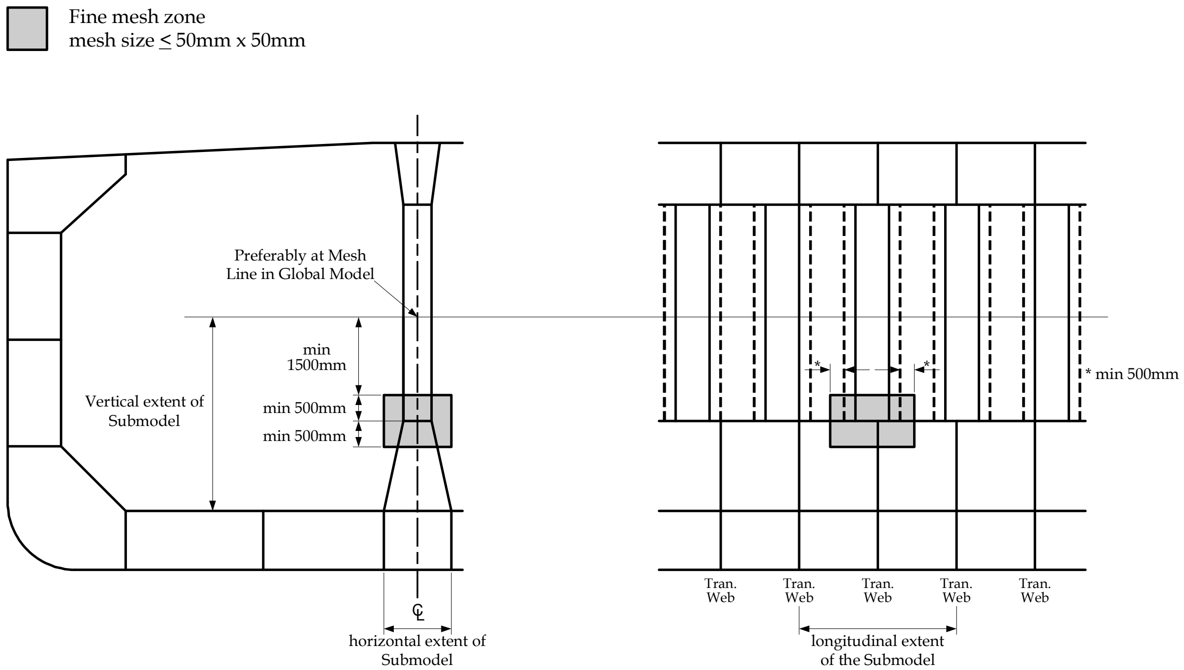
3.2.5.3 The fine mesh zone is to be extended at least 500mm (10 elements) from the corrugation connection in a vertical direction, see *Figure B.3.1.4*. In a horizontal direction, the fine mesh zone is to cover at least the corrugation flange under investigation, the adjacent corrugation webs and a further extension of 500mm from each end of the corrugation web (i.e. the fine mesh zone covers four corrugation knuckles), see *Figure B.3.14*. The mesh size within the fine mesh zone is not to be greater than 50mm x 50mm.

3.2.5.4 Diaphragm webs, brackets inside the lower stool and vertical stiffeners on the stool side plate are to be modelled at their actual positions within the extent of the sub-model. Shell elements are to be used for modelling of diaphragm, bracket and stiffener webs. Beam elements may be used to represent the flange of stiffeners and brackets.

3.2.5.5 Horizontal stiffeners on the lower stool side plate are to be represented by beam elements.

3.2.5.6 *Figure B.3.15* shows the finite element sub-model for the fine mesh analysis of longitudinal bulkhead to lower stool connection.

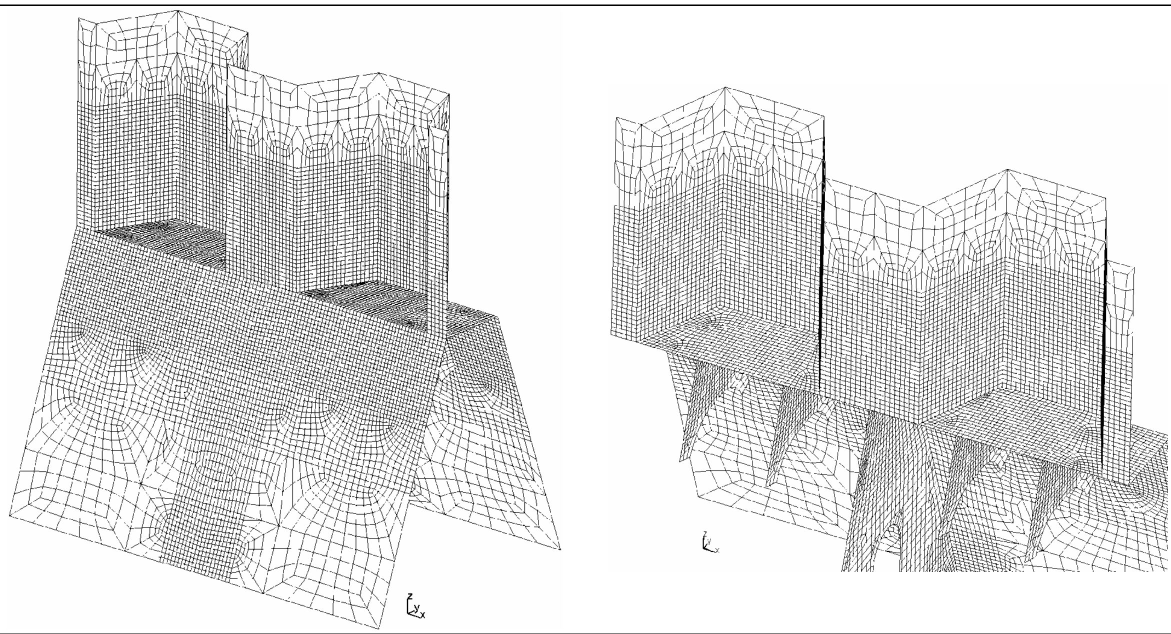
Figure B.3.14
Extent of Sub-Model and Fine Mesh Zone for the Analysis of Corrugated Bulkhead Connection to Lower Stool



Note

Above figures show extent of sub-model and fine mesh zone on longitudinal corrugated bulkhead connection to lower stool. Similar extent applies to transverse corrugated bulkhead.

Figure B.3.15
Sub-Model for the Analysis of Connection of Longitudinal Corrugated Bulkhead to Lower Stool



3.3 Loading Conditions

3.3.1 Stress analysis

3.3.1.1 The fine mesh detailed stress analysis is to be carried out for the standard load cases specified in *2.3.1*, and any other load cases specially considered as required by *Section 9/2.2.3*.

3.4 Application of Loads and Boundary Conditions

3.4.1 General

3.4.1.1 Where a separate local finite element model is used for the fine mesh detailed stress analysis, the nodal displacements from the cargo tank model are to be applied to the corresponding boundary nodes on the local model as prescribed displacements. Alternatively, equivalent nodal forces from the cargo tank model may be applied to the boundary nodes.

3.4.1.2 Where there are nodes on the local model boundaries which are not coincident with the nodal points on the cargo tank model, it is acceptable to impose prescribed displacements on these nodes using multi-point constraints. The use of linear multi-point constraint equations connecting two neighbouring coincident nodes is considered sufficient.

3.4.1.3 All local loads, including any vertical loads applied for hull girder shear force correction, in way of the structure represented by the separate local finite element model are to be applied to the model.

3.5 Result Evaluation and Acceptance Criteria

3.5.1 Stress assessment

3.5.1.1 Stress assessment of the fine mesh analysis is to be carried out for the load cases specified in *3.3.1.*

3.5.1.2 The von Mises stress, σ_{vm}, is to be calculated based on the membrane direct axial and shear stresses of the plate element evaluated at the element centroid. Where shell elements are used, the stresses are to be evaluated at the mid plane of the element.

3.5.1.3 The resulting von Mises stresses are not to exceed the permissible membrane values specified in *Section 9/2.3.5*.

3.5.1.4 The maximum permissible stresses are based on the mesh size of 50mm x 50mm as specified in *3.2.1*. Where a smaller mesh size is used, an average von Mises stress calculated over an area equal to the specified mesh size may be used to compare with the permissible stresses. The averaging is to be based only on elements with their entire boundary located within the desired area. The average stress is to be calculated based on stresses at element centroid; stress values obtained by interpolation and/or extrapolation are not to be used. Stress averaging is not to be carried across structural discontinuities and abutting structure.

4 EVALUATION OF HOT SPOT STRESS FOR FATIGUE ANALYSIS

4.1 Application

4.1.1 General

4.1.1.1 This Section describes the procedure to perform a finite element analysis using very fine meshes for the evaluation of geometric hot spot stresses for use in the determination of fatigue damage ratio in accordance with *Appendix C/2*.

4.1.1.2 The locations where a finite element analysis based fatigue assessment is to be carried out are specified in *Section 9/3.3*.

4.2 Structural Modelling

4.2.1 General

4.2.1.1 Evaluation of hot spot stresses for fatigue assessment requires the use of very fine finite element meshes in way of areas of high stress concentration. This very fine mesh analysis can be carried out by means of separate local finite element models with very fine mesh zones in conjunction with the boundary conditions obtained from a cargo tank model. Alternatively, very fine mesh zones incorporated into the cargo tank model may be used.

4.2.1.2 All structural parts, within an extent of at least 500mm in all directions leading up to the fatigue hot spot position, are to be modelled based on the net thickness, obtained by deducting half the corrosion addition (i.e. $0.5t_{corr}$) from the gross thickness.

4.2.1.3 The cargo tank finite element model for fatigue assessment is to be modelled in accordance with 2.2, but based on net thickness obtained by deducting a quarter of the corrosion addition (i.e. $0.25t_{corr}$) from the proposed thickness. Alternatively, if the cargo tank FE model for the strength assessment is used, which is based on a thickness deduction of $0.5t_{corr}$, the calculated stresses are to be corrected using the modelling reduction factor, f_{model}, given in *Appendix C/2.4.2.7*.

4.2.1.4 Where a separate local finite element model is used, the extent of the local model is to be such that the calculated stresses are not significantly affected by the imposed boundary conditions and application of loads. The boundary of the fine mesh model is to coincide with the primary support members, such as girders, stringers and floors, in the cargo tank model. The extent of the local finite element model of a hopper knuckle is described in *4.2.2*.

4.2.1.5 The evaluation of hot spot stress is to be based on shell element of mesh size t_{net50} x t_{net50}, where t_{net50} is the net thickness of the plate where a potential fatigue crack is most likely to initiate. This mesh size is to be maintained within the very fine mesh zone, extending over at least 10 elements in all directions leading to the fatigue hot spot position. A uniform quadratic mesh is to be used within the very fine mesh zone. A smooth transition of mesh density leading up to the very fine mesh zone is to be maintained.

4.2.1.6 Four-node shell elements with bending and membrane properties are to be used inside the very fine mesh zone. The shell elements are to represent the mid plane of the plating and the bending properties of the plate. The geometry of the weld and structural misalignment is not required to be modelled.

4.2.1.7 Where stresses are to be evaluated on a free edge or corner welds, such as cut-outs for stiffener connections at web frames, butt welds on edge of plating and around hatch corners, a rod element of negligible cross-section area, e.g. 1mm^2, is to be used to obtain the required stress value.

4.2.1.8 All structure in close proximity to the very fine mesh zones is to be modelled explicitly with shell elements. Triangular elements are to be avoided where possible. Use of extreme aspect ratio (e.g. aspect ratio greater than 3) and distorted elements (e.g. element's corner angle less than 60° or greater than 120°) are to be avoided.

4.2.2 Hopper knuckle connection

4.2.2.1 In addition to the general requirements in *4.2.1*, the modelling requirements in this sub-section are applicable to the modelling of welded hopper knuckle connections.

4.2.2.2 Fatigue assessment is to be carried out for the knuckle joint between inner bottom and hopper plate for at least one transverse frame in the midship cargo tank region, see *Section 9/3.3.3*. The fatigue assessment is only required to be carried out on the structural detail at one side of the hull.

4.2.2.3 In general, the hopper knuckle connection at the mid position between transverse bulkheads is to be assessed. Where a wash bulkhead exists, the hopper knuckle connection at the mid position between the wash bulkhead and cargo tank end bulkhead is generally to be assessed. The results from the cargo tank FE analysis described in *2.2* should be examined for the highest transverse in-plane stress on the inner bottom plate adjacent to the lower hopper knuckle line to identify the exact frame position and the side of the hull where the fatigue assessment should be carried out.

4.2.2.4 Where a separate local finite element model is used, the minimum extent of the local model is as follows:

(a) longitudinally, the model is to cover two web frame spaces (i.e. one web frame space extending either side of the transverse web frame of interest). Transverse web frames at the end of the local model need not to be represented in the sub-model

(b) vertically, the model is to extend from the base line to the lower stringer in the double side water ballast tank. Where a fatigue assessment is also carried out for the upper knuckle connection, the model is to be extended to 4 longitudinal spaces above the lower stringer in the double side ballast tank

(c) transversely, the model is to extend from the ship side to 4 longitudinal spaces inboard of the double bottom side girder.

4.2.2.5 Mesh size in way of the knuckle connection is to be t_{net50} x t_{net50}, where t_{net50} is the net thickness of the inner bottom plate in way of the connection obtained by deducting $0.5t_{corr}$ from the gross thickness as specified in *4.2.1.2*. The minimum extent of the t_{net50} x t_{net50} mesh is to be (see also *Figure B.4.1*):

(a) inner bottom plate – 10 elements from knuckle in transverse direction, 10 elements forward and aft of the floor in the longitudinal direction

(b) scarfing bracket/inner bottom overhang – 10 elements from knuckle in transverse direction, 10 elements forward and aft of the floor in the longitudinal direction

(c) hopper sloping plate – 10 elements from knuckle in transverse direction, 10 elements forward and aft of the hopper web in the longitudinal direction

(d) girder – 10 elements from knuckle in vertical direction, 10 elements forward and aft of the floor/hopper web in the longitudinal direction

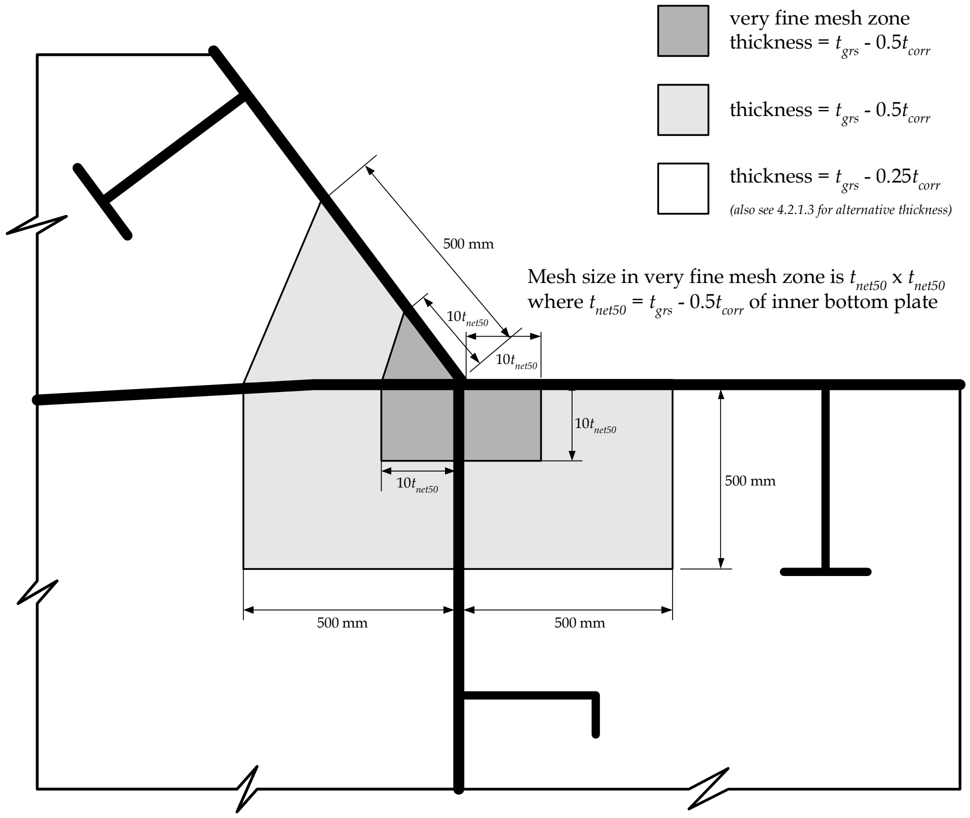
(e) floor/hopper web – 10 elements from the hopper knuckle in transverse and vertical directions respectively.

4.2.2.6 Any scarfing brackets on the web frame adjoining the inner bottom plating, the first longitudinal stiffeners away from the knuckle as well as any carlings and brackets offset from the main frames are to be modelled explicitly using shell elements. Longitudinal stiffeners further away from the knuckle may be modelled by beam elements. The inner bottom plate "overhang" outboard of the girder is to be modelled using shell elements up to the extent of the scarfing bracket. Away from the scarfing bracket, the inner bottom plate "overhang" may be modelled using line elements of equivalent area. Any perforations, such as cut-outs for cabling, pipes and access that are within one stiffener space from the knuckle point are to be modelled explicitly.

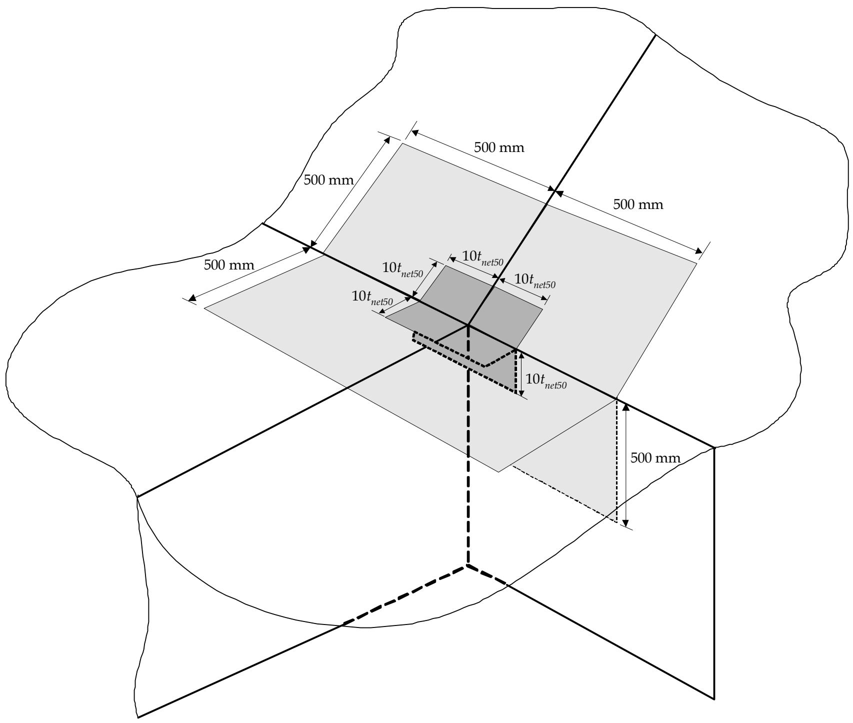
4.2.2.7 *Figure B.4.1* shows extent of the t_{net50} x t_{net50} mesh zone and extension of the areas of local thickness reduction.

4.2.2.8 *Figures B.4.2* to *B.4.4* show typical local finite element models of the hopper knuckle connection and close-up views of the t_{net50} x t_{net50} mesh zone.

Figure B.4.1
Minimum Extent of t_{net50} x t_{net50} Mesh Zone and Local Thickness Reduction Zone at Lower Hopper Joint



Floor and hopper web



Girder, inner bottom and hopper sloping plate

Figure B.4.2
Typical Local Finite Element Model of Hopper Knuckle Connection
t_{net50} x t_{net50} Mesh on Inner Bottom and Hopper Plate

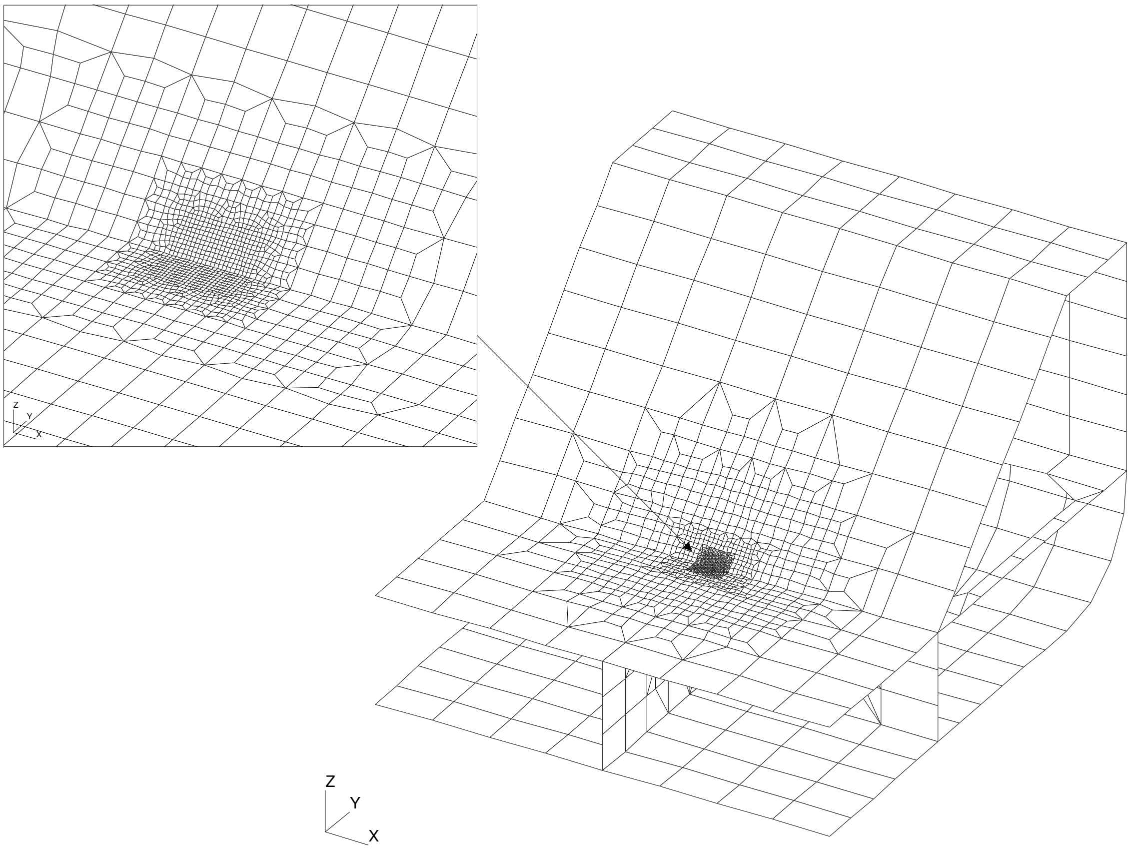
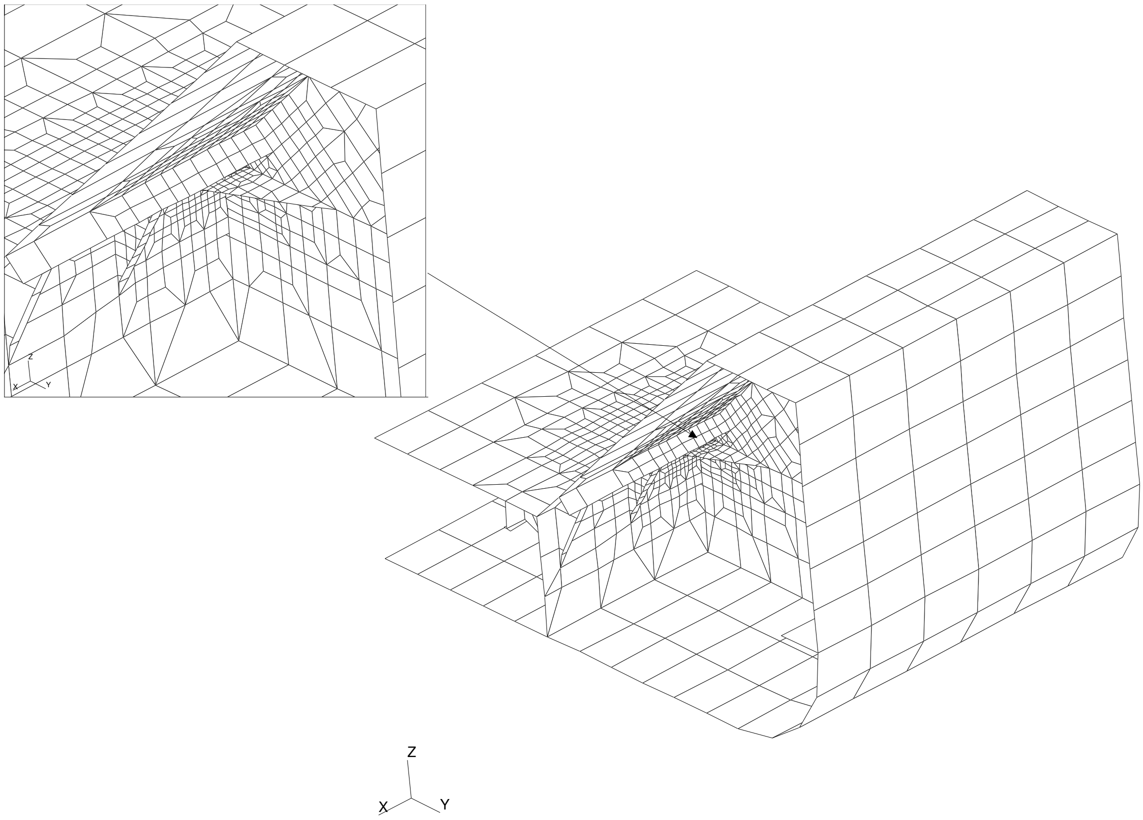


Figure B.4.3
Typical Local Finite Element Model of Hopper Knuckle Connection
t_{net50} x t_{net50} Mesh on Hopper Plate, Web Frame, Girder and Bracket in way



4.3 Loading Conditions

4.3.1 General

4.3.1.1 The ship loading conditions to be used to evaluate dynamic stress ranges for fatigue assessment are to be in accordance with *Appendix C/1.3.2*.

4.3.1.2 The cargo density to be used for the fatigue assessment is to be:

(a) longitudinal end connections - the greater of the cargo density specified for the homogeneous scantling draught condition and 0.9t/m^3

(b) connection between inner bottom and hopper plate – 0.9t/m^3.

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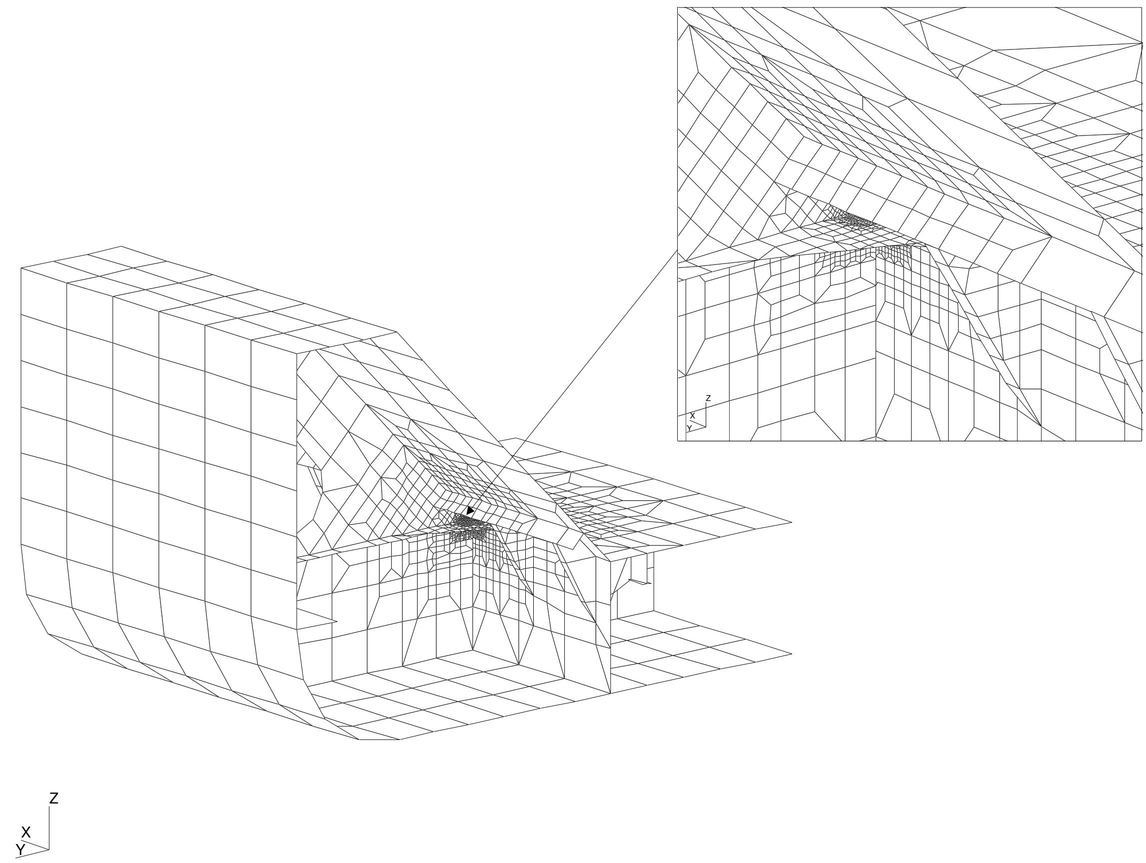
Figure B.4.4
Typical Local Finite Element Model of Hopper Knuckle Connection
t_{net50} x t_{net50} Mesh on Hopper Plate, Web Frame, Girder and Bracket in way



4.3.2 Finite element load cases for hopper knuckle connection

4.3.2.1 The requirements given in this sub-section are specifically applicable to the evaluation of hot spot stress range at hopper knuckle connection.

4.3.2.2 Only dynamic loads are considered for the evaluation of fatigue stress range. Static loads need not be included in the finite element analysis.

4.3.2.3 The load cases required to derive the component stress ranges for determining the combined stress ranges, see *Appendix C/2.4.2.7*, are given in *Table B.4.1*.

4.3.2.4 Stresses induced by vertical and horizontal hull girder bending moments are not to be included in the stress range for fatigue assessment. Stress caused by the bending effect of the hull girder is to be calculated and deduced from the fatigue stress range result in accordance with the procedure described in *4.5.2*.

Table B.4.1
Load Cases for the Evaluation of Component Stress Range for Hopper Knuckle Joint

Load case	Component Stress	Applied Load	Parameters for calculation of loads
Full load condition			
L1	s_{e1}	Dynamic wave pressure (full range) applies only to the side of the hull where the hopper knuckle is analysed.	Ship draught = midship draught from departure homogeneous full load condition in the ship loading manual, see *Appendix C/1.3.2.* GM: see *Section 7/3.1.3.4* $r_{roll\text{-}gyr}$: see *Section 7/3.1.3.4* Cargo density = 0.9t/m^3 (minimum, see *4.3.1.2*)
L2	s_{e2}	Dynamic wave pressure (full range) applies only to the side of the hull where the hopper knuckle is not analysed.	
L3	s_{ix}	Dynamic tank pressure (full range) due to longitudinal acceleration.	
L4	s_{iy}	Dynamic tank pressure (full range) due to transverse accelerations.	
L5	s_{iz}	Dynamic tank pressure (full range) due to vertical acceleration.	
Ballast condition			
L6	s_{e1}	Dynamic wave pressure (full range) applies only to the side of the hull where the hopper knuckle is analysed.	Ship draught = midship draught from departure normal ballast condition in the ship loading manual. If normal ballast condition is not defined, then the midship draught from light ballast condition is to be used, see *Appendix C/1.3.2*
L7	s_{e2}	Dynamic wave pressure (full range) applies only to the side of the hull where the hopper knuckle is not analysed.	
Load cases for bending moment correction			
C1	s_{VBM}	Unit vertical bending moment applies to ends of cargo tank model	No other loads are to be applied
C2	s_{HBM}	Unit horizontal bending moment applies to ends of cargo tank model	

Table B.4.1 (Continued)
Load Cases for the Evaluation of Component Stress Range for Hopper Knuckle Joint

Where:

s_{e1}, s_{e2}, s_{ix}, s_{iy}, s_{iz}	component stresses (with proper sign convention used) before correction for bending moment effect (5)
s_{VBM}	stress response due to the application of unit vertical bending moment at ends of cargo tank model
s_{HBM}	stress response due to the application of unit horizontal bending moment at ends of cargo tank models

Notes

1. For dynamic wave pressure load cases, the pressure distribution is to be calculated at mid-ship and this distribution is to be applied along the full length of the cargo tank FE model.
2. For dynamic tank pressure load cases, vertical, transverse and longitudinal accelerations are calculated at the centre of gravity position of the midship cargo tanks. The accelerations calculated for each tank are to be applied to all corresponding cargo tanks along the length of the FE model.
3. Longitudinal, transverse and vertical accelerations at tank centre of gravity position are to be calculated in accordance with *Section 7/3.3.* The dynamic tank pressure amplitudes due to accelerations are to be calculated in accordance with *Section 7/3.5.4.7*. The dynamic tank pressure (full range) is to be obtained as two times the dynamic tank pressure amplitude and distributed in accordance with *Figure 7.3.9*. Note that these pressure distributions are different from those used for strength analysis.
4. The dynamic wave pressure amplitude is to be calculated according to *Section 7/3.5.2.3*. The dynamic wave pressure (full range) is to be obtained as two times the dynamic wave pressure amplitude. Note that the dynamic wave pressure and distribution is different from that used for strength analysis.
5. Component stresses (with proper sign convention used) calculated from load cases L1 to L7 are to be corrected to deduct the component due to vertical and horizontal bending moment effect, see *4.5.2.2.*

4.4 Boundary Conditions

4.4.1 Cargo tank model

4.4.1.1 The boundary conditions to be applied to the ends of the cargo tank model are to be in accordance with *2.6*. The application of unit vertical and horizontal bending moment at the model ends is to be in accordance with *2.5.4.5* or *2.5.4.6*.

4.4.2 Local finite element models

4.4.2.1 Where a separate local finite element model is used for evaluating the hot spot stress range, the nodal displacements or equivalent nodal forces from the cargo tank model are to be applied to the corresponding boundary nodes on the local model.

4.4.2.2 Where there are nodes on the local model boundaries which are not coincident with the nodal points on the cargo tank model, it is acceptable to impose prescribed displacements on these nodes using multi-point constraints. The use of linear multi-point constraint equations connecting two neighbouring coincident nodes is considered sufficient.

4.4.2.3 All local loads in way of the structure represented by the separate local finite element model are to be applied to the model.

4.5 Result Evaluation

4.5.1 General

4.5.1.1 The fatigue damage calculation is to be based on the hot spot stress range evaluated close to the potential crack location in a direction perpendicular to the potential direction of the crack.

4.5.1.2 For welded structural details, the hot spot stress range is to be obtained as surface stress acting in a direction perpendicular to the weld at a distance of $0.5t_{net50}$ from the weld toe location, where t_{net50} is the net thickness of the plate where the fatigue crack is likely to initiate, see *Appendix C/2.4.2.6*.

4.5.1.3 For fatigue assessment of the free edge, a rod element is used to obtain stress at free edge. The stress range is to be based on the axial stress in the rod element.

4.5.1.4 For fatigue damage calculation of hopper knuckle connection, see *4.5.2*.

4.5.2 Hopper knuckle connection

4.5.2.1 Hot spot stress ranges for fatigue assessment of welded hopper knuckle joints are to be based on element direct stress along a direction perpendicular to intersection of the inner bottom plate and hopper plate. The stress ranges are to be evaluated on the upper surface of the hopper and inner bottom plate at a distance of $0.5t_{net50} + x_{wt}$ from the intersection line, where t_{net50} is the net thickness of the inner bottom plate and x_{wt} is weld toe distance, see *Figure C.2.1.* The stress at the required location can be obtained by linear interpolation based on the surface stresses evaluated at the centroid of the 1st and 2nd elements from the intersection of the hopper slope plate, and the inner bottom plate.

4.5.2.2 The component stress ranges are to be obtained by eliminating the stress induced by hull girder vertical and horizontal bending moments from the component stress determined from load cases L1 to L7 in *Table B.4.1* as follows:

$$S_{c\_i} = \left| s_{c\_i} - M_{V\_i}\, s_{VBM} - M_{H\_i}\, s_{HBM} \right|$$

Where:

S_{c_i} S_{e1}, S_{e2}, S_{ix}, S_{iy} or S_{iz}, component stress range after correction for bending moment effects

s_{c_i} s_{e1}, s_{e2}, s_{ix}, s_{iy} or s_{iz}, component stress (with proper sign convention used) including vertical and horizontal bending moment effects obtained from load cases L1 to L7, see *Table B.4.1*

M_{V_i} is the vertical hull girder bending moment due to loads applied to the cargo tank FE model obtained from load case L1, L2, L3, L4, L5, L6 or L7. The bending moment is to be calculated at the longitudinal position where the centroid of shell element under evaluation is located

M_{H_i} is the horizontal hull girder bending moment due to loads applied to the cargo tank FE model obtained from load case L1, L2, L3, L4, L5, L6 or L7. The bending moment is to be calculated at the longitudinal position where the centroid of shell element under evaluation is located

s_{VBM} stress due to unit vertical bending moment obtained from load

case C1, see *Table B.4.1*

s_{HBM} stress due to unit horizontal bending moment obtained from load case C2, see *Table B.4.1*

4.5.2.3 The hull girder vertical and horizontal bending moments in *4.5.2.2* may be evaluated at the frame position where the hopper knuckle is under evaluation if the longitudinal distance from the element centroid to the frame position is less than 500mm.

4.5.2.4 The component stress range, S_i, due to dynamic tank pressure resulting from longitudinal, transverse and vertical accelerations for the full load condition is given by:

$$S_i = 0.4|S_{ix}| + 0.9|S_{iy}| + 0.9|S_{iz}|$$

4.5.2.5 The combined hot spot stress ranges required for fatigue damage calculation are to be calculated in accordance with *Appendix C/2.4.2.7*.

4.5.2.6 Fatigue damage and fatigue life calculation is to be in accordance with *Appendix C/1.4.1*.

APPENDIX C

FATIGUE STRENGTH ASSESSMENT

1 NOMINAL STRESS APPROACH

1.1 General

1.1.1 Applicability

1.1.1.1 This sub-section defines the procedure for a simplified fatigue assessment which is to be used to evaluate the fatigue strength of the ships structural details. The fatigue assessment uses a nominal stress approach based on beam theory.

1.1.1.2 The fatigue assessment is to be applied to welded connections where the steel has a minimum yield strength of less than 400N/mm^2.

1.1.2 Assumptions

1.1.2.1 The following assumptions are made in the fatigue assessment:

(a) a linear cumulative damage model, i.e. Palmgren-Miner's Rule, has been used in connection with the S-N data in *1.4.5*

(b) for longitudinal stiffener end connections, nominal stresses obtained by empirical formulae, see *1.4.2* to *1.4.4*, and Rule based loads, see *1.3*, form the basis of the nominal stress based fatigue assessment

(c) the long term stress ranges of a structural detail can be characterized using a modified Weibull probability distribution parameter, ξ, as described in *1.4.1.5* and *1.4.1.6*

(d) structural details are idealised and classified in *1.5*.

1.1.2.2 The structural detail classification in *1.5* is based on typical joint geometry under simple loadings. When a structural detail is considered different from those shown in *1.5*, a suitable finite element (FE) analysis should be used to demonstrate the adequacy of the detail in terms of fatigue strength. See *2.1.1.3*.

1.1.2.3 Where the loading or geometry considered is too complex for a simple classification, a finite element (FE) analysis of the detail is to be carried out to determine the fatigue stress of that detail. *Sub-section 2* defines the procedure for a finite element based assessment to determine hot spot stresses that is to be used for weld toe locations that are typically found at welded hopper knuckle connections in way of transverse primary support members. For bent type knuckle connections, recommendation is given in *2.1.1.2*.

1.2 Corrosion Model

1.2.1 Net thickness

1.2.1.1 The net thickness and corrosion additions, as indicated in *Section 6/3* are to be incorporated into the representation of the structural capacity models.

1.3 Loads

1.3.1 General

1.3.1.1 Ship structures are subjected to various types of loads, which include:

(a) static loads including cargo and lightship weights

(b) wave induced loads

(c) impact loads, such as bottom slamming, bow flare impacts and sloshing in partially filled tanks

(d) cyclic loads resulting from main engine or propeller induced vibratory forces

(e) transient loads such as thermal loads

(f) residual stresses.

1.3.1.2 The fatigue strength analysis considers the following wave induced loads for calculation of the long term distribution of stresses:

(a) hull girder loads (i.e. vertical and horizontal wave bending moments)

(b) dynamic wave pressures

(c) dynamic tank pressure loads resulting from ship motions.

1.3.2 Selection of loading conditions

1.3.2.1 Fatigue analyses are to be carried out for representative loading conditions according to the intended ship's operation. The following two loading conditions are to be examined:

(a) full load condition at design draught at departure, T_{full}, see *Section 4/1.1.5.4*

(b) ballast condition at normal ballast draught at departure, T_{bal-n}, see *Section 4/1.1.5.3*. If a normal ballast condition is not defined in the loading manual, minimum ballast draught, T_{bal}, see *Section 4/1.1.5.2*, should be used.

1.3.2.2 The relevant draught at midships is to be used for the determination of fatigue loads.

1.3.3 Determination of loads

1.3.3.1 Loads applied to the structure are to be calculated in order to determine the stress ranges for the relevant loading conditions.

1.3.3.2 Combined stresses resulting from the action of global and local loads are to be calculated in accordance with *1.4.4,* with consideration given to the probability level of 10^{-4}.

1.3.4 Vertical wave bending moment

1.3.4.1 The vertical wave bending moment is to be calculated based on *Section 7/3.4.1*. The pseudo amplitude (half range) values of the vertical wave bending moment, $M_{wv-v-amp}$, for full load and ballast condition are to be taken as:

$$M_{wv-v-amp} = 0.5(M_{wv-hog} - M_{wv-sag}) \quad \text{kNm}$$

Where:

M_{wv-hog} hogging vertical wave bending moment, in kNm

M_{wv-sag} sagging vertical wave bending moment, in kNm

1.3.5 Horizontal wave bending moment

1.3.5.1 The horizontal wave bending moment is to be calculated based on *Section 7/3.4.2*. The pseudo amplitude (half range) values of the horizontal wave bending moment, $M_{wv-h-amp}$, for full load and ballast condition are to be taken as:

$$M_{wv-h-amp} = 0.5(M_{wv-h-pos} - M_{wv-h-neg}) \quad \text{kNm}$$

Where:

$M_{wv-h-pos}$ positive horizontal wave bending moment, in kNm
$= M_{wv-h}$

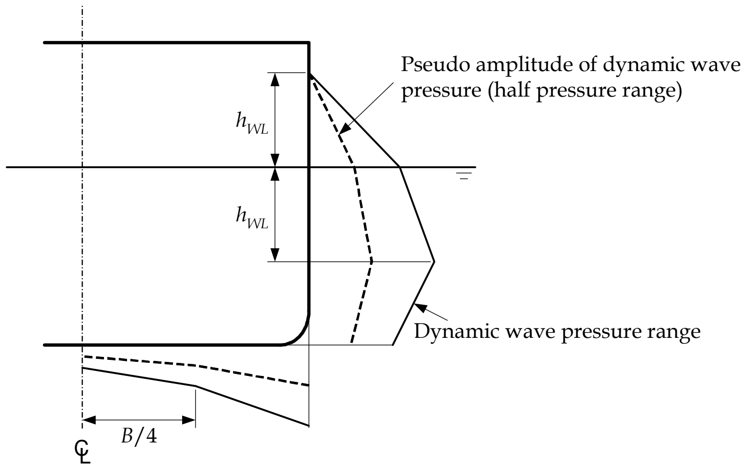
$M_{wv\text{-}h\text{-}neg}$ negative horizontal wave bending moment, in kNm
$= -M_{wv\text{-}h}$

1.3.6 Dynamic wave pressure

1.3.6.1 The dynamic wave pressure is to be calculated according to *Section 7/3.5.2*.

1.3.6.2 Considering the stretching of the external pressure due to intermittent wet and dry area, a pseudo amplitude of external pressure (half pressure range), $P_{ex\text{-}amp}$, is defined in *Section 7/3.5.2.3* in detail and illustrated in *Figure C.1.1*.

Figure C.1.1
Dynamic Pressure



1.3.7 Dynamic tank pressure

1.3.7.1 The dynamic tank pressure amplitude, $P_{in\text{-}amp}$, is to be calculated according to *Section 7/3.5.4.5* and *Section 7/3.5.4.6*. No dynamic internal pressure is considered for the deck.

1.4 Fatigue Damage Calculation

1.4.1 Fatigue strength determination

1.4.1.1 The fatigue assessment of the structure is based on the application of the Palmgren-Miner cumulative damage rule given below. When the cumulative fatigue damage ratio, *DM*, is greater than 1, the fatigue capability of the structure is not acceptable. *DM* is to be taken as:

$$DM = \sum_{i=1}^{i=n_{tot}} \frac{n_i}{N_i}$$

Where:

n_i number of cycles of stress range S_i

N_i number of cycles to failure at stress range S_i

n_{tot} total number of stress range blocks

1.4.1.2 Assessment of the fatigue strength of welded structural members includes the following three phases:

(a) calculation of stress ranges

(b) selection of the design S-N curve

(c) calculation of the cumulative damage.

1.4.1.3 The cumulative fatigue damage ratio, *DM*, is to be less than 1 for the design life of the ship. The design life is not to be less than 25 years. Unless otherwise specified the resultant cumulative damage is to be taken as:

$$DM = \sum_{i=1}^{2} DM_i$$

Where:

DM_i cumulative fatigue damage ratio for the applicable loading condition

i = 1 for full load condition

= 2 for normal ballast condition

1.4.1.4 Assuming the long term distribution of stress ranges fit a two-parameter Weibull probability distribution, the cumulative fatigue damage DM_i for each relevant condition is to be taken as:

$$DM_i = \frac{\alpha_i N_L}{K_2} \frac{S_{Ri}^m}{(lnN_R)^{m/\xi}} \mu_i \Gamma(1 + \frac{m}{\xi})$$

Where:

N_L Number of cycles for the expected design life. Unless stated otherwise, N_L to be taken as:

$$= \frac{f_0 U}{4logL}$$

The value is generally between 0.6×10^8 and 0.8×10^8 cycles for a design life of 25 years

f_o 0.85, factor taking into account non-sailing time for operations such as loading and unloading, repairs, etc.

U Design life, in seconds

= $0.788 \times 10_9$ for a design life of 25 years

L rule length, in m, as defined in *Section 4/1.1.1.1*

m S-N curve parameter as defined in *1.4.5.5*

K_2 S-N curve parameter as defined in *1.4.5.5*

α_i proportion of the ship's life:

α_1 = 0.5 for full load condition

α_2 = 0.5 for ballast condition

S_{Ri} stress range at the representative probability level of 10^{-4}, in N/mm^2

N_R 10 000, number of cycles corresponding to the probability level of 10^{-4}

ξ Weibull probability distribution parameter, as defined in *1.4.1.6*

Γ	Gamma function
μ_i	coefficient taking into account the change in slope of the S-N curve

$$\mu_i = 1 - \frac{\left\{ \gamma\left(1+\frac{m}{\xi}, \nu_i\right) - \nu_i^{-\Delta m/\xi} \gamma\left(1+\frac{m+\Delta m}{\xi}, \nu_i\right) \right\}}{\Gamma(1+\frac{m}{\xi})}$$

v_i	$\left(\frac{S_q}{S_{Ri}}\right)^{\xi} lnN_R$
S_q	stress range at the intersection of the two segments of the S-N curve, see *Table C.1.6*, in N/mm²
Δm	slope change of the upper-lower segment of the S-N curve =2
$\gamma(a,x)$	incomplete Gamma function, Legendre form

1.4.1.5 The probability density function of the long term distribution of stress ranges (hull girder + local bending) is to be represented by a two-parameter Weibull distribution. This assumption enables the use of a closed form equation for calculation of the fatigue life when the two parameters of the Weibull distribution are determined. The probability density function, *f(S)*, is to be taken as:

$$f(S) = \frac{\xi}{f_1}\left(\frac{S}{f_1}\right)^{\xi-1} exp\left(-\left(\frac{S}{f_1}\right)^{\xi}\right)$$

Where:

S	stress range, in N/mm²
ξ	Weibull probability distribution parameter, as defined in *1.4.1.6*
f_1	scale parameter $= \frac{S_R}{(lnN_R)^{1/\xi}}$
N_R	number of cycles corresponding to the probability of exceedance of 1/ N_R
S_R	stress range with probability of exceedance of 1/N_R, in N/mm²

1.4.1.6 For each structural detail considered, the Weibull shape parameter is to be selected with due consideration given to the load categories contributing to the cyclic stresses. The Weibull probability distribution parameter, ξ, is to be taken as:

$$\xi = f_{Weibull}\,(1.1 - 0.35\,\frac{L-100}{300})$$

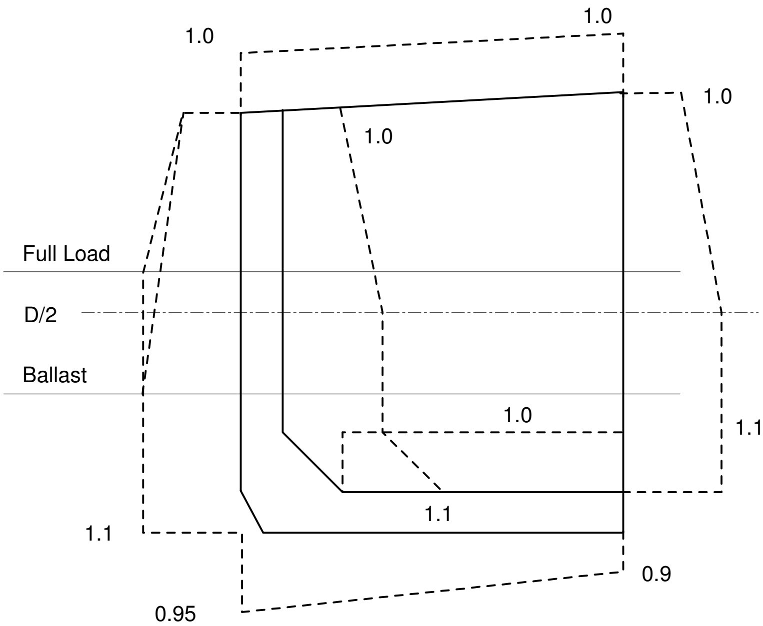
Where:

L	rule length, in m, as defined in *Section 4/1.1.1.1*
D	moulded depth, in m, as defined in *Section 4/1.1.4.1*
$f_{Weibull}$	area dependent modification factor, as given in *Table C.1.1* and *Figure C.1.2*

Table C.1.1
Distribution of $f_{Weibull}$ factors

Plating Area	$f_{Weibull}$ (see note)
Bottom	0.9 at centreline and 0.95 at side
Side and bilge	1.1 at up to draught T_{LC} and 1.0 at deck
Deck	1.0
Inner bottom	1.0
Inner Hull Longitudinal Bulkhead	1.1 up to D/2 and 1.0 at deck
Inner Longitudinal Bulkhead	1.1 up to D/2 and 1.0 at deck
Centreline Longitudinal Bulkhead	1.1 up to D/2 and 1.0 at deck
Note: Intermediate values to be linearly interpolated	

Figure C.1.2
Distribution of $f_{Weibull}$ factors



1.4.1.7 The cumulative fatigue damage ratio, DM, may be converted to a calculated fatigue life using the relationship given below. In this format, the calculated fatigue life is to be equal or greater than the design life of the ship.

$$Fatigue\ life = \frac{Design\ life}{DM} \quad \text{years}$$

1.4.2 Stresses to be used

1.4.2.1 The nominal stresses are to be determined taking into account the overall geometric changes of the detail. The effect of stress concentrations due to structural discontinuities, presence of attachments and the weld profile is not considered.

1.4.3 Nominal stress calculation

1.4.3.1 This Sub-Section outlines a simplified approach to determine the combination of global and local stress components of the stress response of the ship.

1.4.3.2 Stress responses are to be calculated with varying levels of detail. The following approach has been adopted in this simplified procedure:

(a) the hull girder is treated as a simple beam as a way of obtaining reasonable approximations to the nominal stress level in longitudinal hull girder elements. This is used for the evaluation of hull girder stress levels in way of critical details

(b) the structural member with effective attached plating is used in determining the nominal stress response of longitudinal and transverse frames due to dynamic wave pressure and dynamic tank pressure loads. The member end restraints and moments are considered.

1.4.4 Definition of stress components

1.4.4.1 Dynamic stress variations are referred to as either *stress range*, *S*, or *stress amplitude*, σ.

1.4.4.2 The global dynamic stress components (primary stresses) considered in fatigue analysis are vertical wave hull girder bending stress, σ_v, and horizontal wave hull girder bending stress, σ_h.

1.4.4.3 The local dynamic stress amplitudes considered are defined as the total local stress amplitude due to dynamic wave pressure loads or dynamic tank pressure loads, σ_{e-i}.

1.4.4.4 The local stress components are defined as secondary stress resulting from bending of girder systems, σ_2, stress amplitude produced by bending of stiffeners between girder supports, σ_{2A}, and tertiary stress amplitude produced by bending of un-stiffened plate elements between longitudinals and transverse frames, σ_3. See figure *C.1.3*.

1.4.4.5 The total local stress due to dynamic wave or dynamic tank pressure loads, σ_{e-i}, is to be taken as:

$$\sigma_{e-i} = \sigma_2 + \sigma_{2A} + \sigma_3 \quad \text{N/mm}^2$$

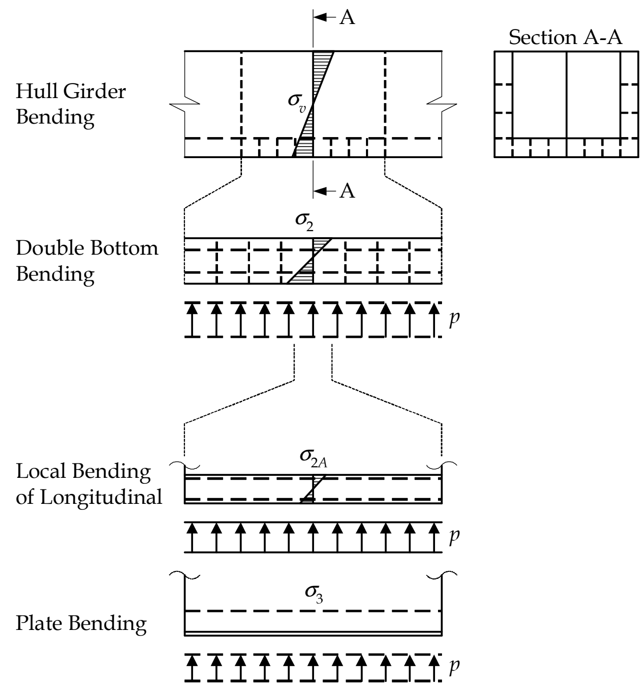
Where:

σ_2 local stress component, in N/mm², as defined in *1.4.4.4*

σ_{2A} local stress component, in N/mm², as defined in *1.4.4.4*

σ_3 local stress component, in N/mm², as defined in *1.4.4.4*

Figure C.1.3
Definition of Local Stress Components



1.4.4.6 For the calculation of stress components, the vertical wave hull girder stress, σ_v, is given by:

$$\sigma_v = \frac{M_{wv-v-amp}}{Z_{v-net75}} 10^{-3} \quad \text{N/mm}^2$$

Where:

$M_{wv-v-amp}$ pseudo amplitude (half range), in kNm, as defined in *1.3.4*

$Z_{v-net75}$ $= \dfrac{I_{v-net75}}{\left|z - z_{NA-net75}\right|}$ m^3 see *Section 4/2.6.1*

$I_{v-net75}$ net vertical hull girder moment of inertia, of hull cross-section about transverse neutral axis, in m^4

$I_{v-net75}$ is to be calculated based on gross thickness, minus the corrosion addition $0.25t_{corr}$ of all effective structural elements, see *Section 4/2.6.1*

z distance from baseline to the critical location of the considered member, i.e. top of flange of longitudinal stiffener, in m

$z_{NA-net75}$ distance from baseline to horizontal neutral axis consistent with $I_{v-net75}$, in m

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1.4.4.7 The corresponding stress range due to vertical wave bending moment, S_v, is to be taken as:

$$S_v = 2\sigma_v \quad \text{N/mm}^2$$

Where:

σ_v vertical wave hull girder stress, in N/mm², as defined in *1.4.4.6*

1.4.4.8 The horizontal wave hull girder stress, σ_h, is to be taken as:

$$\sigma_h = \frac{M_{wv-h-amp}}{Z_{h-net75}} 10^{-3} \quad \text{N/mm}^2$$

Where:

$M_{wv-h-amp}$ in kNm, as defined in *1.3.5*

$Z_{h-net75}$ $\dfrac{I_{h-net75}}{|y|}$ m³ see *Section 4/2.6.2*

y distance from vertical neutral axis of hull cross section to the critical location of the considered member, in m. i.e. top of face plate of longitudinal stiffener

$I_{h-net75}$ net horizontal hull girder moment of inertia, of the hull cross-section about the vertical neutral axis, in m⁴.
$I_{h-net75}$ is to be calculated based on gross thickness, minus the corrosion addition $0.25t_{corr}$ for all effective structural elements, see *Section 4/2.6.2*

RCN 2 to July 2008 version (effective from 1 July 2010)

1.4.4.9 The corresponding stress range due to horizontal wave bending moment, S_h, is to be taken as:

$$S_h = 2\sigma_h \quad \text{N/mm}^2$$

Where:

σ_h horizontal wave hull girder stress, in N/mm², as defined in *1.4.4.8*

1.4.4.10 The effect of secondary stress σ_2, as defined in *1.4.4.4*, is in general small for double hull tankers and is therefore not taken into consideration.

1.4.4.11 The stress amplitude produced by bending of stiffeners between girder supports (e.g. frames, bulkheads), σ_{2A}, is to be taken as:

$$\sigma_{2A} = K_n K_d \frac{M}{Z_{net50}} 10^3 \quad \text{N/mm}^2$$

Where:

K_n stress factor for unsymmetrical profiles, as defined in *1.4.4.15*

K_d stress factor for bending stress in longitudinal stiffeners caused by relative deformation between supports, may be determined by FE analysis of the cargo hold model where the actual relative deformation is taken into account or taken as follows:

1.0 at frame connections

1.15 for all longitudinals at transverse bulkhead connections including wash bulkheads except:

(a) in full load condition:

1.3 for side and bilge longitudinals at mid position between lowest side stringer and deck at side

1.15 for side and bilge longitudinals at lowest side stringer and deck at side

to be linearly interpolated between these two positions

1.5 for bottom longitudinals at mid position between longitudinal bulkhead, bottom girders or buttress structure
1.15 for bottom longitudinals at longitudinal bulkhead, bottom girders or buttress structure
to be linearly interpolated between these two positions

See *Figure C.1.4*

(b) in ballast condition:
1.5 for bottom longitudinals in the mid position between longitudinal bulkhead, bottom girders or buttress structure
1.15 for bottom longitudinals at longitudinal bulkhead, bottom girders or buttress structure
to be linearly interpolated between these two positions

M moment at stiffener support adjusted to weld toe location at the stiffener (e.g. at bracket toe), in kNm:

$$= \frac{P s\, l_{bdg}^2 10^{-3}}{12} r_p$$

s stiffener spacing, in mm

l_{bdg} effective bending span, of longitudinal stiffener, as shown in *Figure C.1.5*, in m. See also *Figure 4.2.1* and *4.2.2* in *Section 4* for soft toe brackets. Top stiffeners with a soft toe are to be treated the same as flat bars with a soft toe bracket. The span point is to be taken at the point where the depth of the end bracket, measured from the face of the member, is equal to half the depth of the member

Z_{-net50} section modulus of longitudinal stiffener with associated effective plate flange b_{eff}, in cm^3, calculated based on gross thickness minus the corrosion addition $0.5t_{corr}$.

b_{eff} as defined in *Section 4/2.3.3*

r_p moment interpolation factor, for interpolation to weld toe location along the stiffener length:

$$= \left| 6\left(\frac{x}{l_{bdg}}\right)^2 - 6\left(\frac{x}{l_{bdg}}\right) + 1.0 \right| \quad \text{where} \quad 0 \le x \le l_{bdg}$$

where x is the distance to the hot spot, in m. See *Figure C.1.5*.

P lateral dynamic pressure amplitude at the mid-span between the frame considered and the neighbouring frame, in kN/m^2.
P_{in-amp} for dynamic tank pressure, is to be taken as defined in *1.3.7*

P_{ex-amp} for dynamic wave pressure, is to be taken as defined in *1.3.6*

Figure C.1.4
Variation of Bulkhead Factor K_d in Full Load Condition for a Vessel with Two Longitudinal Bulkheads

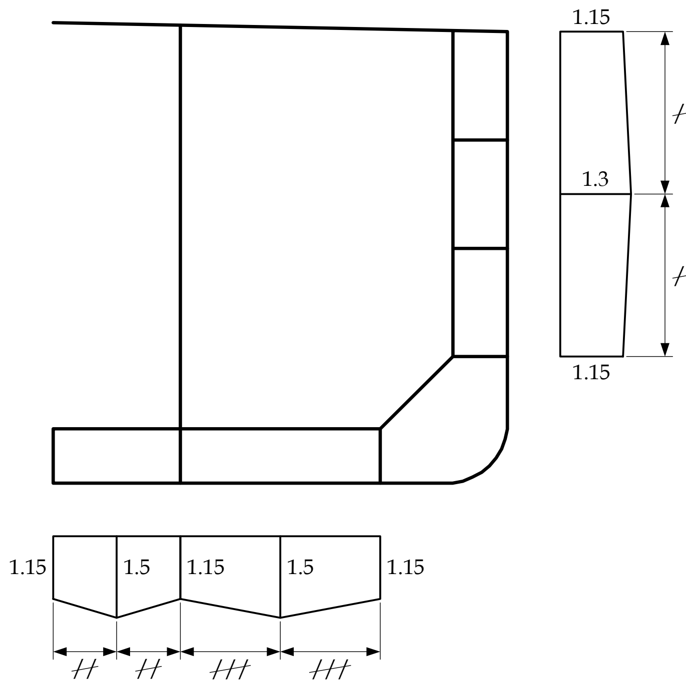
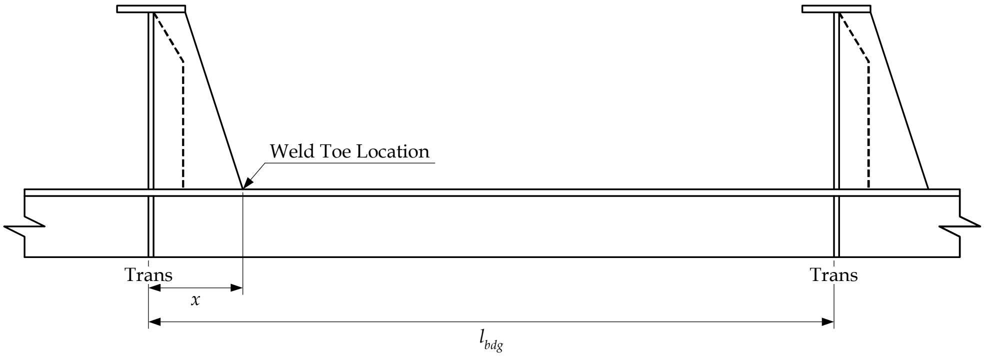
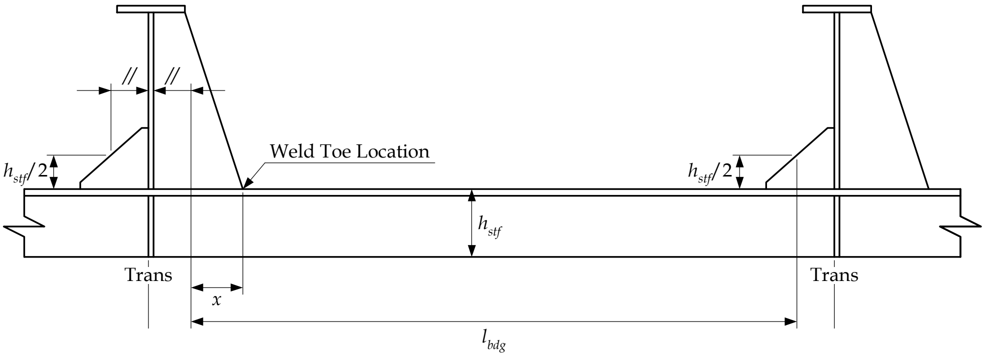


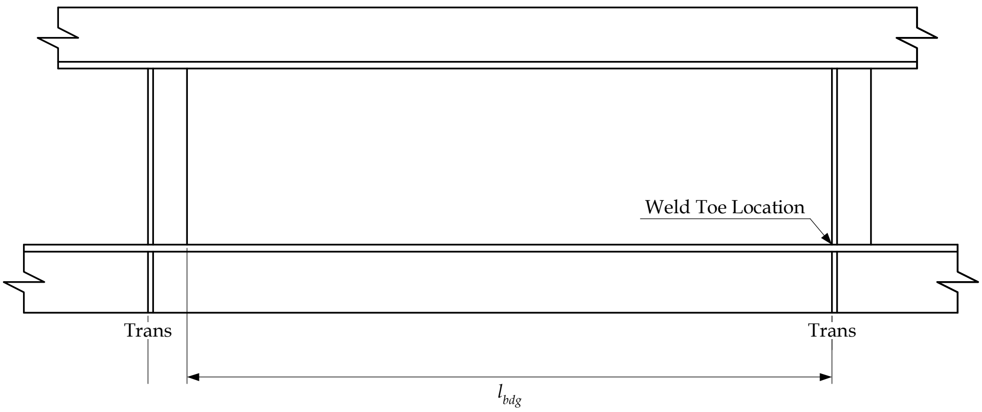
Figure C.1.5
Definition of Effective Span Lengths



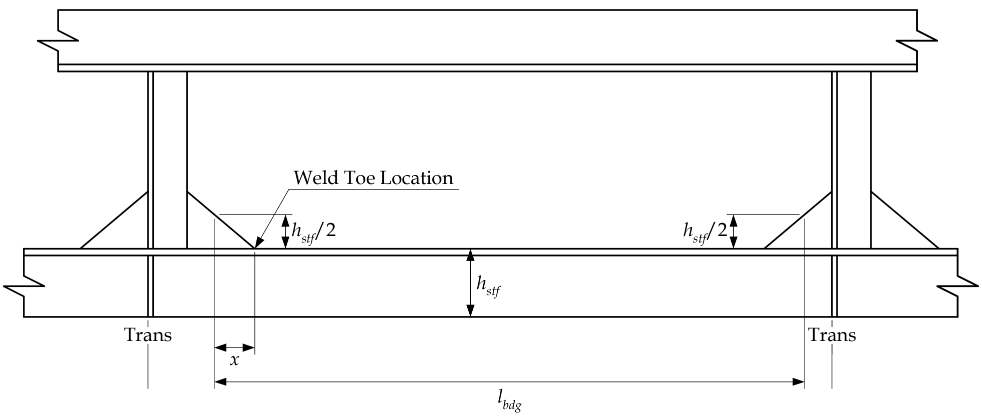
Supported by free flange transverses (1)



Supported by free flange transverses (2)



Supported by double skin / transverse bulkheads (1)



Supported by double skin / transverse bulkheads (2)

1.4.4.12 The stress range due to external wave or internal tank pressure, S_e or S_i, is to be determined as:

$S_e = 2\sigma_{2Ae}$ N/mm²

$S_i = 2\sigma_{2Ai}$ N/mm²

Where:

σ_{2Ae} stress amplitude, in N/mm², as defined in *1.4.4.11* when $P_{ex\text{-}amp}$ is used

σ_{2Ai} stress amplitude, in N/mm², as defined in *1.4.4.11* when $P_{in\text{-}amp}$ is used

1.4.4.13 Longitudinal local tertiary plate bending stress amplitude in the weld at the plate, transverse frame or bulkhead intersection, σ_3, is not relevant to the critical locations being considered and is to be neglected.

1.4.4.14 The effective breadth of plate flanges of stiffeners (longitudinals) in bending (due to the shear lag effect), exposed to uniform lateral load for bending at ends, is defined in *Section 4/2.3.3*.

1.4.4.15 The stress concentration factors at the flange of un-symmetrical stiffeners on laterally loaded panels, K_{n1} and K_{n2}, as shown in *Figure C.1.6*, are to be taken as:

$K_{n1} = \dfrac{1+\lambda\beta}{1+\lambda\beta^2\psi_z}$ at the flange edge

$K_{n2} = \dfrac{1+\lambda\beta^2}{1+\lambda\beta^2\psi_z}$ at the web

K_{n2} is typically used in the fatigue analysis of longitudinal end connections

Where:

β $1-\dfrac{2b_g}{b_f}$ for built-up profiles

$1-\dfrac{t_{w-net50}}{b_f}$ for rolled angle profiles

b_g breadth of flange from web centreline, in mm, see *Figure C.1.7*

$t_{w-net50}$ net web thickness, in mm

d_w depth of stiffener web, see *Figure C.1.7*, in mm

λ factor, as defined in *1.4.4.17*

ψ_z ratio between section modulus of the stiffener web with plate flange, as calculated at the flange and the section modulus of the complete panel stiffener

$\dfrac{d_w^2\, t_{w-net50}}{4Z_{net50}10^3}$ may be used as an approximate value

Z_{net50} section modulus of stiffener including the full width of the attached plate, s, with respect to a neutral axis normal to the stiffener web, in cm³. It is to be calculated based on the gross thickness minus the corrosion addition $0.5t_{corr}$

Figure C.1.6
Bending Stress in Symmetrical and Un-symmetrical Panel Stiffener with Same Web and Flange Areas

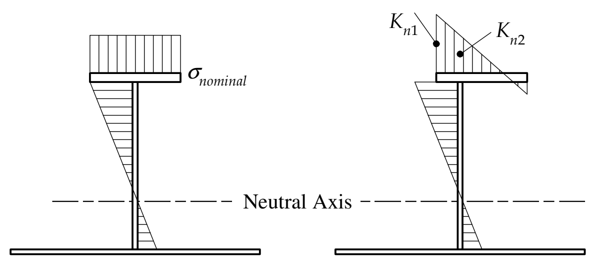
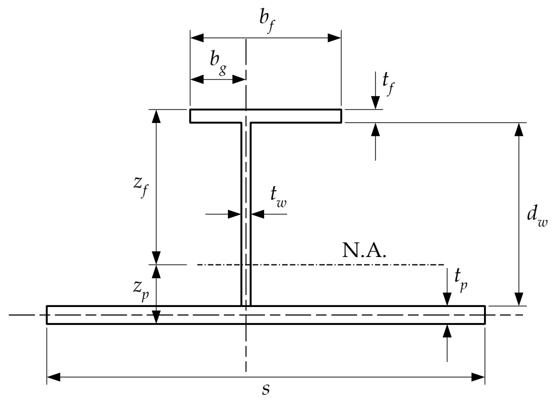


Figure C.1.7
Stiffener Geometry



1.4.4.16 The formulations are not directly applicable for bulb profiles. For these, the equivalent built-up profile is to be considered, see *Figure C.1.8*. The assumed built-up flange is to have the same properties as the bulb flange for cross-sectional area and moment of inertia about the vertical axis and neutral axis position. For HP bulb profiles, the equivalent built up profile dimensions are to be determined. Several examples are tabulated in *Table C.1.2*.

1.4.4.17 For continuous stiffeners (fixed ends) the λ-factor at supports is to be taken as:

$$\lambda = \frac{3(1+\frac{\eta}{280})}{1+\frac{\eta}{40}}$$

Where:

η $$= \frac{l_{bdg}^4\, 10^{12}}{b_f^3\, t_{f-net50}\, h_{stf}^2 \left(\frac{4h_{stf}}{t_{w-net50}^3} + \frac{s}{t_{p-net50}^3}\right)}$$

l_{bdg} effective bending span, of longitudinal stiffener, in m

b_f breadth of flange, in mm

$t_{f-net50}$ net flange thickness, in mm

h_{stf} stiffener height, including face plate, in mm

$t_{w\text{-}net50}$	net web thickness, in mm
$t_{p\text{-}net50}$	net plate thickness, in mm
s	plate width between stiffeners, in mm

Figure C.1.8
Bulb Profile and Equivalent Built-up Flange

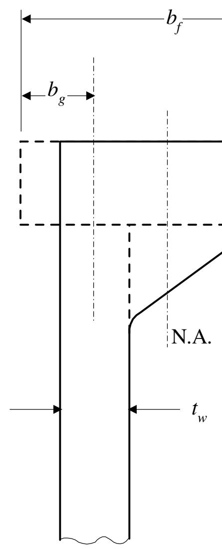


Table C.1.2
HP Equivalent Built-up Profile Dimensions

HP- bulb		Equivalent built-up flange		
Height (mm)	**Web thickness t_w (mm)**	**b_f (mm)**	**t_f (mm)**	**b_g (mm)**
200	9 – 13	t_w + 24.5	22.9	(t_w + 0.9)/2
220	9 - 13	t_w + 27.6	25.4	(t_w + 1.0)/2
240	10 – 14	t_w + 30.3	28.0	(t_w + 1.1)/2
260	10 – 14	t_w + 33.0	30.6	(t_w + 1.3)/2
280	10 – 14	t_w + 35.4	33.3	(t_w + 1.4)/2
300	11 – 16	t_w + 38.4	35.9	(t_w + 1.5)/2
320	11 – 16	t_w + 41.0	38.5	(t_w + 1.6)/2
340	12 – 17	t_w + 43.3	41.3	(t_w + 1.7)/2
370	13 – 19	t_w + 47.5	45.2	(t_w + 1.9)/2
400	14 – 19	t_w + 51.7	49.1	(t_w + 2.1)/2
430	15 – 21	t_w + 55.8	53.1	(t_w + 2.3)/2

1.4.4.18 For each loading condition, combined local stress components due to simultaneous dynamic tank and dynamic wave pressure loads are to be combined with global stress components induced by hull girder wave bending.

1.4.4.19 Total combined stress range, S, is given by:

$$S = f_{SN} \left| f_1 S_v + f_2 S_h + f_3 S_e + f_4 S_i \right| \quad \text{N/mm}^2$$

Where:

f_1, f_2, f_3 and f_4	stress range combination factors, representing the phase correlation between total stress range and each stress range component which is between 1.0 and –1.0, as defined in *Tables C.1.3* to *C.1.5*. Where the factor is greater than 1.0 it is to be taken as 1.0. Where the factor is less than -1.0 it is to be taken as -1.0
f_{SN}	1.06, factor to account for joints in combined protected and unprotected environment.
S_v	corresponding stress range due to vertical bending moment, in N/mm², as defined in *1.4.4.7*
S_h	corresponding stress range due to horizontal bending moment, in N/mm², as defined in *1.4.4.9*
S_e	stress range due to external wave or internal tank pressure, in N/mm², as defined in *1.4.4.12*
S_i	stress range due to external wave or internal tank pressure, in N/mm², as defined in *1.4.4.12*

1.4.4.20 The stress range combination factors, f_1, f_2, f_3 and f_4, which are to be applied to the following zones, are given in *Tables C.1.3* to *C.1.5*:

(a) Zone M: Midship region. This zone extends over the full length of all tanks where the tank LCG lies between 0.35L and 0.8L from AP.

(b) Zone A: Aft region. This zone starts at the middle of the tank immediately aft of Zone M and extends aftwards to include all the aftmost tanks.

(c) Zone F: Forward region. This zone starts at the middle of the tank immediately forward of Zone M and extends forwards to include all the foremost tanks.

(d) Zone AT: Aft transition region between Zone M and Zone A. The stress range combination factors are to be calculated by linear interpolation between the stress range combination factors for Zones M and A.

(e) Zone FT: Forward transition region between Zone M and Zone F. The stress range combination factors are to be calculated by linear interpolation between the stress range combination factors for Zones M and F.

Note

Where ballast tanks, centre and wing cargo tanks do not have the same lengths e.g. if slop tank is present, the middle position is to be taken at the middle of the longer tank.

RCN 1 to July 2010 version (effective from 1 July 2012)

Table C.1.3
Stress Range Combination Factors for Zone M

	Stiffener location		f_1	f_2	f_3	f_4	f_i
Ballast	Bottom shell	a_i	-0.49	0.49	-1.04	-0.13	$a_i\ (\lvert y\rvert/B) + b_i$
		b_i	0.97	0.17	0.87	0.56	
	Side shell and bilge below $D/2$	a_i	-1.48	0.50	-0.64	0.72	$a_i\ (z/D) + b_i$
		b_i	0.94	0.40	0.72	0.04	
	Side shell above $D/2$	a_i	1.70	-1.00	-1.10	-0.60	$a_i\ (z/D) + b_i$
		b_i	-0.65	1.15	0.95	0.70	
	Inner bottom and Lower stool	a_i	-0.18	0.34	0.00	-0.30	$a_i\ (\lvert y\rvert/B) + b_i$
		b_i	0.90	0.22	0.00	0.74	
	Inner hull below $D/2$ (including hopper plate)	a_i	-1.70	-0.90	0.00	1.04	$a_i\ (z/D) + b_i$
		b_i	1.15	0.70	0.00	0.45	
	Inner hull above $D/2$	a_i	1.40	0.50	0.00	-1.94	$a_i\ (z/D) + b_i$
		b_i	-0.40	0.00	0.00	1.94	
	Deck and Upper stool	a_i	-0.15	1.05	0.00	0.00	$a_i\ (\lvert y\rvert/B) + b_i$
		b_i	1.02	-0.27	0.00	0.00	
	Centreline longitudinal bulkhead Below $D/2$	a_i	0.00	0.00	0.00	0.00	$a_i\ (z/D) + b_i$
		b_i	1.00	0.00	0.00	0.00	
	Centreline longitudinal bulkhead Above $D/2$	a_i	0.00	0.00	0.00	0.00	$a_i\ (z/D) + b_i$
		b_i	1.00	0.00	0.00	0.00	
	Longitudinal bulkhead below $D/2$	a_i	-0.20	1.30	0.00	0.00	$a_i\ (z/D) + b_i$
		b_i	1.00	0.10	0.00	0.00	
	Longitudinal bulkhead above $D/2$	a_i	0.20	-1.30	0.00	0.00	$a_i\ (z/D) + b_i$
		b_i	0.80	1.40	0.00	0.00	
Loaded	Bottom shell	a_i	-0.43	0.78	-0.77	0.00	$a_i\ (\lvert y\rvert/B) + b_i$
		b_i	0.98	0.13	0.75	0.00	
	Side shell and bilge below $D/2$	a_i	-0.29	-0.47	0.14	0.00	$a_i\ (z/D) + b_i$
		b_i	0.19	0.78	0.92	0.00	
	Side shell above $D/2$	a_i	1.77	-0.05	-1.20	0.00	$a_i\ (z/D) + b_i$
		b_i	-0.84	0.57	1.59	0.00	
	Inner bottom and Lower stool	a_i	-0.71	1.13	0.00	0.55	$a_i\ (\lvert y\rvert/B) + b_i$
		b_i	1.03	0.18	0.00	-0.18	
	Inner hull below $D/2$ (including hopper plate)	a_i	-0.80	-1.70	0.00	2.60	$a_i\ (z/D) + b_i$
		b_i	0.55	1.20	0.00	-0.35	
	Inner hull above $D/2$	a_i	1.90	0.30	0.00	-1.70	$a_i\ (z/D) + b_i$
		b_i	-0.80	0.20	0.00	1.80	
	Deck and Upper stool	a_i	-0.26	1.40	0.00	0.00	$a_i\ (\lvert y\rvert/B) + b_i$
		b_i	1.02	-0.16	0.00	0.00	
	Centreline longitudinal bulkhead below $D/2$	a_i	-1.40	0.00	0.00	1.00	$a_i\ (z/D) + b_i$
		b_i	0.75	0.00	0.00	0.60	
	Centreline longitudinal bulkhead above $D/2$	a_i	1.70	0.00	0.00	-1.20	$a_i\ (z/D) + b_i$
		b_i	-0.80	0.00	0.00	1.70	
	Longitudinal bulkhead below $D/2$	a_i	-0.60	0.40	0.00	1.10	$a_i\ (z/D) + b_i$
		b_i	1.00	0.40	0.00	0.05	
	Longitudinal bulkhead above $D/2$	a_i	0.60	-0.84	0.00	-0.84	$a_i\ (z/D) + b_i$
		b_i	0.40	1.02	0.00	1.02	

Table C.1.4
Stress Range Combination Factors for Zone A

	Stiffener location		f_1	f_2	f_3	f_4	f_i
Ballast	Bottom shell	a_i	-0.20	-0.80	1.20	1.50	$a_i(\lvert y\rvert/B)+b_i$
		b_i	0.00	0.50	-0.25	1.07	
	Side shell and bilge below D/2	a_i	-1.00	1.20	-0.80	2.00	$a_i(z/D)+b_i$
		b_i	0.20	0.00	0.60	-0.40	
	Side shell above D/2	a_i	3.40	-1.20	-2.80	0.80	$a_i(z/D)+b_i$
		b_i	-2.00	1.20	1.60	0.20	
	Inner bottom and Lower stool	a_i	-0.50	-1.90	0.00	0.30	$a_i(\lvert y\rvert/B)+b_i$
		b_i	-0.05	0.60	0.00	0.85	
	Inner hull below D/2	a_i	8.20	-2.80	0.00	0.20	$a_i(z/D)+b_i$
		b_i	-3.50	1.00	0.00	0.90	
	Inner hull above D/2	a_i	0.60	2.80	0.00	-0.50	$a_i(z/D)+b_i$
		b_i	0.30	-1.80	0.00	1.25	
	Deck and Upper stool	a_i	0.00	0.70	0.00	0.00	$a_i(\lvert y\rvert/B)+b_i$
		b_i	1.00	0.00	0.00	0.00	
	Inner longitudinal bulkhead Below D/2	a_i	-1.20	2.00	0.00	0.00	$a_i(z/D)+b_i$
		b_i	1.10	0.00	0.00	0.00	
	Inner longitudinal bulkhead Above D/2	a_i	1.50	-2.70	0.00	0.00	$a_i(z/D)+b_i$
		b_i	-0.25	2.35	0.00	0.00	
	Centreline longitudinal bulkhead Below D/2	a_i	0.00	0.00	0.00	0.00	$a_i(z/D)+b_i$
		b_i	1.00	0.00	0.00	0.00	$a_i(z/D)+b_i$
	Centreline longitudinal bulkhead Above D/2	a_i	0.00	0.00	0.00	0.00	$a_i(z/D)+b_i$
		b_i	1.00	0.00	0.00	0.00	$a_i(z/D)+b_i$
Loaded	Bottom shell	a_i	-2.20	1.50	2.60	0.00	$a_i(\lvert y\rvert/B)+b_i$
		b_i	1.20	-0.15	-0.30	0.00	
	Side shell and bilge below D/2	a_i	-1.20	-1.20	0.60	0.00	$a_i(z/D)+b_i$
		b_i	0.30	0.80	0.70	0.00	
	Side shell above D/2	a_i	3.00	-0.30	-0.50	0.00	$a_i(z/D)+b_i$
		b_i	-1.80	0.35	1.25	0.00	
	Inner bottom and Lower stool	a_i	-1.00	2.30	0.00	-0.20	$a_i(\lvert y\rvert/B)+b_i$
		b_i	1.00	-0.10	0.00	0.00	
	Inner hull below D/2	a_i	-0.80	1.00	0.00	1.00	$a_i(z/D)+b_i$
		b_i	0.20	0.00	0.00	0.50	
	Inner hull above D/2	a_i	3.20	-1.00	0.00	-0.80	$a_i(z/D)+b_i$
		b_i	-1.80	1.00	0.00	1.40	
	Deck and Upper stool	a_i	-0.10	1.50	0.00	0.00	$a_i(\lvert y\rvert/B)+b_i$
		b_i	1.00	-0.15	0.00	0.00	
	Inner longitudinal bulkhead Below D/2	a_i	-0.80	0.30	0.00	1.00	$a_i(z/D)+b_i$
		b_i	1.00	0.50	0.00	0.30	
	Inner longitudinal bulkhead Above D/2	a_i	0.20	-0.90	0.00	-0.08	$a_i(z/D)+b_i$
		b_i	0.50	1.10	0.00	0.84	
	Centreline longitudinal bulkhead Below D/2	a_i	-1.10	0.00	0.00	0.44	$a_i(z/D)+b_i$
		b_i	0.60	0.00	0.00	0.80	$a_i(z/D)+b_i$
	Centreline longitudinal bulkhead Above D/2	a_i	1.30	0.00	0.00	-0.56	$a_i(z/D)+b_i$
		b_i	-0.60	0.00	0.00	1.30	$a_i(z/D)+b_i$

Table C.1.5
Stress Range Combination Factors for Zone F

	Stiffener location		f_1	f_2	f_3	f_4	f_i
Ballast	Bottom shell	a_i	-0.90	1.00	2.40	-1.20	a_i (|y|/B) + b_i
		b_i	0.85	-0.10	-1.00	1.10	
	Side shell and bilge below D/2	a_i	-0.60	-0.40	1.00	-1.80	a_i (z/D) + b_i
		b_i	0.00	0.50	-0.15	0.90	
	Side shell above D/2	a_i	0.60	-0.90	-2.70	3.00	a_i (z/D) + b_i
		b_i	-0.60	0.75	1.70	-1.50	
	Inner bottom and Lower stool	a_i	-0.30	-1.00	0.00	0.00	a_i (|y|/B) + b_i
		b_i	0.90	0.25	0.00	1.00	
	Inner hull below D/2	a_i	-12.00	-2.40	0.00	1.20	a_i (z/D) + b_i
		b_i	5.00	1.00	0.00	0.50	
	Inner hull above D/2	a_i	3.00	1.40	0.00	-0.90	a_i (z/D) + b_i
		b_i	-2.50	-0.90	0.00	1.55	
	Deck and Upper stool	a_i	0.00	1.00	0.00	0.00	a_i (|y|/B) + b_i
		b_i	1.00	-0.10	0.00	0.00	
	Inner longitudinal bulkhead Below D/2	a_i	-1.80	1.90	0.00	0.00	a_i (z/D) + b_i
		b_i	1.30	0.00	0.00	0.00	
	Inner longitudinal bulkhead Above D/2	a_i	1.80	-2.50	0.00	0.00	a_i (z/D) + b_i
		b_i	-0.50	2.20	0.00	0.00	
	Centreline longitudinal bulkhead Below D/2	a_i	0.00	0.00	0.00	0.00	a_i (z/D) + b_i
		b_i	1.00	0.00	0.00	0.00	a_i (z/D) + b_i
	Centreline longitudinal bulkhead Above D/2	a_i	0.00	0.00	0.00	0.00	a_i (z/D) + b_i
		b_i	1.00	0.00	0.00	0.00	a_i (z/D) + b_i
Loaded	Bottom shell	a_i	-0.60	-0.15	0.00	0.00	a_i (|y|/B) + b_i
		b_i	-0.45	0.05	1.00	0.00	
	Side shell and bilge below D/2	a_i	-1.20	0.18	0.00	0.00	a_i (z/D) + b_i
		b_i	0.00	-0.03	1.00	0.00	
	Side shell above D/2	a_i	4.00	0.02	0.00	0.00	a_i (z/D) + b_i
		b_i	-2.60	0.05	1.00	0.00	
	Inner bottom and Lower stool	a_i	2.80	2.20	0.00	-1.00	a_i (|y|/B) + b_i
		b_i	-0.80	-0.30	0.00	1.10	
	Inner hull below D/2	a_i	10.20	1.60	0.00	0.00	a_i (z/D) + b_i
		b_i	-4.50	-0.60	0.00	1.00	
	Inner hull above D/2	a_i	-0.80	-0.90	0.00	0.00	a_i (z/D) + b_i
		b_i	1.00	0.65	0.00	1.00	
	Deck and Upper stool	a_i	-0.24	1.80	0.00	0.00	a_i (|y|/B) + b_i
		b_i	1.00	0.00	0.00	0.00	
	Inner longitudinal bulkhead Below D/2	a_i	-2.10	-1.00	0.00	1.50	a_i (z/D) + b_i
		b_i	1.15	0.60	0.00	0.35	
	Inner longitudinal bulkhead Above D/2	a_i	0.40	-0.30	0.00	-0.40	a_i (z/D) + b_i
		b_i	-0.10	0.25	0.00	1.30	
	Centreline longitudinal bulkhead Below D/2	a_i	-0.60	0.00	0.00	0.00	a_i (z/D) + b_i
		b_i	0.25	0.00	0.00	1.00	a_i (z/D) + b_i
	Centreline longitudinal bulkhead Above D/2	a_i	0.20	0.00	0.00	0.00	a_i (z/D) + b_i
		b_i	-0.15	0.00	0.00	1.00	a_i (z/D) + b_i

1.4.5 Selection of S-N curves

1.4.5.1 The capacity of welded steel joints with respect to fatigue strength is characterized by S-N curves which give the relationship between the stress ranges applied to a given detail and the number of constant amplitude load cycles to failure.

1.4.5.2 For ship structural details, S-N curves are represented by:

$$S^m N = K_2$$

Where:

S stress range, in N/mm², as defined in *1.4.4.19*

N predicted number of cycles to failure under stress range S

m constant depending on material and weld type, type of loading, geometrical configuration and environmental conditions (air or sea water), as defined in *1.4.5.5*.

K_2 constant depending on material and weld type, type of loading, geometrical configuration and environmental conditions (air or sea water), as defined in *1.4.5.5*.

1.4.5.3 Experimental S-N curves are defined by their mean fatigue life and standard deviation. The mean S-N curve gives the stress level S at which the structural detail will fail with a probability level of 50 percent after N loading cycles. S-N curves considered in the present Rules are based upon a statistical analysis of appropriate experimental data and represent two standard deviations below the mean lines.

1.4.5.4 Unless direct experimental measurements are available, the S-N curves described in *1.4.5.5* to *1.4.5.16* are to be used for assessment of the fatigue strength of structural details.

1.4.5.5 As shown in *Figure C.1.9*, the basic design curves consist of linear relationships between log(S) and log(N), which are to be expressed as follows. The S-N curves have a change of inverse slope from m to $m + 2$ at $N = 10^7$ cycles (which corresponds to stress range S_q).

$$\log(N) = \log(K_2) - m\log(S)$$

Where:

$\log(K_2)$ $= \log(K_1) - 2\delta$

N predicted number of cycles to failure under stress range S

K_1 constant relating to the mean S-N curve, as given in *Table C.1.6*

δ standard deviation of log(N)

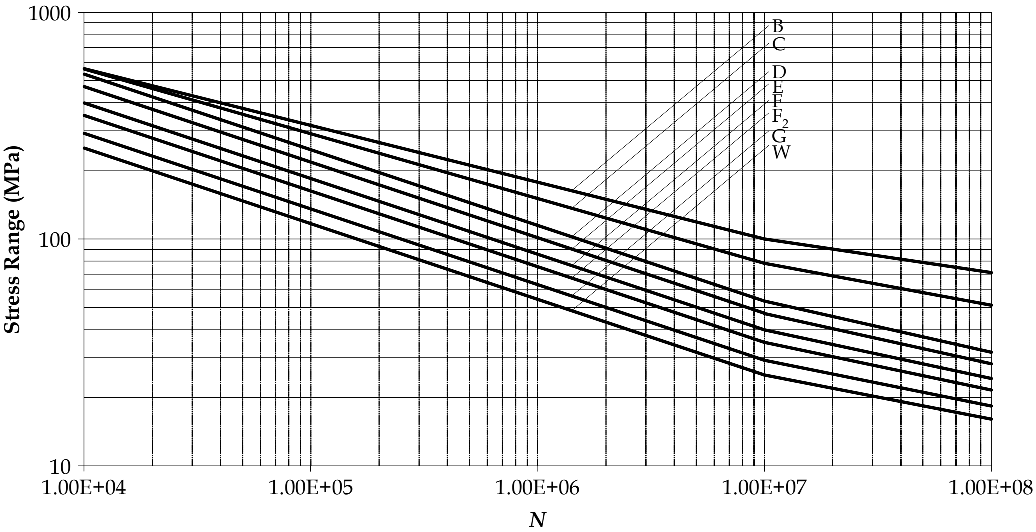
m inverse slope of the S-N curve, as given in *Table C.1.6*

S_q Stress range corresponding to 10^7 cycles of the S-N curve, in N/mm², as given in *Table C.1.6*

Table C.1.6
Basic S-N Curve Data, In-Air

Class	K_1			*m*	*Standard Deviation*		K_2	S_q N/mm²
		log_{10}	log_e		Log_{10}	log_e		
B	2.343 E15	15.3697	35.3900	4.0	0.1821	0.4194	1.01E15	100.2
C	1.082 E14	14.0342	32.3153	3.5	0.2041	0.4700	4.23E13	78.2
D	3.988 E12	12.6007	29.0144	3.0	0.2095	0.4824	1.52E12	53.4
E	3.289 E12	12.5169	28.8216	3.0	0.2509	0.5777	1.04E12	47.0
F	1.726 E12	12.2370	28.1770	3.0	0.2183	0.5027	0.63E12	39.8
F_2	1.231 E12	12.0900	27.8387	3.0	0.2279	0.5248	0.43E12	35.0
G	0.566E12	11.7525	27.0614	3.0	0.1793	0.4129	0.25E12	29.2
W	0.368 E12	11.5662	26.6324	3.0	0.1846	0.4251	0.16E12	25.2

Figure C.1.9
Basic design S-N curves, In-Air



1.4.5.6 The class of S-N curve selected for determination of the cumulative fatigue damage, *DM*, is to be consistent with the fatigue assessment methods used and the type of detail to be analyzed.

1.4.5.7 Experimental S-N curves give the relationship between the nominal stress range and the number of cycles to failure. Therefore, when using these S-N curves, the calculated stresses are to correspond to the nominal stresses used in creating these curves.

1.4.5.8 The basic S-N curves to be used in this Appendix for fatigue assessment of longitudinal stiffener end connections are given in *1.4.5.5*, with the S-N curve parameters given in *Table C.1.6*.

1.4.5.9 Generally, adjustments to the S-N curves to take into account the following can be made:

a) effect of mean stresses
b) effect of plate thickness
c) weld improvement
d) influence of the environment.

1.4.5.10 The stress range may be reduced depending on whether the mean stress is tensile or compressive. In the event that it can be demonstrated that a compressive stress exists and can be quantified, the effect of mean stress may be considered by assuming a stress range equal to the tensile component plus 60% of the compressive component. The actual still water bending moment (SWBM) and the applicable static sea and tank pressures for the full load condition or ballast condition as appropriate are to be used in determining the mean stress level.

1.4.5.11 The total stress range considering the mean stress effect is to be taken as follows:

$S_{Ri} = \sigma_{tensile} - 0.6\,\sigma_{compressive}$ if $\sigma_{compressive} < 0$ and $\sigma_{tensile} > 0$

$S_{Ri} = S$ if $\sigma_{compressive} \geq 0$

$S_{Ri} = 0.6S$ if $\sigma_{tensile} \leq 0$

Where:

$\sigma_{tensile}$ mean stress plus half stress range, in N/mm²
$= \sigma_{mean} + S/2$

$\sigma_{compressive}$ mean stress minus half stress range, in N/mm²
$= \sigma_{mean} - S/2$

σ_{mean} mean stress due to static load components in the full load condition or ballast condition as appropriate, in N/mm², see *1.3.2*

For the nominal stress approach, S and σ_{mean} are to be calculated as follows:

S total combined stress range, in N/mm², as defined in *1.4.4.19*
$= \sigma_{tensile} - \sigma_{compressive}$

σ_{mean} $= \sigma_{hg} + \sigma_{ex} + \sigma_{in}$

σ_{hg} mean stress due to hull girder bending, to be derived using σ_v from *1.4.4.6* with $M_{wv\text{-}v\text{-}amp}$ taken as the actual SWBM for the full load condition or ballast condition as appropriate, see *1.3.2*.

σ_{ex} mean local bending stress due to external static sea pressure, if applicable. σ_{ex} is to be derived using σ_{2A} from *1.4.4.11* with P calculated based on the actual draught for the full load condition or ballast condition as appropriate, see *1.3.2*, where $P = P_{hys}$, see *Section 7/2.2.2.1*.

σ_{in} mean local bending stress due to internal static tank pressure, if applicable. σ_{in} is to be derived using σ_{2A} from *1.4.4.11* with P calculated based on the head to the top of tank and the tank contents for the full load condition or ballast condition as appropriate, see *1.3.2*, where $P = P_{in\text{-}tk}$, see *Section 7/2.2.3.1*.

Notes

1 P is to be taken as negative when the pressure is acting on the plate side and positive when acting on the stiffener side. This gives compressive stress with a negative sign

2 Where the stiffener is on the boundary between two cargo tanks, then the mean stress is to be taken as the net stress acting on the stiffener.

3 It is to be assumed that water ballast and cargo tanks are 100% full. The fluid density is to be taken in accordance with *Section 7/2.2.3.1*, where cargo density is not to be less than 0.9 tonnes/m³

For the hot spot stress approach in *Sub Section 2*, the mean stress, σ_{mean}, is to be calculated by applying the applicable static loads to the FE model for the full load condition or ballast condition as appropriate. Alternatively, in lieu of applying the static loads to the FE model, the total stress range is to be calculated in accordance with *2.4.2.8*.

RCN 2 to July 2008 version (effective from 1 July 2010)

1.4.5.12 The fatigue performance of a structural detail depends on member thickness. For the same stress range the joint's fatigue resistance may decrease as the member thickness increases. This effect (also called the 'scale effect') is caused by the local geometry of the weld toe in relation to the thickness of the adjoining plates and the stress gradient over the thickness. The basic design S-N curves are applicable to thicknesses that do not exceed the reference thickness of 22mm. For members with thickness greater than 22mm, the S-N curve for a joint member, with net thickness, t_{net50}, in mm, is to be taken as:

$$\log(N) = \log(K_2) - m\log\left(\frac{S_{Ri}}{(22/t_{net50})^{0.25}}\right)$$

Where:

$\log(K_2)$ $= \log(K_1) - 2\delta$

N the predicted number of cycles to failure under stress range S

K_1 constant relating to the mean S-N curve, as given in *Table C.1.6*

δ standard deviation of $\log(N)$

m inverse slope of the S-N curve, as given in *Table C.1.6*

S_{Ri} stress range, as defined in *1.4.5.11*, in N/mm²

1.4.5.13 Where the longitudinal stiffeners are flat bars or bulb plates, the thickness effect described in *1.4.5.12* is not applicable.

1.4.5.14 The benefits of weld toe grinding should not be taken into consideration at the design stage. However, an exception may be made for the weld connection between the hopper plate and inner bottom if the calculated fatigue life is greater than one half of the design fatigue life or minimum 17 years excluding the grinding effects, whichever is greater. Where grinding is applied, full details of the grinding standard including the extent, smoothness particulars, final weld profile, and grinding workmanship and quality acceptance criteria are to be clearly shown on the applicable drawings and submitted for review together with supporting calculations indicating the proposed factor on the calculated fatigue life. Grinding is preferably to be carried out by rotary burr and to extend below the plate surface in order to remove toe defects and the ground area is to have effective corrosion protection. The treatment is to produce a smooth concave profile at the weld toe with the depth of the depression penetrating into the plate surface to at least 0.5mm below the bottom of any visible undercut. The depth of groove produced is to be kept to a minimum, and, in general, kept to a maximum of 1mm. In no circumstances is the grinding depth to exceed 2mm or 7% of the plate gross thickness, whichever is smaller. Grinding has to extend to areas well outside the highest stress region. Provided these recommendations are followed, an improvement in fatigue life up to the design fatigue life will be granted.

RCN 1 to July 2008 version (effective from 1 February 2010)

1.4.5.15 The basic design S-N curves, as shown in *Figure C.1.9*, are valid for joints located in air or details exposed to sea water but adequately protected from corrosion by effective coating. For unprotected joints in sea water, the basic S-N curves are to be reduced by a factor of 2 on fatigue life.

1.4.5.16 The basic design S-N curves, as shown in *Figure C.1.9*, are used in this Appendix. To account for the fact that the joint will spend part of the time in a protected environment and part of time in an unprotected environment, a factor f_{SN}, has been introduced into the total nominal stress range calculation.

1.5 Classification of Structural Details

1.5.1 General

1.5.1.1 The joint classification of structural details is to be made using *Table C.1.7* where the design of soft toes and backing brackets corresponds to those shown in *Figure C.1.10*. When alternative designs are proposed, the adequacy in terms of fatigue strength is to be demonstrated using a suitable finite element analysis. See *2.1.1.3*.

1.5.1.2 Where the primary support member web stiffeners are omitted or not connected to the longitudinals in way of bottom, side and inner hull, see Note 6 of *Table C.1.7*.

Table C.1.7
Classification of Structural Details

Notes

1. Where the attachment length is less than or equal to 150mm, the S-N curve may be upgraded one class from those specified in the table. For example, if the class shown in the table is F2, upgrade to F. Attachment length is defined as the length of the weld attachment on the longitudinal stiffener face plate without deduction of scallop.
2. Where the longitudinal stiffener is a flat bar and there is a stiffener/bracket welded to the face, the S-N curve is to be downgraded by one class from those specified in the table. For example, if the class shown in the table is F, downgrade to F2; if the class shown in the table is F2, downgrade to G. This also applies to unsymmetrical profiles where there is less than 8mm clearance between the edge of the stiffener flange and the face of the attachment, e.g. bulb or angle profiles where the stated clearance cannot be achieved.
3. Lapped connections (attachments welded to the web of the longitudinals) should not be adopted and therefore these are not covered by the table.
4. For connections fitted with a soft heel, class F may be used if it is predominantly subjected to axial loading. Stiffeners fitted on deck and within 0.1D below deck at side are considered to satisfy this condition.
5. For connections fitted with a collar around the face plate (i.e., connection type ID25 through 30) or full collar (i.e., connection type ID31), class F may be used if subjected to axial loading. Stiffeners fitted on deck and within 0.1D below deck at side are considered to satisfy this condition
6. ID31 and 32 show details where web stiffeners are omitted or are not connected to the longitudinal stiffener face plate. A full collar (i.e. connection type ID31) or alternatively a detail design for cut-outs as shown in Figure C.1.11 or equivalent is required in way of:
   - Side below the highest point of the wave wetted zone or below 0.1D from the deck at side, whichever is lower.
   - Bottom
   - Inner hull longitudinal bulkhead below 0.1D from the deck at side
   - Hopper
   - Inner bottom

   The highest point of the wave wetted zone is defined as the full load draft plus h_{WL} as shown in Fig. C.1.1. Equivalence to Figure C.1.11 is to be demonstrated through a satisfactory fatigue assessment by using comparative FEM based hot spot stress of the cut-out in the primary support member and the collar.
7. For connection type ID32 having no collar welded to the face plate, class F is to be used in way of longitudinals in the strength deck irrespective of slot configuration. In other areas class E may be used irrespective of slot configuration.

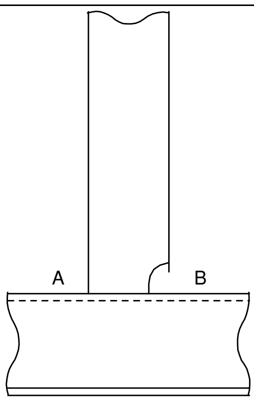
ID	Connection type	Critical Locations Notes (1), (2), (3)	
		A	B
1		F2	F2

Table C.1.7 (Continued)
Classification of Structural Details

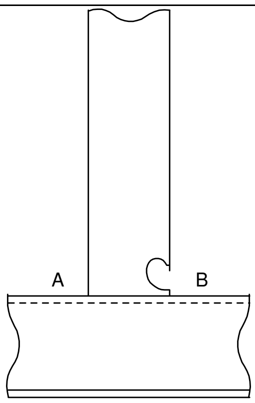
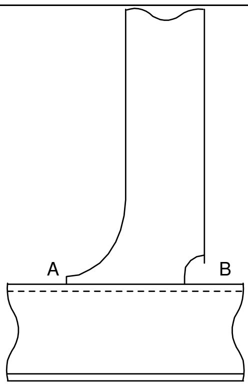
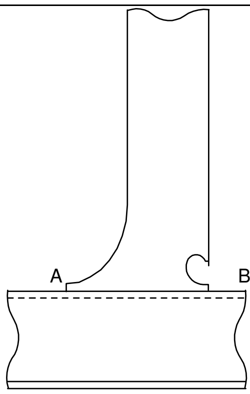
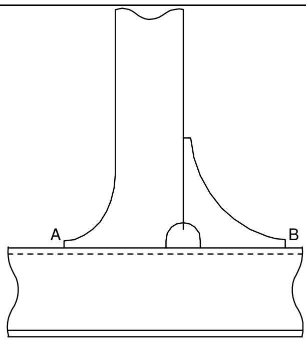
ID	Connection type	Critical Locations Notes (1), (2), (3)	
		A	B
2		F2	F2(4)
3		F	F2
4		F	F2(4)
5		F	F

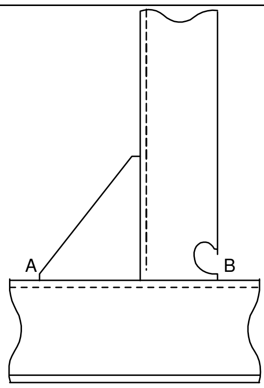
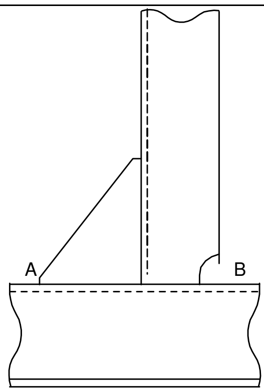
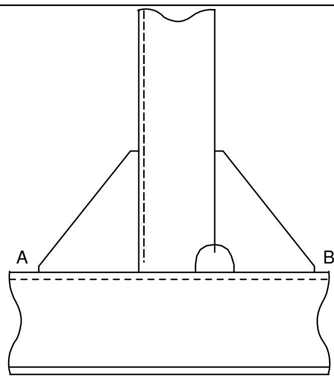
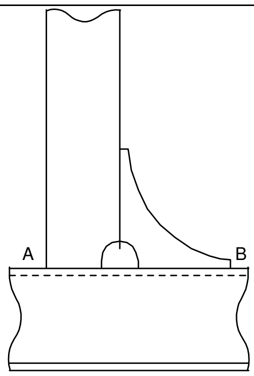
Table C.1.7 (Continued) Classification of Structural Details			
ID	**Connection type**	**Critical Locations Notes (1), (2), (3)**	
		A	**B**
6		F2	F2(4)
7		F2	F2
8		F2	F2
9		F2	F

**Table C.1.7 (Continued)
Classification of Structural Details**

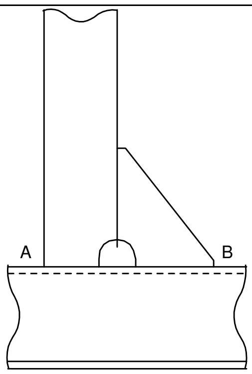
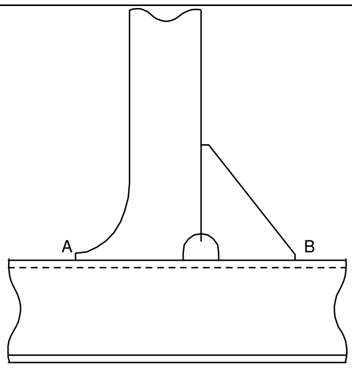
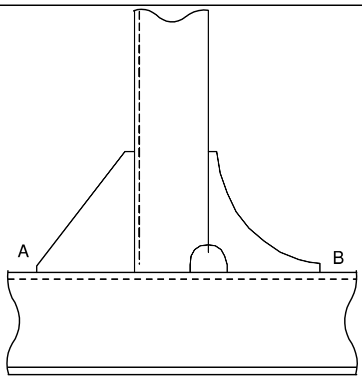
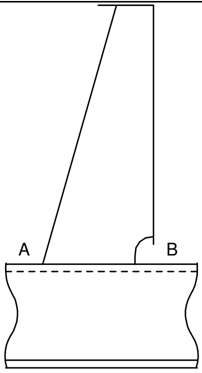
ID	Connection type	Critical Locations Notes (1), (2), (3)	
		A	B
10		F2	F2
11		F	F2
12		F2	F
13		F2	F2

Table C.1.7 (Continued)
Classification of Structural Details

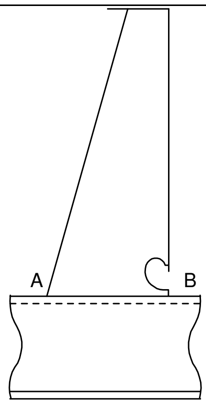
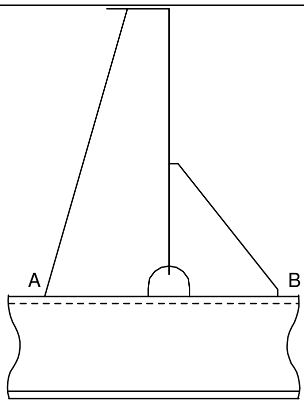
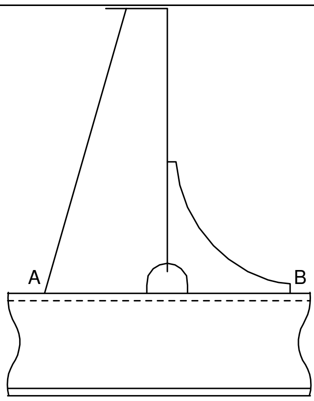
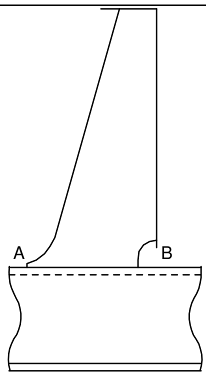
ID	Connection type	Critical Locations Notes (1), (2), (3)	
		A	B
14		F2	F2(4)
15		F2	F2
16		F2	F
17		F	F2

Table C.1.7 (Continued)
Classification of Structural Details

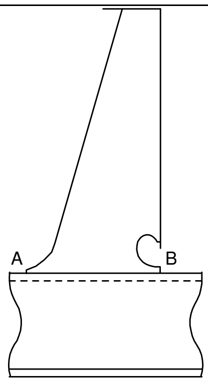
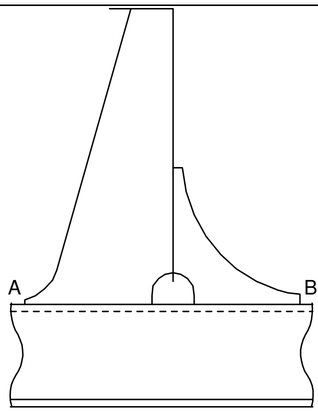
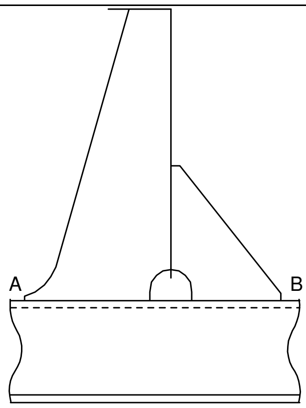
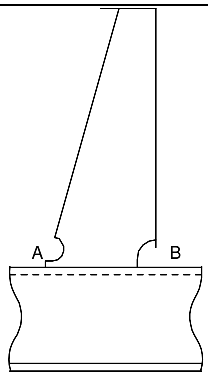
ID	Connection type	Critical Locations Notes (1), (2), (3)	
		A	B
18		F	F2(4)
19		F	F
20		F	F2
21		F	F2

Table C.1.7 (Continued)
Classification of Structural Details

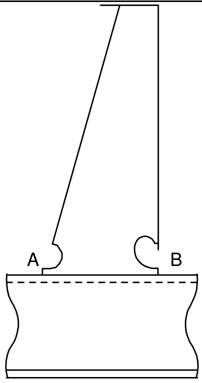
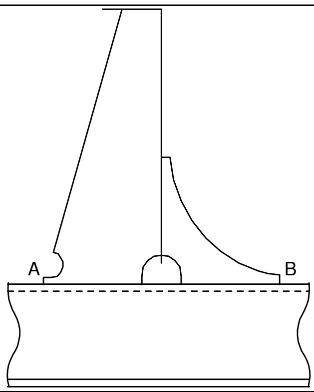
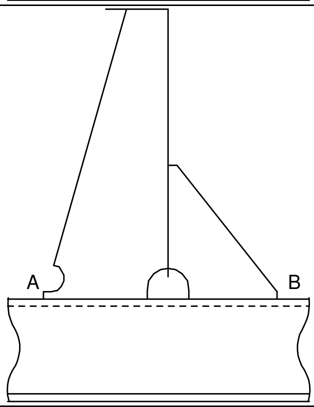
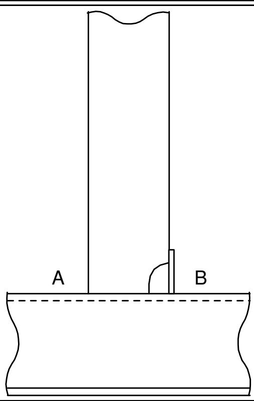
ID	Connection type	Critical Locations Notes (1), (2), (3)	
		A	B
22		F	F2(4)
23		F	F
24		F	F2
25		F2	F2(5 only)

Table C.1.7 (Continued)
Classification of Structural Details

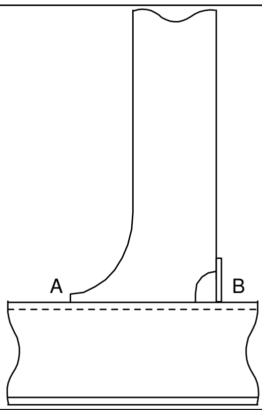
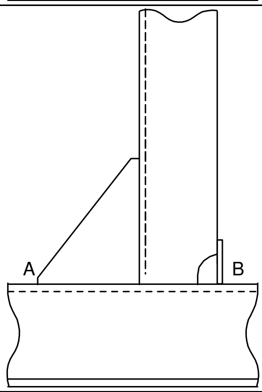
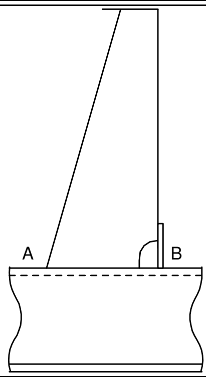
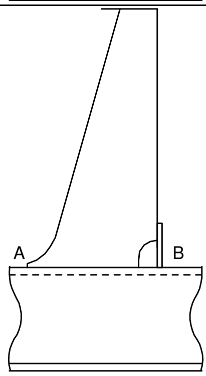
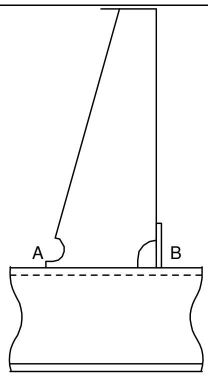
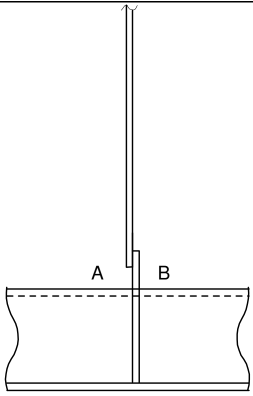
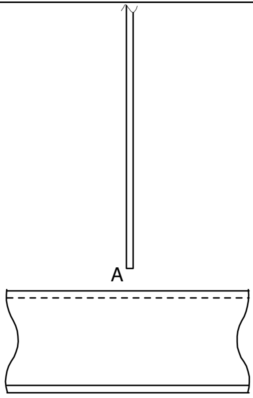
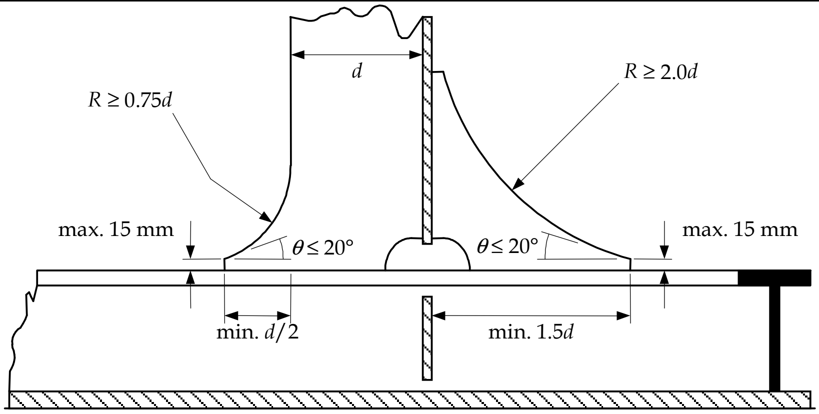
ID	Connection type	Critical Locations Notes (1), (2), (3)	
		A	B
26		F	F2(5 only)
27		F2	F2(5 only)
28		F2	F2(5 only)
29		F	F2(5 only)

Table C.1.7 (Continued)
Classification of Structural Details

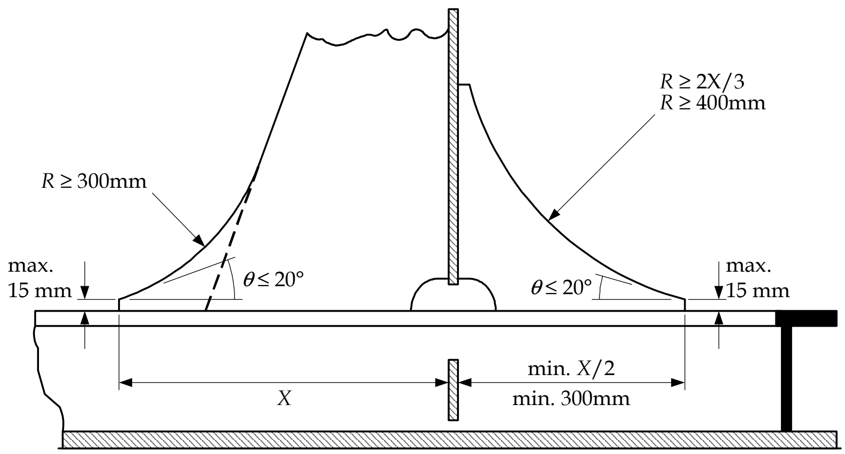
ID	Connection type	Critical Locations Notes (1), (2), (3)	
		A	**B**
30		F	F2(5 only)
31		F2(5, 6 only)	F2(5, 6 only)
32		F(6, 7 only)	N/A

(RCN 2, effective from 1 July 2008)

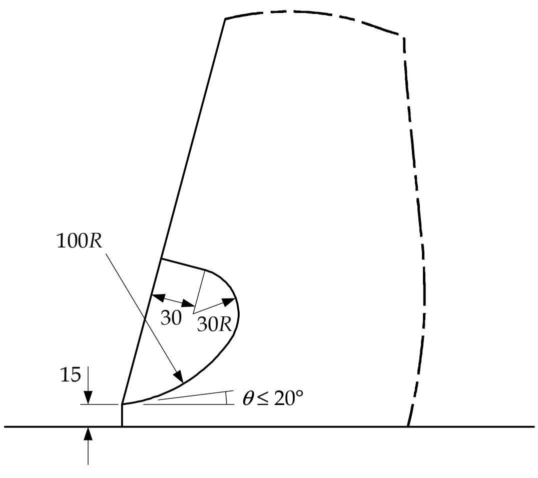
Figure C.1.10
Detail Design for Soft Toes and Backing Brackets



Recommended Design of Soft Toes and Backing Bracket of Pillar Stiffeners



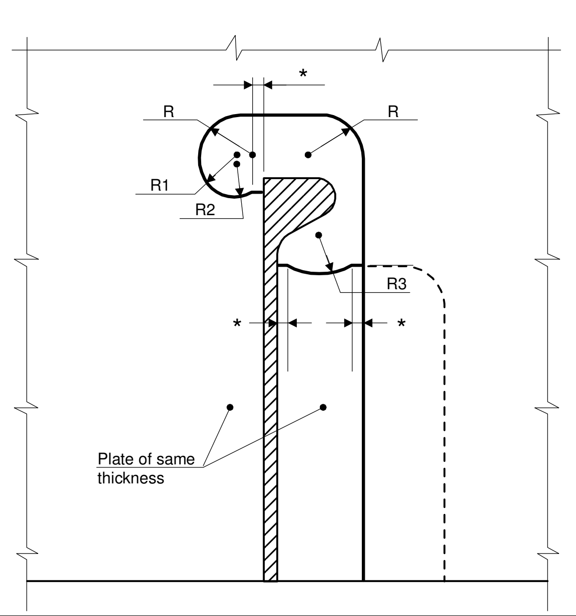
Recommended Design of Soft Toes and Backing Bracket of Tripping Brackets



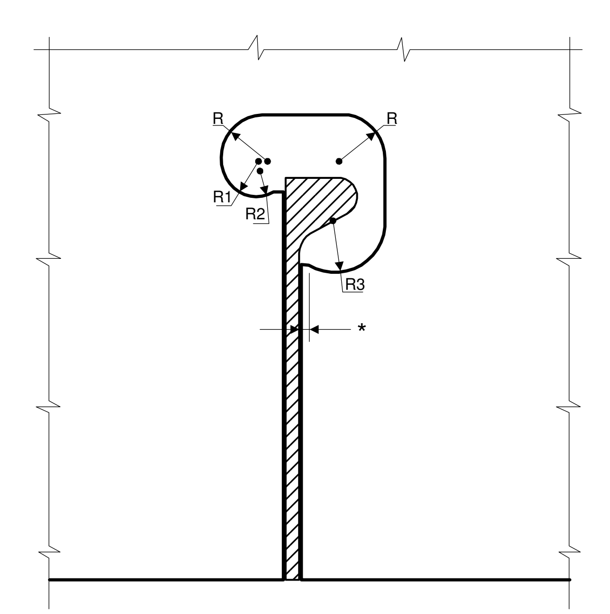
Recommended Alternative Design of Soft Toes of Tripping Brackets

Figure C.1.11
Design for Cut Outs in cases where Web Stiffeners are Omitted

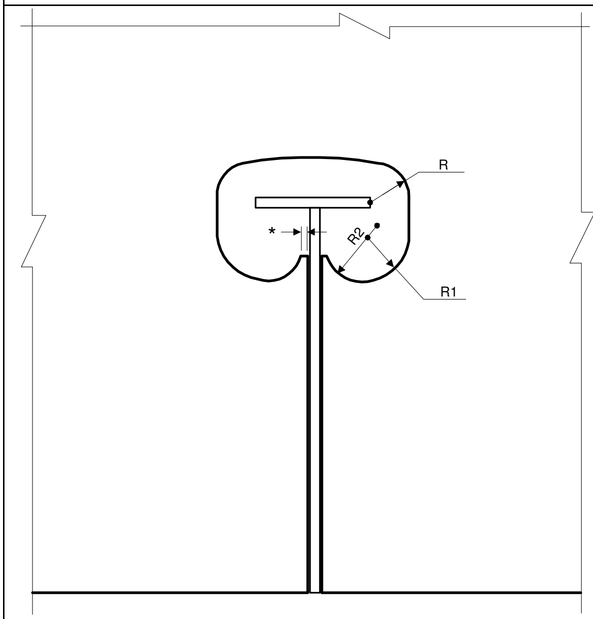
1



2



3



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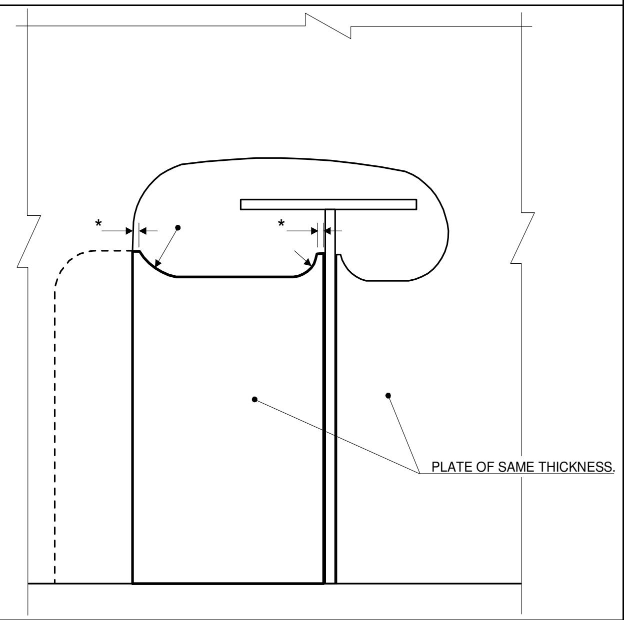


<u>Notes</u>

1. Soft toes marked "*" are to be dimensioned to suit the weld leg length such that smooth transition from the weld to the radiused part can be achieved. Max. 15 mm.
2. Configurations 1 and 4 indicate acceptable lapped lug plate connections, alternatively, butted lug plates with similar shape may be adopted.
3. Designs that are different than shown in the above sketches are acceptable subject to a satisfactory fatigue assessment by using comparative FEM based hot spot stress.

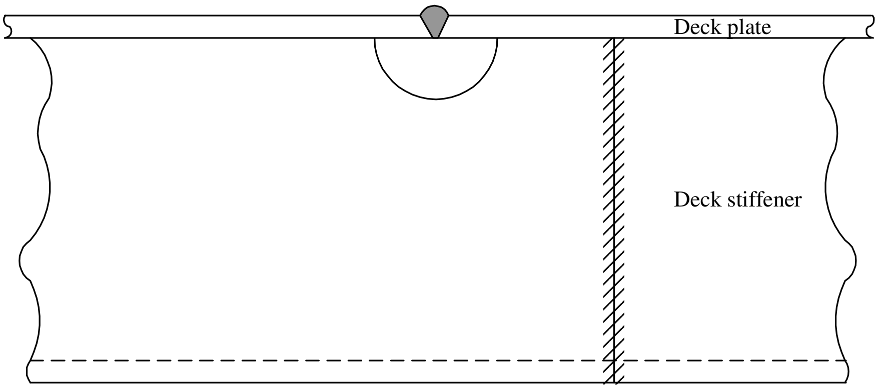
1.6 Other Details

1.6.1 Scallops in way of block joints

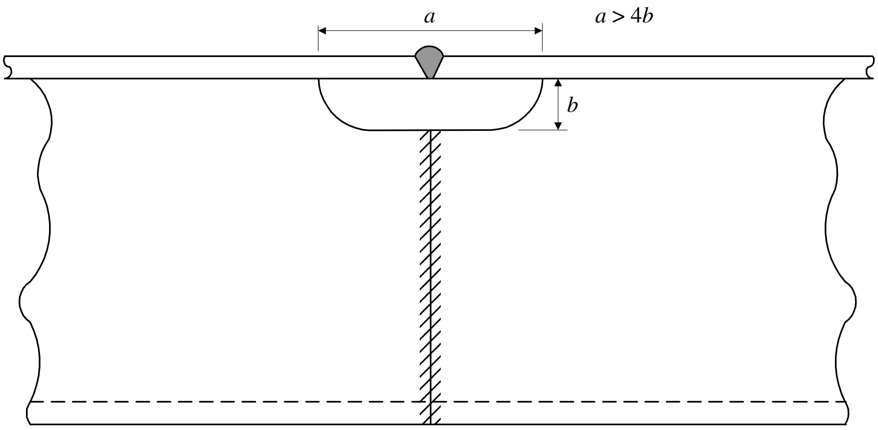
1.6.1.1 Scallops in way of block joints in the cargo tank region, located on the strength deck, and down to 0.1*D* from the deck at side are to be designed according to *Figure C.1.12* unless the specification in *Section 8/1.5.1.3* for class F2 is satisfied.

Figure C.1.12
Welding of Deck Stiffeners in way of Block Joints

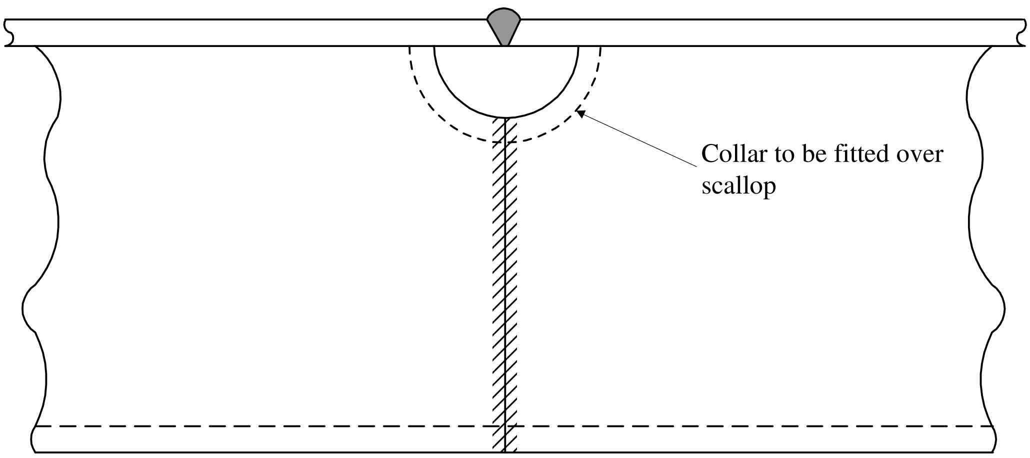
(I) Offset butt on stiffener



(II) Elongated scallop on stiffener



(III) Closing scallop with collar



Notes

Alternative scallop geometry to that shown in option II may be accepted subject to demonstration of satisfactory fatigue life based on hull girder loads taking into account additional stress concentration factor in way of weld, determined using fine mesh FEM and applying class D S-N curve.

2 HOT SPOT STRESS (FE BASED) APPROACH

2.1 General

2.1.1 Applicability

2.1.1.1 The procedure in this section applies to welded knuckles between inner bottom and hopper plate fatigue analysis using a finite element (FE) based hot spot stress approach. A similar application method as described in *Sub-Section 1* for the nominal stress approach is used except where indicated in the following sections.

2.1.1.2 Where the hopper knuckle between inner bottom and hopper plate is of the bent type, hot spot stress fatigue assessment is not a requirement provided the detail design standard described in *2.5.1.2* is followed. When alternative design is proposed, a suitable finite element (FE) analysis should be used to demonstrate the equivalency of the detail in terms of fatigue strength.

2.1.1.3 Where the hot spot stress approach is considered necessary for demonstration of the adequacy of longitudinal stiffener end connection in lieu of the nominal stress approach, the procedure described in *Sub-Section 1* is generally to be followed with the exception that S_v, S_h, S_i, and S_e are to be determined directly from the finite element analysis using the surface hot spot stress component perpendicular to the weld obtained by linear extrapolation to the centre-line of the attachment, and then to the weld toe position. The S-N curve according to *2.4.3* is applicable.

2.1.2 Assumptions

2.1.2.1 The assumptions made are given in *1.1.2*.

2.2 Corrosion Model

2.2.1 Net thickness

2.2.1.1 The net thickness and corrosion additions given in *Section 6/3* are to be incorporated into the representation of the FE structural capacity models as described in *Appendix B/4*.

2.3 Loads

2.3.1 General

2.3.1.1 Dynamic wave and tank pressures are to be considered for the FE based fatigue analysis of knuckles between inner bottom and hopper plates, see *1.3.6* and *1.3.7*.

2.4 Fatigue Damage Calculation

2.4.1 Fatigue strength determination

2.4.1.1 The procedure outlined in *1.4* is to be applied.

2.4.1.2 The Weibull probability distribution parameter applicable to welded knuckles between inner bottom and hopper plate, ξ, is to be taken as:

$$\xi = 1.1 - 0.35\frac{L-100}{300}$$

Where:

L rule length, in m, as defined in *Section 4/1.1.1.1*

2.4.2 Stresses to be used

2.4.2.1 To determine hot spot stresses, local 2D or 3D very fine mesh stress analyses, in conjunction with a 3D coarse mesh analysis are to be used. In highly stressed areas, in particular in the vicinity of structural discontinuities, the level of stresses depends on the size of elements because of the high stress gradient. If the stress field is more complex than a uniaxial field, the stresses adjacent to the potential crack location are to be used. A uniform mesh is to be used with smooth transition and avoidance of abrupt changes in mesh size.

2.4.2.2 The following defines a general basis for the modelling of local structures:

(a) hot spot stresses are to be calculated using an idealized welded joint with no misalignments. The finite element mesh is to be fine enough near the hot spot such that stresses and stress gradients can be determined with sufficient accuracy

(b) plating, webs and face plates of primary and secondary members are modelled by 4-node thin shell elements. In cases of steep stress gradients, 8-node thin shell elements are to be used.

(c) when thin shell elements are used, the structure is to be modelled at the mid face of the plates. For practical purposes, adjoining plates of different thickness may be assumed to be median line aligned, i.e., no staggering in way of thickness change is required.

(d) the aspect ratio of elements is not to be greater than three in the vicinity of the hot spot.

(e) the size of elements located in the vicinity of the hot spot is to be comparative to the net thickness of the structural member

(f) stresses are to be calculated at the surface of the plate with a view to taking into account the plate bending moment, where relevant.

2.4.2.3 A detailed description of hot spot stress calculation using finite element modelling is given by *Appendix B/4*.

2.4.2.4 Generally, the element stresses are derived at the Gaussian integration points. Depending on the element type, it may be necessary to perform several interpolations in order to determine the actual stress at the considered hot spot location.

2.4.2.5 For critical structural details, hot spot stresses are generally highly dependent on the finite element model used for representation of the structure. Alternative procedures to those described here, for the derivation of the hot spot stress, are to be confirmed or documented by reference to available fatigue test results for similar structural details.

2.4.2.6 The hot spot stress is defined as the surface stress at $0.5t$ away from the weld toe location, as shown in *Figure C.2.1*. The hot spot stress is to be obtained by linear interpolation in the ship's transverse direction using the respective stress at the 1st and 2nd element from the structure intersection.

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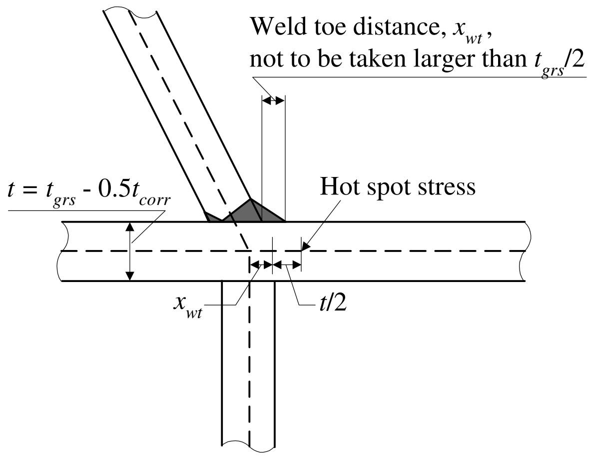
Figure C.2.1
Hot Spot Stress



2.4.2.7 Stress range components along the direction perpendicular to the weld, due to the loads defined in *2.3*, are to be calculated based on *Appendix B/4*. The total combined stress range, S, is to be taken as:

$S = f_{model}\left|0.85(S_{e1} + 0.25S_{e2}) - 0.3S_i\right|$ for full load condition

$S = f_{model}\left|0.85(S_{e1} - 0.2S_{e2})\right|$ for ballast load condition

Where:

S_{e1} stress range due to dynamic wave pressure applied to FE-model on the side where the hopper knuckle is to be investigated, in N/mm^2, see *Table B.4.1*

S_{e2} stress range due to dynamic wave pressure applied to FE-model on the side of the hull where the hopper knuckle is not analysed, in N/mm^2, see *Table B.4.1*

S_i stress range due to dynamic tank pressure applied to FE-model, in N/mm^2, see *Appendix B/4.5.2.4* and *Table B.4.1*

f_{model} 1.0 if the FE model is made according to net thickness for fatigue, i.e. using corrosion addition of 0.25t_{corr} for the FE model except in way of critical location (in way of a knuckle and within 500mm in all directions), which uses corrosion addition of 0.5t_{corr}

0.95 if the FE model for strength assessment is used. FE model for strength assessment applies a corrosion addition of 0.5t_{corr} for the whole model including structure in way of critical location

2.4.2.8 To account for the mean stress effect, in lieu of applying the static loads to the FE model, the total stress range may be taken as:

$S_{Ri} = 1.0S$ for full load condition

$S_{Ri} = 0.6S$ for ballast load condition

Where:

S total combined stress range, in N/mm², as defined in *2.4.2.7*

2.4.3 Selection of S-N curves

2.4.3.1 The fatigue analysis is to be carried out applying the Class D S-N curve for welded details if the hot spot stress is calculated according to *2.4.2.8*. The thickness effect according to *1.4.5.12* will be applicable.

2.5 Detail Design Standard

2.5.1 Hopper knuckles

2.5.1.1 Design details for the welded knuckle between hopper plating and inner bottom plating are to be as shown in *Figure C.2.2*.

Guidance Note:

Figure C.2.3 may be used as an option to increase fatigue strength at the hopper connection.

2.5.1.2 Design details for the bent knuckle between hopper plating and inner bottom plating are to be as shown in *Figure C.2.4*.

2.5.2 Transverse Bulkhead Horizontal Stringer Heel

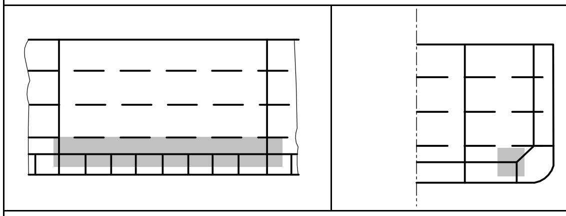
2.5.2.1 Detail design improvement given in *Figure C.2.5* is recommended for reducing the stress level and increasing fatigue strength at the horizontal stringer heel location between transverse oil-tight and wash bulkhead plating and inner hull longitudinal bulkhead plating. This recommendation should be considered in association with fine mesh FE analysis as required in *Appendix B/3.1.3.*

Figure C.2.2
Hopper Knuckle Connection Detail, Without Bracket

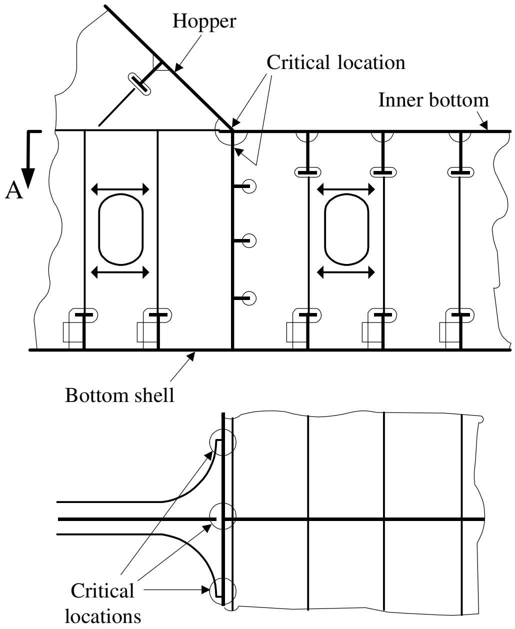
Connections of floors in double bottom tanks to hopper tanks

Hopper corner connections employing welded inner bottom and hopper sloping plating

CRITICAL AREAS

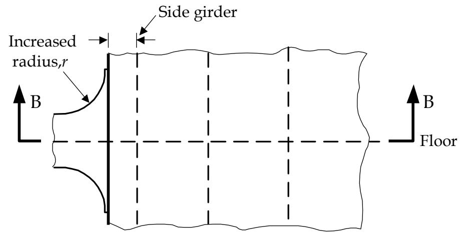


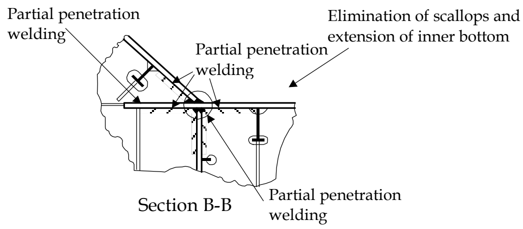
CRITICAL LOCATIONS



Section A-A

DETAIL DESIGN STANDARD A





Weld between hopper plating and inner bottom plating to be extended and ground smooth. Visible undercuts are to be removed. Weld extension and grinding to be applied 200 mm either side of the floor.

Note:

1. A root face with a maximum of 1/3 of the abutting plate thickness is acceptable for the partial penetration welding, see *Section 6/5.3.4*.
2. Grinding need not be applied in the No.1 tank in which floor spans are reduced due to shape.
3. Grinding need not be applied for the knuckle joints at transverse bulkhead positions, or at the floor adjacent to the transverse bulkhead.

Minimum Requirement	As a minimum, detail design standard A or B is to be fitted. Further consideration will be given where the hopper angle exceeds 50 degrees. The ground surface is to be protected by a stripe coat, of suitable paint composition, where the lower hopper knuckle region of cargo tanks is not coated.
Critical Location	Hopper sloping plating connections to inner bottom plating in way of floors. Floor connections to inner bottom plating and side girders in way of hopper corners.
Detail Design Standard	Elimination of scallops in way of hopper corners, extension of inner bottom plating to reduce level of resultant stresses arising from cyclic external hydrodynamic pressure, cargo inertia pressure and hull girder loads. Scarfing bracket thickness is to be close to that of the inner bottom in way of knuckle.
Building Tolerances	Median line of hopper sloping plate is to be in line with the median line of the girder with an allowable tolerance of t/3 or 5mm, whichever is less, where *t* is the inner bottom thickness. The allowable tolerance is to be measured parallel to the inner bottom.
Welding Requirements	Partial penetration welding (hopper sloping plating to inner bottom plating). Partial penetration weld (connection of floors to inner bottom plating and to side girders, connection of hopper transverse webs to sloping plating, to inner bottom plating, and to side girders in way of hopper corners).

(RCN 1, effective from 1 April 2007)

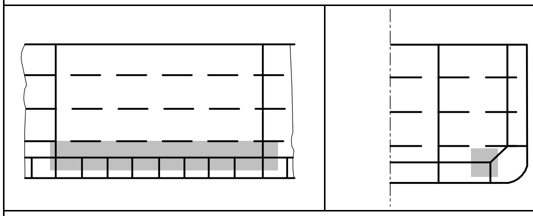
RCN 2 to July 2008 version (effective from 1 July 2010)

Figure C.2.3
Option: Hopper Knuckle Connection Detail, With Bracket

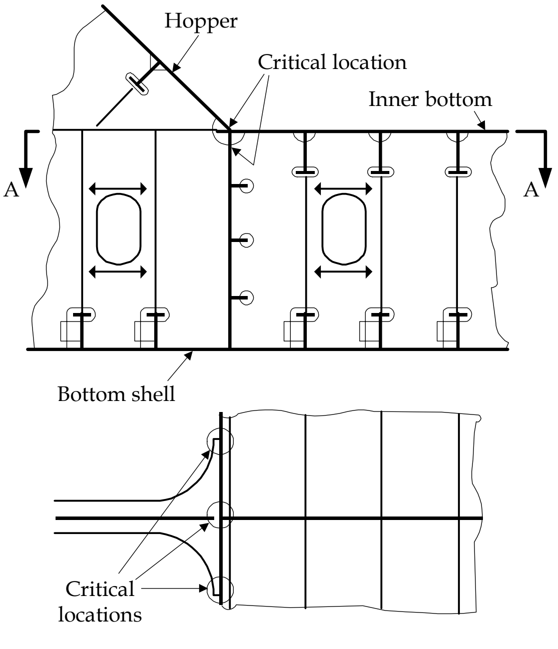
Connections of floors in double bottom tanks to hopper tanks

Hopper corner connections employing welded inner bottom and hopper sloping plating

CRITICAL AREAS

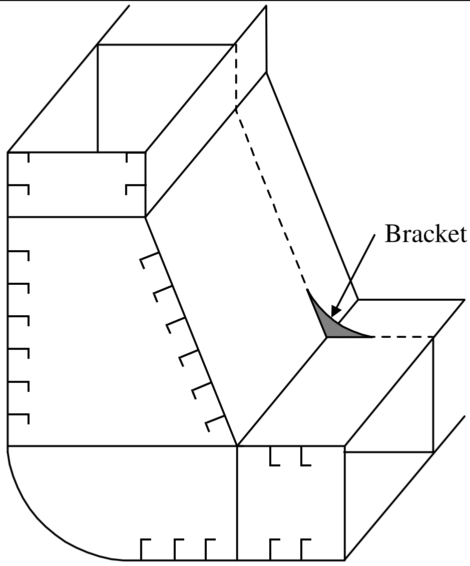


CRITICAL LOCATIONS



Section A-A

DETAIL DESIGN STANDARD B



Note:

1. Bracket to be fitted inside cargo tank
2. Bracket to extend approximately to the first longitudinal
3. The bracket toes are to have a soft nose design
4. Full penetration welding at bracket toes
5. Bracket material to be same as that of inner bottom
6. Buckling of bracket to be checked:

$$\frac{d}{t_{bkt}} < 21\sqrt{\frac{235}{\sigma_{yd}}}$$

where:

d = bracket max depth, as defined in *Table 10.2.3*

t_{bkt} = bracket thickness

σ_{yd} = specified minimum yield stress of material

Minimum Requirement	As a minimum, detail design standard A or B is to be fitted. Further consideration will be given where hopper angle exceeds 50 degrees.
Critical Location	Hopper sloping plating connections to inner bottom plating in way of floors. Floor connections to inner bottom plating and side girders in way of hopper corners.
Detail Design Standard	Elimination of scallops in way of hopper corners, extension of inner bottom plating to reduce level of resultant stresses arising from cyclic external hydrodynamic pressure, cargo inertia pressure and hull girder loads. Scarfing bracket thickness to be close to that of the inner bottom in way of knuckle.
Building Tolerances	Median line of hopper sloping plate is to be in line with the median line of girder with an allowable tolerance of t/3 or 5mm, whichever is less, where *t* is the inner bottom thickness.
Welding Requirements	Partial penetration welding (hopper sloping plating to inner bottom plating). Partial penetration weld (connection of floors to inner bottom plating and to side girders, connection of hopper transverse webs to sloping plating, to inner bottom plating, and to side girders in way of hopper corners).

(RCN 1, effective from 1 April 2007)

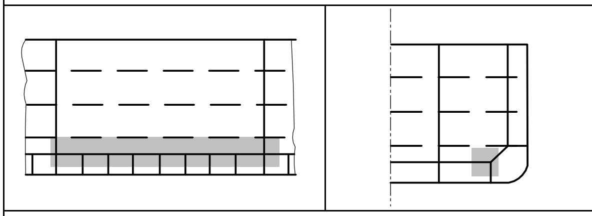
RCN 2 to July 2008 version (effective from 1 July 2010)

Figure C.2.4
Hopper Knuckle Connection Detail, Bent Type

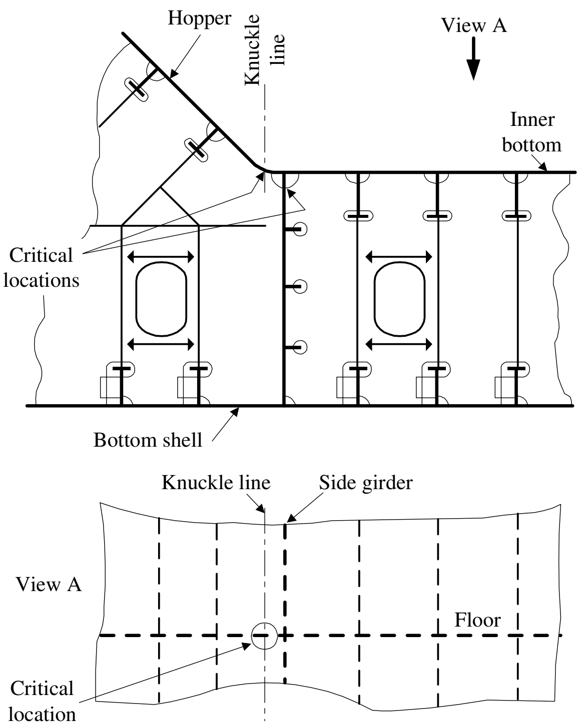
Connections of floors in double bottom tanks to hopper tanks

Hopper corner connections employing bent knuckle inner bottom and hopper sloping plating

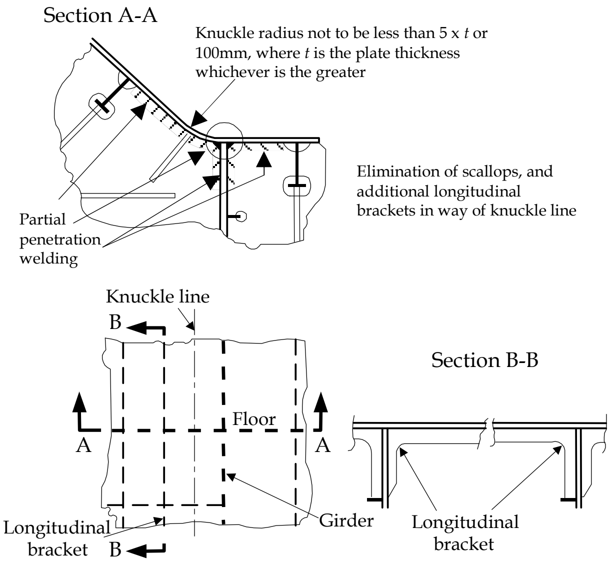
CRITICAL AREAS



CRITICAL LOCATIONS



DETAIL DESIGN STANDARD C



Note: Longitudinal brackets may be omitted if it can be demonstrated that the girder provides sufficient support at the knuckle line.

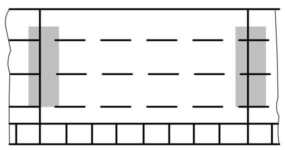
Minimum Requirement	As a minimum, the detail design standard C is to be fitted.
Critical Location	Side girder connections to inner bottom plating in way of floors. Floor and hopper transverse web connections to inner bottom plating and to side girders in way of hopper corners.
Detail Design Standard	Elimination of scallops in way of hopper corners and additional longitudinal brackets to reduce peak and range of resultant stresses arising from cyclic external hydrodynamic pressure, cargo inertia pressure, and hull girder global loading.
Building Tolerances	Enhanced alignment standard. The nominal distance between the centres of thickness of the two abutting members (e.g. floor and hopper web plate and additional supporting brackets) should not exceed 1/3 of the table member thickness.
Welding Requirements	Partial penetration welding with a maximum root face of 1/3 of the abutting plate thickness (Connection of side girders to inner bottom plating. Connection of floors to inner bottom plating and to side girders. Connection of hopper transverse webs to sloped inner bottom plating and to side girders in way of hopper corners).

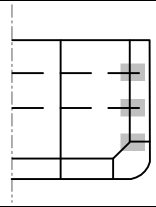
Figure C.2.5
Option: Transverse Bulkhead Horizontal Stringer Heel

Connections of horizontal girder in double side tanks to transverse bulkheads

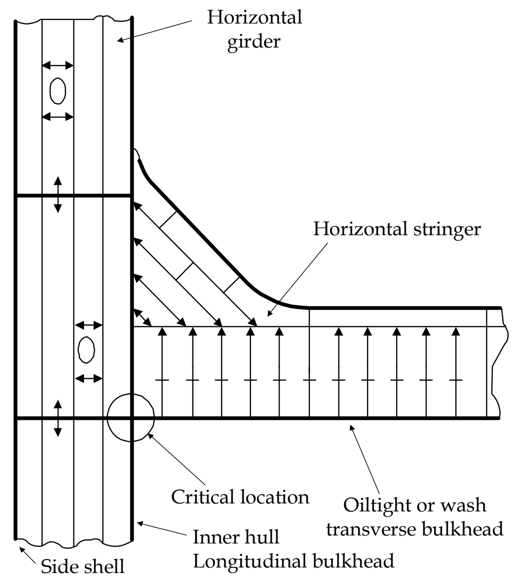
Connection of horizontal stringer on plane oiltight transverse or wash bulkheads to inner hull longitudinal bulkhead

CRITICAL AREAS

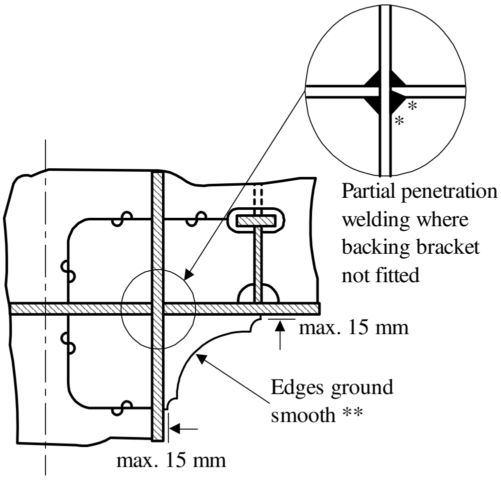




CRITICAL LOCATIONS



DETAIL DESIGN IMPROVEMENT



Note:

* Weld toe to be ground smooth, visible undercuts to be removed where brackets not fitted.

** Where a face plate is considered necessary, it is recommended that design features be adopted to reduce the stress concentration at the face plate termination (e.g., taper and soft nose).

Critical Location	Intersections of webs of transverse bulkhead horizontal stringer and double side tank horizontal girder forming square corners.
Detail Design Improvement	Elimination of scallops in way of cruciform joint and fitting a localized 'D' grade steel insert plate, with minimum thickness of 7 mm in addition to the Rule required thickness, to reduce the peak and range of resultant stresses arising from cyclic cargo inertia pressure and hull girder global loading. In addition, a soft toed backing bracket of suitable dimension is to be fitted. The following bracket sizes are recommended: • VLCC: 800x800x30 R600 with soft toe as shown in Figure • Suezmax and Aframax tankers: 800x600x25 R550 with soft toe as shown in Figure, where the longer arm length is in way of the inner skin. The actual bracket design is to be verified by fine mesh finite element analysis in accordance with *Appendix B/3.1.3.*
Building Tolerances	Enhanced alignment standard. The nominal distance between the centres of thickness of the two abutting members should not exceed 1/3 of the table member thickness.
Welding Requirements	Fillet welding having minimum weld factor of 0.44, where backing bracket is fitted or partial penetration welding where backing bracket is not fitted. The extent of partial penetration should be of the order of longitudinal spacing. A small scallop of suitable shape, which is to be closed by welding after completion of the continuous welding of bulkhead, should be provided where scallop is eliminated.

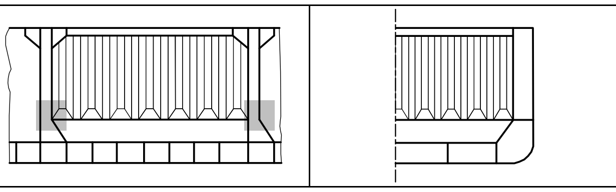
2.5.3 Transverse and longitudinal corrugated bulkhead connection to lower stool

2.5.3.1 Detail design improvement given in *Figure C.2.6* is recommended for reducing the stress level at the connection of transverse and longitudinal corrugated bulkhead to lower stool. This recommendation should be considered in association with fine mesh FE analysis as required in *Appendix B/3.1.5*.

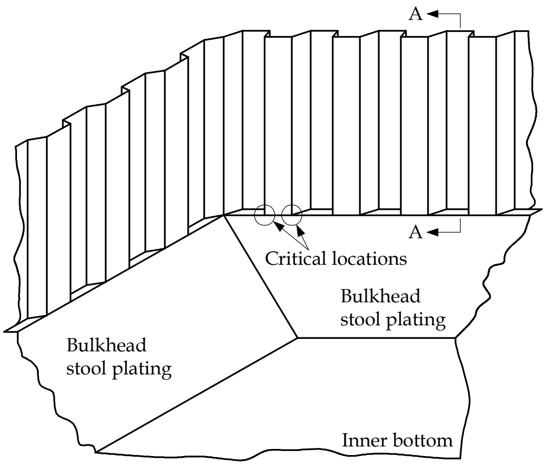
Figure C.2.6
Transverse and Longitudinal Bulkhead Connection to Lower Stool

Connections of side stringers in double side tanks to transverse bulkheads
Higher tensile stringers to horizontal girders on plane oiltight transverse or wash bulkheads

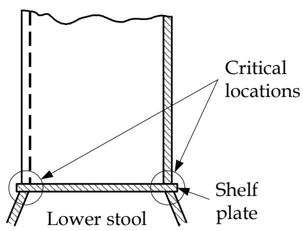
CRITICAL AREAS



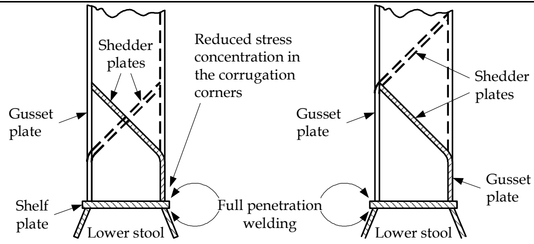
CRITICAL LOCATIONS



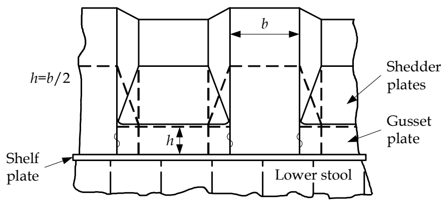
Section A-A



DETAIL DESIGN IMPROVEMENT



Section A-A improvement



Note:

* Full penetration weld is to be applied at the connection of the corrugated bulkhead and stool plate to the shelf plate of the lower stool.

** Where adjacent shedder plates cross, a bracket stiffener is to be provided at the crossing point.

Critical Location	1. Connections of corrugated bulkhead to lower stool and shelf plate 2. Connections of corrugated bulkhead to shedder plate if fitted without a gusset plate
Detail Design Improvement	1. Gusset plate should be fitted to the shelf plate in line with the face of the corrugation to reduce stress concentrations at the corrugated corners. The minimum height of the gusset plate should be taken as half the corrugated bulkhead flange width. 2. To reduce stress concentration at the crossing of the shedder plates, shedder plates may be arranged in an alternate configuration as shown in figure. Alternatively, bracketed stiffener may be fitted at the crossing points underneath the shedder plates.
Building Tolerances	Ensure good alignment between lower stool sloping plates and corrugation faces as far as possible. The nominal distance between the centres of thickness of the two abutting members should not exceed 1/3 of the table member thickness.
Welding Requirements	Full penetration welding should be used at the connections of the bulkhead corrugations, gusset plates and the lower stool sloping plates to the lower stool shelf plate (Grade Z steel is recommended). Start and stop of welding should be as far away as practicable from the corners of the corrugations.

APPENDIX D

BUCKLING STRENGTH ASSESSMENT

1 ADVANCED BUCKLING ANALYSIS

1.1 General

1.1.1 Scope

1.1.1.1 This appendix describes the advanced buckling analysis method and its application as required by the Rules. The advanced buckling analysis method is to be based on nonlinear analysis techniques, or equivalent, which predict the complex behaviour of stiffened and un-stiffened panels.

1.1.2 Alternative procedures

1.1.2.1 While this appendix describes the general purpose or direct calculation techniques to be employed, alternative advanced buckling and ultimate strength analysis procedures may be used provided they give comparable and consistent results to those obtained using the reference advanced buckling procedure given in the *Background to Appendix D* which is the basis for the permissible buckling utilisation factors in *Section 9/Table 9.2.2*. See also *1.1.2.3*.

1.1.2.2 Where an alternative advanced procedure is used, documentation of the alternative advanced buckling analysis methodologies and detailed comparison of its results with those of the reference advanced buckling procedure given in *Background to Appendix D* and software tools are to be supplied for review and acceptance.

1.1.2.3 Use of alternative buckling procedures to the reference advanced buckling procedure is acceptable provided that the alternative procedure is verified against the test cases specified in the *Background to Appendix D* and where the permissible utilisation buckling factor for the alternative method, $\eta_{all-alt}$, complies with:

$$\eta_{all-alt} \le \eta_{all} \cdot \left(\frac{\eta_{alt-i}}{\eta_{reft-i}} \right)_{\min}$$

Where:

η_{all}	permissible utilisation factor against buckling for plate and stiffened panels as specified in *Section 9/Table 9.2.2*
η_{ref-i}	utilisation factor for reference advanced buckling procedure for test case *I* specified in *Background to Appendix D*
η_{alt-i}	utilisation factor for alternative buckling procedure for test case *I* specified in *Background to Appendix D*

1.1.3 Definitions

1.1.3.1 "Buckling" is used as a generic term to describe the strength of structures, generally under in-plane compressions and/or shear. The buckling strength or capacity can take into account the internal redistribution of loads depending on the situation.

1.1.3.2 Buckling capacity accepting local elastic plate buckling with load redistribution is referred to as Method 1. The buckling capacity is the load that results in the first occurrence of membrane yield stress anywhere in the stiffened panel. Buckling capacity based on this principle gives a lower bound estimate of ultimate capacity, or the maximum load the panel can carry without suffering major permanent set. Method 1 buckling capacity assessment utilizes the positive elastic post-buckling effect for plates and accounts for load redistribution between the structural components, such as between plating and stiffeners. For slender structures the

capacity calculated using this method is typically higher than the ideal elastic buckling stress (minimum Eigen-value). Accepting elastic buckling of structural components in slender stiffened panels implies that large elastic deflections and reduced in-plane stiffness will occur at higher buckling utilization levels.

1.1.3.3 Method 2 buckling capacity does not accept load redistribution between structural components and refers to the minimum of value of the ideal elastic buckling stress and the Method 1 buckling capacity. Method 2 buckling capacity normally equals the same strength as Method 1 for stocky panels, while it is the ideal elastic buckling stress (minimum Eigen-value cut-off) for slender panels. By applying the ideal elastic buckling stress limitation, large elastic deflections and reduced in-plane stiffness will be avoided at higher buckling utilization levels.

1.1.3.4 A "buckling failure mode" refers to a specific pattern of buckling failure. Typical failure modes of stiffened panels with open profiles are:

(a) plate buckling

(b) torsional stiffener buckling

(c) stiffener web plate buckling

(d) lateral stiffener buckling.

2 ADVANCED BUCKLING ANALYSIS METHOD

2.1 General

2.1.1 Effects to consider

2.1.1.1 The advanced buckling assessment method is to be capable of considering the following effects:

(a) non linear geometrical behaviour

(b) inelastic material behaviour

(c) initial deflections – geometrical imperfections/out-of flatness

(d) welding residual stresses

(e) interactions between buckling modes and structural elements; plates, stiffeners, girders etc.

(f) simultaneous acting loads; bi-axial compression/tension, shear and lateral pressure

(g) boundary conditions.

2.1.1.2 Detailed requirements for items listed in *2.1.1.1* are given in *2.1.2* to *2.1.8*. Additional requirements applicable to non-linear finite element models are given in *2.1.9* and *2.1.10*.

2.1.2 Non linear geometrical behaviour

2.1.2.1 The buckling method is to be based on non-linear large deflection plate theory or equivalent. Second order membrane strains due to geometrical non-linearity are to be accounted for.

2.1.2.2 Non-linear plate theory according to von Karman and Marguerre is acceptable for assessing the strength beyond the ideal elastic buckling level.

2.1.3 Material behaviour and properties

2.1.3.1 Inelastic material behaviour is to be considered. If the buckling method is not capable of handling non linear material and spread of plasticity, then the redistributed stress fields due to non-linear geometrical behaviour and geometrical imperfections are to be limited to below the von Mises yield criterion.

2.1.3.2 Alternatively, if the buckling method is capable of handling non linear material, then a bi-linear material model is to be used with a conservative strain-hardening coefficient in the plastic region.

2.1.3.3 The material property assumptions are to use the characteristic values of yield strength and Young's Modulus. Where appropriate, a bi-linear isotropic elasto-plastic material model excluding strain rate effects is to be used or the Tangent Modulus is to be taken as a conservative value. A plastic tangent modulus of 1000Mpa is acceptable for normal and higher strength steel.

2.1.4 Initial deflections – geometrical imperfections/out-of-flatness

2.1.4.1 Initial deflections are to be included in the buckling assessment.

2.1.4.2 For the deterministic strength assessment the geometrical imperfections are to be transformed to a regular model pattern.

2.1.4.3 The imperfections may be divided into local imperfections (plate out-of-flatness and stiffener sideways out-of-straightness), and global imperfections of the stiffeners (stiffener lateral/vertical out-of-straightness).

2.1.4.4 The shape of the initial deflections is to be such that the most critical failure modes are represented and triggered by the analysis. In general, a combination of the lowest buckling Eigen-modes will be appropriate. Consideration is to be given in the case of plates with high slenderness and in the case of simultaneously acting loads, where the critical failure mode may be different from the lowest Eigen-modes.

2.1.4.5 The default maximum values of the imperfections are to be taken to be consistent with the *IACS Shipbuilding and Quality Repair Standard*. However, regular model imperfection amplitudes may generally be taken less than the maximum tolerance specified. The regular model imperfections may typically be case dependant (load ratio dependant) and are also to cover imperfections due to welding. The actual level of model imperfections will depend on the method of analysis, extension of model, etc. and is to be approved by the individual Classification Society.

2.1.5 Welding induced residual stress

2.1.5.1 Residual stresses are not required to be explicitly included in the buckling assessment, see *2.1.4.5*.

2.1.6 Interactions between buckling modes and structural elements

2.1.6.1 The advanced buckling analysis method is to accurately model the interactions between the various structural components and hence between the different buckling modes.

2.1.6.2 All the critical initial imperfection shapes are to be included, see *2.1.4*.

2.1.7 Simultaneous acting loads

2.1.7.1 The method is to be able to model any combination of biaxial in-plane compressive and shear membrane loads and lateral pressure.

2.1.7.2 Any lateral pressure is to be applied first, in order to generate the deformed shape. The lateral pressure is then to be kept constant.

2.1.7.3 The effect of lateral pressure enforcing deflections in different patterns than in-plane loads is to be included in such a way that the most critical buckling mode is developed.

2.1.8 Boundary conditions

2.1.8.1 The boundary conditions are to represent the actual response of the plate or stiffened panel. In-plane and out-of-plane boundary conditions are to be considered.

2.1.8.2 Where a panel is an integral part of a larger continuous area of stiffened plating, such as bottom or side panels, the edges may be taken as free to move in-plane, but forced to remain straight. Where a panel is not supported in-plane by adjacent structure, such as a stringer web panel or bottom girder web, then the edges are to be considered as completely free.

2.1.8.3 Rotational restraint on the plate from the stiffeners is to be accounted for by direct analysis of the plate and stiffener interaction. Prescribed boundary conditions are, in general, not acceptable.

2.1.8.4 The panels can be taken as supported in the lateral/vertical direction at the primary support members. The stiffeners may be taken as horizontally supported at the crossing of primary support members (preventing tilting at crossings). Geometrical rotational restraint of the plate from the primary support members is to be neglected.

2.1.9 Model extent

2.1.9.1 The extent of the model used in the buckling assessment is to be sufficient to account for the structure that is surrounding the panel of interest, and to reduce the uncertainties introduced through the boundary conditions.

2.1.9.2 In general, the model is to include more than one stiffener span in the stiffener direction and the portion between two primary support members in the direction normal to the stiffeners.

2.1.10 Element size for non-linear finite element models

2.1.10.1 The element size is to be small enough to describe the buckling deflections accurately.

2.1.10.2 The mesh size will depend on the complexity of the geometry and loads and the type of element used, but a minimum of five elements across a half-buckling wave length is generally required.

3 APPLICATION AND STRUCTURAL MODELLING PRINCIPLES

3.1 General

3.1.1 Scope

3.1.1.1 The following specifies the standard assumptions to be applied for the application of the advanced buckling method. These assumptions may be refined when the advanced buckling method is capable of more accurate representation of the structure.

3.1.2 Boundary conditions

3.1.2.1 The boundary conditions are to accurately account for the in-plane and rotational constraints imposed by the adjacent structures (such as stiffeners, primary support members and adjacent plates). The assumptions defined in *3.1.2.3* to *3.1.2.4* are to be applied.

3.1.2.2 The boundary conditions are divided into two main groups being representative for "free edge plating" and "continuous plating". The latter group represents large stiffened panels such as deck plating, bottom plating, ship sides, etc., while the other represents girders, floors, stringers, etc.

3.1.2.3 The continuous plating condition is representative for elements having in-plane support conditions by the surrounding structure. The boundary conditions for stiffened panels are to be taken as:

(a) panel edges perpendicular to stiffeners are to be considered simply supported

(b) panel edges parallel to stiffeners are to be considered as having rotational support equivalent to that provided by stiffeners within the panel

(c) the ends of stiffeners are to be considered as part of a continuous panel and supported sideways by the primary support members

(d) all edges of the panel are to be constrained to remain straight but are free to displace inwards.

3.1.2.4 Free edge plating conditions are representative for elements having weak in-plane support along one or more edges, e.g. vertically stiffened double bottom floors. The boundary conditions for stiffened panels are to be taken as:

(a) panel edges perpendicular to stiffeners are to be considered simply supported

(b) panel edges parallel to stiffeners are to be considered as having rotational support equivalent to that provided by stiffeners within the panel

(c) the ends of stiffeners are to be considered as supported sideways when attached directly to adjacent structure, otherwise they are to be assumed simply supported

(d) all free edges of the panel are free to displace inwards. Rotational restraints of the edge reinforcements on the free edges may be considered.

3.1.2.5 The boundary conditions for un-stiffened panels are to be taken as:

(a) panel edges are to be considered simply supported unless otherwise stated

(b) free edges of the panel, if any, are free to displace inwards. The continuous edges are to be constrained to remain straight.

3.1.3 Structural idealisation

3.1.3.1 The structural modelling and buckling assessment method applicable for free edge plating is to be taken as:

(a) parallel to the stiffener direction: one frame bay is normally sufficient for structures having significant stress gradients. For uniformly compressed elements with the free edges parallel to the stiffener direction, such as longitudinal girders, multi-bay models are to be considered

(b) normal to the stiffener direction: between primary support members, but may be limited to six stiffener spacings

(c) assessment method: Method 2 – buckling capacity with no allowance for redistribution of load unless otherwise specified.

3.1.3.2 The structural modelling and buckling assessment method applicable for continuous plating is to be taken as:

(a) parallel to the stiffener direction: at least two frame bays, in order to model imperfections between adjacent panels

(b) normal to the stiffener direction: between primary support members, but may be limited to six stiffener spacings

(c) assessment method: Method 1 – buckling capacity with allowance for redistribution of load unless otherwise specified.

4 ASSESSMENT CRITERIA

4.1 General

4.1.1 Buckling strength assessment methods

4.1.1.1 The buckling capacity value is to be based on one of the following assessment methods:

1. Buckling Capacity with allowance for redistribution of load
2. Buckling Capacity with no allowance for redistribution of load

The application of which assessment method to use is given in *3.1.3*

4.1.2 Method 1: Buckling capacity with allowance for redistribution of load

4.1.2.1 The buckling capacity value is to be taken as the load that results in the first occurrence of membrane yield stress anywhere in the stiffened panel. This includes the redistribution of load as indicated in *1.1.3.2*. In particular the following locations are to be checked for von Mises stresses equivalent to yield:

(a) at the edges of the plate

(b) along the line of intersection of the plate and stiffeners, especially at the ends of the stiffener and at the stiffener mid point

(c) along the flanges of the stiffeners, especially at the ends of the stiffener and at the stiffener mid point.

4.1.3 Method 2: Buckling capacity with no allowance for redistribution of load

4.1.3.1 The buckling capacity value or the load that results in the first occurrence of membrane yield stress anywhere in the stiffened panel, see *1.1.3.3*.

4.2 Utilisation Factors

4.2.1 General

4.2.1.1 The utilisation factor, η, is used as a measure of safety margin against buckling strength failure. The utilisation factor is defined as the ratio between the applied loads and the corresponding ultimate capacity or buckling strength.

4.2.1.2 A structure is considered to have an acceptable buckling strength if it satisfies the following criteria:

$$\eta_{act} \le \eta_{allow}$$

Where:

η_{allow} allowable buckling utilisation factor, as defined in *Section 9/2.2.5*

η_{act} actual buckling utilisation factor based on the applied design loads

4.2.1.3 For combined loads, the utilisation factor, η, is to be taken as the ratio between the applied equivalent load and the corresponding buckling capacity, see *Figure D.4.1*, and is to be taken as:

$$\eta = \frac{W_{act}}{W_u}$$

Where:

W_{act} applied equivalent load due to the combined membrane loads

$= \sqrt{\sigma_{dx}^2 + \sigma_{dy}^2 + \tau_d^2}$ N/mm²

W_u equivalent load due to the combined membrane loads which results in the buckling capacity point, see *Figure D.4.1*

$= \sqrt{\sigma_{cx}^2 + \sigma_{cy}^2 + \tau_{cr}^2}$ N/mm²

Where the combined loads are all factored by the same ratio and the applied pressure load is to be kept constant

σ_{dx} applied axial stress in x direction, in N/mm²

σ_{dy} applied axial stress in y direction, in N/mm²

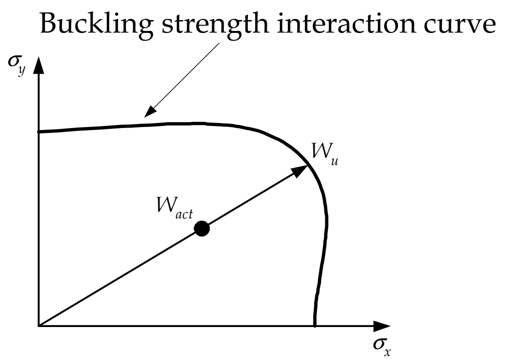
τ_d applied shear stress, in N/mm²

σ_{cx} buckling strength due to compression in x direction, in N/mm²

σ_{cy} buckling strength due to compression in y direction, in N/mm²

τ_{cr} buckling strength in shear, in N/mm²

Figure D.4.1
Definition of Utilisation Factor Example Showing a Bi-Axial Loading Pattern



5 STRENGTH ASSESSMENT (FEM) – BUCKLING PROCEDURE

5.1 General

5.1.1 Scope

5.1.1.1 The following procedure is to be used for the assessment of the buckling requirements for the Strength Assessment (FEM) as part of the Design Verification procedure, see *Section 9/2*.

5.1.1.2 All structural elements in the finite element analysis are to be assessed individually. Each stiffener with attached plate and all un-stiffened panels are to be assessed.

5.1.1.3 The buckling performance of each member is considered acceptable if it satisfies the following criterion:

$$\eta_{act} \leq \eta_{allow}$$

Where

η_{allow} allowable buckling utilisation factor, as defined in *Section 9/2.2.5*

η_{act} actual buckling utilisation factor based on the applied design loads, see *4.2.1*

5.2 Structural Modelling and Capacity Assessment Method

5.2.1 General

5.2.1.1 The longitudinally effective structure of the hull girder is to be modelled as stiffened panels or un-stiffened panels as specified in *Table D.5.1* and *Figure D.5.1*. These provide the standard assumptions to be used for the buckling capacity assessment method.

5.2.1.2 The structural models are to be based on the net thickness obtained by deducting the full corrosion addition, i.e. -1.0t_{corr}, and any owner's extras from the proposed thickness. This thickness reduction applies to the plating and the stiffener web and face plate.

5.2.2 Stiffened panels

5.2.2.1 Each stiffener with attached plate is to be represented as a stiffened panel of the extent defined in *Table D.5.1* and hence is assumed to be part of a larger structural entity to correctly model the overall buckling behaviour.

5.2.2.2 In general, the assessment method is to model changes in plate thickness, stiffener size and spacing. However where the advanced buckling method is unable to correctly model these changes, the calculations are to be performed separately for each stiffener and plate between the stiffeners. Plate thickness, stiffener properties and stiffener spacing at the considered location are to be assumed for the whole panel. If the plate thickness, stiffener properties and stiffener spacing varies within the stiffened panel, the calculations are to be performed for all configurations of the panel. Where the panel between stiffeners consists of several plate thickness the weighted average thickness may by used for the thickness of the plating for assessment of the corresponding stiffener/plating combination. Calculation of weighted average is to be in accordance with *5.2.3.3*. See *Figure D.5.6.*

5.2.3 Un-stiffened panels

5.2.3.1 The assessment method is to model changes in plate thickness and panel geometry.

5.2.3.2 In way of web frames, stringers and brackets, the geometry of the panel (i.e. plate bounded by web stiffeners/face plate) may not have a rectangular shape. Where the advanced buckling method is unable to correctly model the panel geometry, then an equivalent rectangular panel is to be defined as shown in *Figure D.5.5*. Where web stiffeners are not connected to the intersecting stiffeners, then the panel may be defined as shown in *Figure D.5.6*. The FE analysis is to represent the actual structure in order to derive realistic stress values for application to the equivalent rectangular panel. The stresses of all elements whose centroids are within the equivalent plate panel are to be considered for stress average in accordance with *5.3.2.1*.

5.2.3.3 Where the advanced buckling method is unable to correctly model changes in net plate thickness across a panel, and the panel consists of a number of finite plate elements, then the average thickness is to be taken as:

$$t_{avr} = \frac{\sum A_j \ t_j}{\sum A_j}$$

Where:

A_j area of the jth plate element making up the panel

t_j net thickness of the jth plate element making up the panel

Table D.5.1
Structural Elements for the Strength Assessment (FEM)

Structural Elements	Idealisation	Assessment method(1)	Normal panel definition(2)
Longitudinal structure, see *Figure D.5.1*			
Longitudinally stiffened panels Shell envelope Deck Inner hull Hopper tank side Longitudinal bulkheads Centreline bulkheads	Stiffened panel	Method 1	Length: between web frames Width: between primary support members (PSM)(2)
Double bottom longitudinal girders in line with longitudinal bulkhead or connected to hopper tank side	Stiffened panel	Method 1	Length: between web frames Width: full web depth
Web of horizontal girders in double side tank connected to hopper tank side	Stiffened panel	Method 1	Length: between web frames Width: full web depth
Web of double bottom longitudinal girders not in line with longitudinal bulkhead or not connected to hopper tank side	Stiffened panel	Method 2	Length: between web frames Width: full web depth
Web of horizontal girders in double side tank not connected to hopper tank side	Stiffened panel	Method 2	Length: between web frames Width: full web depth
Web of single skin longitudinal girders	Un-stiffened panel	Method 2	Between local stiffeners/face plate/PSM
Transverse structure, see *Figure D.5.2*			
Web of transverse deck girders including brackets	Un-stiffened panel	Method 2	Between local stiffeners/face plate/PSM
Vertical web in double side tank	Stiffened panel	Method 2	Length: full web depth Width: between primary support members
All irregularly stiffened panels, e.g. Web panels in way of hopper tank and bilge	Un-stiffened panel	Method 2	Between local stiffeners/face plate/PSM
Double bottom floors	Stiffened panel	Method 2	Length: full web depth Width: between primary support members
Vertical web frame including brackets	Un-stiffened panel	Method 2	Between vertical web stiffeners/face plate/PSM
Cross tie web plate	Un-stiffened panel	Method 2	Between vertical web stiffeners/face plate/PSM
Transverse Oil-tight and Watertight bulkheads, see *Figure D.5.3* and Transverse wash bulkheads, see *Figure D.5.4*			
All regularly stiffened bulkhead panels	Stiffened panel	Method 1	Length: between primary support members Width: between primary support members
Regularly stiffened bulkhead with secondary buckling stiffeners perpendicular to regular stiffeners (3)	Stiffened panel	Method 1	Length: between primary support members Width: between primary support members
All irregularly stiffened bulkhead panels, e.g. web panels in way of hopper tank and bilge	Un-stiffened panel	Method 2	Between local stiffeners/face plate
Web plate of bulkhead stringers including brackets	Un-stiffened panel	Method 2	Between web stiffeners /face plate
Transverse Corrugated bulkheads			
Upper/lower stool including stiffeners	Stiffened panel	Method 1	Length: between internal web diaphragms Width: length of stool side
Stool internal web diaphragm	Un-stiffened panel	Method 2	Between local stiffeners /face plate / PSM

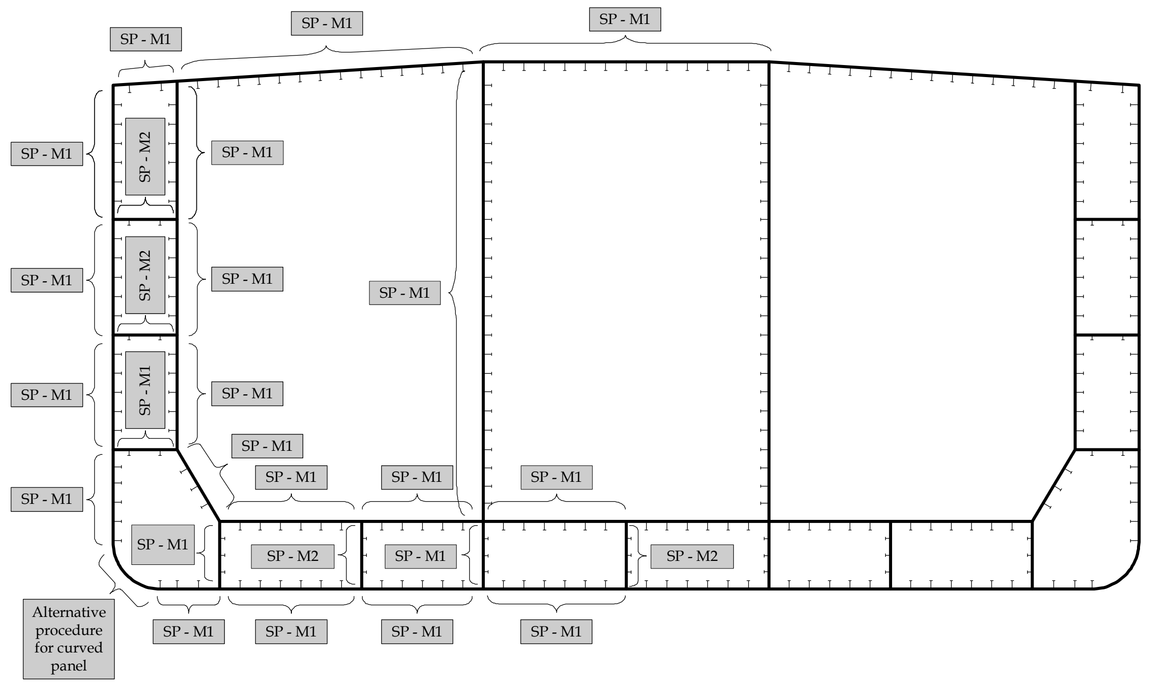
<u>Note</u>

1. The assessment method specifies which buckling strength assessment method is to be used, see *4.1*
2. See structural idealisation, *3.1.3*.

3. The secondary stiffener can be modelled as “sniped” or “continuous”. The stiffener is considered “sniped” unless rotational end supports are provided at both ends

An area stiffened by irregular buckling stiffeners only should be assessed by considering each plate in the panel as Unstiffened panel using Method 2.

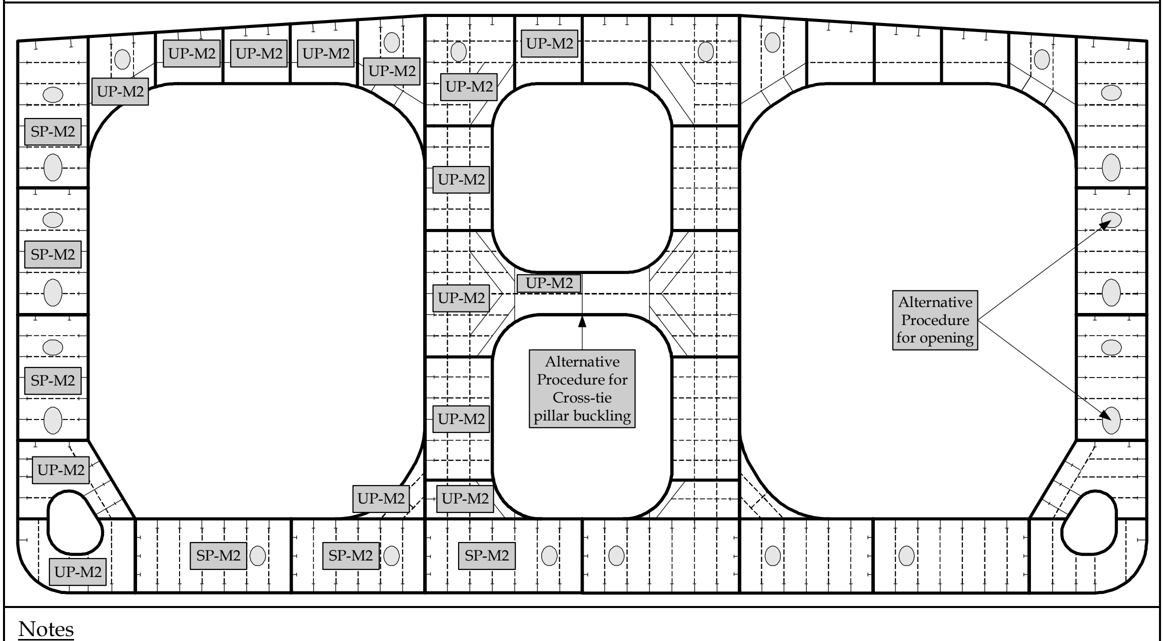
Figure D.5.1
Advanced Buckling Assessment for longitudinal strength



Notes

1. SP – M1 denotes stiffened panel – buckling strength assessed using Method 1
2. SP – M2 denotes stiffened panel – buckling strength assessed using Method 2

Figure D.5.2
Transverse Web Frames



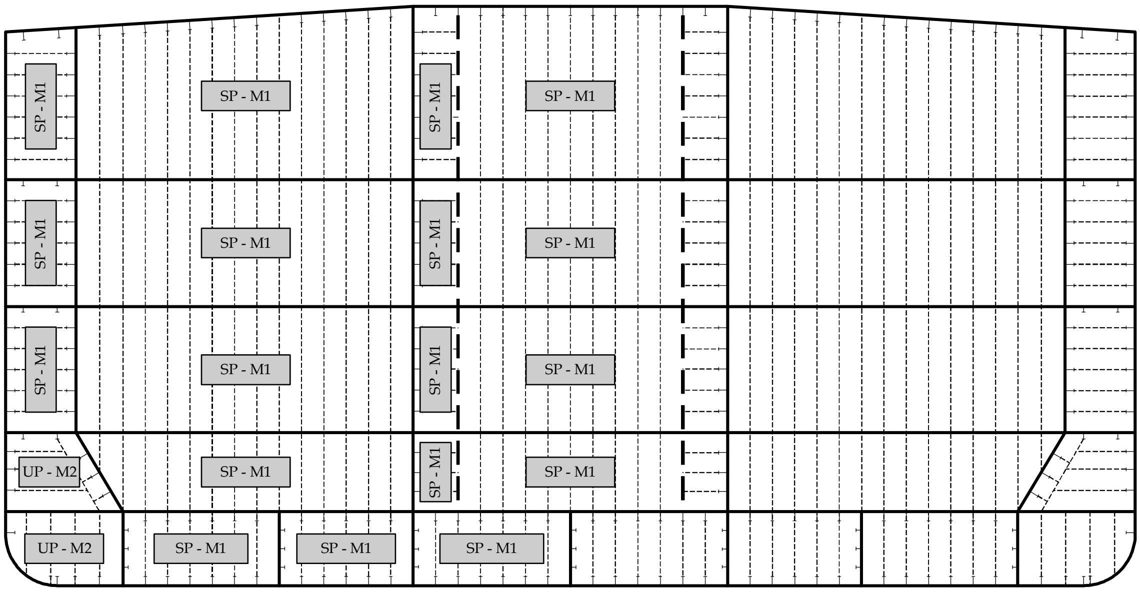
Notes

SP – M1 denotes Stiffened Panel – buckling strength assessed using Method 1

UP – M2 denotes Un-stiffened Panel – buckling strength assessed using Method 2

SP – M2 denotes Stiffened Panel – buckling strength assessed using Method 2

Figure D.5.3
Transverse Bulkhead

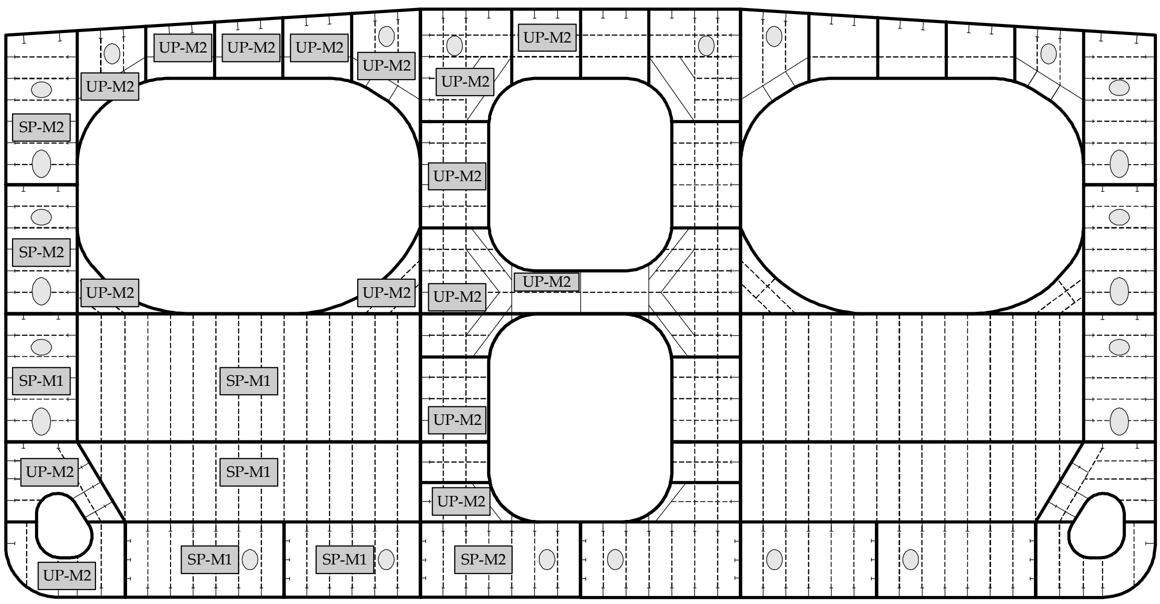


Notes

SP – M1 denotes Stiffened Panel – buckling strength assessed using Method 1.

UP – M2 denotes Un-stiffened Panel – buckling strength assessed using Method 2

Figure D.5.4
Cross Tie



Notes

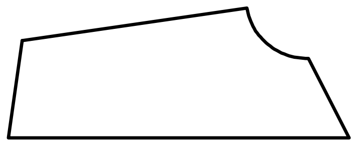
SP – M1 denotes Stiffened Panel – buckling strength assessed using Method 1

UP – M2 denotes Un-stiffened Panel – buckling strength assessed using Method 2

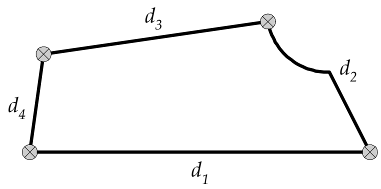
SP – M2 denotes Stiffened Panel – buckling strength assessed using Method 2

Figure D.5.5
Modelling of an Un-stiffened Panel with Irregular Geometry

(a) The four corners closest to a right angle, 90 degrees, in the bounding polygon for the plate are identified

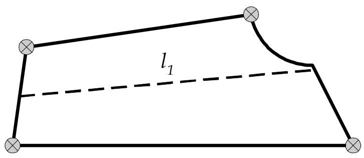


(b) The distances along the plate bounding polygon between the corners are calculated, i.e. the sum of all the straight line segments between the end points



(c) The pair of opposite edges with the smallest total length is identified, i.e. minimum of d_1+d_3 and d_2+d_4

(d) A line is joined between the middle points of the chosen opposite edges (i.e. a mid point is defined as the point at half the distance from one end). This line defines the longitudinal direction, x_1, for the capacity model. The length of the line defines the length of the capacity model, l_1 or d_2 measured from one end point.

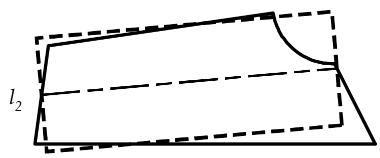


(e) The width of the model, l_2, is to be taken as:

$l_2 = A_{pt}/l_1$

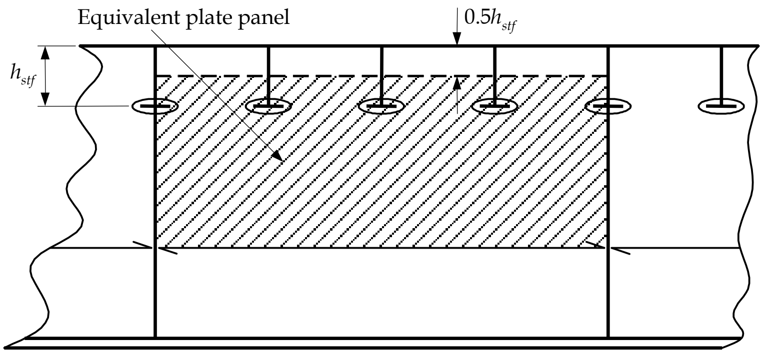
Where:

A_{pt} area of the plate



(f) The stress from the FE analysis are to be resolved into the local coordinate system of the equivalent rectangular panel. These stresses are to be used for the buckling assessment.

Figure D.5.6
Capacity Model for Web Plate



Note
The correction of panel breadth is applicable also for other slot configurations provided that the web or collar plate is attached to at least one side of the passing stiffener.

5.3 Load Application

5.3.1 General

5.3.1.1 The ultimate capacity or buckling strength is to be assessed for the effects of the combined bi-axial and shear membrane stresses acting on the structural panel.

5.3.1.2 The axial compressive and shear stress distribution is to be taken from the FE analysis and applied to the buckling model. The stresses from the FE analysis are not to be adjusted for the required change in thickness for buckling, i.e. -0.5t_{corr} used in the FE analysis and 1.0t_{corr} used for the buckling assessment.

5.3.1.3 The lateral pressure applied to the FE analysis is also to be applied to the buckling assessment.

5.3.1.4 The stresses may be applied by means of enforced displacements obtained from the finite element analysis to the panel edges or by loads applied to the panel edges.

5.3.1.5 Where the advanced buckling method is unable to correctly model changes in axial or shear stress across a panel, then the stresses and pressures may be averaged as defined in *5.3.2* and *5.3.3*.

5.3.2 Average membrane stresses

5.3.2.1 When the plate panel consists of a number of finite plate elements, the average membrane stress is to be calculated using a weighted average approach, as given by:

$$\sigma_{xm} = \frac{\sum_1^n A_i \sigma_{xmi}}{\sum_1^n A_i} \quad \text{N/mm}^2$$

$$\sigma_{ym} = \frac{\sum_1^n A_i \sigma_{ymi}}{\sum_1^n A_i} \quad \text{N/mm}^2$$

$$\tau_{xym} = \frac{\sum_1^n A_i \tau_{xymi}}{\sum_1^n A_i} \quad \text{N/mm}^2$$

Where:

σ_{xmi} membrane stress in x-direction at the centroid of the ith plate element of the panel, in N/mm²

σ_{ymi} membrane stress in y-direction at the centroid of the ith plate element of the panel, in N/mm²

τ_{xymi} membrane shear stress at the centroid of the ith plate element of the panel, in N/mm²

A_i area of the ith plate element making up the panel, in mm²

n number of elements in the panel

When σ_{xmi} or σ_{ymi} are in tension, then the respective value is to be taken as zero.

5.3.3 Average lateral pressure

5.3.3.1 Where the plate panel consists of a number of finite elements, the average pressure, P_{avr}, is to be calculated using a weighted average approach, as given by:

$$P_{avr} = \frac{\sum_1^n A_i \; P_i}{\sum_1^n A_i} \quad \text{kN/m}^2$$

Where:

P_i pressure acting on the ith plate element making up the panel, in kN/m²

A_i area of the ith plate element making up the panel, in mm²

n number of elements in the panel

5.4 Limitations of the Advanced Buckling Assessment Method

5.4.1 General

5.4.1.1 In the absence of a suitable advanced buckling method, then the following structural elements can be assessed according to *Table D.5.2.*

Table D.5.2
Requirements for structures where there is no advanced buckling method available

Structural elements	Buckling mode	Rule Reference
bilge plate	transverse elastic buckling	*Section 8/2.2.3*
primary support members	global (overall) buckling and torsional buckling	*Section 10/2.3*
web plate of primary support members in way of openings	buckling of web plate	*Section 10/3.4*
cross ties	global (overall) buckling	*Section 10/3.5*
corrugated bulkheads	flange panel buckling global (overall) buckling	*Section 10/3.2* *Section 10/3.5*

6 ULTIMATE HULL GIRDER STRENGTH ASSESSMENT

6.1 General

6.1.1 Scope

6.1.1.1 This procedure is required for the assessment of the ultimate hull girder strength assessment as part of the Design Verification procedure, see *Section 9/1*.

6.1.1.2 All structural elements of the strength deck are to be assessed individually.

6.2 Load Application

6.2.1 General

6.2.1.1 The uni-axial compressive stress used for the ultimate capacity assessment of longitudinally stiffened deck panels is to be calculated at the stiffener/plate intersection point.

6.2.1.2 The hull girder stresses are based on the section modulus properties using a deduction of half the corrosion addition, i.e. $-0.5t_{corr}$, and owner's extra from the proposed thickness.

6.2.1.3 Lateral pressure is not to be included in the buckling assessment for hull girder ultimate strength.

6.3 Structural Modelling and Buckling Assessment

6.3.1 General

6.3.1.1 The longitudinally effective structure of the strength deck is to be modelled as stiffened panels using Method 1 to derive the ultimate capacity.

6.3.1.2 Each deck stiffener with attached plate is to be represented as a stiffened panel with the transverse extent being between two adjacent primary support members.

6.3.1.3 The buckling capacity models are to be based on the net thickness obtained by deducting half the corrosion addition, i.e. $-0.5t_{corr}$, and any owner's extras from the proposed thickness. This thickness reduction applies to the plating and the stiffener web and face plate.

6.3.1.4 In general, the assessment method is to correctly model changes in plate thickness, stiffener size and spacing. However where the advanced buckling method is unable to correctly model these changes, the calculations are to be performed separately for each stiffener and plate between the stiffeners. Plate thickness, stiffener properties and stiffener spacing at the considered location are to be assumed for the whole panel. If the plate thickness, stiffener properties and stiffener spacing varies within the stiffened panel, the calculations are to be performed for all configurations of the panel.

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Common Structural Rules for Bulk Carriers and Oil Tankers

January 2014

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Foreword

These Rules were adopted on 18th December 2013.

These Rules enter into force on 1st July 2015 and supersede the following Rules:

- Common Structural Rules for double hull oil tankers, July 2012
- Common Structural Rules for bulk carriers, July 2012

These Common Structural Rules consist of two parts. Part One provides requirements common to both Double Hull Oil Tankers and Bulk Carriers and Part Two provides additional requirements applied to either Double Hull Oil Tankers or Bulk Carriers.

Revision History

The following table provides a revision history of these Rules.

No.	Issue Date	Adoption Date	Effective Date
1	1st Jan 2014	18th Dec 2013	1st Jul 2015

Disclaimer

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PART 1

GENERAL HULL REQUIREMENTS

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1 Jan 2014

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PART 1 CHAPTER 1

RULE GENERAL PRINCIPLES

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SECTION 1
APPLICATION

1 SCOPE OF APPLICATION

1.1 General

1.1.1

These Rules apply to the following ships:

a) Bulk carriers and double hull oil tankers and;

b) Being self-propelled ships with unrestricted navigation, and;

c) Contracted for construction on or after 1st July 2015.

Note 1: Unrestricted navigation means that the ship is not subject to any geographical restrictions (i.e. any oceans, any seasons) except that limited by the ship's capability for operation in ice.

Note 2: The 'contracted for construction' means the date on which the contract to build the ship is signed between the prospective owner and the builder. For further details regarding the date of 'contracted for construction', refer to IACS Procedural Requirement (PR) No. 29.

1.1.2

These Rules apply to ships constructed of welded steel structures and composed of stiffened plate panels. The ship's structure is to be longitudinally or transversely framed with full transverse bulkheads and intermediate web frames.

The typical arrangements of ships covered by the rules assume that the structural arrangements include:

- Double bottom, the depth of which is to be in accordance with applicable statutory requirements.
- Engine room located aft of the cargo tank/hold region.

1.1.3

Ships for which these Rules are not applicable are to comply with the relevant Rules of the Society.

1.2 Scope of application for bulk carriers

1.2.1

These Rules apply to the hull structures of single side skin and double side skin bulk carriers having a length *L* of 90 m or above.

Bulk carriers are ships which are constructed generally with single deck, double bottom, hopper side tanks and topside tanks and with single or double side skin construction in cargo hold region and intended primarily to carry dry cargoes in bulk. Typical arrangements of bulk carriers are shown in Figure 1

Hybrid bulk carriers, where at least one cargo hold is constructed with hopper tank and topside tank, see typical arrangements in Figure 1, and other cargo holds are constructed without hopper tank and/or topside tanks, see examples of a transverse section in Figure 2, are to comply with the strength criteria defined in these Rules.

These Rules are not applicable to the following ship types:

- Ore carriers.
- Combination carrier.
- Woodchip carrier.
- Cement, fly ash and sugar carriers provided that loading and unloading is not carried out by grabs heavier than 10 tons, power shovels and other means which may damage cargo hold structure.
- Ships with inner bottom construction adapted for self-unloading.

Figure 1 : Typical arrangements of bulk carriers

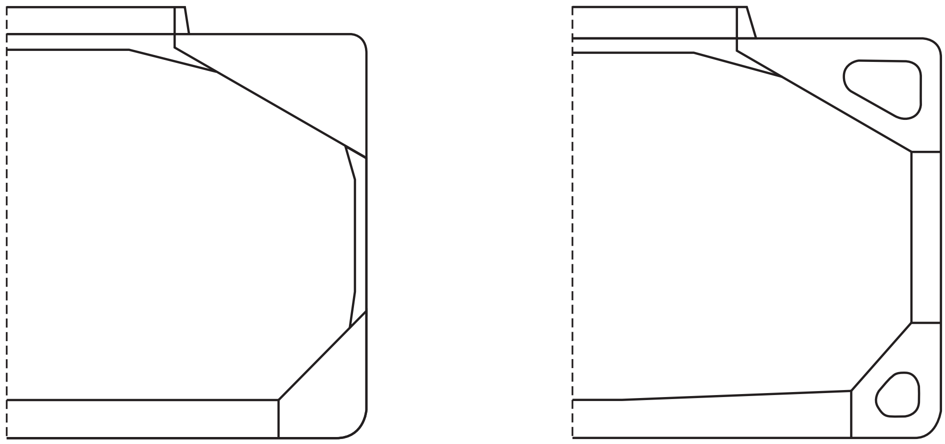
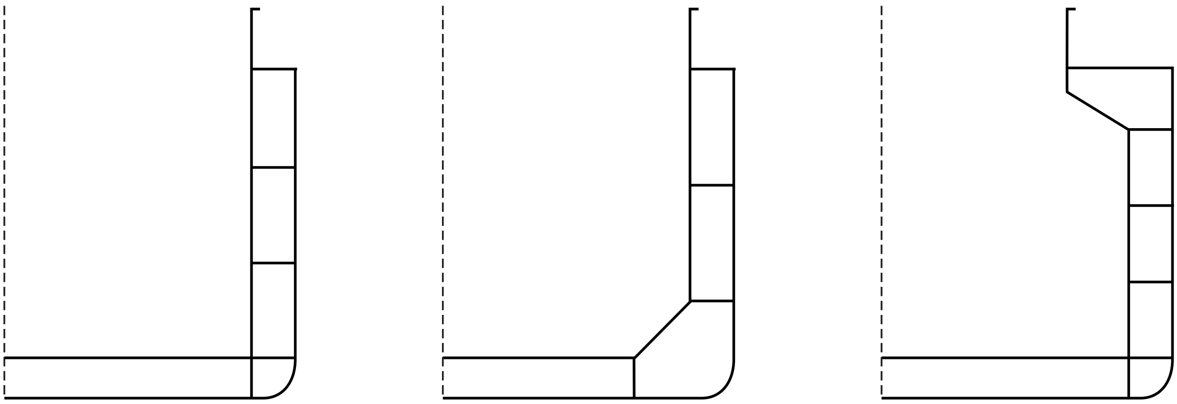


Figure 2 : Examples of transverse sections of cargo hold without hopper tank and/or topside tank



1.3 Scope of application for oil tankers

1.3.1 Length and structural arrangement application

These Rules apply to the hull structures of double hull oil tankers having length *L* of 150 m or above. Oil tanker is defined as a ship which has to comply with Annex I of MARPOL73/78.

The typical arrangements of oil tankers covered by the rules are shown in Figure 3 and assume that the structural arrangements include:

- Double side structure with breadth in accordance with statutory requirements.
- Side longitudinal, centreline longitudinal or transverse bulkheads of plane, corrugated or double skin construction.
- Single deck structure.

The cross sections shown in Figure 3 are typical examples only and other variations of cross tie and web frame arrangements are also covered.

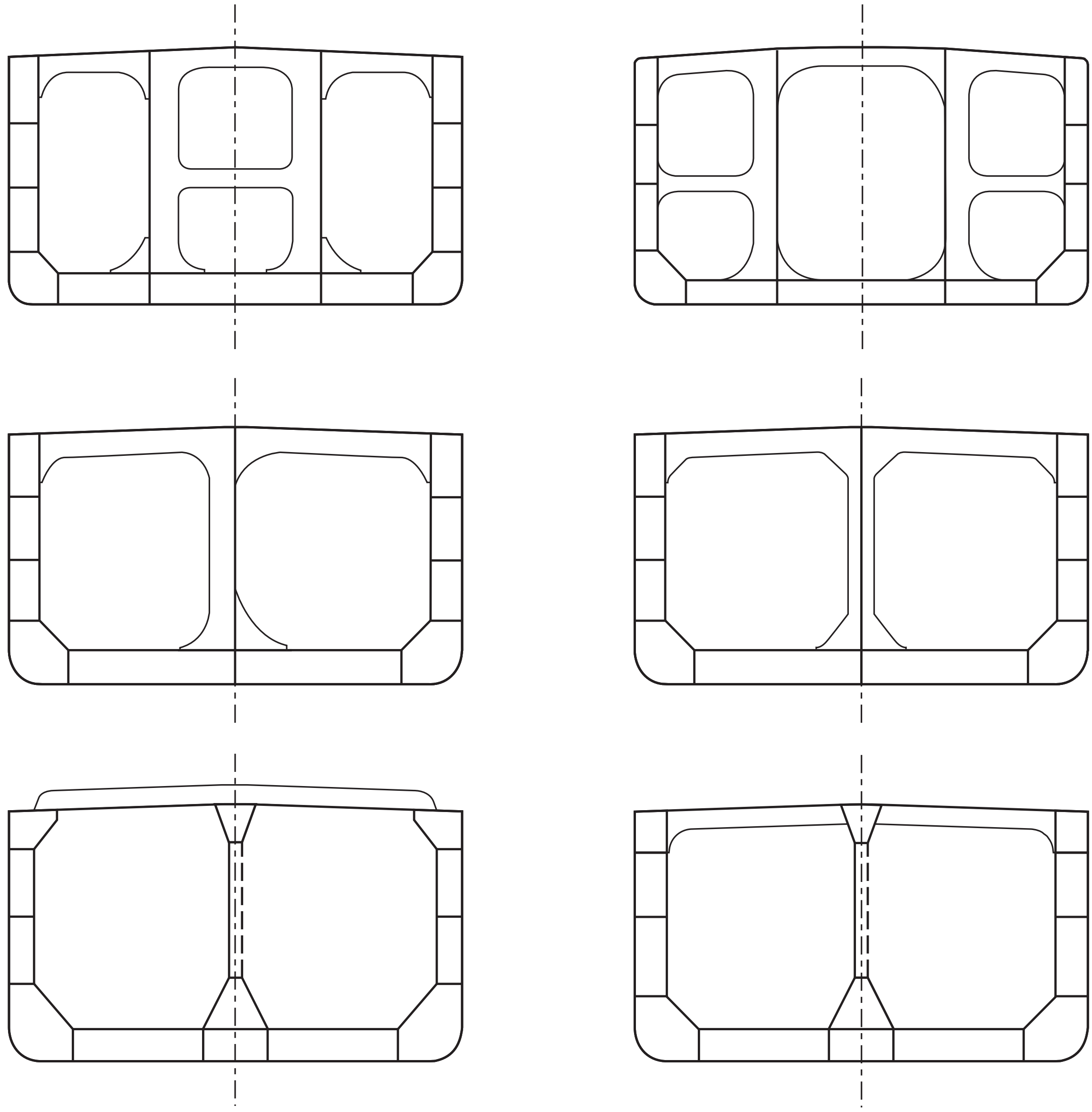
1.3.2 Cargo temperature application

The Rules are based on the following design temperatures for the cargo:

a) maximum temperature: 80°C

b) minimum temperature: 0°C.

Figure 3 : Typical arrangements of double hull oil tankers



2 RULE APPLICATION

2.1 Rule description

2.1.1 Rule structure

The rules contain 2 parts:

- Part 1: General hull requirements.
- Part 2: Ship types.

The parts are structured in chapters giving instructions for detail application and requirements which are applied in order to satisfy the rule objectives.

2.1.2 Numbering

The system of numbering is given in Table 1.

Table 1 : Rule numbering and abbreviations

Order	Levels	Example	Abbreviations
1	Part	Part 1 – General Hull Requirements	Pt 1
2	Chapter	Chapter 1 – Rule General Principle	Ch 1
3	Section	Section 1 – Application	Sec 1
4	Article	1. Scope of Application	[1]
5	Sub-article	1.1 General	[1.1]
6	Requirements	1.1.1 These Rules apply to...	[1.1.1]

2.2 Rule Requirements

2.2.1 Part 1

Part 1 of the Rules provides requirements common to all ship types as follow:

- Chapter 1: Rule General Principles.
- Chapter 2: General Arrangement Design.
- Chapter 3: Structural Design Principles.
- Chapter 4: Loads.
- Chapter 5: Hull Girder Strength.
- Chapter 6: Hull Local Scantling.
- Chapter 7: Direct Strength Analysis.
- Chapter 8: Buckling.
- Chapter 9: Fatigue.
- Chapter 10: Other Structure.
- Chapter 11: Superstructure, Deckhouses and Hull Outfitting.
- Chapter 12: Construction.
- Chapter 13: Ship in Operation - Renewal Criteria.

The provisions of the Ch 1, 2, 3, 4, 5, 6, 8, 12, 13 and Ch 10, Sec 4 are applicable all over the ships length.

The Ch 7, 9, 10 and 11 define their own scope of application.

2.2.2 Part 2

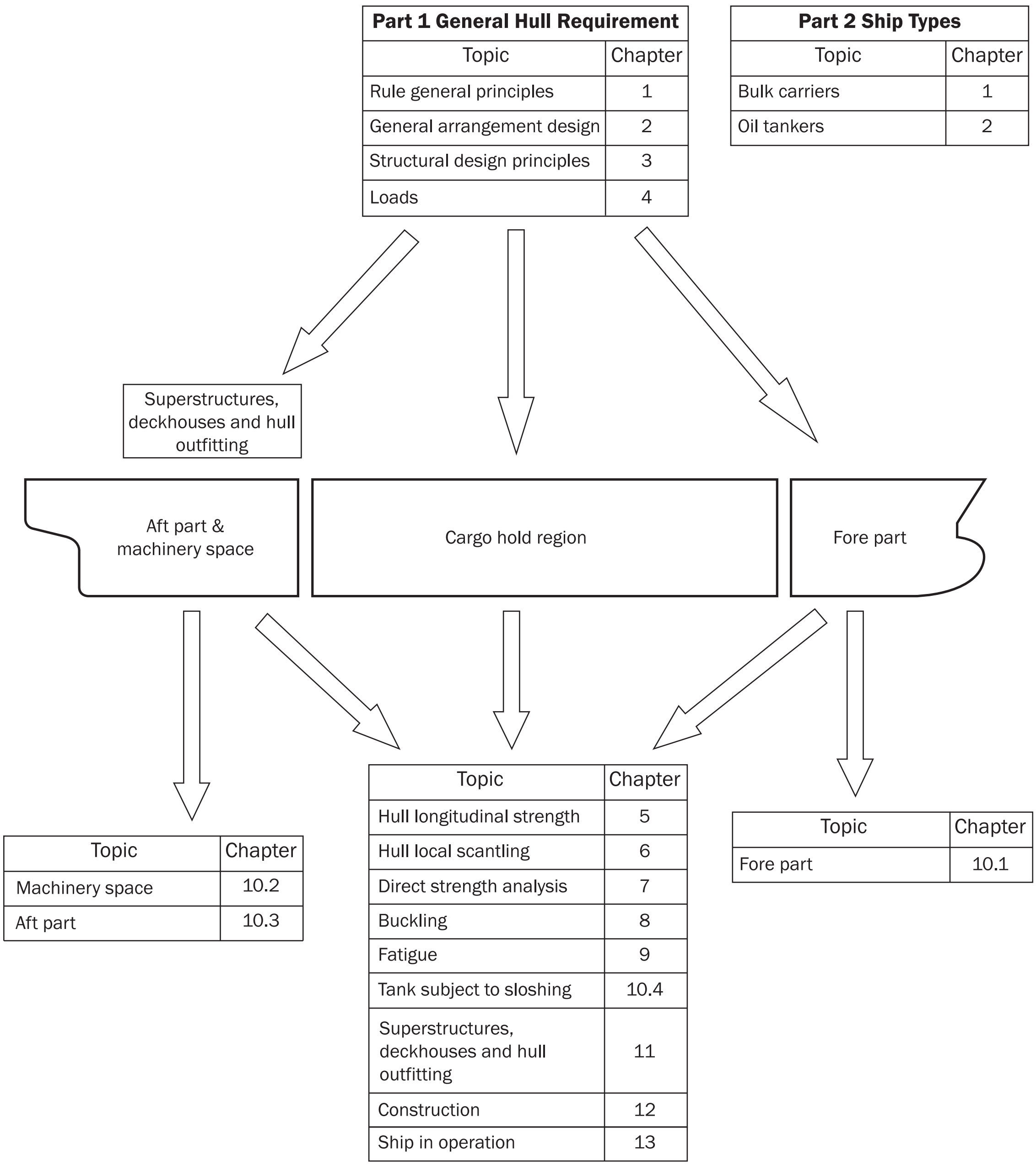
Part 2 of the Rules provides requirements coming in addition to those of Part 1 specific for ship types and is divided as follow:

- Chapter 1: Bulk Carriers.
- Chapter 2: Oil Tankers.

2.2.3 Application of the Rules

The ship arrangement and scantlings are to comply with the relevant parts and chapters of the Rules as it is given in Figure 4.

Figure 4 : Application of the Rules



2.2.4 General criteria

The ship arrangement, the proposed details and the offered scantling in net or gross, as the case may, are to comply with the requirements and the minimum scantling given in the Rules.

2.3 Structural requirements

2.3.1 Materials and welding

The Rules applies to welded hull structures made of steel having characteristics complying with requirements in Ch 3, Sec 1. The Rules applies also to welded steel ships in which parts of the hull, such as superstructures or small hatch covers, are built in material other than steel, complying with requirements in Ch 3, Sec 1.

Ships whose hull materials are different than those given in the first paragraph are to be individually considered by the Society, on the basis of the principles and criteria adopted in the present rules.

2.4 Ship parts

2.4.1 General

For the purpose of application of the present rules, the ship is considered as divided into the following five parts:

- Fore part.
- Cargo hold region.
- Machinery space.
- Aft part.
- Superstructures and deckhouses.

2.4.2 Fore part

The fore part is that part of the ship located forward of the collision bulkhead, i.e.:

- The fore peak structures.
- The stem.

2.4.3 Cargo hold region

The cargo hold region is the part of the ship that contains cargo holds, cargo tanks, and slop tanks. It includes the full breadth and depth of the ship, the collision bulkhead and the transverse bulkhead at its aft end. The cargo hold region does not include the pump room, if any.

2.4.4 Machinery space

The machinery space is the part of the ship between the aft peak bulkhead and the transverse bulkhead at the aft end of the cargo hold region and includes the pump room, if any.

2.4.5 Aft part

The aft part includes the structures located aft of the aft peak bulkhead.

2.4.6 Superstructures and deckhouses

A superstructure is a decked structure on the freeboard deck extending from side to side of the ship or with the side plating not being inboard of the shell plating more than 0.04 B.

A deckhouse is a decked structure on the freeboard or superstructure deck which does not comply with the definition of a superstructure.

2.5 Limits of application to lifting appliances

2.5.1 Definition

The fixed parts of lifting appliances, considered as an integral part of the hull, are the structures permanently connected by welding to the ship's hull (for instance, crane pedestals, masts, king posts, derrick heel seatings, etc, excluding cranes, derrick booms, ropes, rigging accessories, and, generally, any removable parts), only for that part directly interacting with the hull structure.

2.5.2 Rule application for lifting appliances

The fixed parts of lifting appliances and their connections to the ship's structure may be covered by the Society's rules for lifting appliances, and/or by the certification (especially the issuance of the Register of ship's lifting appliances and cargo handling gear) of lifting appliances when required.

2.5.3 Structures supporting fixed lifting appliances

The design of the structure supporting fixed lifting appliances and the structure that might be called to support a mobile appliance is to be designed taking into account the additional loads that may be imposed on them by the operation of the appliance and environmental conditions as declared by the builder or its sub-contractors.

2.6 Novel designs

2.6.1

Ships with novel features or unusual hull design are to comply with Ch 1, Sec 3, [6.2].

3 CLASS NOTATIONS

3.1 Class notation CSR

3.1.1 Application

In addition to the class notations granted by the Society and to the service features and additional class notations defined hereafter, ships fully complying with these Rules are assigned the notation CSR.

3.2 Class notation for bulk carriers

3.2.1 Additional service features BC-A, BC-B and BC-C

The following requirements apply to ships, as defined in [1.2.1], having length *L* of 150 m or above.

Bulk carriers are to be assigned one of the following additional service features:

a) BC-A: For bulk carriers designed to carry dry bulk cargoes of cargo density 1.0 t/m^3 and above with specified holds empty at maximum draught in addition to BC-B conditions.

b) BC-B: For bulk carriers designed to carry dry bulk cargoes of cargo density of 1.0 t/m^3 and above with all cargo holds loaded in addition to BC-C conditions.

c) BC-C: For bulk carriers designed to carry dry bulk cargoes of cargo density less than 1.0 t/m^3.

The following additional service features are to be provided giving further detailed description of limitations to be observed during operation as a consequence of the design loading condition applied during the design in the following cases:

- {Maximum cargo density in t/m^3} for additional service features BC-A and BC-B if the maximum cargo density is less than 3.0 t/m^3, see also Ch 4, Sec 8, [4.1].
- {No MP} for all additional service features when the ship has not been designed for loading and unloading in multiple ports in accordance with the conditions specified in Ch 4, Sec 8, [4.2.2].
- {Holds a, b, ... may be empty} for additional service feature BC-A, see also Ch 4, Sec 8, [4.1].

3.2.2 Additional class notation GRAB [X]

The additional class notation GRAB [X] is mandatory for ships having one of the additional service features BC-A or BC-B, according to [3.2.1]. For these ships, the requirements for the GRAB [X] notation given in Pt 2, Ch 1, Sec 6 are to comply with for an unladen grab weight X taken not less than:

- 35 t for ships with $L \geq 250$ m,
- 30 t for ships with $200 \text{ m} \leq L < 250$ m,
- 20 t otherwise.

For all other ships, the additional class notation GRAB [X] is voluntary.

4 APPLICATION OF THE RULES OF THE SOCIETY

4.1 Structural parts not covered by these Rules

4.1.1

Designer should take care that parts of the structure that these Rules do not cover comply with the relevant requirements of the Society's Rule.

SECTION 2
RULE PRINCIPLES

1 GENERAL

1.1 Rule objectives

1.1.1

The objectives of the Rules are to establish the classification minimum requirements to mitigate the risks of major hull structural failure in order to help improve the safety of life, environment and property and to contribute to the durability of the hull structure for the ship's design life.

1.1.2

The sub-sections contain:

- The general assumptions pertaining to the design, construction and operation of the ship and give information on the assumed roles of the Society, builders, designers and owners.
- The design basis which specifies the premises on which the Rules are based in terms of design parameters and assumptions about the ship operation.
- The design principles which define the fundamental principles used for the structural requirements in the Rules with respect to loads and structural capacity.
- The rule design methods which describe how the design principles are applied and the criteria are used in view of [1.1.1].

2 GENERAL ASSUMPTIONS

2.1 International and national regulations

2.1.1

Ships are to be designed, constructed and operated in compliance with the regulatory framework prescribed by the International Maritime Organisation (IMO) and implemented by National Administrations or the Society on their behalf. The builder is to give due consideration to the influence on the structural design and arrangement from the relevant requirements of the International Labour Organization (ILO) implemented by National Administrations or the Society on their behalf.

2.1.2

The Rules are based on the assumption that the applicable statutory requirements are complied with.

2.2 Application and implementation of the Rules

2.2.1

The Society develops and publishes the rules for classification of ships, containing minimum requirements for the hull structure and essential engineering systems. The Society verifies compliance with the classification requirements and the applicable international regulations when authorised by a National Administration during design, construction and operation of the ship.

2.2.2

These Rules address the hull structural aspects of classification and do not include requirements related to the verification of compliance with the Rules during construction and operation. In order to achieve the safety level targeted by the Rules, a number of aspects related to design, construction and operation of the ship are assumed to be adhered to by the parties involved in the application and implementation of the Rules. A summary of these assumptions are given in the following:

a) General aspects:

- Relevant information and documentation involved in the design, construction and operation is communicated between the builder, the designer, the Society and the owner as agreed between builder and owner. Design documentation according to Rule requirements is provided.
- Quality systems are applied to the design, construction, operation and maintenance activities by owners and other relevant parties to ensure the compliance with the requirements of the Rules.

b) Design aspects:

- The owner specifies the intended use of the ship, and the ship is designed according to operational requirements as well as the structural requirements given in the Rules.
- The builder identifies and documents the operational limits for the ship so that the ship can be safely and efficiently operated within these limits.
- Verification of the design is performed by the builder to check compliance with provisions contained in the Rules in addition to national and international regulations.
- The design is performed by appropriately qualified, competent and experienced personnel.
- The Society performs a technical appraisal of the design plans and related documents for a ship to verify compliance with the appropriate classification Rules.
- For spaces where lighting and ventilation are to be fitted, the builder is to give consideration to the influence on the structural design and arrangement from the relevant requirements of International Conventions such as SOLAS and MLC2006 Regulation 3.1 - Accommodation and recreational facilities, and Society's rules if any. For general guidance, human element factors may be considered based on IACS Recommendation No. 132 and/or an ergonomic standard accepted by the Society.
- For spaces normally occupied or manned by shipboard personnel where noise is to be minimised, the builder is to give consideration to the influence on the structural design and arrangement from the relevant requirements of SOLAS Ch II-1, Reg.3-12 and "The Code on Noise Levels Onboard Ships" adopted at MSC.337(91).
- For spaces normally occupied or manned by shipboard personnel where vibration is to be minimised, the builder is to give consideration to the influence on the structural design and arrangement from the relevant requirements of relevant statutory requirements such as MLC 2006 Regulation 3.1 - Accommodation and recreational facilities. For general guidance, human element factors may be considered based on IACS Recommendation No. 132 or on an ergonomic standard accepted by the Society.

c) Construction aspects:

- The builder provides adequate supervision and quality control during the construction.
- Construction is carried out by qualified and experienced personnel.
- Workmanship, including alignment and tolerances, is in accordance with acceptable shipbuilding standards.
- The Society performs surveys to verify that the construction and quality control are in accordance with the classification features of approved plans and procedures.

d) Operational aspects:

- Personnel involved in operations are aware of, and comply with, the operational limitations of the ship.

- Operations personnel receive sufficient training such that the ship is properly handled so that the loads and resulting stresses imposed on the structure are minimised.
- The ship is maintained in adequate condition and in accordance with the Society survey scheme and international and national regulations and requirements.
- The Society performs surveys to verify that the ship is maintained in class in accordance with the Society survey scheme.

3 DESIGN BASIS

3.1 General

3.1.1

This sub-section specifies the design parameters and the assumptions about the ship operation that are used as the basis of the design principles of the Rules.

3.1.2

Ships are to be designed to withstand, in the intact condition, the environmental conditions as defined in [5.3.2] and [5.3.3] anticipated during the design life, for the appropriate loading conditions. Structural strength is to be determined against buckling and yielding. Ultimate strength calculations have to include ultimate hull girder capacity and ultimate strength of plates and stiffeners.

3.1.3 Residual strength

Ships having a length *L* of 150 m or above are to be designed to have sufficient reserve strength to withstand the loads in damaged conditions, e.g. collision, grounding or flooded scenarios. Residual strength calculations are to take into account the ultimate reserve capacity of the hull girder, considering permanent deformation and post-buckling behaviour as specified in Ch 5, Sec 3.

3.1.4 Finite element analysis

The scantling of the structural members within the cargo hold region of ships having a length *L* of 150 m or above is to be assessed according to the requirements specified in Pt 1, Ch 7.

3.1.5 Fatigue life

Ships having a length *L* of 150 m or above are to be assessed according to the design fatigue life for structural details specified in Pt 1, Ch 9.

3.1.6

The Rules are applicable for ships in compliance with the specified design basis. Special consideration is given to deviations from this design basis.

3.1.7

The design basis used for the design of each ship, as communicated by the builder to the owner, is to be documented and submitted to the Society as part of the design review and approval. All changes of the design basis are to be formally advised to the Society and the owner for approval.

3.2 Hull form limit

3.2.1

The Rules assume the following hull form with respect to environmental loading:

- $L < 500$ m

- $C_B > 0.6$
- $L/B > 5$
- $B/D < 2.5$

For ships over 350 m in length, special consideration is to be made for the wave loads by the Society.

3.3 Design life

3.3.1

A design life of 25 years is assumed for selecting ship design parameters. The specified design life is the nominal period that the ship is assumed to be exposed to operating conditions.

3.4 Environmental conditions

3.4.1 North Atlantic wave environment

The rule requirements are based on a ship trading in the North Atlantic wave environment for its entire design life.

3.4.2 Wind and current

The effects of wind and current with regard to the strength of the structure are not considered.

3.4.3 Ice

The effects of ice and ice accretion are not taken into account by the Rules.

3.4.4 Design temperatures

The Rules assume that the structural assessment of hull strength members is valid for the following design temperatures:

- Lowest mean daily average temperature in air is -10°C.
- Lowest mean daily average temperature in seawater is 0°C.

Ships intended to operate in areas with lower mean daily average temperature, e.g. regular service during winter seasons to Arctic or Antarctic waters are subject to the requirements as specified by the Society.

In the above, the following definitions apply:

Mean : Statistical mean over observation period (at least 20 years).

Daily Average : Average during one day and night.

Lowest : Lowest during year.

For seasonally restricted service the lowest value within the period of operation applies.

3.4.5 Thermal loads

The effects of thermal loads and residual stresses are not taken into account in the Rules.

3.5 Operating conditions

3.5.1

The Rules specify minimum loading conditions that are to be assessed for compliance.

Specification of loading conditions other than those required by the Rules is the responsibility of the owner. These other loading conditions are to be documented and also be assessed for compliance.

3.5.2

The Rules assume the following:

- The ballast cargo hold of bulk carriers is not to be partly filled in seagoing operations.
- Ballasting and deballasting operations in the ballast cargo hold of bulk carriers are not to be performed when the weather is not fair.

3.6 Operating draughts

3.6.1

The design operating draughts are to be specified by the builder/designer subject to acceptance by the owner and are to be used to derive the appropriate structural scantlings. All operational loading conditions in the loading manual are to comply with the specified design operating draughts. The following design operating draughts are as a minimum to be considered:

- Scantling draught for the assessment of structure.
- Minimum ballast draught at midship for assessment of structure.
- Minimum heavy ballast draught at midship for assessment of bulk carrier structure.
- Minimum forward draughts for the assessment of bottom structure forward subjected to slamming loads, T_{F-e} and T_{F-f}, with and without ballast tanks in way filled.

  T_{F-e} and T_{F-f} are defined in Ch 4, Sec 5, [3.2.1]
- For oil tankers: maximum draughts amidships for both conditions:
  - with all cargo tanks abreast empty.
  - with centre cargo tank empty and wing cargo tanks full.
  - with centre cargo tank full and wing cargo tanks empty.
- For bulk carriers carrying steel coils: maximum draught amidships for steel coil loading conditions.

3.7 Internal environment

3.7.1 Oil cargo density for strength assessment

A density of 1.025 t/m^3, or a higher value if specified by the designer, is to be used for oil cargoes for the strength assessment of all relevant tank structures.

3.7.2 Oil cargo density for fatigue assessment

For the fatigue assessment of cargo tank structures, the mean density is to be taken as 0.9 t/m^3, or a higher value if specified by the designer.

3.7.3 Dry cargo density

The density for dry bulk cargo is to be taken according to the specifications in Ch 4, Sec 6, [2.3].

3.7.4 Water ballast density

A density of 1.025 t/m^3 is to be used for water ballast.

3.8 Structural construction and inspection

3.8.1

The structural requirements included in the Rules are developed with the assumption that construction and repair follow acceptable shipbuilding and repair standards and tolerances. The Society may require that

additional attention is paid to critical areas of the structure by the builder during construction and by the owner for repair after the ship's delivery.

3.8.2

As an objective, ships are to be built in accordance with controlled quality production standards using approved materials as necessary.

3.8.3

The Rules define the renewal criteria for the individual structural items. The structural requirements included are developed on the assumption that the structure is subject to appropriate monitoring by the owner once the ship is in operation and to periodical survey in accordance with Society rules and regulations.

3.8.4

Tank strength and tightness testing are to be carried out as a part of the verification scheme according to the Rules and/or documents of the individual Society which incorporate IACS UR S14.

3.8.5

Specifications for material manufacturing, assembling, joining and welding procedures, steel surface preparation and coating are to be included in the ship construction quality procedures. It is assumed that the owner has approved these builder specifications.

3.9 Maximum service speed

3.9.1

The maximum service speed is to be specified in the design specification. Although the hull structure verification criteria takes into account the service speed this does not relieve the responsibilities of the owner and personnel to properly handle the ship, see item (d) in [2.2.2].

3.10 Owner's extras

3.10.1

Owner's specification of requirements above the general classification or statutory requirements may affect the structural design. Owner's extras may include requirements for:

- Vibration analysis.
- Maximum percentage of high strength steel.
- Additional scantlings above that required by the Rules.
- Additional design margin on the loads specified by the Rules, etc.
- Improved fatigue resistance, in the form of a specified increase in design fatigue life or equivalent.

Owner's extras are not specified by these Rules. Owner's extras, if any, that may affect the structural design are to be clearly specified in the design documentation.

4 DESIGN PRINCIPLES

4.1 Overall principles

4.1.1 Introduction

This sub-section defines the underlying design principles of the Rules in terms of loads, structural capacity models and assessment criteria and also construction and in-service aspects.

4.1.2 General

The Rules are based on the following overall principles:

- The safety of the structure can be assessed by addressing the potential structural failure mode(s) when the ship is subjected to operational loads and environmental loads/conditions.
- The design complies with the design basis, see Ch 1, Sec 3.
- The structural requirements are based on consistent design load sets which cover the appropriate operating modes of a bulk carrier or oil tanker.

The ship's structure is designed such that:

- It has a degree of redundancy. The ship's structure should work in a hierarchical manner and, in principle, failure of structural elements lower down in the hierarchy do not result in immediate consequential failure of elements higher up in the hierarchy.
- It has sufficient reserve strength to withstand the wave and internal loads in damaged conditions that are reasonably foreseeable e.g. collision, grounding or flooding scenarios. Residual strength calculations are to take into account the ultimate reserve capacity of the hull girder, considering permanent deformation and post-buckling behaviour.
- The incidence of in-service cracking is minimised, particularly in locations which affect the structural integrity or containment integrity, affect the performance of structural or other systems or are difficult to inspect and repair.
- It has adequate structural redundancy to survive in the event that the structure is accidentally damaged by a minor impact leading to flooding of any compartment.

4.1.3 Limit state design principles

The rules are based on the principles of limit state design.

Limit state design is a systematic approach where each structural element is evaluated with respect to possible failure modes related to the design scenarios identified. For each retained failure mode, one or more limit states may be relevant. By consideration of all relevant limit states, the limit load for the structural element is found as the minimum limit load resulting from all the relevant limit states.

The limit states defined in Ch 3, Sec 5 are divided into the four categories: Serviceability Limit State (SLS), Ultimate Limit State (ULS), Fatigue Limit State (FLS) and Accidental Limit State (ALS).

The Rules include requirements to cover the relevant limit states for the various parts of the structure.

4.2 Loads

4.2.1 Design load scenarios

The structural assessment of the structure is based on the design load scenarios encountered by the ship. Refer to Ch 4, Sec 7.

The design load scenarios are based on static and dynamic loads as given below:

- Static design load scenario (S):

  Covers application of relevant static loads and typically covers load scenarios in harbour, sheltered water, or tank testing.

- Static plus Dynamic design load scenario (S+D):

  Covers application of relevant static loads and simultaneously occurring dynamic load components and typically cover load scenarios for seagoing operations.

- Impact design load scenario (I):

  Covers application of impact loads such as bottom slamming and bow impact encountered during seagoing operations.

- Sloshing design load scenario (SL):

  Covers application of sloshing loads encountered during seagoing operations.
- Fatigue design load scenario (F):

  Covers application of relevant dynamic loads.
- Accidental design load scenario (A):

  Covers application of some loads not occurring during normal operations.

4.3 Structural capacity assessment

4.3.1 General

The basic principle in structural design is to apply the defined design loads, identify plausible failure modes and employ appropriate capacity models to verify the required structural scantlings.

4.3.2 Capacity models for ULS, SLS and ALS

The strength assessment method is to be capable of analysing the failure mode in question to the required degree of accuracy.

The structural capacity assessment methods are in either a prescriptive format or require the use of more advanced calculations such as finite element analysis methods.

The formulae used to determine stresses, deformations and capacity are deemed appropriate for the selected capacity assessment method and the type and magnitude of the design load set.

4.3.3 Capacity models for FLS

The fatigue assessment method provides Rule requirements to assess structural details against fatigue failure.

The fatigue capacity model is based on a linear cumulative damage summation (Palmgren-Miner's rule) in combination with a design S-N curve, a reference stress range and an assumed long-term stress distribution curve.

The fatigue capacity assessment models are in either a prescriptive format or require the use of more advanced calculations, such as finite element analysis methods. These methods account for the combined effects of global and local dynamic loads.

4.3.4 Net scantling approach

The objective of the net scantling approach is to:

- Provide a relationship between the thickness used for strength calculations during the newbuilding stage and the minimum thickness accepted during the operational phase.
- Enable the status of the structure with respect to corrosion to be clearly ascertained throughout the life of the ship.

The net scantling approach distinguishes between local and global corrosion. Local corrosion is defined as uniform corrosion of local structural elements, such as a single plate or stiffener. Global corrosion is defined as the overall average corrosion of larger areas, such as primary supporting members and the hull girder. Both the local and global corrosion are used as a basis for the newbuilding review and are to be assessed during operation of the ship.

No credit is given in the assessment of structural capability for the presence of coatings or similar corrosion protection systems.

The application of the net thickness approach to assess the structural capacity is specified in Ch 3, Sec 2.

4.3.5 Intact structure

All strength calculations for ULS, SLS and FLS are based on the assumption that the structure is intact. The residual strength of the ship in a structurally damaged condition is assessed for ALS.

5 RULE DESIGN METHODS

5.1 General

5.1.1 Design methods

Scantling requirements are specified to cover the relevant limit states (ULS, SLS, FLS and ALS) as necessary for various structural parts.

The criteria for the assessment of the scantlings are based on one of the following design methods:

- Working Stress Design (WSD) method, also known as the permissible or allowable stress method.
- Partial Safety Factor (PSF) method, also known as Load and Resistance Factor Design (LRFD).

For both WSD and PSF, two design assessment conditions and corresponding acceptance criteria are given. These conditions are associated with the probability level of the combined loads, A and B.

- The WSD method has the following composition:

  $W_{stat} \leq \eta_1 R$ for condition A.

  $W_{stat} + W_{dyn} \leq \eta_2 R$ for condition B.

  where:

  W_{stat} : Simultaneously occurring static loads (or load effects in terms of stresses).

  W_{dyn} : Simultaneously occurring dynamic loads. The dynamic loads are typically a combination of local and global load components.

  R : Characteristic structural capacity (e.g. specified minimum yield stress or buckling capacity).

  η_i : Permissible utilisation factor (resistance factor). The utilisation factor includes consideration of uncertainties in loads, structural capacity and the consequence of failure.

- The PSF method has the following composition:

  $\gamma_{stat-1} W_{stat} + \gamma_{dyn-1} W_{dyn} \leq \frac{R}{\gamma_R}$ for condition A.

  $\gamma_{stat-2} W_{stat} + \gamma_{dyn-2} W_{dyn} \leq \frac{R}{\gamma_R}$ for condition B.

  where:

  γ_{stat-i} : Partial safety factor that accounts for the uncertainties related to static loads.

  γ_{dyn-i} : Partial safety factor that accounts for the uncertainties related to dynamic loads.

  γ_R : Partial safety factor that accounts for the uncertainties related to structural capacity.

The acceptance criteria for both the WSD method and PSF method are calibrated for the various requirements such that consistent and acceptable safety levels for all combinations of static and dynamic load effects are derived.

5.2 Minimum requirements

5.2.1

Minimum requirements specify the minimum scantling requirements which are to be applied irrespective of all other requirements, hence thickness below the minimum is not allowed.

The minimum requirements are usually in one of the following forms:

- Minimum thickness, which is independent of the specified minimum yield stress.
- Minimum stiffness and proportion, which are based on buckling failure modes.

5.3 Load-capacity based requirements

5.3.1 General

In general, the Working Stress Design (WSD) method is applied in the requirements, except for the hull girder ultimate strength criteria where the Partial Safety Factor (PSF) method is applied. The partial safety factor format is applied for this highly critical failure mode to better account for uncertainties related to static loads, dynamic loads and capacity formulations.

The identified load scenarios are addressed by the Rules in terms of design loads, design format and acceptance criteria set, as given in Table 2. The table is schematic and only intended to give an overview.

Load based prescriptive requirements provide scantling requirements for all plating, local support members, most primary supporting members and the hull girder and cover all structural elements including deckhouses, foundations for deck equipment.

In general, these requirements explicitly control one particular failure mode and hence several requirements may be applied to assess one particular structural member.

5.3.2 Design loads for SLS, ULS and ALS

The structural assessment of compartment boundaries, e.g. bulkheads, is based on loading condition deemed relevant for the type of ship and the operation the ship is intended for.

To provide consistency of approach, standardised Rule values for parameters, such as GM, R_{roll}, T_{sc} and C_B are applied to calculate the Rule load values.

The probability level of the dynamic global, local and impact loads (see Table 1) is 10^{-8} and is derived using the long-term statistical approach.

The probability level of the sloshing loads (see Table 1) is 10^{-4}.

The design load scenarios for structural verification apply the applicable simultaneously acting local and global load components. The relevant design load scenarios are given in Ch 4, Sec 7.

The simultaneously occurring dynamic loads are specified by applying a dynamic load combination factor to the dynamic load values given in Ch 4. The dynamic load combination factors that define the dynamic load cases are given in Ch 4, Sec 2.

Design load conditions for the hull girder ultimate strength are given in Ch 5, Sec 2.

5.3.3 Design loads for FLS

For the fatigue requirements given in Ch 9, the load assessment is based on the expected load history and an average approach is applied. The expected load history for the design life is characterised by the 10^{-2} probability level of the dynamic load value, the load history for each structural member is represented by Weibull probability distributions of the corresponding stresses.

The considered wave induced loads include:

- Hull girder loads (i.e. vertical and horizontal bending moments).
- Dynamic wave pressures.
- Dynamic pressure from cargo.

The load values are based on Rule parameters corresponding to the loading conditions, e.g. GM, C_B, and the applicable draughts at amidships.

The simultaneously occurring dynamic loads are accounted for by combining the stresses due to the various dynamic load components. The stress combination procedure is given in Ch 9.

Table 1 : Load scenarios and corresponding rule requirements

Operation	Load type	Design load scenario (specified in Ch 4, Sec 7)	Acceptance criteria (specified in Ch 6 and Ch 7)
Seagoing operations			
Transit	Static and dynamic loads in heavy weather	S + D	AC-SD
	Impact loads in heavy weather	Impact (I)	AC-I
	Internal sloshing loads	Sloshing (SL)	AC-S
	Cyclic wave loads	Fatigue (F)	-
BWE by flow through or sequential methods	Static and dynamic loads in heavy weather	S + D	AC-SD
Harbour and sheltered operations			
Loading, unloading and ballasting	Typical maximum loads during loading, unloading and ballasting operations	S	AC-S
Tank testing	Typical maximum loads during tank testing operations	S	AC-S
Special conditions in harbour	Typical maximum loads during special operations in harbour, e.g. propeller inspection afloat or dry-docking loading conditions	S	AC-S
Accidental condition			
Flooded conditions	Typically maximum loads on internal watertight subdivision structure in accidental flooded conditions	A	AC-SD AC-S

Table 2 : Acceptance criteria - prescriptive requirements

Acceptance criteria	Plate panels and local support members (1)		Primary supporting members (1)		Hull girder members	
	Yield	Buckling	Yield	Buckling	Yield	Buckling
AC-S AC-SD	Permissible stress: Ch 6, Sec 4 Ch 6, Sec 5	Control of stiffness and proportions: Ch 8, Sec 2	Permissible stress: Ch 6, Sec 6 Pt 2, Ch 1, Sec 4 Pt 2, Ch 2, Sec 3	Control of stiffness and proportions: Ch 8, Sec 1 Ch 8, Sec 2 Pillar buckling	Permissible stress: Ch 5, Sec 1	Allowable buckling utilisation factor: Ch 8, Sec 1, [3]
AC-I	Plastic criteria: Ch 10, Sec 1, [3]	Control of stiffness and proportions: Ch 8, Sec 2 Ch 10, Sec 1, [3]	Plastic criteria: Ch 10, Sec 1, [3]	Control of stiffness and proportions: Ch 8, Sec 2 Ch 10, Sec 1, [3]	N/A	N/A

(1) Refer to Ch 10 for Other structures and to Ch 11 for Superstructure, deckhouses and hull outfitting

Table 3 : Acceptance criteria - FE analysis

Acceptance criteria	Cargo hold analysis		Fine mesh analysis
	Yield	Buckling	Yield
AC-S AC-SD	Permissible stress: Ch 7, Sec 2, [5]	Allowable buckling utilisation factor: Ch 8, Sec 1, [3]	Permissible Von Mises stress: Ch 7, Sec 3, [6] Screening criteria: Ch 7, Sec 3, [3.3]

5.3.4 Structural response analysis

In general, the following approaches are applied for determination of the structural response to the applied design load combinations.

a) Beam theory:

- Used for prescriptive requirements.

b) FE analysis:

- Coarse mesh for cargo hold model.
- Fine mesh for local models.
- Very fine mesh for fatigue assessment.

5.4 Acceptance criteria

5.4.1 General

The acceptance criteria are categorised into three acceptance criteria sets. These are explained below and shown in Table 2 and Table 3. The specific acceptance criteria set that is applied in the rule requirements is dependent on the probability level of the characteristic combined load.

The acceptance criteria set AC-S is applied for the static design load combinations, and for the sloshing design loads. The allowable stress for such loads is lower than that for an extreme load to take into account effects of:

- Repeated yield.
- Allowance for some dynamics.
- Margins for some selected limited operational mistakes.

The acceptance criteria set AC-SD is applied for the S+D design load combinations where considered loads are extreme loads with a low probability of occurrence.

The acceptance criteria set AC-I is typically applied for impact loads, such as bottom slamming and bow impact loads.

5.4.2 Acceptance criteria

The specific acceptance criteria applied in the working stress design requirements are given in the detailed Rule requirements in Pt 1, Ch 5 to Ch 8, Ch 10, Ch 11 and Pt 2, Ch 1 and Ch 2.

To provide a general informational summary overview of the acceptance criteria, refer to Table 2 and Table 3 below for the different design load scenarios covered by these Rules for the yield and buckling failure modes. For the yield criteria the permissible stress is proportional to the specified minimum yield stress of the material. For the buckling failure mode, the acceptance criteria are based on the control of stiffness and proportions as well as on the buckling utilisation factor.

5.5 Design verification

5.5.1 Design verification – hull girder ultimate strength

The requirements for the ultimate strength of the hull girder are based on a Partial Safety Factor (PSF) method. A safety factor is assigned to each of the basic variables, the still water bending moment, wave bending moment and ultimate capacity. The safety factors were determined using a structural reliability assessment approach, the long-term load history distribution of the wave bending moment was derived using ship motion analysis techniques suitable for determining extreme wave bending moments.

The purpose of the hull girder ultimate strength verification is to demonstrate that one of the most critical failure modes of a ship is controlled.

5.5.2 Design verification – global finite element analysis

The global finite element analysis is used to verify the scantlings given by the load-capacity based prescriptive requirements to better consider the complex interactions between the ship's structural components, complex local structural geometry, change in thicknesses and member section properties as well as the complex load regime with sufficient accuracy.

A linear elastic three dimensional finite element analysis of the cargo region (a FE model length of three holds is required) is carried out to assess and verify the structural response of the proposed hull girder and primary supporting members and assist in specifying the scantling requirements for the primary supporting members. The purpose with the finite element analysis is to verify that the stresses and buckling capability of the primary supporting members are within acceptable limits for the applied design loads.

5.5.3 Design verification – fatigue assessment

The fatigue assessment is required to verify that the fatigue life of critical structural details is adequate. A simplified fatigue requirement is applied to details such as end connections of longitudinal stiffeners using stress concentration factors (SCF) to account the actual detail geometry. A fatigue assessment procedure using finite element analysis for determining the actual hot spot stress of the geometric detail is applied to selected details. In both cases, the fatigue assessment method is based on the Palmgren-Miner linear damage model.

5.5.4 Relationship between prescriptive scantling requirements and FE analysis

The scantlings defined by the prescriptive requirements are not to be reduced by any form of alternative calculations such as FE analysis, unless explicitly stated.

SECTION 3
VERIFICATION OF COMPLIANCE

1 GENERAL

1.1 Newbuilding

1.1.1

For newbuildings, the plans and documents submitted for approval, as indicated in [2], are to comply with applicable requirements in these Rules, taking account of the relevant criteria, such as additional service features and classification notations assigned to the ship or the ship length.

1.1.2

When a ship is surveyed by the Society during construction, the Society:

- Approves the plans and documentation submitted as required by the Rules.
- Proceeds with the appraisal of the design of materials and equipment used in the construction of the ship and their inspection at works.
- Carries out surveys or obtains appropriate evidence to satisfy itself that the scantlings and construction meet the Rule requirements in relation to the approved drawings.
- Attends tests and trials provided for in the Rules.
- Assigns the classification character of the Society's notation.

1.1.3

The Society defines in specific Rules which materials and equipment used for the construction of ships built under survey are, as a rule, subject to appraisal of their design and to inspection at works, and according to which particulars.

1.1.4

As part of his/her interventions during ship's construction, the surveyor:

- Conducts an overall examination of the parts of the ship covered by the Rules.
- Examines the construction methods and procedures when required by the Rules.
- Checks selected items covered by the Rule requirements.
- Attends tests and trials where applicable and deemed necessary.

1.1.5

Through all stages of ship construction, it is the builder's responsibility to inform promptly the Society of the modifications or departures from approved arrangements and to deal with as necessary. The builder is to ensure that deviations from the requirements of the Rules or approved plans, other than those of a minor nature not affecting the structural strength of the vessel, are, in any case, accepted by the Society's approval office.

1.2 Ships in service

1.2.1

For ships in service, the requirements in Ch 13 are to be complied with.

2 DOCUMENTS TO BE SUBMITTED

2.1 Documentation and data requirements

2.1.1 Loading information

Loading information containing sufficient information to enable the master of the ship to maintain the ship within the stipulated operational limitations is to be provided on board the ship. The loading information is to include an approved loading manual and loading instrument complying with the requirements given in Ch 1, Sec 5.

2.1.2 Calculation data and results

Where calculations have been carried out in accordance with the procedures given in the Rules, one copy of the following is to be submitted for information as applicable:

a) Reference to the calculation procedure and technical program used.

b) A description of the structural modelling.

c) A summary of the analysed parameter including properties and boundary conditions for direct analysis, when applicable.

d) Details of the loading conditions and the means of applying loads for direct analysis, when applicable.

e) A comprehensive summary of calculation results.

f) Sample calculations where appropriate.

The responsibility for error free specification and input of program data and the subsequent correct transposal of output resides with the designer.

Reference is made to Ch 7, Sec 1, [4.1] for required reporting of finite element analysis.

2.2 Submission of plans and supporting calculations

2.2.1 Plans and supporting calculations are to be submitted for approval

For the application of these Rules, the plans and supporting calculations to be submitted to the Society for approval are listed in Table 1.

Plans are to be submitted electronically or physically. When physically submitted plans are to be submitted in triplicate, with one copy necessary for supporting documents and calculations. In addition, the Society may request the submission of information, other plans and documents deemed necessary for the review of the design.

Structural plans are to show scantling, details of connection of the various parts and are to specify the design materials including, in general, their grades, manufacturing processes, welding procedures and heat treatments, and are to include information related to the renewal thickness as specified in Ch 13.

For welding requirements, see Ch 12, Sec 2 and Ch 12, Sec 3.

In case there are deviations from the design basis, then these are to be documented and submitted to the Society.

Table 1 : Plans and supporting calculation to be submitted for approval

Plan or supporting calculation	Containing also information on
Midship section Transverse sections Shell expansion Decks and profiles Double bottom Pillar arrangements Framing plan Deep tank and ballast tank bulkheads, Wash bulkheads Standard construction details	Class characteristics Ship's main dimensions Minimum ballast draught Frame spacing Maximum service speed Density of cargoes Design loads on decks and double bottom Steel grades Corrosion protection Openings in decks and shell and relevant compensations Boundaries of flat areas in bottom and sides Details of structural reinforcements and/or discontinuities Bilge keel with details of connections to hull structures Welding
Watertight subdivision bulkheads Watertight tunnels	Openings and their closing appliances, if any
Fore part structure	-
Aft part structure	-
Machinery space structures Foundations of propulsion machinery and boilers	Type, power and RPM of propulsion machinery Mass and centre of gravity of machinery and boilers
Superstructures and deckhouses Machinery space casing	Extension and mechanical properties of the aluminium alloy used (where applicable)
Hatch covers and hatch coamings	Design loads on hatch covers Sealing and securing arrangements, type and position of locking bolts Distance of hatch covers from the summer load waterline and from the fore end
Transverse thruster, if any, general arrangement, tunnel structure, connections of thruster with tunnel and hull structures	-
Bulwarks and freeing ports	Arrangement and dimensions of bulwarks and freeing ports on the freeboard deck and superstructure deck
Windows and side scuttles, arrangements and details	-
Scuppers and sanitary discharges	-
Mooring and towing arrangement	-
Supporting structure and foundations for shipboard fittings associated with mooring and towing operations	Design loads and directions of load actions, rated pull and holding load for mooring winches Reaction forces Details of connection of the foundations to the deck, including specifications for holding down bolts for mooring winches Material specifications and welding

Plan or supporting calculation	Containing also information on
Supporting structure and foundations for windlasses and chain stoppers	Design loads and directions of load actions Reaction forces Details of connection of the foundations to the deck, including specifications for holding down bolts for windlasses Material specifications and welding
Stern frame or sternpost, sterntube Propeller shaft boss and brackets (1)	-
Plan of watertight doors and scheme of relevant closing devices	Closing devices Electrical diagrams of power control and position indication circuits
Plan of weathertight or outer doors and hatchways	-
Supporting structure for lifting appliances	Design loads (forces and moments) SWL and self weight of lifting appliances Maximum sea state in offshore operation, if any Connections to the hull structures
Supporting structure for life saving appliances	Design loads (forces and moments) SWL and self weight of lifting appliances Connections to the hull structure
Sea chests, stabiliser recesses, etc	-
Plan of manholes	-
Plan of access to and escape from spaces	-
Plan of ventilation including ventilators and tank vents	Use of spaces and location and height of air vent outlets of various compartments
Plan of tank testing	Testing procedures for the various compartments Height of pipes for testing
Equipment number calculation	Geometrical elements for calculation List of equipment Construction and breaking load of steel wires Material, construction, breaking load and relevant elongation of synthetic ropes
Anchoring arrangement	-
Hawse pipes	-
Loading manual and/or trim and stability booklet	-
(1) Where other steering or propulsion systems are adopted (e.g. steering nozzles or azimuth propulsion systems), the plans showing the relevant arrangement and structural scantlings are to be submitted.	

2.2.2 Plans to be submitted for information

In addition to those in [2.2.1], the following plans are to be submitted to the Society for information:

a) General arrangement.

b) Capacity plan, indicating the volume and position of the centre of gravity of all compartments and tanks.

c) Lines plan, when deemed necessary by the Society.

d) Hydrostatic curves.

e) Lightweight distribution.

f) Docking plan.

g) Arrangement of lifting appliances

2.2.3 Plans and instruments to be supplied onboard the ship

As a minimum, the following plans and instrument are to be supplied onboard:

a) One copy of the following plans indicating the newbuilding and renewal thickness for each structural item is to be supplied onboard the ship: plans of midship sections, construction profiles, shell expansion, transverse bulkheads, aft and fore part structures, machinery space structures and casing.

   One copy of the following plans indicating the newbuilding thickness for each structural item is to be supplied onboard the ship: plans of superstructures and deckhouses.

b) One copy of the final approved loading manual, see [2.1.1].

c) One copy of the final approved loading instrument, see [2.1.1].

d) Welding.

e) Details of the extent and location of higher tensile steel together with details of the specification and mechanical properties, and any recommendations for welding, working and treatment of these steels.

f) Details and information on use of special materials, such as an aluminium alloy, used in the hull construction.

g) Towing and mooring arrangements plan, see Ch 11, Sec 3.

h) Structural access manual.

Other plans or instrument may be required by the Society.

3 SCOPE OF APPROVAL

3.1 General

3.1.1

The attention of owners, designers and builders is directed to the regulations of international, national, canal, and other authorities dealing with those requirements which may affect structural aspects, in addition to or in excess of the classification requirements.

3.1.2

The documentation, plans and data requirements specified in [2] are to be submitted. The Society is to review such documentation to verify compliance with the requirements.

3.1.3

An appropriate term to indicate that the plans, reports or documents have been reviewed for compliance with these Rules is to be used according to the procedures of the Society.

3.2 Requirements of international and national regulations

3.2.1 Responsibility

It is the responsibility of the designer to ensure that the design complies with the national and international regulations applicable to the ship.

The Society is not responsible for assessing compliance with international and national regulations as part of the general classification process. However, the Society may enter into an agreement with the flag administration of the ship under which they are explicitly instructed to review and approve a ship design for compliance with specified regulations.

4 WORKMANSHIP

4.1 Requirements to be complied with by the manufacturer

4.1.1

The manufacturing plant is to be provided with suitable equipment and facilities to enable proper handling of the materials, manufacturing processes and structural components. The manufacturing plant is to have at its disposal sufficiently qualified personnel. The Society is to be advised of the names and areas of responsibility of the supervisory and control personnel in charge of the project.

4.2 Quality control

4.2.1

As far as required and expedient, the manufacturer's personnel has to examine all structural components both during manufacture and on completion, to verify that they are complete, that the dimensions are correct and that workmanship is satisfactory and meets the standard of good shipbuilding practice.

Upon inspection and corrections by the manufacturing plant, the structural components are to be shown to the surveyor of the Society for inspection, in suitable sections, normally unpainted condition and enabling proper access for inspection.

The Surveyor may reject components that have not been adequately checked by the plant and may demand their re-submission upon successful completion of such checks and corrections by the plant.

5 STRUCTURAL DETAILS

5.1 Details in manufacturing documents

5.1.1

Significant details concerning quality and functional ability of the component concerned are to be entered in the manufacturing documents (e.g. workshop drawing). This includes not only scantlings but, where relevant, such items as surface conditions (e.g. finishing of flame cut edges and weld seams), and special methods of manufacture involved as well as inspection and acceptance requirements and where relevant permissible tolerances. When a standard is used (works or national standard), it is to be submitted to the Society. For weld joint details, see Ch 12, Sec 2.

If, due to missing or insufficient details in the manufacturing documents, the quality or functional ability of the component is doubtful, the Society may require appropriate improvements to be submitted by the manufacturer. This includes the provision of supplementary or additional parts (for example, reinforcements) even if these were not required at the time of plan approval.

6 EQUIVALENCE PROCEDURES

6.1 Rule applications

6.1.1

These Rules apply to ships of normal form, proportions, speed and structural arrangements. Relevant design parameters defining the assumptions made are given in Ch 1, Sec 2, [3].

6.1.2

Special consideration is to be given to the application of the Rules incorporating design parameters which are outside the design basis as specified in Ch 1, Sec 2, [3], for example, increased fatigue life.

6.2 Novel designs

6.2.1

Ships of novel design, i.e. those of unusual form, proportions, speed and structural arrangements outside those specified in Ch 1, Sec 2, [3.2], are specially considered according to the contents of [6.2.2] to [6.2.4].

6.2.2

Information is to be submitted to the Society to demonstrate that the structural safety of the novel design is at least equivalent to that intended by the Rules.

6.2.3

In such cases, the Society is to be contacted at an early stage in the design process to establish the applicability of the Rules and additional information required for submission.

6.2.4

Dependent on the nature of the deviation, a systematic review may be required to document equivalence with the Rules.

6.3 Alternative calculation methods

6.3.1

Where indicated in specific sections of the Rules, alternative calculation methods to those shown in the Rules may be accepted provided it is demonstrated that the scantling and arrangements are of at least equivalent strength to those derived using the Rules.

SECTION 4
SYMBOLS AND DEFINITIONS

1 PRIMARY SYMBOLS AND UNITS

1.1 General

1.1.1

Unless otherwise specified, the general symbols and their units used in these Rules are those defined in Table 1.

Table 1 : Primary symbols

Symbol	Meaning	Units
A	Area	m²
	Sectional area of stiffeners and primary members	cm^2
C	Coefficient	-
F	Force and concentrated loads	kN
I	Hull girder inertia	m^4
	Inertia of stiffeners and primary members	cm^4
M	Bending moment	kNm
M	Mass	t
P	Pressure	kN/m^2
Q	Shear force	kN
T	Draught of ship, see [3.1.5]	m
Z	Hull girder section modulus	m^3
	Section modulus of stiffeners and primary supporting members	cm^3
a_i	Acceleration for the effect 'i'	m/s^2
b	Width of attached plating	mm
	Width of face plate of stiffeners and primary supporting members	mm
g	Gravity acceleration, taken equal to 9.81 m/s^2	m/s^2
h	Height	m
	Web height of stiffeners and primary supporting members	mm
ℓ	Length/span of stiffeners and primary supporting members	m
n	Number of items	-
r	Radius	mm
	Radius of curvature of plating or bilge radius	mm
t	Thickness	mm
x	*X* coordinate along longitudinal axis, see [3.6]	m
y	*Y* coordinate along transverse axis, see [3.6]	m
z	*Z* coordinate along vertical axis, see [3.6]	m
η	Permissible utilisation factor (usage factor)	-

Symbol	Meaning	Units
γ	Safety factor	-
δ	Deflection/displacement	mm
θ	Angle	deg
ρ	Density of seawater, taken equal to 1.025 t/m^3	t/m^3
σ	Normal stress	N/mm^2
τ	Shear stress	N/mm^2

2 SYMBOLS

2.1 Ship's main data

2.1.1

Unless otherwise specified, symbols regarding ship's main data and their units used in these Rules are those defined in Table 2.

Table 2 : Ship's main data

Symbol	Meaning	Units
L	Rule length	m
L_{LL}	Freeboard length	m
L_{PP}	Length between perpendiculars	m
L_0	Rule length, L, but not to be taken less than 110 m	m
L_1	Rule length, L, but need not be taken greater than 250 m	m
L_2	Rule length, L, but need not be taken greater than 300 m	m
B	Moulded breadth of ship	m
D	Moulded depth of ship	m
T	Moulded draught	m
T_{SC}	Scantling draught	m
T_{BAL}	Ballast draught (minimum midship)	m
T_{BAL-H}	Heavy ballast draught	m
T_{BAL-E}	Emergency ballast draught or gale ballast draught	m
T_{LC}	Midship draught at considered loading condition	m
T_{F-f}, T_{F-e}	Minimum draught at forward perpendicular for bottom slamming, with respectively all ballast tanks full or with any tank empty in bottom slamming area	m
Δ	Moulded displacement at draught T_{SC}	t
C_B	Block coefficient at draught T_{SC}	-
V	Maximum service speed	knot
x, y, z	X,Y, Z coordinates of the calculation point with respect to the reference coordinate system	m

2.2 Materials

2.2.1

Unless otherwise specified, symbols regarding materials and their units used in these Rules are those defined in Table 3.

Table 3 : Materials

Symbol	Meaning	Units
E	Young's modulus, see Ch 3, Sec 1, [2]	N/mm^2
G	Shear modulus, $G = \dfrac{E}{2(1+\nu)}$	N/mm^2
R_{eH}	Specified minimum yield stress, see Ch 3, Sec 1, [2]	N/mm^2
τ_{eH}	Specified shear yield stress, $\tau_{eH} = \dfrac{R_{eH}}{\sqrt{3}}$	N/mm^2
ν	Poisson's ratio, see Ch 3, Sec 1, [2]	-
k	Material factor, see Ch 3, Sec 1, [2]	-
R_m	Specified minimum tensile strength, see Ch 3, Sec 1, [2]	N/mm^2
R_Y	Nominal yield stress, taken equal to $235/k$	N/mm^2

2.3 Loads

2.3.1

Unless otherwise specified, symbols regarding loads and their units used in these Rules are those defined in Table 4.

Table 4 : Loads

Symbol	Meaning	Units
C_w	Wave coefficient	-
T_θ	Roll period	s
θ	Roll angle	deg
T_φ	Pitch period	s
φ	Pitch angle	deg
a_o	Common acceleration parameter	-
a_z	Vertical acceleration	m/s^2
a_y	Transverse acceleration	m/s^2
a_x	Longitudinal acceleration	m/s^2
f_p	Probability factor	-
k_r	Roll amplitude of gyration	m
GM	Metacentric height	m
λ	Wave length	m
S	Static load case	-
S+D	Dynamic load case	-
P_{ex}	Total sea pressure, see Ch 4, Sec 5, [1.1]	kN/m^2

Symbol	Meaning	Units
P_{in}	Total internal pressure due to liquid, see Ch 4, Sec 6, [1], or due to dry bulk cargo, see Ch 4, Sec 6, [2.4.1]	kN/m^2
P_s	Static sea pressure	kN/m^2
P_{ls}	Static tank pressure	kN/m^2
P_w	Dynamic wave pressure	kN/m^2
P_{ld}	Dynamic tank pressure	kN/m^2
P_D	Green sea deck pressure	kN/m^2
$P_{slh\text{-}j}$	Sloshing pressure, j=direction	kN/m^2
P_{dl}	Total pressure due to distributed load on deck or platform, see Ch 4, Sec 5, [2.3] or Ch 4, Sec 6, [5.2]	kN/m^2
P_{SL}	Bottom slamming pressure	kN/m^2
P_{FB}	Bow impact pressure	kN/m^2
P_{fs}	Static pressure in flooded conditions	kN/m^2
P_{fd}	Dynamic pressure in flooded conditions	kN/m^2
P_{ST}	Tank testing pressure (static)	kN/m^2
F_U	Total force due to concentrated load on deck or platform, see Ch 4, Sec 5, [2.3] or Ch 4, Sec 6, [5.3]	kN
$M_{sw\text{-}j}$	Vertical still water bending moment, $j = h, s, p$ (hog, sag, harbour)	kNm
Q_{sw}	Vertical still water shear force	kN
$M_{wv\text{-}j}$	Vertical wave bending moment, $j = h, s$ (hog, sag)	kNm
Q_{wv}	Vertical wave shear force	kN
M_{wt}	Torsional wave moment	kNm
M_{wh}	Horizontal wave bending moment	kNm

2.4 Scantlings

2.4.1

Unless otherwise specified, symbols regarding scantlings and their units used in these Rules are those defined in Table 5.

Table 5 : Scantlings

Symbol	Meaning	Units
$I_{y\text{-}n50}$	Net vertical moment of inertia of hull girder	m^4
$I_{z\text{-}n50}$	Net horizontal moment of inertia of hull girder	m^4
$Z_{D\text{-}n50}$, $Z_{B\text{-}n50}$	Net vertical hull girder section moduli, at deck and bottom respectively	m^3
z_n	Vertical distance from BL to horizontal neutral axis	m
a	Length of EPP, as defined in Ch 3, Sec 7, [2.1.1]	mm
b	Breadth of EPP, as defined in Ch 3, Sec 7, [2.1.1]	mm
s	Stiffener spacing (see Ch 3, Sec 7, [1.2.1])	mm
S	Primary supporting member spacing (see Ch 3, Sec 7, [1.2.2])	m
ℓ	Span of stiffeners or primary supporting member (see Ch 3, Sec 7, [1])	m
ℓ_b	Bracket arm length	m

Symbol	Meaning	Units
t	Net thickness with full corrosion reduction	mm
t_{n50}	Net thickness with half corrosion reduction	mm
t_c	Corrosion addition	mm
t_{gr}	Gross thickness	mm
t_{as_built}	As built thickness	mm
t_{gr_off}	Gross thickness offered	mm
t_{gr_req}	Gross thickness required	mm
t_{off}	Net thickness offered	mm
t_{req}	Net thickness required	mm
t_{vol_add}	Thickness for voluntary addition	mm
t_{res}	Reserve thickness	mm
t_{c1}, t_{c2}	Corrosion addition on each side of structural member	mm
h_w	Web height of stiffener or primary supporting member	mm
t_w	Web thickness of stiffener or primary supporting member	mm
b_f	Face plate width stiffener or primary supporting member	mm
h_{stf}	Height of stiffener	mm
t_f	Face plate/flange thickness of stiffener or primary supporting member	mm
t_p	Thickness of the plating attached to a stiffener or a primary supporting member	mm
d_e	Distance from the upper edge of the web to the top of the flange for *L3* profiles	mm
b_{eff}	Effective breadth of attached plating, in bending, for yield and fatigue	mm
A_{eff} or $A_{eff\text{-}n50}$	Net sectional area of stiffeners or primary supporting members, with attached plating (of width *s*)	cm^2
A_{shr} or $A_{shr\text{-}n50}$	Net shear sectional area of stiffeners or primary supporting members	cm^2
I_p	Net polar moment of inertia of stiffener about its connection to plating	cm^4
I	Net moment of inertia of the stiffener, with attached shell plating, about its neutral axis parallel to the plating	cm^4
Z or Z_{n50}	Net section modulus of a stiffener or primary supporting member with attached plating (of breadth b_{eff})	cm^3

3 DEFINITIONS

3.1 Principal Particulars

3.1.1 *L*, Rule length

The Rule length L is the distance, in m, measured on the waterline at the scantling draught T_{SC} from the forward side of the stem to the centre of the rudder stock. L is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught T_{SC}.

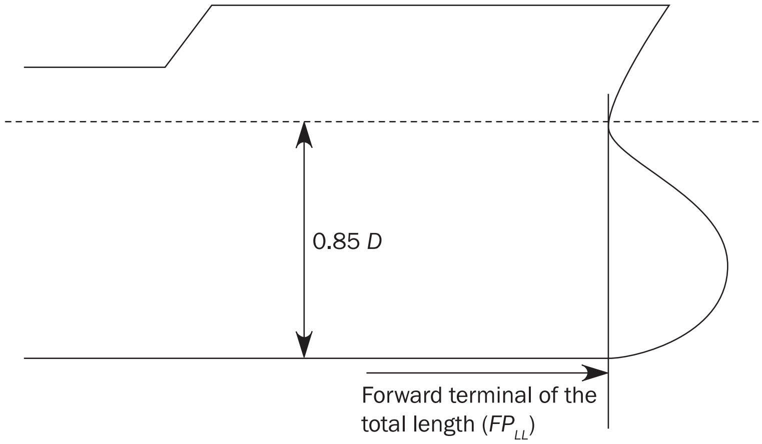
In ships without rudder stock (e.g. ships fitted with azimuth thrusters), the Rule length L is to be taken equal to 97% of the extreme length on the waterline at the scantling draught T_{SC}.

In ships with unusual stem or stern arrangements, the Rule length is considered on a case-by-case basis.

3.1.2 L_{LL}, freeboard length

The freeboard length L_{LL}, in m, is to be taken as 96% of the total length on a waterline at 85% of the least moulded depth measured from the top of the keel, or as the length from the fore side of the stem to the axis of the rudder stock on that waterline, if that be greater.
For ships without a rudder stock, the length L_{LL} is to be taken as 96% of the waterline at 85% of the least moulded depth.
Where the stem contour is concave above the waterline at 85% of the least moulded depth, both the forward end of the extreme length and the forward side of the stem are to be taken at the vertical projection to that waterline of the aftermost point of the stem contour (above that waterline), see Figure 1.

Figure 1 : Concave stem contour



3.1.3 Moulded breadth

The moulded breadth B is the greatest moulded breadth, in m, measured amidships at the scantling draught, T_{SC}.

3.1.4 Moulded depth

D, the moulded depth, is the vertical distance, in m, amidships, from the moulded baseline to the moulded deck line of the uppermost continuous deck measured at deck at side. On ships with a rounded gunwale, D is to be measured to the continuation of the moulded deck line.

3.1.5 Draughts

T, the draught in m, is the summer load line draught for the ship in operation, measured from the moulded baseline at midship. Note this may be less than the maximum permissible summer load waterline draught.

T_{SC} is the scantling draught, in m, at which the strength requirements for the scantlings of the ship are met and represents the full load condition. The scantling draught T_{SC} is to be not less than that corresponding to the assigned freeboard. The draught of ships to which timber freeboards are assigned corresponds to the loading condition of timber, and the requirements of the Society are to be applied to this draught.

T_{BAL} is the minimum design normal ballast draught amidships, in m, at which the strength requirements for the scantlings of the ship are met. This normal ballast draught is the minimum draught of ballast conditions including ballast water exchange operation, for any ballast conditions in the loading manual including both departure and arrival conditions.

$T_{BAL\text{-}H}$ is the minimum design heavy ballast draught, in m, at which the strength requirements for the scantlings of the ship are met. This heavy ballast draught is to be considered for ships having heavy ballast condition.

3.1.6 Moulded displacement

Moulded displacement, in t, corresponds to the underwater volume of the ship, at a draught, in seawater with a density of 1.025 t/m³.

3.1.7 Maximum service speed

V, the maximum ahead service speed, in knots, means the greatest speed which the ship is designed to maintain in service at her deepest seagoing draught at the maximum propeller RPM and corresponding engine MCR (Maximum Continuous Rating).

3.1.8 Block coefficient

C_B, the block coefficient at the draught, T_{SC} is defined in the following equation:

$$C_B = \frac{\Delta}{1.025\ L\ B\ T_{SC}}$$

where:

Δ : Moulded displacement of the ship at draught T_{SC}.

3.1.9 Lightweight

The lightweight is the ship displacement, in t, complete in all respects, but without cargo, consumable, stores, passengers and crew and their effects, and without any liquids on board except that machinery and piping fluids, such as lubricants and hydraulics, are at operating levels.

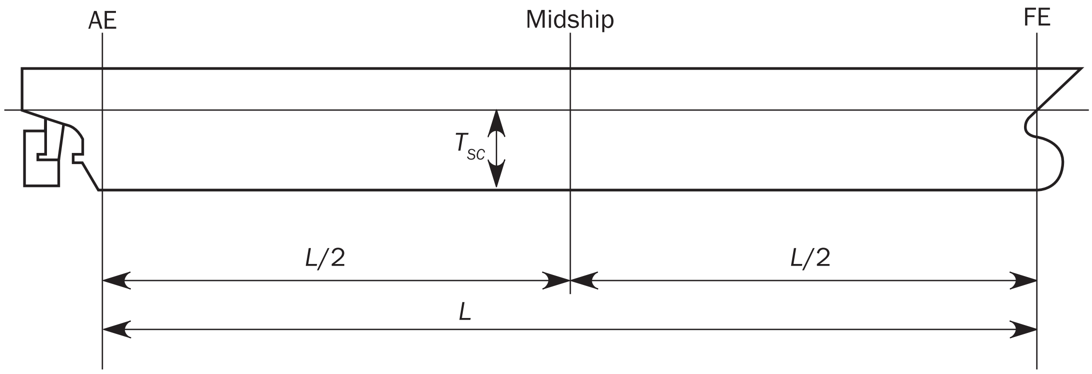
3.1.10 Deadweight

The deadweight DWT is the difference, in t, between the displacement, at the summer draught in seawater of density $\rho = 1.025$ t/m^3, and the lightweight.

3.1.11 Fore end

The fore end (FE) of the rule length L, see Figure 2, is the perpendicular to the scantling draught waterline at the forward side of the stem.

Figure 2 : Ends and midship



3.1.12 Aft end

The aft end (AE) of the rule length L, see Figure 2, is the perpendicular to the scantling draught waterline at a distance L aft of the fore end.

3.1.13 Midship

The midship is the perpendicular to the scantling draught waterline at a distance 0.5 L aft of the fore end.

3.1.14 Midship part

The midship part of a ship is the part extending 0.4 L amidships, unless otherwise specified.

3.1.15 Forward freeboard perpendicular

The forward freeboard perpendicular, FP_{LL}, is to be taken at the forward end of the length L_{LL} and is to coincide with the foreside of the stem on the waterline on which the length L_{LL} is measured.

3.1.16 After freeboard perpendicular

The after freeboard perpendicular, AP_{LL}, is to be taken at the aft end of the length L_{LL}.

3.2 Position 1 and Position 2

3.2.1 Position 1

Position 1 includes:

- Exposed freeboard and raised quarter decks.
- Exposed superstructure decks situated forward of 0.25 L_{LL} from FP_{LL}.

3.2.2 Position 2

Position 2 includes:

- Exposed superstructure decks situated aft of 0.25 L_{LL} from FP_{LL} and located at least one standard height of superstructure above the freeboard deck.
- Exposed superstructure decks situated forward of 0.25 L_{LL} from FP_{LL} and located at least two standard heights of superstructure above the freeboard deck.

3.3 Standard height of superstructure

3.3.1

The standard height of superstructure is defined in Table 6.

Table 6 : Standard height of superstructure

Freeboard length L_{LL}, in m	Standard height h_S, in m	
	Raised quarter deck	All other superstructures
$90 < L_{LL} \le 125$	$0.3 + 0.012\ L_{LL}$	$1.05 + 0.01\ L_{LL}$
$L_{LL} > 125$	1.80	2.30

3.3.2

A tier is defined as a measure of the extent of a deckhouse. A deckhouse tier consists of a deck and external bulkheads. In general, the first tier is the tier situated on the freeboard deck.

3.4 Type A and Type B freeboard ships

3.4.1 Type A ship

Type A ship is one which:

- Is designed to carry only liquid cargoes in bulk.
- Has a high integrity of the exposed deck with only small access openings to cargo compartments, closed by watertight gasketed covers of steel or equivalent material.
- Has low permeability of loaded cargo compartments.

Type A ship is to be assigned a freeboard following the requirements specified in the ICLL.

3.4.2 Type B ship

All ships which do not come within the provisions regarding Type A ships stated in [3.4.1] are to be considered as Type B ships.

Type B ship is to be assigned a freeboard following the requirements specified in ICLL.

3.4.3 Type B-60 ship

Type B-60 ship is any Type B ship of over 100 m in length which, according to applicable requirements of ICLL is assigned with a value of tabular freeboard which can be reduced up to 60% of the difference between the 'B' and 'A' tabular values for the appropriate ship lengths.

3.4.4 Type B-100 ship

Type B-100 ship is any Type B ship of over 100 m in length which, according to applicable requirements of ICLL is assigned with a value of tabular freeboard which can be reduced up to 100% of the difference between the 'B' and 'A' tabular values for the appropriate ship lengths.

3.5 Operation definition

3.5.1 Multiport

Multiport corresponds to short voyage with loading and unloading in multiple ports.

3.5.2 Sheltered water

Sheltered waters are generally calm stretches of water when the wind force does not exceed 6 Beaufort scale, i.e. harbours, estuaries, roadsteads, bays, lagoons.

3.6 Reference coordinate system

3.6.1

The ship's geometry, motions, accelerations and loads are defined with respect to the following right-hand coordinate system, see Figure 3:

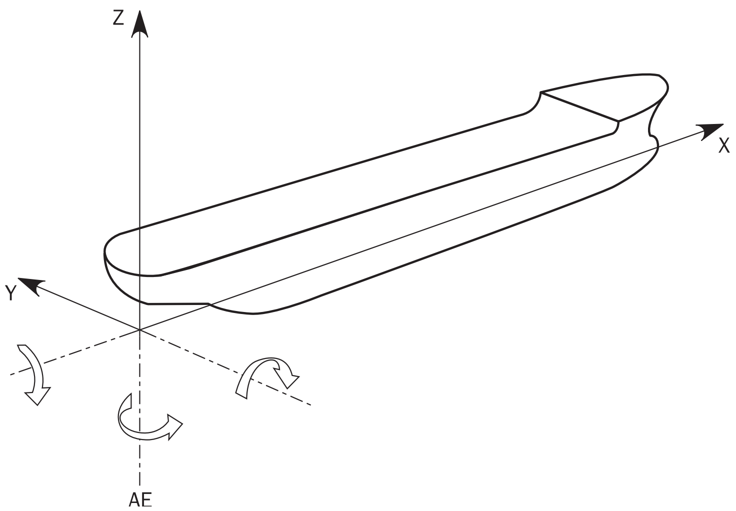
Origin : At the intersection among the longitudinal plane of symmetry of ship, the aft end of *L* and the baseline.

X axis : Longitudinal axis, positive forwards.

Y axis : Transverse axis, positive towards portside.

Z axis : Vertical axis, positive upwards.

Figure 3 : Reference coordinate system



3.7 Naming convention

3.7.1 Structural nomenclature

Figure 4 to Figure 8 show the common structural nomenclature used within these Rules.

Figure 4 : Corrugated transverse bulkhead of double hull tanker

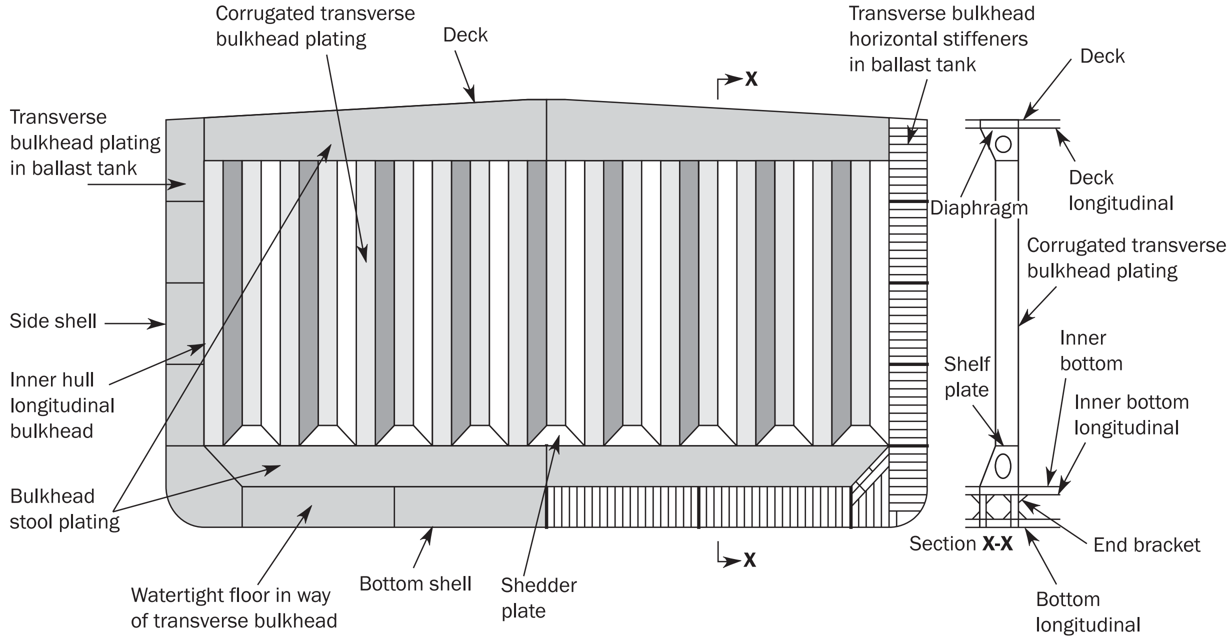


Figure 5 : Transverse bulkhead of double hull tanker

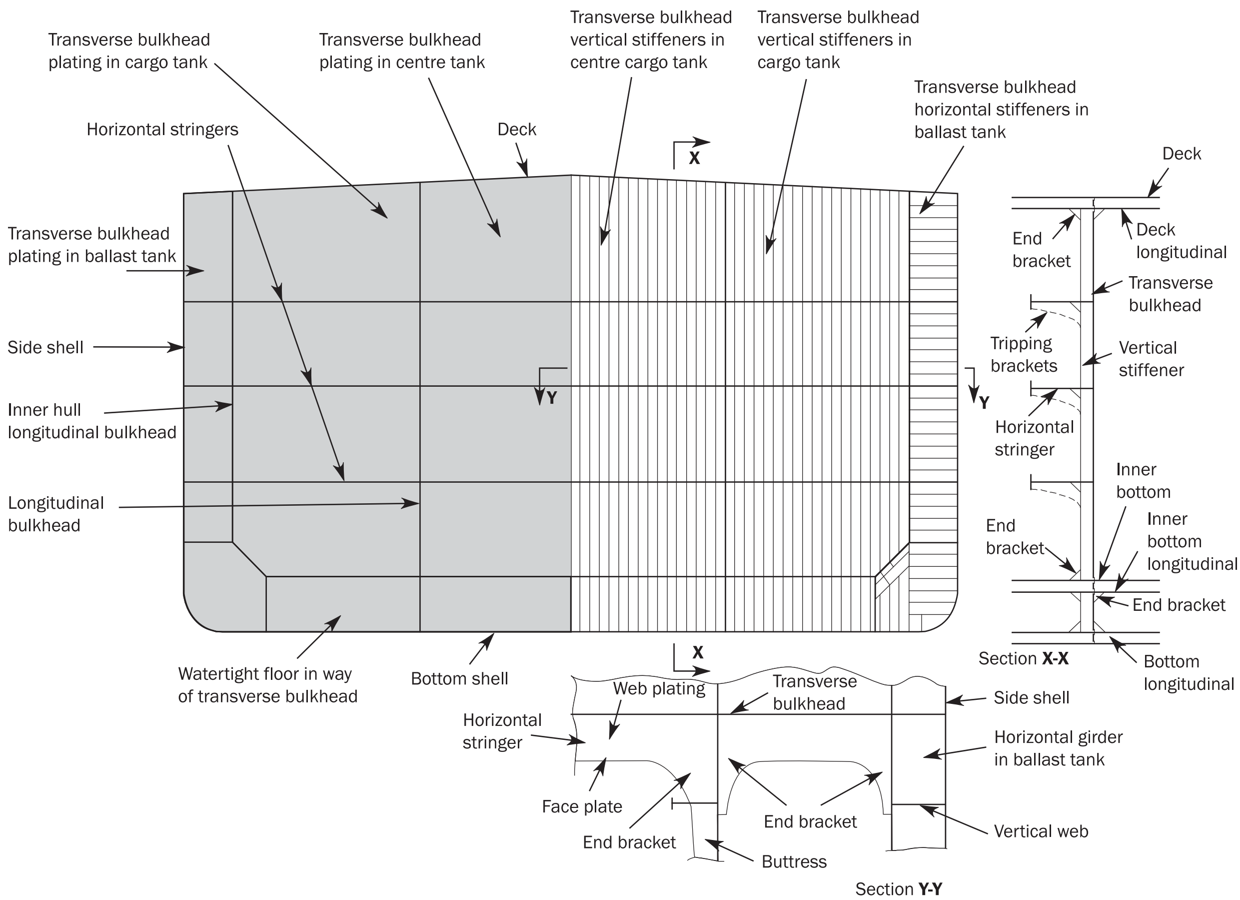


Figure 6 : Mid cargo hold transverse section of double hull tanker

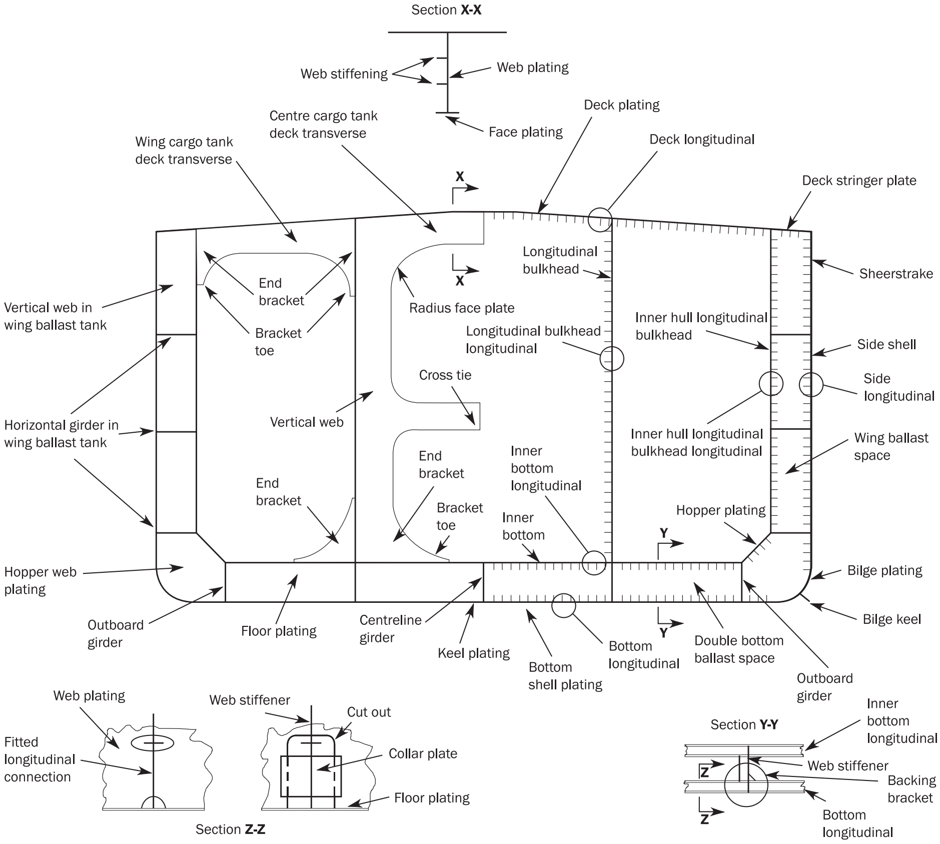


Figure 7 : Mid cargo hold transverse section of single side bulk carrier

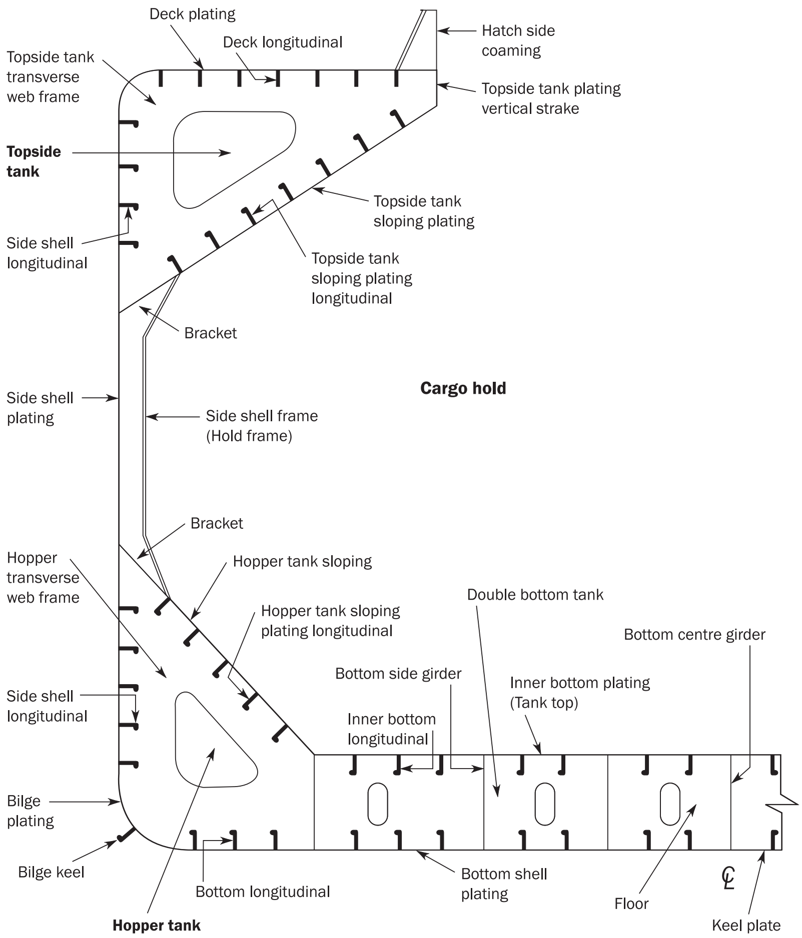
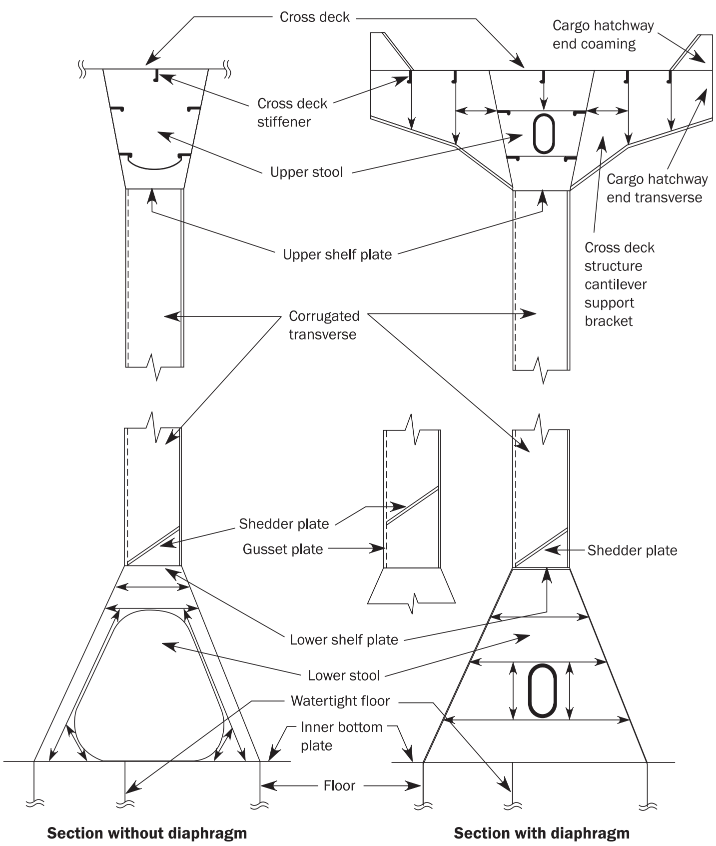


Figure 8 : Transverse bulkhead of bulk carrier



3.8 Glossary

3.8.1 Definitions of terms

Table 7 : Definition of terms

Terms	Definition
Accommodation deck	A deck used primarily for the accommodation of the crew.
Accommodation ladder	A portable set of steps on a ship's side for people boarding from small boats or from a pier.
Aft peak	The area aft of the aft peak bulkhead.
Aft peak bulkhead	The first main transverse watertight bulkhead forward of the stern.
Aft peak tank	The compartment in the narrow part of the stern aft of the aft peak bulkhead.
Anchor	A device which is attached to anchor chain at one end and lowered into the sea bed to hold a ship in position; it is designed to grip the bottom when it is dragged by the ship trying to float away under the influence of wind and current, usually made of heavy casting or casting.
Ballast tank	A compartment used for the storage of water ballast.
Bay	The area between adjacent transverse frames or transverse bulkheads.
Bilge hopper tank	The tank used for ballast or for stability when carrying certain cargoes in bulk carriers.
Bilge keel	A piece of plate set perpendicular to a ship's shell along the bilges to reduce the rolling motion.

Terms	Definition
Bilge plating	The bilge plating is the curved plating between the bottom shell and side shell. It is to be taken as follows: Within the cylindrical part of the ship: From the start of the curvature at the lower turn of bilge on the bottom to the end of the curvature at the upper turn of the bilge, Outside the cylindrical part of the ship: From the start of the curvature at the lower turn of the bilge on the bottom to the lesser of: • A point on the side shell located 0.2*D* above the baseline/local centreline elevation. • The end of the curvature at the upper turn of the bilge.
Bilge strake	The lower strake of bilge plating.
Boss	The boss of the propeller is the central part to which propeller blades are attached and through which the shaft end passes.
Bottom shell	The shell envelope plating forming the predominantly flat bottom portion of the shell envelope including the keel plate.
Bow	The structural arrangement and form of the forward end of the ship.
Bower anchor	An anchor carried at the bow of the ship.
Bracket	An extra structural component used to increase the strength of a joint between two structural members.
Bracket toe	The narrow end of a tapered bracket.
Breakwater	Inclined and stiffened plate structure on a weather deck to break and deflect the flow of water coming over the bow.
Breast hook	A triangular plate bracket joining port and starboard side structural members at the stem.
Bridge	An elevated superstructure having a clear view forward and at each side, and from which a ship is steered.
Buckling panel	Elementary plate panel considered for the buckling analysis.
Builder	The party contracted by the owner to build a ship in compliance with the specifications including Rules.
Bulb profile	A stiffener utilising an increase in steel mass on the outer end of the web instead of a separate flange.
Bulkhead	A structural partition wall sub-dividing the interior of the ship into compartments.
Bulkhead deck	The uppermost continuous deck to which transverse watertight bulkheads and shell are carried.
Bulkhead stool	The lower or upper base of a corrugated bulkhead.
Bulkhead structure	The transverse or longitudinal bulkhead plating with stiffeners and girders.
Bulwark	The vertical plating immediately above the upper edge of the ship's side surrounding the exposed deck(s).
Bunker	A compartment for the storage of fuel oil used by the ship's machinery.
Cable	A rope or chain attached to the anchor.
Camber	The upward rise of the weather deck from both sides towards the centreline of the ship.
Cargo hold region	See Ch 1, Sec 1, [2.4.3].
Cargo hold	Generic term for spaces intended to carry cargo, liquid or dry bulk.
Cargo tank	Tank carrying cargoes
Cargo tank bulkhead	A boundary bulkhead separating cargo tanks.

Terms	Definition
Carlings	A stiffening member used to supplement the regular stiffening arrangement.
Casing	The covering or bulkhead around or about any space for protection.
Cellular construction	A structural arrangement where there are two closely spaced boundaries and internal diaphragm plates arranged in such a manner to create small compartments.
Centreline girder	A longitudinal member located on the centreline of the ship.
Chain	Connected metal rings or links used for holding anchor, fastening timber cargoes, etc.
Chain locker	A compartment usually at the forward end of a ship which is used to store the anchor chain.
Chain pipe	A section of pipe through which the anchor chain enters or leaves the chain locker.
Chain stopper	A device for securing the chain cable when riding at anchor as well as securing the anchor in the housed position in the hawse pipe, thereby relieving the strain on the windlass.
Coaming	The vertical boundary structure of a hatch or skylight.
Cofferdams	See Ch 2, Sec 3, [1].
Collar plate	A patch used to, partly or completely, close a hole cut for a longitudinal stiffener passing through a transverse web.
Collision bulkhead	The foremost main transverse watertight bulkhead.
Companionway	A weathertight entrance leading from a ship's deck to spaces below.
Compartment	An internal space bounded by bulkheads or plating.
Confined space	A space identified by one of the following characteristics: limited openings for entry and exit, unfavourable natural ventilation or not designed for continuous worker occupancy.
Corrugated bulkhead	A bulkhead including corrugations and usually fitted with lower and upper stools.
Corrugation	Plating arranged in a corrugated fashion.
Cross deck	The area between cargo hatches.
Cross ties	Large transverse structural members joining longitudinal bulkheads or joining a longitudinal bulkhead with double side structures and used to support them against hydrostatic and hydrodynamic loads.
Deck	A horizontal structure element that defines the upper or lower boundary of a compartment.
Deckhouse	See Ch 1, Sec 1, [2.4.6].
Deck structure	The deck plating with stiffeners, girders and supporting pillars.
Deck transverse	Transverse PSM at the deck.
Deep tank	Any tank which extends between two decks or the shell/inner bottom and the deck above or higher.
Designer	A party who creates documentation submitted to the Society necessary for approval or for information. The designer can be the builder or a party contracted by the builder or owner to create this documentation.
Discharges	Any piping leading through the ship's sides for conveying bilge water, circulating water, drains etc.
Docking bracket	A bracket located in the double bottom to locally strengthen the bottom structure for the purposes of docking.

Terms	Definition
Double bottom structure	The shell plating with stiffeners below the top of the inner bottom and other elements below and including the inner bottom plating.
Doubler	Small piece of plate which is attached to a larger area of plate that requires strengthening in that location. Usually at the attachment point of a stiffener.
Double skin member	Double skin member is defined as a structural member where the idealised beam comprises webs, with top and bottom flanges formed by attached plating.
Duct keel	A keel built of plates in box form extending the length of the cargo tank. It is used to house ballast and other piping leading forward which otherwise would have to run through the cargo tanks.
Enclosed superstructure	The superstructure with bulkheads forward and/or aft fitted with weather tight doors and closing appliances.
Engine room bulkhead	A transverse bulkhead either directly forward or aft of the engine room.
EPP	Elementary plate panel, the smallest plate element surrounded by structural members, such as stiffeners, PSM, bulkheads, etc.
Face plate	The section of a stiffening member attached to the plate via a web and is usually parallel to the plated surface.
Flange	The section of a stiffening member, typically attached to the web, but is sometimes formed by bending the web over. It is usually parallel to the plated surface.
Flat bar	A stiffener comprised only of a web.
Floor	A bottom transverse member.
Forecastle	A short superstructure situated at the bow.
Fore peak	The area of the ship forward of the collision bulkhead.
Fore peak deck	A short raised deck extending aft from the bow of the ship.
Freeboard deck	Generally the uppermost complete deck exposed to weather and sea, which has permanent means of closing all exposed openings.
Freeing port	An opening in the bulwarks to allow water shipped on deck to run freely overboard.
Gangway	The raised walkway between superstructure, such as between the forecastle and bridge, or between the bridge and poop.
Girder	A collective term for primary supporting structural members.
Gudgeon	A block with a hole in the centre to receive the pintle of a rudder; located on the stern post, it supports and allows the rudder to swing.
Gunwale	The upper edge of the ship’s sides.
Gusset	A plate, usually fitted to distribute forces at a strength connection between two structural members.
Hatch cover	A cover fitted over a hatchway to prevent the ingress of water into the ship’s hold.
Hatchways	Openings, generally rectangular, in a ship’s deck affording access into the compartment below.
Hawse pipe	Steel pipe through which the hawser or cable of anchor passes, located in the ship's bow on either side of the stem, also known as spurling pipe.
Hawser	Large steel wire or fibre rope used for towing or mooring.
Hopper plating	Plating running the length of a compartment sloping between the inner bottom and vertical portion of inner hull longitudinal bulkhead.
HP	Bulb profile in accordance with the Holland profile standard.

IACS

Terms	Definition
IACS	International Association of Classification Societies
ICLL	IMO International Convention on Load Lines, 1966, as amended.
IMO	International Maritime Organisation
Independent tank	A self supporting tank.
Inner hull	The innermost plating forming a second layer to the hull of the ship.
Intercostal	Non-continuous member between stiffeners or PSM.
JIS	Japanese industrial standard.
Keel	The main structural member or backbone of a ship running longitudinally along the centreline of the bottom. Usually a flat plate stiffened by a vertical plate on its centreline inside the shell.
Keel line	Keel line is the line parallel to the slope of the keel intersecting the top of the keel at amidships.
Knuckle	A discontinuity in a structural member.
Lightening hole	A hole cut in a structural member to reduce its weight.
Limber hole	A small drain hole cut in a frame or plate to prevent water or oil from collecting.
Local support members	Local stiffening members which only influence the structural integrity of a single panel, e.g. deck beams.
Longitudinal centreline bulkhead	A longitudinal bulkhead located on the centreline of the ship.
Longitudinal hull girder structural members	Structural members that contribute to the longitudinal strength of the hull girder, including: deck, side, bottom, inner bottom, inner hull longitudinal bulkheads including upper sloped plating where fitted, hopper, bilge plate, longitudinal bulkheads, double bottom girders and horizontal girders in wing ballast tanks.
Longitudinal hull girder shear structural members	Structural members that contribute to strength against hull girder vertical shear loads, including: side, inner hull longitudinal bulkheads, hopper, longitudinal bulkheads and double bottom girders.
Manhole	A round or oval hole cut in decks, tanks, etc, for the purpose of providing access.
Margin plate	The outboard strake of the inner bottom and when turned down at the bilge the margin plate (or girder) forms the outer boundary of the double bottom.
MARPOL	IMO International Convention for the Prevention of Pollution from Ships, 1973 and Protocol of 1978, as amended.
Mid-hold	Middle hold(s) of the three cargo hold length FE model as defined in Pt 1, Ch 7, Sec 2, [1.2.2]
Notch	A discontinuity in a structural member caused by welding.
Oil fuel tank	A tank used for the storage of fuel oil.
Outer shell	Same as shell envelope.
Owner	The party that has assumed all duties and responsibilities for registration and operation of the ship and who on assuming such responsibilities has agreed to take over all the duties and responsibilities on delivery of the ship from the builder with valid certificates prepared for the owner.
Pillar	A vertical support placed between decks where the deck is unsupported by the shell or bulkhead.
Pipe tunnel	The void space running in the midships fore and aft lines between the inner bottom and shell plating forming a protective space for bilge, ballast and other lines extending from the engine room to the tanks.

Terms	Definition
Plate panel	Unstiffened plate surrounded and supported by structural members, such as stiffeners, PSM, bulkheads, etc. See also EPP.
Plating	Sheet of steel supported by stiffeners, primary supporting members or bulkheads.
Poop	The space below an enclosed superstructure at the extreme aft end of a ship.
Poop deck	The first deck above the shelter deck at the aft end of a ship.
Primary supporting members PSM	Members of the beam, girder or stringer type which provide the overall structural integrity of the hull envelope and tank boundaries, e.g. double bottom floors and girders, transverse side structure, deck transverses, bulkhead stringers and vertical webs on longitudinal bulkheads.
Scallop	A hole cut into a stiffening member to allow continuous welding of a plate seam.
Scarfing bracket	A bracket used between two offset structural items.
Scantlings	The physical dimensions of a structural item.
Scupper	Any opening for carrying off water from a deck, either directly or through piping.
Scuttle	A small opening in a deck or elsewhere, usually fitted with a cover or lid or a door for access to a compartment.
Shedder plates	Slanted plates that are fitted to minimise pocketing of residual cargo in way of corrugated bulkheads.
Sheer strake	The top strake of a ship's side shell plating.
Shelf plate	A horizontal plate located on the top of a bulkhead stool.
Shell envelope plating	The shell plating forming the effective hull girder exclusive of the strength deck plating.
Side frame	A vertical member attached to the side shell in bulk carriers.
Side shell	The shell envelope plating forming the side portion of the shell envelope above the bilge plating.
Single skin member	A structural member where the idealised beam comprises a web, with a top flange formed by attached plating and a bottom flange formed by a face plate.
Skylight	A deck opening fitted with or without a glass port light and serving as a ventilator for engine room, quarters, etc.
Slop tank	A tank in an oil tanker which is used to collect the oil and water mixtures from cargo tanks after tank washing.
SOLAS	IMO International Convention for the Safety of Life at Sea, 1974 as amended.
Spaces	Separate compartments including tanks.
Stay	Bulwark and hatch coaming brackets.
Stem	The piece of bar or plating at which a ship's outside plating terminates at forward end.
Stern frame	The heavy strength member in single or triple screw ships, combining the rudder post.
Stern tube	A tube through which the shaft passes to the propeller; and acts as an after bearing for the shafting. It may be water or oil lubricated.
Stiffener	A collective term for secondary supporting structural members.
Stool	A structure supporting tank bulkheads.
Strake	A course, or row, of shell, deck, bulkhead, or other plating.
Strength deck	The uppermost continuous deck.

Terms	Definition
Stringer	Horizontal girders linking vertical web frames.
Stringer plate	The outside strake of deck plating.
Superstructure	See Ch 1, Sec 1, [2.4.6].
SWL	Safe working load
Tank	Generic term for spaces intended to carry liquid, such as, seawater, fresh water, oil, liquid cargoes, FO, DO, etc.
Tank top	The horizontal plating forming the bottom of a cargo tank.
Towing pennant	A long rope which is used to effect the tow of a ship.
Topside tank	The tank that normally stretches along the length of the ship's side and occupies the upper corners of the cargo hold in bulk carriers.
Transom	The structural arrangement and form of the aft end of the ship.
Transverse ring	All transverse material appearing in a cross section of the ship's hull, in way of a double bottom floor, vertical web and deck transverse girder.
Transverse web frame	The primary transverse girders which join the ships longitudinal structure.
Tripping bracket	A bracket used to strengthen a structural member under compression against torsional forces.
Trunk	A decked structure similar to a deckhouse, but not provided with a lower deck.
'Tween deck	An abbreviation of between decks, placed between the upper deck and the tank top in the cargo tanks.
Ullage	The quantity represented by the unoccupied space in a tank.
Void	An enclosed empty space in a ship.
Wash bulkhead	A perforated or partial bulkhead in a tank.
Watertight	Watertight means capable of preventing the passage of water through the structure under a head of water for which the surrounding structure is designed.
Weather deck	A deck or section of deck exposed to the elements which has means of closing weathertight, all hatches and openings.
Weathertight	Weathertight means that in any sea conditions water will not penetrate into the ship.
Web	The section of a stiffening member attached perpendicular to the plated surface.
Web frame	Transverse PSM including deck transverse.
Wind and water strakes	The strakes of a ship's side shell plating between the ballast and the deepest load waterline.
Windlass	A winch for lifting and lowering the anchor chain.
Wing tank	The space bounded by the inner hull longitudinal bulkhead and side shell.

SECTION 5
LOADING MANUAL AND LOADING INSTRUMENTS

1 GENERAL REQUIREMENTS

1.1 Application

1.1.1

This Section contains minimum requirements for loading guidance information.

1.1.2

An approved loading manual and an approved loading instrument are to be supplied onboard.

1.1.3

A ship may in actual operation be loaded differently from the loading conditions specified in the loading manual, provided limitations for longitudinal and local strength as defined in the loading manual and loading instrument onboard and applicable stability requirements are not exceeded.

1.1.4

The requirements concerning the loading manual are given in [2] and those concerning the loading instruments in [3].

1.2 Annual and class renewal survey

1.2.1

At each annual and class renewal survey, it is to be checked that the approved loading manual is available onboard.

1.2.2

The loading instrument is to be checked for accuracy at regular intervals by the ship's master by applying test loading conditions.

1.2.3

At each class renewal survey this checking is to be done in the presence of the surveyor.

2 LOADING MANUALS

2.1 General requirements

2.1.1 Definition

The approved loading manual is to be based on the final data of the ship.

A loading manual is a document which describes:

- The loading conditions on which the design of the ship has been based for seagoing and harbour/sheltered water, including permissible limits of still water bending moment and shear force. The conditions specified in the ballast water exchanging procedure and dry docking procedure are to be included in the loading manual,
- The results of the calculations of still water bending moments, shear forces and where applicable limitations due to lateral loads,
- The allowable local loading for the structure (e.g. hatch covers, decks, double bottom, etc), where applicable,
- The relevant operational limitations.

2.1.2 Condition of approval

The approved loading manual is to be based on the final data of the ship.

Modifications resulting in changes to the main data of the ship (e.g. lightship weight, buoyancy distribution, tank volumes or usage, etc), require the loading manual to be updated and re-approved, and subsequently the loading computer system to be updated and re-approved. However, new loading guidance and an updated loading manual need not be resubmitted provided that the resulting draughts, still water bending moments and shear forces do not differ from the originally approved data by more than 2%.

The loading manual is to be prepared in a language understood by the users. If this language is not English, a translation into English is to be included.

2.1.3 Loading conditions

The loading manual is to include the design (cargo and ballast) loading conditions, subdivided into departure and arrival conditions as appropriate, upon which the approval of the hull scantlings is based, as defined in Ch 4, Sec 8.

The loading conditions common to both oil tankers and bulk carriers are listed in Ch 4, Sec 8, [2].

2.1.4 Operational limitations

The loading manual is to describe relevant operational limitations:

- Scantling draught,
- Design minimum ballast draught at midships,
- Design slamming ballast draught forward with forward double bottom ballast tanks filled,
- Design slamming ballast draught forward with any of the forward double bottom ballast tanks empty,
- Maximum allowable cargo density,
- Maximum cargo density in any loading condition in the Loading Manual,
- Maximum service speed,
- Envelope results and permissible limits of still water bending moments and shear forces.

The loading manual must indicate that bulk carriers cannot be operated in seagoing conditions with ballast cargo holds partially filled.

2.2 Requirements specific to oil tankers

2.2.1

The loading manual is to contain the loading conditions described in Ch 4, Sec 8, [3].

This requirement applies in addition to [2.1].

2.3 Requirements specific to bulk carriers

2.3.1

The loading manual is to contain the loading conditions described in Ch 4, Sec 8, [4].

This requirement applies in addition to [2.1].

2.3.2

The loading manual is to describe:

- Envelope results and permissible limits of still water bending moments and shear forces in the hold flooded condition according to Ch 4, Sec 4,
- The cargo hold(s) or combination of cargo holds that might be empty at full draught. If no cargo hold is allowed to be empty at full draught, this is to be clearly stated in the loading manual,
- Maximum allowable and minimum required mass of cargo and double bottom contents of each hold as a function of the draught at mid-hold position as defined in Ch 4, Sec 8, [4.3],
- Maximum allowable and minimum required mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds. This mean draught may be calculated by averaging the draught of the two mid-hold positions as defined in Ch 4, Sec 8, [4.3],
- Maximum allowable tank top loading together with specification of the nature of the cargo for cargoes other than bulk cargoes,
- Maximum allowable load on deck and hatch covers. If the ship is not approved to carry load on deck or hatch covers, this is to be clearly stated in the loading manual,
- Maximum rate of ballast change together with the advice that a load plan is to be agreed with the terminal on the basis of the achievable rates of change of ballast.

2.3.3

The additional following loading conditions, subdivided into departure and arrival conditions as appropriate, are to be included in the loading manual:

- Homogeneous light and heavy cargo loading conditions at maximum draught,
- Alternate light and heavy cargo loading conditions at maximum draught, where applicable,
- *Ballast conditions. For ships having ballast holds adjacent to topside wing, hopper and double bottom tanks, it shall be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty,*
- Short voyage conditions, i.e. the ship is loaded to maximum draught but with a limited amount of bunkers, where appropriate,
- Multiple port loading/unloading conditions,
- Deck cargo conditions, where applicable,
- Typical sequences for change of ballast at sea, where applicable,
- Typical loading sequences where the ship is loaded from commencement of cargo loading to reaching full deadweight capacity, for homogeneous conditions, relevant part load conditions and alternate conditions where applicable. Typical unloading sequences for these conditions are also to be included. The typical loading/unloading sequences are also to be developed to not exceed applicable strength limitations. The typical loading sequences are also to be developed paying due attention to loading rate and the deballasting capability. Figure 1 contains, as guidance only, an example of a Loading Sequence Summary Form.

3 LOADING INSTRUMENT

3.1 General requirements

3.1.1 Definition

A loading computer system is a system, which is either analog or digital, by means of which it can be easily and quickly ascertained that, at specified read-out points, relevant operational limitations, such as the still water bending moments, shear forces, and lateral loads, where applicable, in any load or ballast condition do not exceed the specified permissible values.

The loading instrument is ship specific onboard equipment and the results of the calculations are only applicable to the ship for which it has been approved.

An approved loading instrument can not replace an approved loading manual.

3.1.2 Conditions of approval of loading instruments

The loading instrument is subject to approval based on the Rules of the individual Society. The approval is to include:

- Verification of type approval, if any,
- Verification that the final data of the ship has been used,
- Acceptance of number and position of read-out points,
- Acceptance of relevant limits for all read-out points,
- Checking of proper installation and operation of the instrument onboard, in accordance with agreed test conditions, and that a copy of the operation manual is available.

Modifications resulting in changes to the main data of the ship (e.g. lightship weight, buoyancy distribution, tank volumes or usage, etc), require the loading manual to be updated and re-approved, and subsequently the loading instrument to be updated and re-approved. However, new loading guidance and an updated loading instrument need not be resubmitted provided that the resulting draughts, still water bending moments and shear forces do not differ from the originally approved data by more than 2%.

An operational manual is always to be provided for the loading instrument. The operation manual and the instrument output are to be prepared in a language understood by the users. If this language is not English, a translation into English is to be included.

The operation of the loading instrument is to be verified upon installation. It is to be checked that the agreed test conditions and the operation manual for the instrument is available onboard.

3.2 Requirements specific to bulk carriers

3.2.1 General

For BC-A, BC-B and BC-C ships, the loading instrument is to ascertain as applicable:

- The mass of cargo and double bottom contents in way of each hold as a function of the draught at mid-hold position,
- The mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds,
- That the still water bending moment and shear forces in the hold flooded conditions do not exceed the specified permissible values.

3.2.2 Condition of approval

For BC-A, BC-B and BC-C ships, the approval is to include, as applicable:

- Acceptance of hull girder bending moment limits for all read-out points,
- Acceptance of hull girder shear force limits for all read-out points,

- Acceptance of limits for the mass of cargo and double bottom contents of each hold as a function of draught,
- Acceptance of limits for the mass of cargo and double bottom contents in any two adjacent holds as a function of draught.

4 LOADING SPECIFIC TO BULK CARRIERS

4.1 Guidance for loading/unloading sequences

4.1.1 Scope of application

The requirements given in [4] are applicable to bulk carriers of 150 m in length and above.

4.1.2

The typical loading/unloading sequences are to be developed paying due attention to the loading/unloading rate, the ballasting/deballasting capacity and the applicable strength limitations.

4.1.3

Typical loading and unloading sequences are to be prepared and submitted for approval by the builder.

4.1.4

The typical loading sequences as relevant are to include:

- Alternate light and heavy cargo load condition,
- Homogeneous light and heavy cargo load condition,
- Short voyage condition where the ship is loaded to maximum draught but with limited bunkers,
- Multiple port loading/unloading condition,
- Deck cargo condition,
- Block loading.

4.1.5

The loading/unloading sequences may be port specific or typical.

4.1.6

The sequence is to be built up step by step from commencement of cargo loading to reach full deadweight capacity. Each time the loading equipment changes position to a new hold defines a step. Each step is to be documented and submitted to the Society. In addition to longitudinal strength, the local strength of each hold is to be considered.

4.1.7

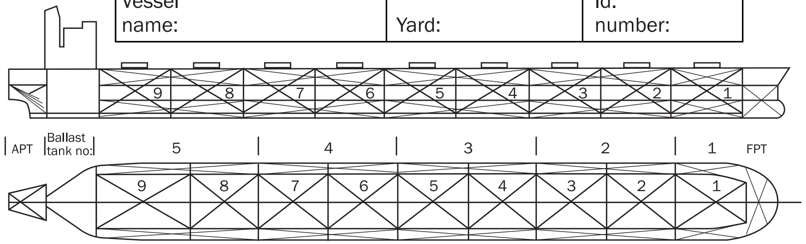
For each loading condition, a summary of all steps is to be included. This summary is to highlight the essential information for each step, such as:

- How much cargo is filled in each hold during the different steps,
- How much ballast is discharged from each ballast tank during the different steps,
- The maximum still water bending moment and shear force at the end of each step,
- The ship's trim and draught at the end of each step.

IACS

Figure 1 : Loading Sequence Summary Form

Vessel name:	Yard:	Id. number:



Port (specific or typical):	Condition at commencement of loading/discharging:	
Total mass of cargo to be loaded/discharged:	Condition at end of loading/discharging:	
Dock water density (t/m³):	Maximum loading/discharging rate:	Average loading/discharging rate:
Number of loaders/dischargers:	Maximum ballasting/deballasting rate:	Average ballasting/deballasting rate:

Volume of Hold, Vh (m³)									
Height of hold, h (m)									

Note: During each pour it it has to be controlled that allowable limits for hull girder shear forces, bending moments and mass in holds are not exceeded. Loading/discharging operations may have to be paused to allow fo ballasting/deballasting in order to keep actual values within limits.

	Hold content at commencement of loading/discharging								
Cargo mass									
Density (t/m³)									
Grade									

Ballast content at commencement of loading/discharging	APT	Ball. no. 5	Ball. no. 4	Hold. no. 6	Ball. no. 3	Hold. no. 4	Ball. no. 2	Ball. no. 1	FPT
Wings or peaks									
Upper									
Lower/Peaks									

Commencement of loading/discharging (sea)				
T aft (m)	T rim (m)	T fwd (m)	Maximum S.F. (%)	Maximum B.M. (%)

CARGO OPERATIONS									
Pour no. /grade	Hold 9	Hold 8	Hold 7	Hold 6	Hold 5	Hold 4	Hold 3	Hold 2	Hold 1
1									
2									
3									
4									
5									
6									
7									
8									
Draft Survey (for loading):	Total cargo onboard (t):				Remaining cargo to be loaded (t):				
n-1									
n									

BALLAST OPERATIONS	APT	Ballast tank no. 5	Ballast tank no. 4	No.5 Ballast hold	Ballast tank no.3	No.4 Ballast hold	Balalst tank no. 2	Ballast tank no.1	FPT
Upper / Lower/Peaks									
Upper									
Lower/Peaks									
Upper									
Lower/Peaks									
Upper									
Lower/Peaks									
Upper									
Lower/Peaks									
Upper									
Lower/Peaks									
Upper									
Lower/Peaks									
Upper									
Lower/Peaks									
Upper									
Lower/Peaks									
Upper									
Lower/Peaks									
Total amount of bunkers onboard (t):									
Upper									
Lower/Peaks									
Upper									
Lower/Peaks									

Values at end of pour (from harbour to sea)				
T aft (m)	T rim (m)	T fwd (m)	Maximum S.F. (%)	Maximum B.M. (%)

	Hold content at end of loading/discharging								
Cargo mass:									
Total mass loaded/discharge (t):									

Ballast content at end of loading/discharging	APT	Ball. no. 5	Ball. no. 4	No. 6 hold	Ball. no. 3	No. 4 hold	Ball. no. 2	Ball. no. 1	FPT
Wings or peaks									
Upper									
Lower/Peaks									

Values at end of loading/discharging (sea)				
T aft (m)	T rim (m)	T fwd (m)	Maximum S.F. (%)	Maximum B.M. (%)

	Maximum occuring values among all conditions above									
Net load on Double Bottom:										tons/m²
Net load in two adjacent holds:										tons

Net load on double bottom = (Mh/V) h-T (t/m²)
- where: Mh = Mass in hold + mass in DB (t)
V = Total volume of hold (m³)
h = height of hold from inner bottom to top of coaming (m)
T = draught (m)

Approved by:

Place, date, stamp and sign

PART 1 CHAPTER 2

GENERAL ARRANGEMENT DESIGN

Table of Contents

SECTION 1
GENERAL

1 GENERAL

1.1 General

1.1.1

This chapter covers the general structural arrangement requirements for the ship.

SECTION 2
SUBDIVISION ARRANGEMENT

1 WATERTIGHT BULKHEAD ARRANGEMENT

1.1 Number and disposition of watertight bulkheads

1.1.1

All ships are to have at least the following transverse watertight bulkheads:

a) One collision bulkhead.

b) One aft peak bulkhead.

c) One bulkhead at each end of the machinery space.

1.1.2

In the case of ships with an electrical propulsion plant, both the generator room and the engine room are to be enclosed by watertight bulkheads.

1.1.3

In addition to the requirements of [1.1.1] and [1.1.2], the number and disposition of bulkheads are to be arranged to suit the requirements for subdivision, floodability and damage stability, and are to be in accordance with the requirements of national regulations.

1.1.4

For bulk carriers less than 150 m in length not required to comply with subdivision requirements, bulkheads not less in number than indicated in Table 1 are to be fitted.

Table 1 : Number of bulkheads for bulk carriers less than 150 m in length

Length in m	Number of bulkheads for ships with aft machinery (1)
$90 \le L < 105$	4
$105 \le L < 120$	5
$120 \le L < 145$	6
$145 \le L < 150$	7
(1) Aft peak bulkhead and aft machinery bulkhead are the same.	

1.1.5

The bulkheads in the cargo hold region are to be spaced at uniform intervals as far as practicable.

1.2 Openings in watertight bulkheads

1.2.1

The number of openings in watertight bulkheads is to be kept a minimum, where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables. Arrangements are to be made to maintain the watertight integrity.

1.2.2

The tightness, operability and indication of the doors in watertight bulkheads are to be in accordance with Ch II-1, Reg 13-1 of SOLAS Convention, as amended.

2 COLLISION BULKHEAD

2.1 Extent and position of collision bulkhead

2.1.1

A collision bulkhead is to be fitted on all ships and is to extend to the freeboard deck. It is to be located between 0.05 L_{LL} or 10 m, whichever is less, and except as may be permitted by the Administration, 0.08 L_{LL} or 0.05 L_{LL} + 3 m, whichever is the greater, aft of the reference point, where the reference point is as defined in [2.1.2].

2.1.2

For ships without bulbous bows the reference point is to be taken where the forward end of L_{LL} coincides with the forward side of stem, on the waterline which L_{LL} is measured. For ships with bulbous bows, it is to be measured from the forward end of L_{LL} a distance x forward; where x is to be taken as the lesser of the following:

a) Half the distance, from FP_{LL} to the extreme forward end of the bulb extension.

b) 0.015 L_{LL}.

c) 3.0 m.

2.2 Arrangement of collision bulkhead

2.2.1

In general, the collision bulkhead is to be in one plane; however, the bulkhead may have steps or recesses provided that they are within the limits prescribed in [2.1.1] and [2.1.2].

2.2.2

Doors, manholes, permanent access openings or ventilation ducts are not to be cut in the collision bulkhead below the freeboard deck. Where the collision bulkhead is extended above the freeboard deck, the number of openings in the extension is to be kept to a minimum compatible with the design and proper working of the ship. Reference is made to Ch 1, Sec 2, [2.1].

3 AFT PEAK BULKHEAD

3.1 General

3.1.1

An aft peak bulkhead, enclosing the stern tube and rudder trunk in a watertight compartment, is to be provided. Where the shafting arrangements make enclosure of the stern tube in a watertight compartment impractical, alternative arrangements are specially considered.

3.1.2

The aft peak bulkhead may be stepped below the bulkhead deck, provided that the degree of safety of the ship as regards subdivision is not thereby diminished.

3.1.3

The aft peak bulkhead location on ships powered and/or controlled by equipment that do not require the fitting of a stern tube and/or rudder trunk are also subject to special consideration.

3.1.4

The aft peak bulkhead may terminate at the first deck above the deepest draught at the aft perpendicular, provided that this deck is made watertight to the stern or to the transom.

SECTION 3
COMPARTMENT ARRANGEMENT

1 COFFERDAMS

1.1 Definition

1.1.1

A cofferdam means an empty space arranged so that compartments on each side have no common boundary; a cofferdam may be located vertically or horizontally. As a rule, a cofferdam is to be kept gas-tight and is to be properly ventilated and of sufficient size to allow proper inspection, maintenance and safe evacuation.

1.2 Arrangement of cofferdams

1.2.1

Cofferdams are to be provided between compartments intended for liquid hydrocarbons (including fuel oil, lubricating oil) and those intended for fresh water (drinking water, water for propelling machinery and boilers) as well as tanks intended for the carriage of liquid foam for fire extinguishing.

1.2.2

Furthermore, tanks carrying fresh water for human consumption are to be separated from other tanks containing substances hazardous to human health by cofferdams or other means as approved by the Society.

Note 1: Normally, tanks for fresh water and water ballast are considered non-hazardous.

1.2.3

Where a corner to corner situation occurs, tanks are not considered to be adjacent.

2 DOUBLE BOTTOM

2.1 General

2.1.1

A double bottom need not be fitted in way of watertight tanks, including dry tanks of moderate size provided the safety of the ship is not impaired in the event of bottom or side damage as regulated in SOLAS II-1, Reg 9.

2.2 Extent of double bottom

2.2.1

For bulk carriers, a double bottom is to be fitted extending from the collision bulkhead to the aft peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

For oil tankers, a double bottom is to be fitted to protect the cargo hold region and pump rooms. However the double bottom below pump rooms may be omitted provided that it is in compliance with MARPOL, Annex I, Ch 4, Reg 22.

2.2.2

Where double bottom is required to be fitted, the inner bottom is to be continued out to the ship side in such a manner as to protect the bottom to the turn of the bilge in areas where hopper or double side spaces are not provided.

2.3 Height of double bottom

2.3.1

Unless otherwise specified, the height of the double bottom is not to be less than the lesser of:

- For oil tankers: $B/15$ or 2 m, however not less than 1.0 m.
- For bulk carriers: $B/20$ or 2 m, however not less than 0.76 m measured vertically from the plane parallel with keel line to inner bottom.

2.4 Small wells in double bottom tank

2.4.1

Small wells constructed in the double bottom are not to extend in depth more than necessary. A well extending to the outer bottom, may, however, be permitted at the after end of the shaft tunnel of the ship. Other wells may be permitted by the Society if it is satisfied that the arrangements give protection equivalent to that afforded by a double bottom that complies with [2.1].

3 DOUBLE SIDE

3.1 Double side width

3.1.1 Oil tankers

The minimum double side width, W_{ds}, in m, is to be taken as the lesser of:

$$W_{ds} = 0.5 + \frac{DWT}{20000} \text{ but not less than 1.0}$$

$$W_{ds} = 2.0$$

3.1.2 Bulk carriers

Double side skin means a configuration where each ship side is constructed by the side shell and a longitudinal bulkhead connecting the double bottom and the deck. Hopper side tanks and topside tanks may, where fitted, be integral parts of the double side skin configuration.

The minimum double side width, W_{ds}, is not to be less than 1 m measured perpendicular to the side shell.

3.2 Minimum clearance inside the double side

3.2.1 Definition

The minimum clearance is defined as the shortest distance measured between assumed lines connecting the inner surfaces of the stiffeners on the inner and outer hulls.

3.2.2 Minimum clearance dimensions

The minimum clearance between the inner surfaces of the stiffeners inside the double side is not to be less than:

- 600 mm when the inner and/or the outer hulls are transversely framed,
- 800 mm when the inner and the outer hulls are longitudinally framed.

Outside the parallel part of the cargo hold, the clearance may be reduced but is not to be less than 600 mm.

4 FORE END COMPARTMENTS

4.1 General

4.1.1

The fore peak and other compartments located forward of the collision bulkhead may not be arranged for the carriage of fuel oil or other flammable products.

5 FUEL OIL TANKS

5.1 Arrangement of fuel oil tanks

5.1.1

Fuel oil tanks are to be arranged in accordance with the requirements in SOLAS Ch II-2, Reg 4.2 and MARPOL, Annex I, Ch 3, Reg 12A.

6 AFT END COMPARTMENTS

6.1 Sterntube

6.1.1

Sterntubes are to be enclosed in a watertight space (or spaces) of moderate volume. Other measures to minimise the danger of water penetrating into the ship in case of damage to the sterntube arrangement may be taken at the discretion of the Society.

7 BALLAST TANKS

7.1 Capacity and disposition of ballast tanks

7.1.1

All ships are to have ballast tanks of sufficient capacity that the ship may operate safely on ballast voyage. The capacity of ballast is to be at least such that, in any ballast condition at any part of the voyage, including the conditions consisting of lightweight plus ballast only, the ship’s draught and trim can meet the requirements defined in:

- For oil tankers, Ch 4, Sec 8, [3.1].
- In addition, for oil tankers, the moulded draught amidships, T_{mid}, excluding any hogging or sagging correction, is not to be less than:

  $T_{mid} = 2.0 + 0.02\, L$, in m.

- For bulk carriers, Ch 4, Sec 8, [4.1].

SECTION 4
ACCESS ARRANGEMENT

1 CLOSED SPACES

1.1 General

1.1.1

All closed spaces are to be accessible for easy inspection. Special measures for inspection and maintenance are to be put in place for small closed spaces for which the design causes impracticality for the access.

1.1.2

For areas which are not explicitly covered by SOLAS, Ch II-1, Reg 3-6, the builder is to provide accesses in accordance with industry standards accepted by the Society. For general guidance, human element factors may be considered based on IACS Recommendation No. 132 or with an ergonomic standard accepted by the Society.

2 CARGO AREA AND FORWARD SPACES

2.1 General

2.1.1 Ship structure access manual

Ship structures subject to overall and close-up inspection and thickness measurements are to be provided with means of access which are to be described in a “Ship Structure Access Manual“. Reference is made to SOLAS, Ch II-1, Reg 3-6.

2.1.2

All tanks are to be accessible for easy inspection.

PART 1 CHAPTER 3

STRUCTURAL DESIGN PRINCIPLES

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SECTION 7
Structural Idealisation

SECTION 1
MATERIALS

1 GENERAL

1.1 Standard of material

1.1.1

Materials used during construction are to comply with the Rules for Materials of the Society.

1.1.2

Other materials than those covered under [1.1.1] may be accepted, provided their specification (e.g. manufacture, chemical composition, mechanical properties, welding) is submitted to the Society for approval.

1.2 Testing of materials

1.2.1

Materials are to be tested in compliance with the applicable requirements of Rules for Materials of the Society.

1.3 Manufacturing process

1.3.1

The requirements of this section presume that welding and other cold or hot manufacturing processes are carried out in compliance with current sound working practice defined in the Rules and/or documents of the individual Society which incorporate IACS UR W and the applicable requirements of Rules for Materials of the Society.

In particular:

- Parent material and welding processes are to be within the limits stated for the specified type of material for which they are intended.
- Specific preheating may be required before welding.
- Welding or other cold or hot manufacturing processes may need to be followed by an adequate heat treatment.

2 HULL STRUCTURAL STEEL

2.1 General

2.1.1 Young's modulus and Poisson's ratio

The Young's modulus for Carbon steel materials is equal to 206,000 N/mm^2 and the Poisson's ratio equal to 0.3.

2.1.2 Steel material grades and mechanical properties

Steel having a specified minimum yield stress of 235 N/mm^2 is regarded as normal strength hull structural steel and is denoted by 'MS' for mild steel. Steel having a higher specified minimum yield stress is regarded as higher strength hull structural steel and is denoted 'HT' for high tensile steel.

Material grades of hull structural steels are referred to as follows:

a) A, B, D and E denote normal strength steel grades.

b) AH, DH and EH denote higher strength steel grades.

Table 1 gives the mechanical characteristics of steels generally used in the construction of ships.

Table 1 : Mechanical properties of hull steels

Steel grades for plates with $t_{as\_built} \leq 100$ mm	R_{eH}, specified minimum yield stress, in N/mm^2	R_m, specified tensile strength, in N/mm^2
A-B-D-E	235	400 – 520
AH32-DH32-EH32-FH32	315	440 – 570
AH36-DH36-EH36-FH36	355	490 – 630
AH40-DH40-EH40-FH40	390	510 – 660

2.1.3

Higher strength steels other than those indicated in Table 1 are considered by the Society on a case-by-case basis.

2.1.4 High tensile steel

When steels with a specified minimum yield stress R_{eH} other than 235 N/mm^2 are used, hull girder strength and hull scantlings are to be determined by taking into account the material factor, k defined in [2.2].

2.1.5 Onboard documents

It is required to keep onboard a plan indicating the steel types and grades adopted for the hull structures. Where steels other than those indicated in Table 1 are used, their mechanical and chemical properties, as well as any workmanship requirements or recommendations, are to be available onboard together with the above plan.

2.2 Material factor, k

2.2.1

Unless otherwise specified, the material factor, k of normal and higher strength steel for hull girder strength and scantling purposes is to be taken as defined in Table 2, as a function of the specified minimum yield stress R_{eH}.

For intermediate values of R_{eH}, k is obtained by linear interpolation.

Steels with a specified minimum yield stress R_{eH}, greater than 390 N/mm^2 are considered by the Society on a case-by-case basis.

Table 2 : Material factor, k

R_{eH}, specified minimum yield stress, in N/mm^2	k
235	1.00
315	0.78
355	0.72
390	0.68

2.3 Steel grades

2.3.1

Materials in the various strength members are not to be of lower grade than those corresponding to the material classes and grades specified in Table 3 to Table 8. General requirements are given in Table 3, while additional minimum requirements for ships with length exceeding 150 m and 250 m, single side bulk carriers with length exceeding 150 m, and ships with ice strengthening are given in Table 4 to Table 7. The material grade requirements for hull members of each class depending on the thickness are defined in Table 8.

Table 3 : Material classes and grades

Structural member category		Material class/grade
Secondary	A1. Longitudinal bulkhead strakes, other than those belonging to the Primary category A2. Deck plating exposed to weather, other than that belonging to the Primary or Special category A3. Side plating	- Class I within 0.4 *L* amidships - Grade A/AH outside 0.4 *L* amidships
Primary	B1. Bottom plating, including keel plate B2. Strength deck plating, excluding that belonging to the Special category B3. Continuous longitudinal plating of strength members above strength deck, excluding hatch coamings B4. Uppermost strake in longitudinal bulkhead B5. Vertical strake (hatch side girder) and uppermost sloped strake in topside tank	- Class II within 0.4 *L* amidships - Grade A/AH outside 0.4 *L* amidships
Special	C1. Sheer strake at strength deck (1) C2. Stringer plate in strength deck (1) C3. Deck strake at longitudinal bulkhead, excluding deck plating in way of inner-skin bulkhead of double-hull ships (1)	- Class III within 0.4 *L* amidships - Class II outside 0.4 *L* amidships - Class I outside 0.6 *L* amidships
	C4. Strength deck plating at outboard corners of cargo hatch openings for ships with hatch opening configurations similar to those of container carriers	- Class III within 0.4 *L* amidships - Class II outside 0.4 *L* amidships - Class I outside 0.6 *L* amidships - Min. Class III within cargo hold region
	C5. Strength deck plating at corners of cargo hatch openings	- Class III within 0.6 *L* amidships - Class II within rest of cargo hold region
	C6. Bilge strake of ships with double bottom over the full breadth and with length less than 150 m	- Class II within 0.6 *L* amidships - Class I outside 0.6 *L* amidships
	C7. Bilge strake in other ships (1)	- Class III within 0.4 *L* amidships - Class II outside 0.4 *L* amidships - Class I outside 0.6 *L* amidships
	C8. Longitudinal hatch coamings of length greater than 0.15 *L* including coaming top plate and flange C9. End brackets and deckhouse transition of longitudinal cargo hatch coamings	- Class III within 0.4 *L* amidships - Class II outside 0.4 *L* amidships - Class I outside 0.6 *L* amidships - Not to be less than Grade D/DH
(1)	Single strakes required to be of class III within 0.4*L* amidships are to have breadths not less than 800+5*L*, in mm, need not be greater than 1800 mm, unless limited by the geometry of the ship's design.	

Table 4 : Minimum material grades for ships with length exceeding 150 m

Structural member category	Material grade
Longitudinal plating of strength deck where contributing to the longitudinal strength	Grade B/AH within 0.4 *L* amidships
Continuous longitudinal plating of strength members above strength deck	Grade B/AH within 0.4 *L* amidships
Single side strakes for ships without inner continuous longitudinal bulkhead(s) between bottom and the strength deck	Grade B/AH within cargo hold region

Table 5 : Minimum material grades for ships with length exceeding 250 m

Structural member category (1)	Material grade
Shear strake at strength deck	Grade E/EH within 0.4 *L* amidships
Stringer plate in strength deck	Grade E/EH within 0.4 *L* amidships
Bilge strake	Grade D/DH within 0.4 *L* amidships
(1) Single strakes required to be of Grade E/EH and within 0.4 *L* amidships are to have breadths not less than 800+5 *L* (mm), need not be greater than 1800 (mm), unless limited by the geometry of the ship's design.	

Table 6 : Minimum material grades for single side skin bulk carriers with length exceeding 150 m

Structural member category	Material grade
Lower bracket of ordinary side frame (1), (2)	Grade D/DH
Side shell strakes included totally or partially between the two points located to 0.125ℓ above and below the intersection of side shell and bilge hopper sloping plate or inner bottom plate (2)	Grade D/DH
(1) The term 'lower bracket' means webs of lower brackets and webs of the lower part of side frames up to the point of 0.125ℓ above the intersection of side shell and bilge hopper sloping plate or inner bottom plate. **(2)** The span of the side frame, ℓ, is defined as the distance between the supporting structures (see Pt 2, Ch 1, Sec 2, Figure 2).	

Table 7 : Minimum material grades for ships with ice strengthening

Structural member category	Material grade
Shell strakes in way of ice strengthening area for plates	Grade B/AH

Table 8 : Material grade requirements for classes I, II and III

Class	I		II		III	
As-built thickness, in mm	MS	HT	MS	HT	MS	HT
$t \leq 15$	A	AH	A	AH	A	AH
$15 < t \leq 20$	A	AH	A	AH	B	AH
$20 < t \leq 25$	A	AH	B	AH	D	DH
$25 < t \leq 30$	A	AH	D	DH	D	DH
$30 < t \leq 35$	B	AH	D	DH	E	EH
$35 < t \leq 40$	B	AH	D	DH	E	EH
$40 < t \leq 50$	D	DH	E	EH	E	EH

2.3.2

For strength members not mentioned in Table 3 to Table 7, Grade A/AH may be used upon agreement of the Society.

2.3.3

Plating materials for stern frames and shaft brackets are in general not to be of lower grades than corresponding to Class II.

2.4 Structures exposed to low air temperature

2.4.1

For ships intended to operate in areas with low air temperatures refer to Ch 1, Sec 2, [3.4.4].

2.5 Through thickness property

2.5.1

Where tee or cruciform connections employ partial or full penetration welds, and the plate material is subject to significant tensile strain in a direction perpendicular to the rolled surfaces, consideration is to be given to the use of special material with specified through thickness properties, in accordance with the Rules for Materials of the Society. These steels are to be designated on the approved plan by the required steel strength grade followed by the letter Z (e.g. EH36Z).

2.6 Stainless steel

2.6.1

The reduction of strength of stainless steel with increasing temperature is to be taken into account in the calculation of the material factor, *k* and in the material Young's modulus, *E*.

Stainless steels are considered by the Society on a case-by-case basis.

3 STEELS FOR FORGING AND CASTING

3.1 General

3.1.1

Mechanical and chemical properties of steels for forging and casting to be used for structural members are to comply with the applicable requirements of the Rules for Materials of the Society.

3.1.2

Steels of structural members intended to be welded are to have mechanical and chemical properties deemed appropriate for this purpose by the Society on a case-by-case basis.

3.1.3

The steels used are to be tested in accordance with the applicable requirements of the Rules for Materials of the Society.

3.2 Steels for forging

3.2.1

Rolled bars may be accepted in lieu of forged products, after consideration by the Society on a case-by-case basis. In such case, compliance with the applicable requirements of the Rules for Materials of the Society, relevant to the quality and testing of rolled parts accepted in lieu of forged parts, may be required.

3.3 Steels for casting

3.3.1

Cast parts intended for stems and stern frames in general may be made of C and C-Mn weldable steels, having specified minimum tensile strength, R_m = 400 N/mm^2, in accordance with the applicable requirements of the Society's Rules for Materials.

3.3.2

The welding of cast parts to main plating contributing to hull strength members is considered by the Society on a case-by-case basis.

The Society may require additional properties and tests for such casting, in particular impact properties which are appropriate to those of the steel plating on which the cast parts are to be welded and non-destructive examinations.

4 ALUMINIUM ALLOYS

4.1 General

4.1.1

The use of aluminium alloys in superstructures, deckhouses, hatch covers, helicopter platforms, or other local components is to be specially considered. A specification of the proposed alloys and their proposed method of fabrication is to be submitted for approval.

Material requirements and scantlings are to comply with the Rules for Materials of the Society. Series 5000 aluminium-magnesium alloys or series 6000 aluminium-magnesium-silicon alloys are to be used.

4.1.2

In the case of structures subjected to low service temperatures or intended for other specific applications, the alloys to be employed are to be agreed by the Society.

4.1.3

Unless otherwise agreed, the Young's modulus for aluminium alloys is equal to 70,000 N/mm^2 and the Poisson's ratio equal to 0.33.

4.1.4

Details of the proposed method of joining any aluminium and steel structures are to be submitted for approval.

4.2 Extruded plating

4.2.1

Extrusions with built-in plating and stiffeners, referred to as extruded plating, may be used.

4.2.2

In general, the application of extruded plating is limited to decks, bulkheads, superstructures and deckhouses. Other uses may be permitted by the Society on a case-by-case basis.

4.2.3

Extruded plating is to be oriented so that the stiffeners are parallel to the direction of main stresses.

4.2.4

Connections between extruded plating and primary members are to be given special attention.

4.3 Mechanical properties of weld joints

4.3.1

Welding heat input lowers locally the mechanical strength of aluminium alloys hardened by work hardening (series 5000 other than condition O or H111) or by heat treatment (series 6000).

4.3.2

The as-welded properties of aluminium alloys of series 5000 are in general those of condition O or H111. Higher mechanical characteristics may be considered, provided they are duly justified.

4.3.3

The as-welded properties of aluminium alloys of series 6000 are to be agreed by the Society.

4.4 Material factor, *k*

4.4.1

The material factor, *k* for aluminium alloys is to be obtained from the following formula:

$$k = \frac{235}{R'_{lim}}$$

where:

R'_{lim} : Minimum guaranteed yield stress of the parent metal in welded condition $R'_{p0.2}$, in N/mm^2, but not to be taken greater than 70% of the minimum guaranteed tensile strength of the parent metal in welded condition R'_m, in N/mm^2.

$R'_{p0.2}$: Minimum guaranteed yield stress, in N/mm^2, of material in welded condition.

$$R'_{p0.2} = \eta_1 R_{p0.2}$$

R'_m : Minimum guaranteed tensile strength, in N/mm^2, of material in welded condition.

$$R'_m = \eta_2 R_m$$

$R_{p0.2}$: Minimum guaranteed yield stress, in N/mm^2, of the parent metal in delivery condition.

R_m : Minimum guaranteed tensile strength, in N/mm^2, of the parent metal in delivery condition.

η_1, η_2 : Specified in Table 9.

Table 9 : Aluminium alloys - Coefficients for welded construction

Aluminium alloy	η_1	η_2
Alloys without work-hardening treatment (series 5000 in annealed condition O or annealed flattened condition H111)	1	1
Alloys hardened by work hardening (series 5000 other than condition O or H111)	$R'_{p0.2} / R_{p0.2}$	R'_m / R_m
Alloys hardened by heat treatment (series 6000) (1)	$R'_{p0.2} / R_{p0.2}$	0.6
(1) When no information is available, coefficient η_1 is to be taken equal to the metallurgical efficiency coefficient β as defined in Table 10.		

Table 10 : Aluminium alloys - Metallurgical efficiency coefficient β

Aluminium alloy	Temper condition	As-built thickness, in mm	β
6005A (Open sections)	T5 or T6	$t \leq 6$	0.45
		$t > 6$	0.40
6005A (Closed sections)	T5 or T6	All	0.50
6061 (Sections)	T6	All	0.53
6082 (Sections)	T6	All	0.45

4.4.2

In the case of welding of two different aluminium alloys, the material factor, *k* to be considered for the scantlings is the greater material factor of the aluminium alloys of the assembly.

4.5 Others

4.5.1

Aluminium fittings in tanks used for the carriage of oil, and in cofferdams and pump rooms are to be avoided. Where fitted, aluminium fittings, units and supports, in tanks used for the carriage of oil, cofferdams and pump rooms are to satisfy the requirements of Pt 2, Ch 2, Sec 2, [1.2] for aluminium anodes.

4.5.2

The underside of heavy portable aluminium structures such as gangways, is to be protected by means of a hard plastic or wood cover, or other approved means, in order to avoid the creation of smears. Such protection is to be permanently and securely attached to the structures.

5 OTHER MATERIALS AND PRODUCTS

5.1 General

5.1.1

Other materials and products such as parts made of iron castings, where allowed, products made of copper and copper alloys, rivets, anchors, chain cables, cranes, masts, derrick posts, derricks, accessories and wire ropes are to comply with the applicable requirements of the Rules for Materials of the Society.

5.1.2

The use of plastics or other special materials not covered by these Rules is to be considered by the Society on a case-by-case basis. In such cases, the requirements for the acceptance of the materials concerned are to be agreed by the Society.

5.2 Iron cast parts

5.2.1

As a rule, the use of grey iron, malleable iron or spheroidal graphite iron cast parts with combined ferritic/perlitic structure is allowed only to manufacture low stressed elements of secondary importance.

5.2.2

Ordinary iron cast parts may not be used for windows or sidescuttles; the use of high grade iron cast parts of a suitable type is to be considered by the Society on a case-by-case basis.

SECTION 2
NET SCANTLING APPROACH

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4

t : Net thickness in mm.

t_c : Corrosion addition in mm.

t_{gr} : Gross thickness in mm.

h_{stf} : Height of stiffener or primary supporting member in mm.

h_w : Web height of stiffener or primary supporting member in mm.

t_w : Web thickness of stiffener or primary supporting member in mm.

b_f : Face plate width of stiffener or primary supporting member in mm.

t_f : Face plate thickness of stiffener or primary supporting member in mm.

t_p : Thickness of the plating attached to a stiffener or to a primary supporting member in mm.

d_e : Distance in mm, from the upper edge of the web to the top of the flange for *L3* profiles, see Figure 3.

t_{as_built} : As-built thickness, in mm, taken as the actual thickness provided at the newbuilding stage.

t_{gr_off} : Gross offered thickness, in mm, as defined in [1.2.2].

t_{gr_req} : Gross required thickness, in mm, as defined in [1.2.1].

t_{off} : Net offered thickness, in mm, as defined in [1.2.3].

t_{dm} : Design production margin, in mm, taken as the thickness difference between offered gross thickness and required gross thickness (equal also to the difference between offered net and required net thickness) as a result of scantlings applied by the designer or builder to suit design or production situation. This difference in thickness is not to be considered as an additional corrosion margin.

t_{req} : Net required thickness, in mm, as required in [1.3.1].

t_{vol_add} : Thickness for voluntary addition, in mm, taken as the thickness voluntarily added as the owner's extra margin or builder's extra margin for corrosion wastage in addition to t_c.

t_{res} : Reserve thickness, in mm, taken equal to 0.5 mm.

t_{c1}, t_{c2} : Corrosion addition on one side of the considered structural member, in mm, as defined in Ch 3, Sec 3, Table 1.

1 GENERAL

1.1 Application

1.1.1 Net thickness approach

The net thickness, t, of a structural element is required for structural strength in compliance with the design basis. The corrosion addition, t_c, for a structural element is derived independently from the net scantling requirements as shown in Figure 1. This approach clearly separates the net thickness from the thickness added to address the corrosion that is likely to occur during the ship-in-operation phase. This approach

enables the status of the structure with respect to corrosion to be clearly ascertained throughout the life of the ship.

1.1.2 Local and global corrosion

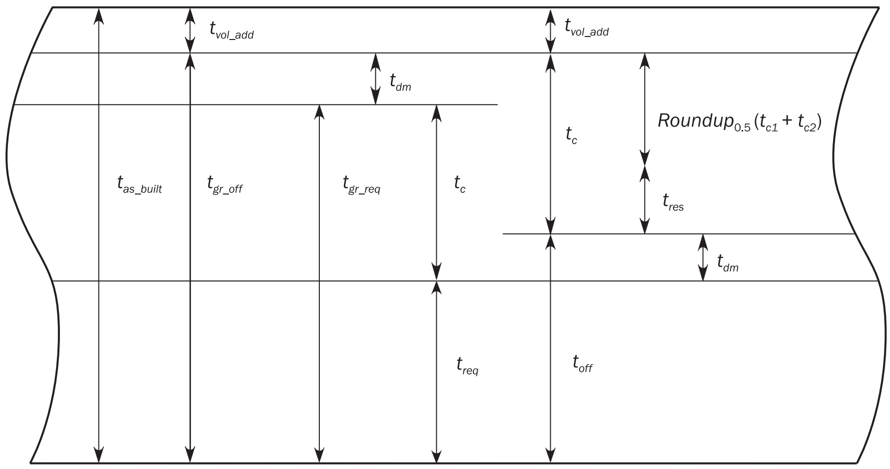
The net thickness approach distinguishes between local and global corrosion. Local corrosion is defined as uniform corrosion of local structural elements, such as a single plate or stiffener. Global corrosion is defined as the average corrosion of larger areas, such as primary supporting members and the hull girder.

1.1.3 Exceptions in gross scantling

Items that are directly determined in terms of gross scantlings do not follow the net scantling approach, i.e. they already include additions for corrosion but without any owner's extra margin. Gross scantling requirements are identified with the suffix "gr" and examples are:

- Scantlings of superstructures and deckhouses as given in Ch 11, Sec 1.
- Scantlings of massive pieces made of steel forgings and steel castings.

Figure 1 : Net scantling approach scheme



1.2 Gross and net scantling definitions

1.2.1 Gross required thickness

The gross required thickness, t_{gr_req}, is the thickness obtained by adding the corrosion addition as defined in Ch 3, Sec 3 to the net required thickness, as follows:

$$t_{gr\_req} = t_{req} + t_c$$

1.2.2 Gross offered thickness

The gross offered thickness, t_{gr_off}, is the gross thickness provided at the newbuilding stage, which is obtained by deducting any thickness for voluntary addition from the as-built thickness, as follows:

$$t_{gr\_off} = t_{as\_built} - t_{vol\_add}$$

1.2.3 Net offered thickness

The net offered thickness, t_{off}, is obtained by subtracting the corrosion addition from the gross offered thickness, as follows:

$$t_{off} = t_{gr\_off} - t_c = t_{as\_built} - t_{vol\_add} - t_c$$

1.3 Scantling compliance

1.3.1

The net required thickness, t_{req}, is obtained by rounding the net thickness calculated according to the Rules to the nearest half millimetre. For example:

- For $10.75 \le t < 11.25$ mm, the Rule required net thickness is 11.0 mm.
- For $11.25 \le t < 11.75$ mm, the Rule required net thickness is 11.5 mm.

1.3.2

Scantling compliance in relation to the Rules is as follow:

- The net offered thickness of plating is to be equal to or greater than the net required thickness of plating.
- The required net section modulus, moment of inertia and shear area properties of local supporting members are to be calculated using the net thickness of the attached plate, web and flange. The net sectional dimensions of local supporting members are defined in Figure 2. The required section modulus and web net thickness apply to areas clear of the end brackets.
- The offered net sectional properties of primary supporting members and the hull girder are to be equal to or greater than the required net sectional properties which are to be based on the gross offered scantling with a reduction of the applicable corrosion addition, as specified in Table 1, applied to all component structural members.
- The strength assessment methods prescribed are to be assessed by applying the corrosion reduction specified in Table 1 to the offered gross scantlings. Half of the applied corrosion addition specified in Table 1 is to be deducted from both sides of the structural members being considered.
- Corrosion additions are not to be taken less than those given in Ch 3, Sec 3, [1.2].

Any additional thickness specified by the owner or the builder is not to be included when considering the compliance with the Rules.

Table 1 : Assessment for corrosion applied to the gross scantlings

Structural requirement	Property/analysis type	Applied corrosion addition
Minimum thickness (all members including PSM)	Thickness	t_c
Local strength (plates, stiffeners, and hold frames)	Thickness/sectional properties	t_c
	Stiffness / proportions / Buckling capacity	t_c
Primary supporting members (prescriptive)	Sectional properties	$0.5\ t_c$
	Stiffness/proportions of web and flange Buckling capacity	t_c
Strength assessment by FEM	Cargo tank/cargo hold	$0.5\ t_c$
	Buckling capacity	t_c
	Local fine mesh	$0.5\ t_c$
	Specified fine mesh areas	$0.5\ t_c$
Hull girder strength	Sectional properties	$0.5\ t_c$
	Buckling capacity	t_c
Hull girder ultimate strength Hull girder residual strength	Sectional properties	$0.5\ t_c$
	Buckling/collapse capacity	$0.5\ t_c$
Fatigue assessment (simplified stress analysis)	Hull girder section properties Local support member	$0.5\ t_c$
Fatigue assessment (FE Stress analysis)	Coarse mesh FE model Very fine mesh portion	$0.5\ t_c$

Figure 2 : Net sectional properties of local supporting members

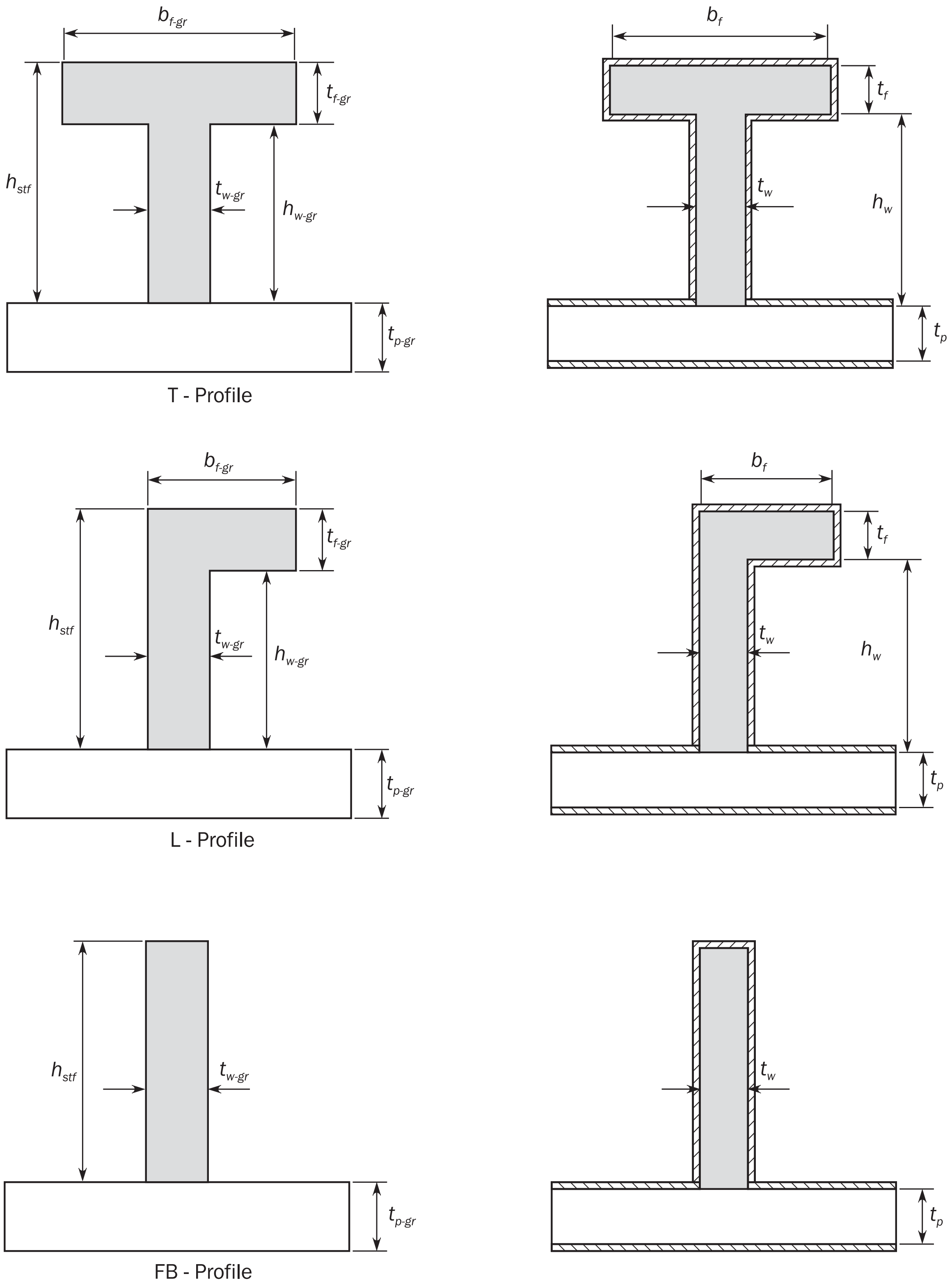
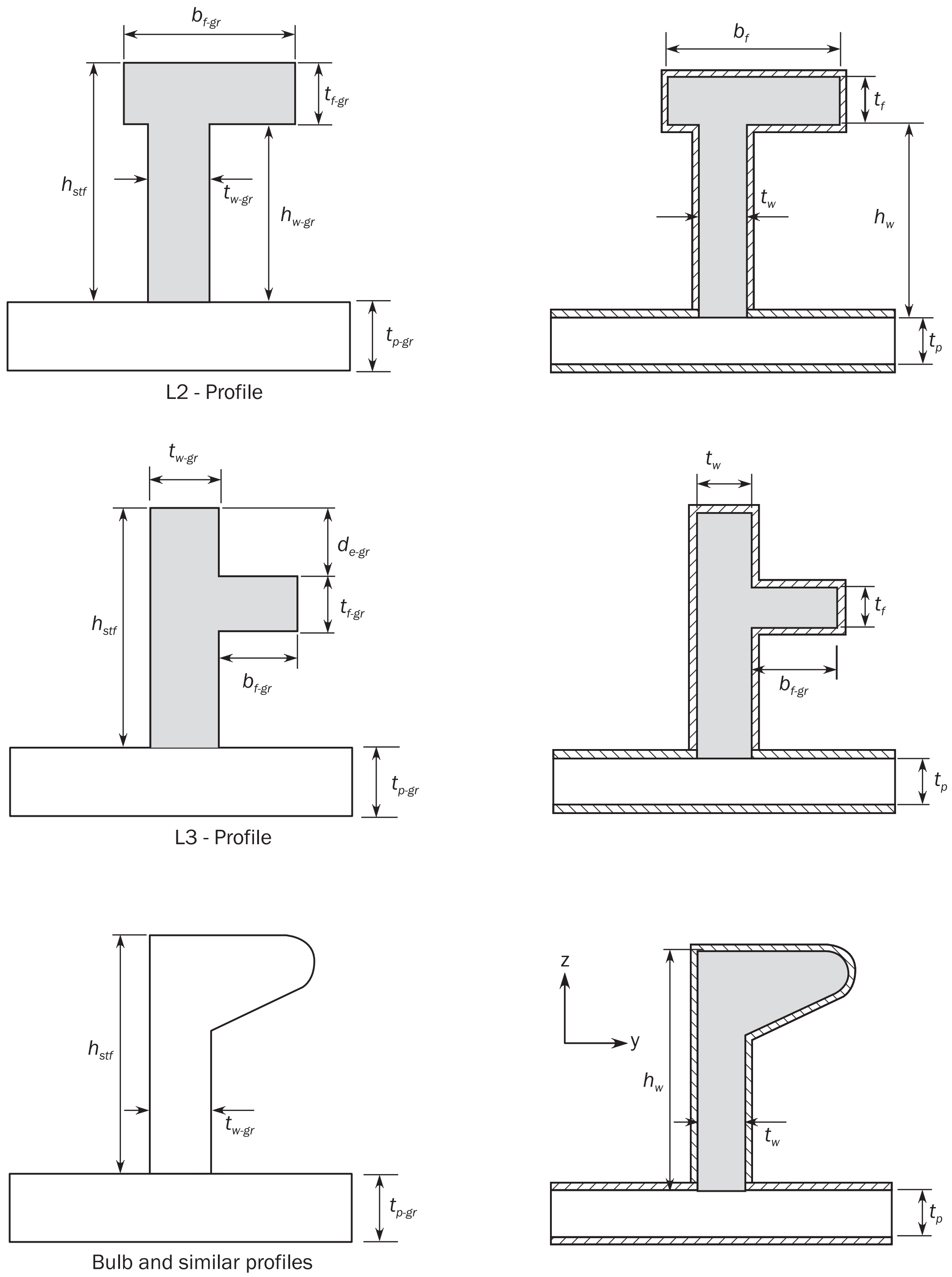


Figure 3 : Net sectional properties of local supporting members (continued)



The net cross-sectional area, the moment of inertia about the y-axis and the assosiated neutral axis position are to be determined applying a corrosion magnitude of 0.5 t_c deducted from the surface of the profile cross-section.

SECTION 3
CORROSION ADDITIONS

SYMBOLS

t_c : Corrosion addition, in mm.

t_{c1}, t_{c2} : Corrosion addition, in mm, on one side of the considered structural member, as defined in Table 1.

t_{res} : Reserve thickness, taken as 0.5 mm.

1 GENERAL

1.1 Applicability

1.1.1

The corrosion additions given in these Rules are applicable to carbon-manganese steels, stainless steels, stainless clad steels and aluminium alloys. Corrosion addition for the exposed carbon steel side of stainless clad structure is to be as required in Table 1 for the corresponding compartment.

The corrosion additions for other materials are to be in accordance with the requirements of the Society.

1.2 Corrosion addition determination

1.2.1

The corrosion addition for each of the two sides of a structural member, t_{c1} or t_{c2}, is specified in Table 1.

The total corrosion addition, t_c, in mm, for both sides of the structural member is obtained by the following formula:

$$t_c = Roundup_{0.5}\,(t_{c1} + t_{c2}) + t_{res}$$

For an internal member within a given compartment, the total corrosion addition, t_c is obtained from the following formula:

$$t_c = Roundup_{0.5}\,(2t_{c1}) + t_{res}$$

where t_{c1} is the value specified in Table 1 for one side exposure to that compartment.

Roundup$_{0.5}$ (t) means that *t* is rounded to the upper half millimetre.

The total corrosion addition, t_c, in mm, for compartment boundaries and internal members made from stainless steel, or aluminium is to be taken as:

$$t_c = t_{res} = 0.5$$

In case of stainless clad steel, the corrosion additions, t_{c1}, for the carbon steel side and t_{c2}, for the stainless steel side are respectively to be taken as:

- t_{c1} as specified for the corresponding compartment in Table 1
- $t_{c2} = 0$

Table 1 : Corrosion addition for one side of a structural member

<table>
<tr><th rowspan="2">Compartment type</th><th rowspan="2" colspan="2">Structural member</th><th colspan="3">t_{c1} or t_{c2}</th></tr>
<tr><th>Oil tankers</th><th>BC-A or BC-B ships with $L \geq 150$ m</th><th>Other BC ships</th></tr>
<tr><td rowspan="4">Ballast water tank, bilge tank, drain storage tank, chain locker (1)</td><td rowspan="2">Face plate of PSM</td><td>Within 3m below top of tank (4)</td><td colspan="3">2.0</td></tr>
<tr><td>Elsewhere</td><td colspan="3">1.5</td></tr>
<tr><td rowspan="2">Other members (2) (3)</td><td>Within 3m below top of tank (4)</td><td colspan="3">1.7</td></tr>
<tr><td>Elsewhere</td><td colspan="3">1.2</td></tr>
<tr><td rowspan="5">Cargo oil tank</td><td rowspan="2">Face plate of PSM</td><td>Within 3m below top of tank (4)</td><td>1.7</td><td rowspan="5" colspan="2">N/A</td></tr>
<tr><td>Elsewhere</td><td>1.4</td></tr>
<tr><td colspan="2">Inner-bottom plating/bottom of tank</td><td>2.1</td></tr>
<tr><td rowspan="2">Other members</td><td>Within 3m below top of tank (4)</td><td>1.7</td></tr>
<tr><td>Elsewhere</td><td>1.0</td></tr>
<tr><td rowspan="8">Dry bulk cargo hold (5)</td><td rowspan="3">Transverse bulkhead</td><td>Upper part (6)</td><td rowspan="8">N/A</td><td>2.4</td><td>1.0</td></tr>
<tr><td>Lower stool: sloping plate, vertical plate and top plate (7)</td><td>5.2</td><td>2.6</td></tr>
<tr><td>Other parts</td><td>3.0</td><td>1.5</td></tr>
<tr><td colspan="2">Sloped plating of hopper tank, inner bottom plating</td><td>3.7</td><td>2.4</td></tr>
<tr><td rowspan="4">Other members</td><td>Upper part (6)</td><td rowspan="2">1.8</td><td rowspan="2">1.0</td></tr>
<tr><td>Webs and flanges of the upper end brackets of side frames of single side bulk carriers</td></tr>
<tr><td>Webs and flanges of lower brackets of side frames of single side bulk carriers</td><td>2.2</td><td>1.2</td></tr>
<tr><td>Other parts</td><td>2.0</td><td>1.2</td></tr>
<tr><td rowspan="2">Exposed to atmosphere</td><td colspan="2">Weather deck plating</td><td colspan="3">1.7</td></tr>
<tr><td colspan="2">Other members</td><td colspan="3">1.0</td></tr>
<tr><td rowspan="2">Exposed to seawater</td><td colspan="2">Shell plating between the minimum design ballast draught waterline and the scantling draught waterline</td><td colspan="3">1.5</td></tr>
<tr><td colspan="2">Shell plating elsewhere</td><td colspan="3">1.0</td></tr>
<tr><td colspan="3">Fuel and lube oil tank</td><td colspan="3">0.7</td></tr>
<tr><td colspan="3">Fresh water tank</td><td colspan="3">0.7</td></tr>
<tr><td>Void spaces (8)</td><td colspan="2">Spaces not normally accessed, e.g. access only via bolted manhole openings, pipe tunnels, inner surface of stool space not common with a dry bulk cargo hold or ballast cargo hold, etc.</td><td colspan="3">0.7</td></tr>
<tr><td>Dry spaces</td><td colspan="2">Internals of machinery spaces, pump room, store rooms, steering gear space, etc.</td><td colspan="3">0.5</td></tr>
</table>

(1)	1.0 mm is to be added to the plate surface within 3m above the upper surface of the chain locker bottom.
(2)	0.5 mm is to be added to the plate surface exposed to ballast for the plate boundary between water ballast and heated cargo oil tanks. 0.3mm is to be added to each surface of the web and face plate of a stiffener in a ballast tank and attached to the boundary between water ballast and heated cargo oil tanks or heated fuel/lube oil tanks. Heated oil tanks are defined as tanks arranged with any form of heating capability (the most common type is heating coils).
(3)	0.7 mm is to be added to the plate surface exposed to ballast for the plate boundary between water ballast and heated fuel oil or lube oil tanks.
(4)	Only applicable to cargo tanks and ballast tanks with weather deck as the tank top. The 3 m distance is measured vertically from and parallel to the top of the tank.
(5)	Dry bulk cargo hold includes holds intended for the carriage of dry bulk cargoes, which may carry water ballast.
(6)	Upper part of the cargo holds correspond to an area above the connection between the topside and the inner hull or side shell. If there is no topside, the upper part corresponds to the upper one third of the cargo hold height (where a plane bulkhead is fitted in way of a dry bulk cargo hold, the upper part of the bulkhead is defined in the same manner).
(7)	If there is no lower stool fitted (i.e. engine room bulkhead or fore peak bulkhead) or if a plane bulkhead is fitted, then this corrosion addition should be applied up to a height level with the opposing bulkhead stool in that hold. In the case where a stool is not fitted on the opposing bulkhead, the vertical extent of this zone is to be from the inner bottom to a height level with the top of the adjacent hopper sloping plate.
(8)	For the determination of the corrosion addition of the outer shell plating, the pipe tunnel is considered as for a water ballast tank.

1.2.2 Minimum value of total corrosion addition

The total corrosion addition is not to be taken less than 2 mm except for web and face plate of stiffeners or in way of internals of dry spaces where 1.5 mm is applicable.

These minimum values of corrosion addition are not applicable to structural members made of stainless steels, stainless clad steels or aluminium alloys.

1.2.3 Stiffener

The corrosion addition of a stiffener is determined according to the location of its connection to the attached plating.

1.2.4

When a local structural member/plate is affected by more than one value of corrosion addition, the most onerous value is to be applied to the entire strake.

SECTION 4
CORROSION PROTECTION

1 GENERAL

1.1 Structures to be protected

1.1.1 Dedicated seawater ballast tanks

All dedicated seawater ballast tanks are to have an efficient corrosion prevention system.

1.1.2 Cargo oil tanks

Cargo oil tanks are to be protected in compliance with the requirements specified in Pt 2, Ch 2, Sec 2, [1].

1.1.3 Bulk carriers

Void double side skin spaces and cargo holds of bulk carriers are to be protected in compliance with the requirements specified respectively in Pt 2, Ch 1, Sec 2, [2.2] and Pt 2, Ch 1, Sec 2, [2.3].

1.1.4 Narrow spaces

Narrow spaces are generally to be filled by an efficient protective product, particularly at the ends of the ship where inspections and maintenance are not easily practicable due to their inaccessibility.

2 SACRIFICIAL ANODES

2.1 Attachment of anodes to the hull

2.1.1

All anodes are to be attached to the structure in such a way that they remain securely fastened both initially and during service even when it is wasted. The following methods are acceptable:

a) Steel core connected to the structure by continuous fillet welds.

b) Attachment to separate supports by bolting, provided a minimum of two bolts with lock nuts are used. However, other mechanical means of clamping may be accepted.

2.1.2

Anodes are to be attached to stiffeners or aligned in way of stiffeners on plane bulkhead plating, but they are not to be attached to the shell. The two ends are not to be attached to separate members which are capable of relative movement.

2.1.3

Where cores or supports are welded to local support members or primary supporting members, they are to be kept clear of end supports, toes of brackets and similar stress raisers. Where they are welded to asymmetrical members, the welding is to be at least 25 mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the face plate, but well clear of the free edges. Generally, anodes are not to be fitted to a face plate of higher strength steel.

2.1.4 Cargo oil tanks

Cathodic protection systems, if fitted in cargo oil tanks, are to comply the requirements specified Pt 2, Ch 2, Sec 2, [1].

SECTION 5
LIMIT STATES

1 GENERAL

1.1 Limit states

1.1.1 Definition

A limit state is defined as a state beyond which the structure no longer satisfies the requirements. The following categories of limit states are relevant for structures:

- Serviceability limit state (SLS), which corresponds to conditions beyond which specified requirements are no longer met.
- Ultimate limit state (ULS), which corresponds to the maximum load carrying-capacity or, in some cases, to the maximum applicable strain or deformation, under intact (undamaged) conditions.
- Fatigue limit state (FLS), which corresponds to degradation due to effect of time varying (cyclic) loading.
- Accidental limit state (ALS), which concerns the ability of the structure to resist accident situations.

1.1.2 Serviceability limit state

Serviceability limit state, which concerns the normal use, includes:

- Local damage which may reduce the working life of the structure or affect the efficiency or appearance of structural members or non-structural elements.
- Unacceptable deformations which affect the efficient use and appearance of structural or non-structural elements or the functioning of safety equipment.

In the context of serviceability limit state, the term 'appearance' is concerned with such criteria as high deflection and extensive cracking, rather than aesthetics.

1.1.3 Ultimate limit state

Ultimate limit state, which corresponds to the maximum load-carrying capacity, or in some cases, the maximum applicable strain or deformation, includes:

- Attainment of the maximum resistance capacity of sections, members or connections by rupture or excessive deformations or instability (buckling).
- Excessive yielding, transforming the structure or part of it into a plastic mechanism.

1.1.4 Fatigue limit state

Fatigue limit states assess that the fatigue capacity of structural members due to cyclic loads is greater than the design fatigue life.

1.1.5 Accidental limit state

Accidental limit states are concerned with the ability of the structure to resist accident situations or abnormal events. Flooded conditions of any compartment without progression of the flooding to another compartment are considered. The limit states are concerned with the following in intact (undamaged) conditions with

accidental or abnormal loads, or in damaged conditions with environmental loads the ship meets during a limited time frame:

- The safety of life.
- Environment.
- Property (ship and cargo).

Accidental limit state includes:

- Loss of structural strength without loss of containment.
- Loss of structural strength and loss of containment.

1.2 Failure modes

1.2.1

A number of possible failure modes may be relevant for the various parts of the ship structure. For each failure mode, one or more limit states may be relevant. The failure modes to be considered for the assessment of ship structural safety with relation to the limit states are shown in Table 1.

Table 1 : Failure modes in relation to the limit states to be considered

Possible failure modes to be considered	Limit states (1)			
	SLS	ULS	FLS	ALS
Yielding	Y	Y	-	Y
Plastic collapse	-	Y	-	Y
Buckling	Y	Y	-	Y
Rupture	-	Y	-	Y
Fatigue cracking	-	-	Y	-
Brittle fracture (2)	-	-	-	-

(1) "Y" indicates that the structural assessment is to be carried out.
(2) Controlled by the material rule requirement of steel grade.

1.2.2 Yielding

The yielding failure mode is the mode in which plastic strain locally occurs in the structural members to be considered under combined in-plane and normal stresses. Local plastic strain is controlled in SLS, ULS and ALS by checking that the stresses caused in the structural members remains below a permissible value.

1.2.3 Plastic collapse

The plastic collapse failure mode usually appears in the local structural members under large lateral impact pressure. In this failure mode, permanent lateral deflection in the local structural members occurs, but does not influence the global strength. This mode is controlled in ULS and ALS by using conventional plastic design method.

1.2.4 Buckling

The buckling failure mode is the instability phenomena of structural members under compressive loads. When the stress in structural members just attains the elastic buckling stress, elastic (reversible) buckling occurs during the compressive load. This buckling failure mode is controlled in SLS. By further increasing the compressive load, stress redistribution occurs due to buckling of the weakest structural member and the stress in some structural members reaches the yield stress. This buckling failure mode with large elastic deflection is controlled in ULS or ALS. When compression is unloaded, no consequence of failure due to buckling is seen.

On the other hand, plastic (irreversible) buckling occurs when the stress in structural members exceeds the yield stress. As a result, the substantial permanent deflections due to plastic buckling appear. This irreversible buckling failure mode is controlled only in ULS or ALS for global hull girder strength.

1.2.5 Rupture

The rupture failure mode is the mode in which breaking occurs in the structural members to be considered under large tensile stress beyond the yield stress of the material. This failure mode is controlled in ULS or ALS, but the assessment of this failure mode is covered by controlling the yielding failure.

1.2.6 Brittle fracture

Brittle fracture is dependent upon the material, temperature and thickness. Therefore, this mode is controlled by the material rule requirement of steel grade.

1.2.7 Fatigue cracking

This failure mode is different from the failure modes mentioned above and is controlled in FLS.

2 CRITERIA

2.1 General

2.1.1

Criteria are prescribed in the Rules to check the relevant limit states for the various structural elements. The strength assessments included in the Rules are defined in terms of yield check, buckling check, ultimate strength check, and fatigue check as indicated in Table 2.

Table 2 : Structural assessment

Structural Elements (1)		Yielding check	Buckling check	Ultimate strength check	Fatigue check
Local Structures	Stiffeners	Y	Y	Y (2)	Y
	Plating	Y	Y	Y (3)	-
Primary supporting members		Y	Y	Y (2)	Y
Hull girder		Y	Y (4)	Y	-

(1) "Y" indicates that the structural assessment is to be carried out.
(2) The ultimate strength check is included in the buckling check.
(3) The ultimate strength check of plating is included in the yielding check formula of plating.
(4) The buckling check of stiffeners and plating taking part in hull girder strength is performed against stress due to hull girder bending moment and hull girder shear force.

2.2 Serviceability limit states

2.2.1 Hull girder

For the yielding check of the hull girder, the stress corresponds to a load at 10^{-8} probability level.

2.2.2 Plating

For the yielding check and buckling check of platings constituting a primary supporting member, the stress corresponds to a load at 10^{-8} probability level.

2.2.3 Stiffeners

For the yielding check of stiffeners, the stress corresponds to a load at 10^{-8} probability level.

2.3 Ultimate limit states

2.3.1 Hull girder

The ultimate strength of the hull girder is to be checked against the hull girder loads at 10^{-8} probability level, amplified with the partial safety factor.

2.3.2 Plating

The ultimate strength of the plating between stiffeners and primary supporting members is to be checked against the loads at 10^{-8} probability level.

2.3.3 Stiffeners

The ultimate strength of stiffeners is to be checked against the loads at 10^{-8} probability level.

2.4 Fatigue limit state

2.4.1 Structural details

The fatigue life of representative welded structural details such as connections of stiffeners and primary supporting members and free edge of bulk carrier deck plating in way of hatch corner is to be assessed from long term distribution loads based on loads at 10^{-2} probability level including the whipping-springing effects.

2.5 Accidental limit state

2.5.1 Hull girder

For bulk carriers, the yielding and ultimate strength of the hull girder in cargo hold flooded condition and in the damaged condition is to be assessed in accordance with Ch 5, Sec 1 and Ch 5, Sec 2.

The residual strength of oil tankers and bulk carriers is to be assessed according to Ch 5, Sec 3, for damages resulting from collision or grounding.

2.5.2 Double bottom structure

For bulk carriers, the double bottom structure in cargo hold flooded condition is to be assessed in accordance with Pt 2, Ch 1, Sec 3.

2.5.3 Bulkhead structure

For bulk carriers, the bulkhead structure in cargo hold flooded condition is to be assessed in accordance with Pt 2, Ch 1, Sec 3 and Pt 2, Ch 1, Sec 4.

2.5.4 Plating, stiffeners and PSM

The plating, stiffeners and PSM are to be assessed in flooded conditions in accordance with Ch 6 for yielding criteria and with Ch 8, Sec 3 for buckling criteria.

3 STRENGTH CHECK AGAINST IMPACT LOADS

3.1 General

3.1.1

Structural response against impact loads such as forward bottom slamming, bow flare slamming and grab chocks depends on the loaded area, magnitude of loads and structural grillage.

3.1.2

The ultimate strength of structural members that constitute the grillage, i.e. platings between stiffeners and primary supporting members and stiffeners with attached plating, is to be checked against the maximum impact loads acting on them.

SECTION 6
STRUCTURAL DETAIL PRINCIPLES

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

1 APPLICATION

1.1 General

1.1.1

If not specified otherwise, the requirements of this section apply to the hull structure except superstructures and deckhouses.

2 GENERAL PRINCIPLES

2.1 Structural continuity

2.1.1 General

Attention is to be paid to the structural continuity, in particular in the following areas:

- In way of changes in the framing system.
- At end connections of primary supporting members or ordinary stiffeners.
- In way of the transition zones between cargo hold region and fore part, aft part and machinery space.
- In way of side and end bulkheads of superstructures.

At the termination of a structural member, structural continuity is to be maintained by the fitting of suitable supporting structure.

Abrupt changes in transverse section properties of longitudinal members are to be avoided. Smooth transitions are to be provided.

2.1.2 Longitudinal members

Longitudinal members are to be arranged in such a way that continuity of strength is maintained.

Longitudinal members contributing to the hull girder longitudinal strength are to extend continuously as far as practicable towards the ends of the ship.

In particular, the structural continuity in way of longitudinal bulkheads within the cargo hold region, is to be maintained outside the cargo hold region. Large transition brackets (e.g. scarfing brackets) fitted in line with the longitudinal bulkhead are a possible means to achieve such structural continuity.

2.1.3 Primary supporting members

Primary supporting members are to be arranged in such a way that continuity of strength is maintained.

Abrupt changes of web height or cross section are to be avoided.

2.1.4 Stiffeners

Stiffeners are to be arranged in such a way that continuity of strength is maintained.

Stiffeners contributing to the hull girder longitudinal strength are to be continuous when crossing primary supporting members within the 0.4 *L* amidships and as far as practicable outside 0.4 *L* amidships.

Where stiffeners are terminated in way of large openings, foundations and partial girders, compensation is to be arranged to provide structural continuity in way of the end connection.

2.1.5 Plating

Where plates with different thicknesses are joined, the change in the as-built plate thickness is not to exceed 50% of larger plate thickness in the load carrying direction. This also applies to the strengthening by local inserts, e.g. insert plates in double bottom girders, floors and inner bottom.

2.1.6 Weld joints

Weld joints are to be avoided in areas with high stress concentration.

2.2 Local reinforcements

2.2.1 Reinforcements at knuckles

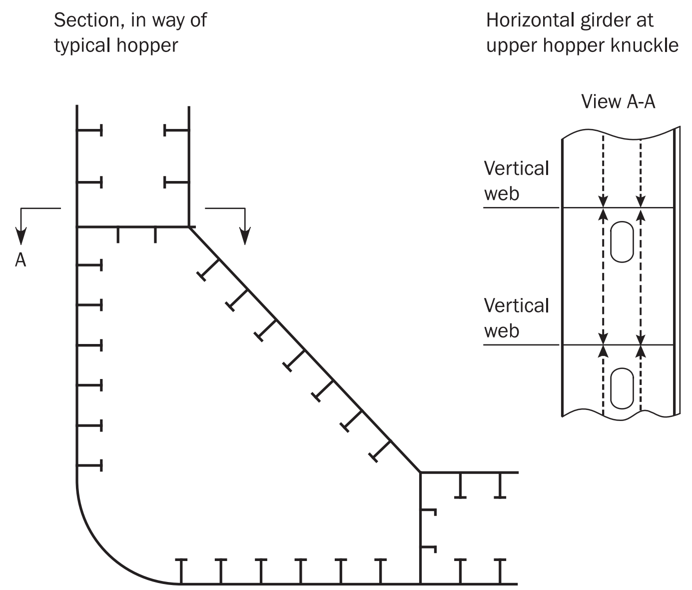
a) Knuckles are in general to be stiffened to achieve out-of-plane stiffness by fitting ordinary stiffeners or equivalent means in line with the knuckle.

b) Whenever a knuckle in a main member (shell, longitudinal bulkhead etc) is arranged, stiffening in the form of webs, brackets or profiles is to be connected to the members to which they are to transfer the load (in shear). See example of reinforcement at upper hopper knuckle in Figure 1.

c) For longitudinal shallow knuckles, closely spaced carlings are to be fitted across the knuckle, between longitudinal members above and below the knuckle. Carlings or other types of reinforcement need not be fitted in way of shallow knuckles that are not subject to high lateral loads and/or high in-plane loads across the knuckle, such as deck camber knuckles.

d) Generally, the distance between the knuckle and the support stiffening in line with the knuckle is not to be greater than 50 mm. Otherwise, fatigue analysis according to Ch 9 is to be submitted by the designer.

Figure 1 : Example of reinforcement at knuckles



2.2.2 Reinforcement in way of attachments for permanent means of access

Local reinforcement, considering location and strength, is to be provided in way of attachments to the hull structure for permanent means of access.

2.2.3 Reinforcement of deck structure in way of concentrated loads

The deck structure is to be reinforced in way of concentrated loads, such as anchor windlass, deck machinery, cranes, masts and derrick posts.

2.2.4 Reinforcement by insert plates

Insert plates are to be made of materials with, at least, the same specified minimum yield stress and the same grade as the plates to which they are welded. See also [2.1.5].

2.3 Connection of longitudinal members not contributing to the hull girder longitudinal strength

2.3.1

Where the hull girder stress at the strength deck or at the bottom as defined in Ch 5, Sec 1, [2.2.2] is higher than the permissible stress as defined in Ch 5, Sec 1, [2.2.1] for normal strength steel, longitudinal members not contributing to the hull girder longitudinal strength and welded to the strength deck or bottom plating and bilge strake, such as longitudinal hatch coamings, gutter bars, strengthening of deck openings, bilge keel, are to be made of steel with the same specified minimum yield stress as the strength deck or bottom structure steel.

2.3.2

The requirement in [2.3.1] is also applicable to non-continuous longitudinal stiffeners welded on the web of a primary structural member contributing to the hull girder longitudinal strength such as hatch coamings, stringers and girders or on the inner bottom when the hull girder stress on those members is higher than the permissible stress as defined in Ch 5, Sec 1, [2.2.1] for normal strength steel.

3 STIFFENERS

3.1 General

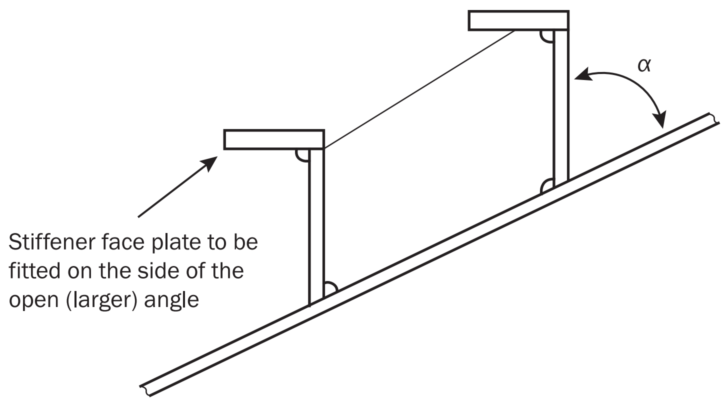
3.1.1

All types of stiffeners (excluding web stiffeners) are to be connected at their ends. However, in special cases such as isolated areas of the ship where end connections cannot be applied, sniped ends may be permitted. Requirements for the various types of connections (bracketed, bracketless or sniped ends) are given in [3.2] to [3.4].

3.1.2

Where the angle between the web plate of the stiffener and the attached plating is less than 50 deg as shown on Figure 2, a tripping bracket is to be fitted. If the angle between the web plate of an unsymmetrical stiffener and the attached plating is less than 50 deg, the face plate of the stiffener is to be fitted on the side of open angle.

Figure 2 : Stiffener on attached plating with an angle less than 50 deg



3.2 Bracketed end connections of non-continuous stiffeners

3.2.1

Where continuity of strength of longitudinal members is provided by brackets, the alignment of the brackets on each side of the primary supporting member is to be ensured, and the scantlings of the brackets are to be such that the combined stiffener/bracket section modulus and effective cross sectional area are not less than those of the member.

3.2.2

At bracketed end connections, continuity of strength is to be maintained at the stiffener connection to the bracket and at the connection of the bracket to the supporting member.

3.2.3

The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection, is the section modulus to be less than that required for the stiffener.

3.2.4 Net web thickness

The net bracket web thickness, t_b, in mm, is to comply with the following:

$$t_b \geq (2 + f_{bkt}\sqrt{Z})\sqrt{\frac{R_{eH-stf}}{R_{eH-bkt}}}$$ and need not be greater than 13.5 mm.

where:

f_{bkt} : Coefficient taken as:

f_{bkt} = 0.2 for brackets with flange or edge stiffener.

f_{bkt} = 0.3 for brackets without flange or edge stiffener.

Z : Net required section modulus, of the stiffener, in cm^3. In the case of two stiffeners connected, Z is the smallest net required section modulus of the two connected stiffeners.

$R_{eH\text{-}stf}$: Specified minimum yield stress of the stiffener material, in N/mm^2.

$R_{eH\text{-}bkt}$: Specified minimum yield stress of the bracket material, in N/mm^2.

3.2.5 Brackets at the ends of non-continuous stiffeners

Brackets are to be fitted at the ends of non-continuous stiffeners, with arm lengths, ℓ_{bkt}, in mm, taken as:

$$\ell_{bkt} = c_{bkt}\sqrt{\frac{Z}{t_b}}$$

ℓ_{bkt} is not to be taken less than:

- ℓ_{bkt} = 1.8 h_{stf} for connections where the end of the stiffener web is supported and the bracket is welded in line with the stiffener web or with offset necessary to enable welding, see item (c) in Figure 3.
- ℓ_{bkt} = 2.0 h_{stf} for other cases, see items (a), (b) and (d) in Figure 3.

where:

c_{bkt} : Coefficient taken as:

c_{bkt} = 65 for brackets with flange or edge stiffener.

c_{bkt} = 70 for brackets without flange or edge stiffener.

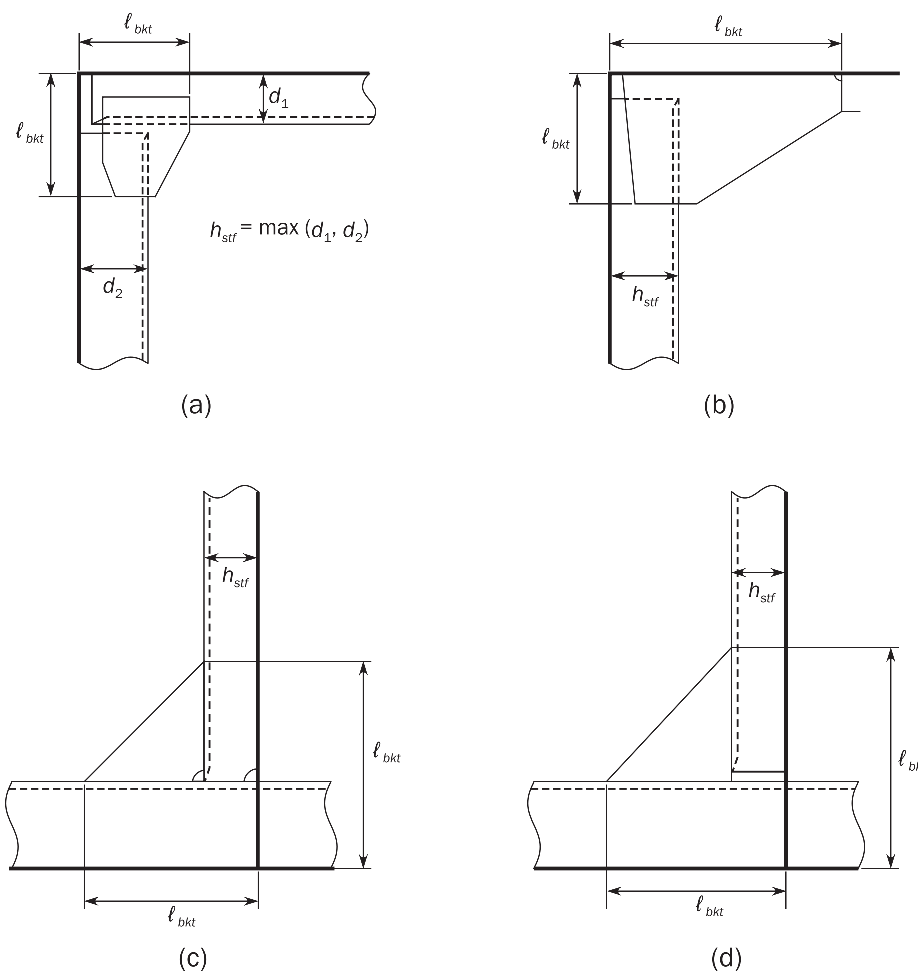
Z : Net required section modulus, for the stiffener, in cm^3, as defined in [3.2.4].

t_b : Minimum net bracket thickness, in mm, as defined in [3.2.4].

For connections similar to item (b) in Figure 3, but not lapped, the bracket arm length is to comply with $\ell_{bkt} \geq h_{stf}$.

For connections similar to items (c) and (d) in Figure 3 where the smaller stiffener is connected to a primary supporting member or bulkhead, the bracket arm length is not to be less than h_{stf}.

Figure 3 : Bracket arm length of non-continuous stiffeners



3.2.6 Brackets with different arm lengths

The lengths of the arms, measured from the plating to the toe of the bracket, are to be such that the sum of them is greater than 2 ℓ_{bkt} and each arm not to be less than 0.8 ℓ_{bkt}, where ℓ_{bkt} is as defined in [3.2.5].

3.2.7 Edge stiffening of bracket

Where an edge stiffener is required, the web height of the edge stiffener, h_w, in mm, is not to be less than:

$$h_w = 45\left(1 + \frac{Z}{2000}\right) \text{ but not less than 50 mm.}$$

where:

Z : Net section modulus, of the stiffener, in cm^3, as defined in [3.2.4].

3.3 Bracketless connections

3.3.1

The design of bracketless connections is to be such as to provide adequate resistance to rotation and displacement of the connection.

3.4 Sniped ends

3.4.1

Sniped ends may be used where dynamic loads are small, provided the net thickness of plating supported by the stiffener, t_p, is not less than:

$$t_p = c_1 \sqrt{\left(1000\ell - \frac{s}{2}\right)\frac{sPk}{10^6}}$$

where:

P : Design pressure for the stiffener for the design load set being considered, in kN/m^2.

c_1 : Coefficient for the design load set being considered, to be taken as:

$c_1 = 1.2$ for acceptance criteria set AC-S.

$c_1 = 1.1$ for acceptance criteria set AC-SD.

Sniped stiffeners are not to be used on structures in the vicinity of engines or generators or propeller impulse zone nor on the shell envelope.

3.4.2

Bracket toes and sniped stiffeners ends are to be terminated close to the adjacent member. The distance is not to exceed 40 mm unless the bracket or member is supported by another member on the opposite side of the plating. Tapering of the sniped end is not to be more than 30 deg. The depth of toe or sniped end is, generally, not to exceed the thickness of the bracket toe or sniped end member, but need not be less than 15 mm.

4 PRIMARY SUPPORTING MEMBERS (PSM)

4.1 General

4.1.1

Primary supporting members web stiffeners, tripping brackets and end brackets are to comply with [4.2] to [4.4]. Where the structural arrangement is such that these requirements cannot be complied with, adequate alternative arrangement has to be demonstrated by the designer.

4.2 Web stiffening arrangement

4.2.1

Web stiffeners arranged on primary supporting members are to comply with the requirements to scantlings of such stiffeners are given in Ch 8, Sec 2, [4.2].

4.3 Tripping bracket arrangement

4.3.1

Tripping brackets (see Figure 4) are generally to be fitted:

- At positions along the member span such that it satisfies the criteria of Ch 8, Sec 2, [5.1] for tripping bracket spacing and flange slenderness.
- At the toe of end brackets.
- At ends of continuous curved face plates.
- In way of concentrated loads.
- Near the change of section.

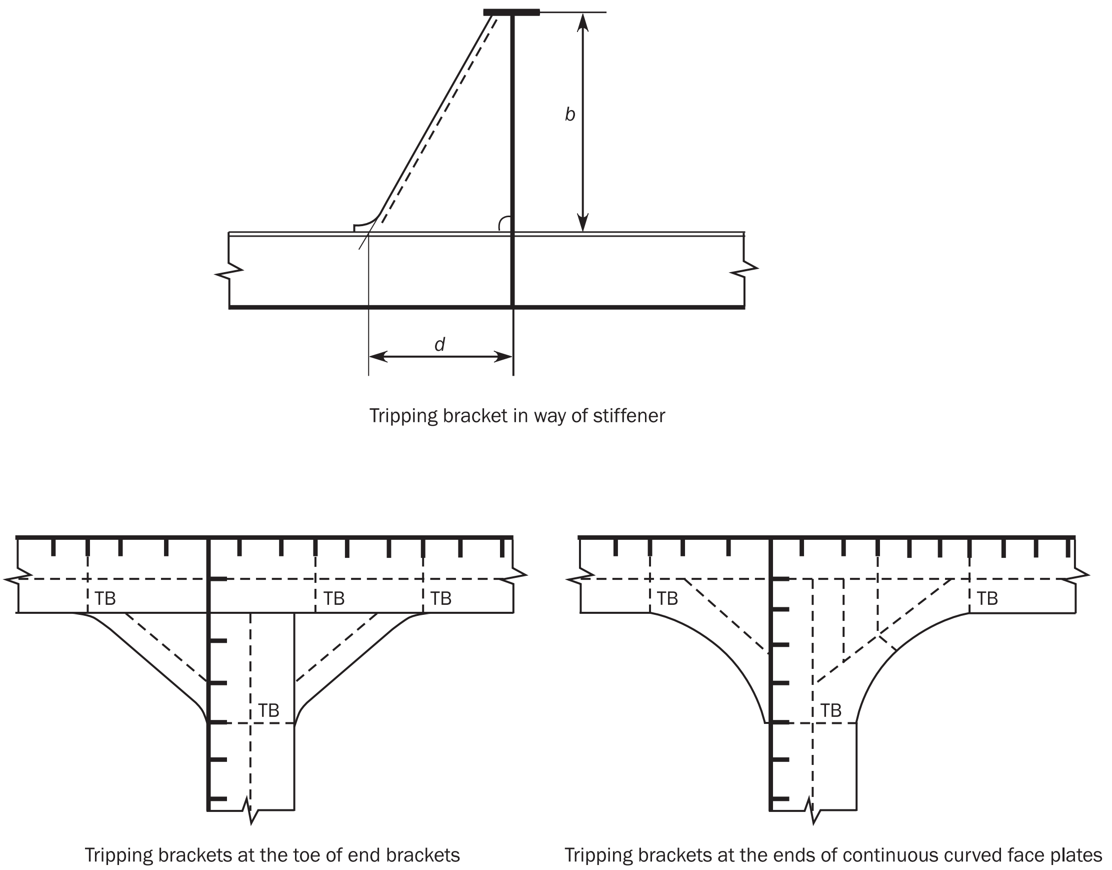
4.3.2

Where the width of the symmetrical face plate is greater than 400 mm, backing brackets are to be fitted in way of the tripping brackets.

4.3.3

Where the face plate of the primary supporting member exceeds 180 mm on either side of the web, a tripping bracket is to support the face plate.

Figure 4 : Primary supporting member: Tripping bracket arrangement



4.3.4 Arm length

The arm length of tripping brackets is not to be less than the greater of the following values, in m:

$$d = 0.38\, b$$

$$d = 0.85 b \sqrt{\frac{s_t}{t}}$$

where:

b : Height, in m, of tripping brackets, shown in Figure 4.

s_t : Spacing, in m, of tripping brackets.

t : Net thickness, in mm, of tripping brackets.

4.4 End connections

4.4.1 General

Brackets or equivalent structure are to be provided at ends of primary supporting members.

End brackets are generally to be soft-toed.

Bracketless connections may be applied provided that there is adequate support of adjoining face plates.

4.4.2 Scantling of end brackets

In general, the arm lengths of brackets connecting PSMs, as shown in Figure 5 are not to be less than the web depth of the member, and need not be taken greater than 1.5 times the web depth.

The thickness of the bracket is, in general, not to be less than that of the PSM web plate.

Scantlings of the end brackets are to be such that the section modulus of the PSM with end bracket, excluding face plate where it is sniped, is not to be less than that of the primary supporting member at mid-span.

The net cross sectional area, A_f, in cm^2, of face plates of brackets is not to be less than:

$$A_f = \ell_b\, t_b$$

where:

ℓ_b : Length of bracket edge, in m, see Figure 5. For brackets that are curved, the length of the bracket edge may be taken as the length of the tangent at the midpoint of the edge.

t_b : Minimum net bracket thickness, in mm, as defined in [3.2.4].

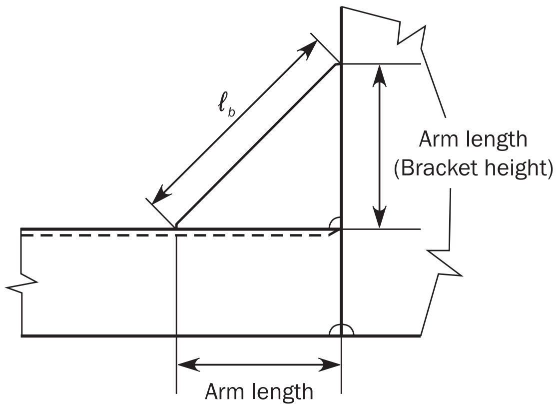
Moreover, the net thickness of the face plate is to be not less than that of the bracket web.

4.4.3 Arrangement of end brackets

Where the length of free edge of bracket, ℓ_b, is greater than 1.5 m, the web of the bracket is to be stiffened as follows:

- The net sectional area, in cm^2, of web stiffeners is to be not less than 16.5ℓ, where ℓ is the span, in m, of the stiffener.
- Tripping flat bars are to be fitted. Where the width of the symmetrical face plate is greater than 400 mm, additional backing brackets are to be fitted.

Figure 5 : Dimension of brackets



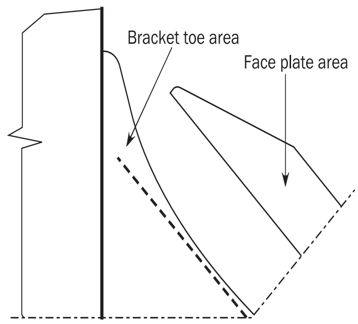
For a ring system where the end bracket is integral with the webs of the members and the face plate is carried continuously along the edges of the members and the bracket, the full area of the largest face plate is to be maintained close to the mid-point of the bracket and gradually tapered to the smaller face plates. Butts in face plates are to be kept well clear of the bracket toes.

Where a wide face plate abuts a narrower one, the taper is not to be greater than 1 to 4.

The toes of brackets are not to land on unstiffened plating. The toe height is not to be greater than the thickness of the bracket toe, but need not be less than 15 mm. In general, the end brackets of primary supporting members are to be soft-toed. Where primary supporting members are constructed of higher strength steel, particular attention is to be paid to the design of the end bracket toes in order to minimise stress concentrations.

Where a face plate is welded onto the edge or welded adjacent to the edge of the end bracket (see Figure 6), the face plate is to be sniped and tapered at an angle not greater than 30°.

Figure 6 : Bracket face plate adjacent to the edge



The details shown in this figure are only used to illustrate items described in the text and are not intended to represent design guidance or recommendations.

5 INTERSECTION OF STIFFENERS AND PRIMARY SUPPORTING MEMBERS

5.1 Cut-outs

5.1.1

Cut-outs for the passage of stiffeners through the web of primary supporting members, and the related collaring arrangements, are to be designed to minimise stress concentrations around the perimeter of the opening and on the attached web stiffeners.

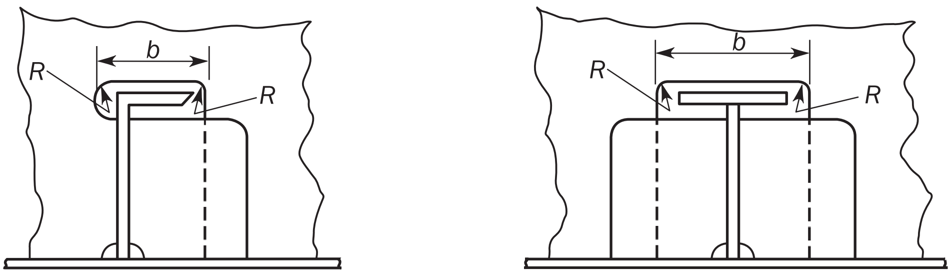
5.1.2

The total depth of cut-outs without collar plate is to be not greater than 50% of the depth of the primary supporting member.

5.1.3

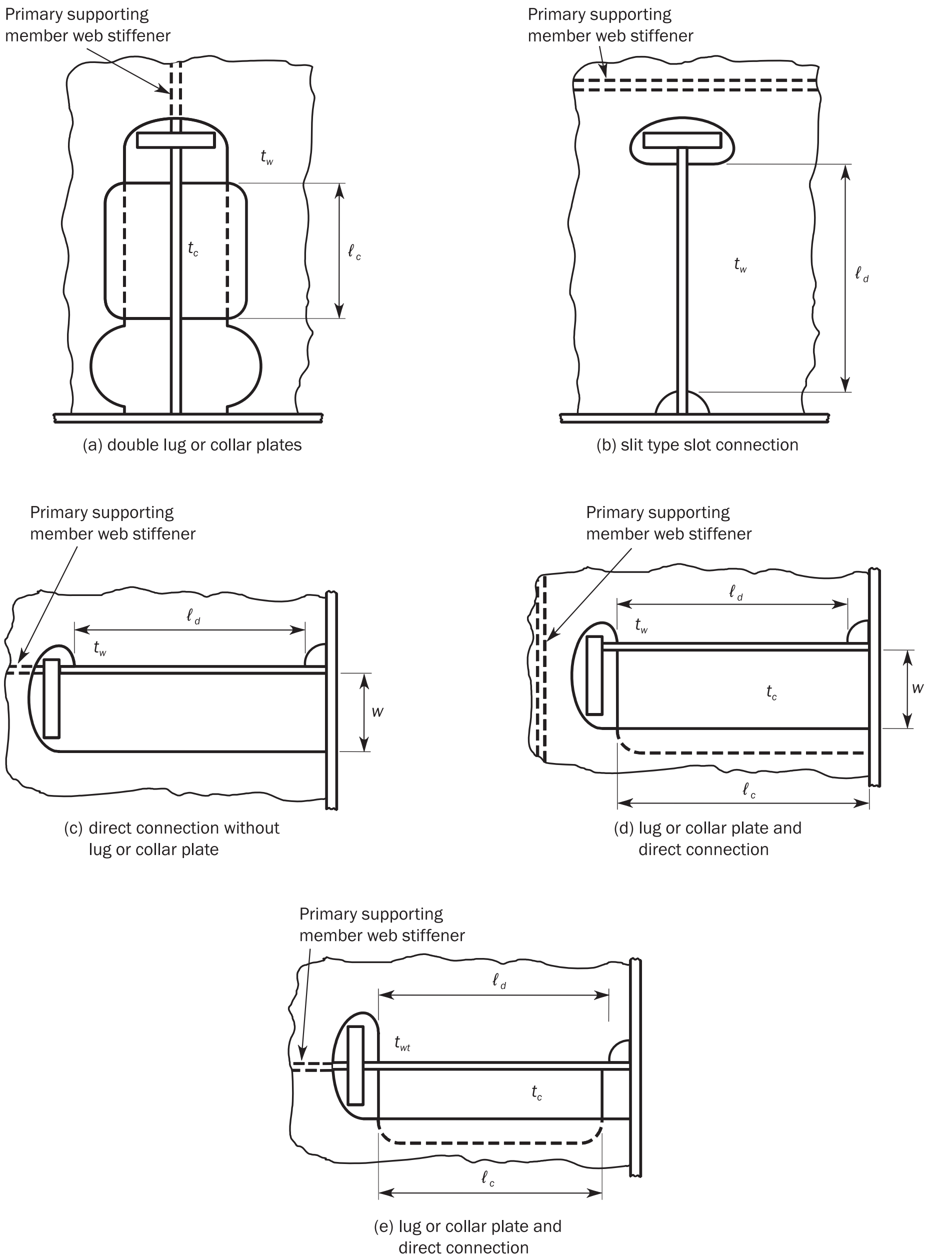
Cut-outs in way of cross tie ends and floors under bulkhead stools or in high stress areas are to be fitted with full collar plates, see Figure 7.

Figure 7 : Full collar plates



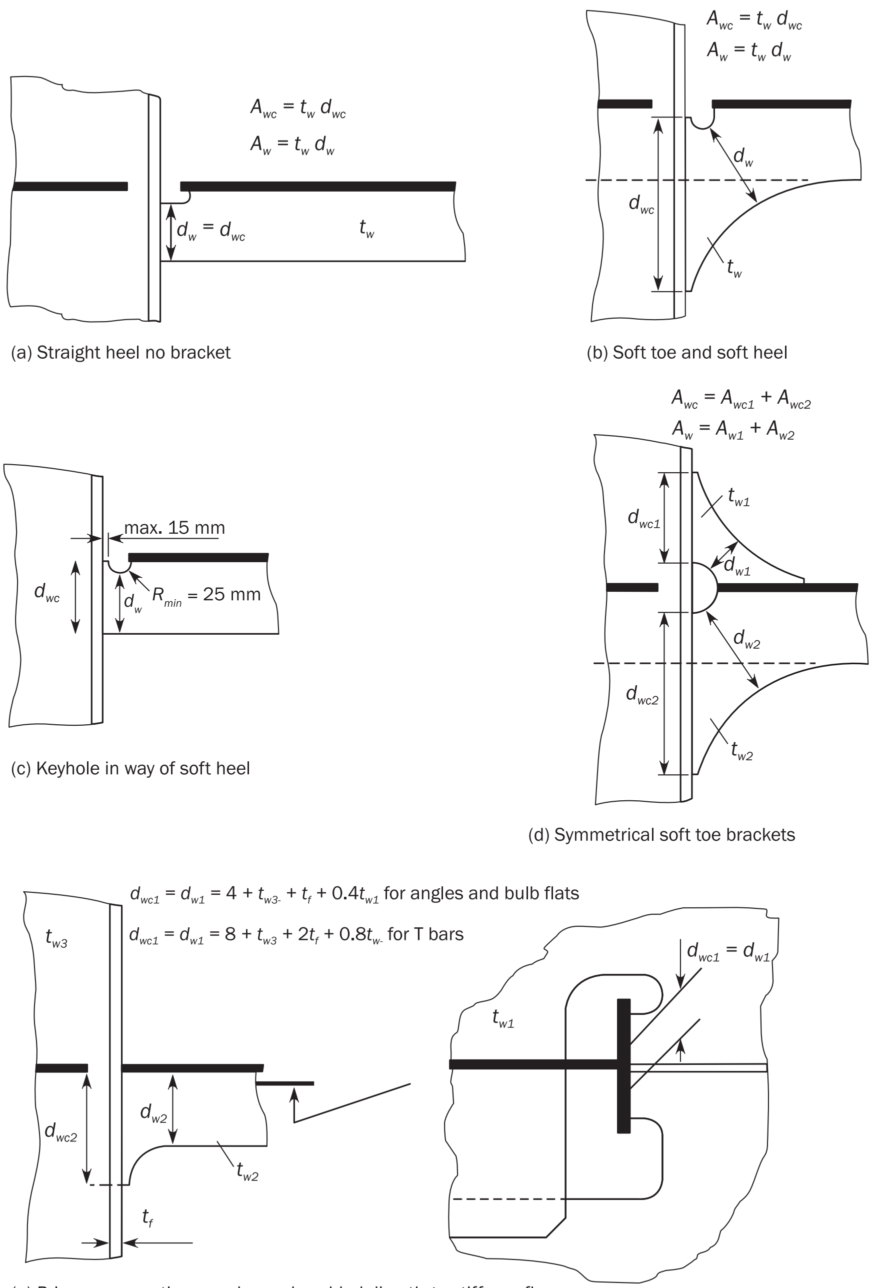
$R \geq 0.2b$ but not less than 25 mm.

Figure 8 : Symmetric and asymmetric cut-outs



The details shown in this figure are only used to illustrate symbols and definitions and are not intended to represent design guidance.

Figure 9 : Primary supporting member web stiffener details



(a) Straight heel no bracket

(b) Soft toe and soft heel

(c) Keyhole in way of soft heel

(d) Symmetrical soft toe brackets

(e) Primary supporting member web welded directly to stiffener flange

t_{ws}, t_{ws1}, t_{ws2} : Net thickness of the primary supporting member web stiffener/backing bracket, in mm.
d_w, d_{w1}, d_{w2} : Minimum depth of the primary supporting member web stiffener/backing bracket, in mm.
d_{wc}, d_{wc1}, d_{wc2} : Length of connection between the primary supporting member web stiffener/backing bracket and the stiffener, in mm.

5.1.4

Lug type collar plates are to be fitted in cut-outs where required for compliance with the requirements of [5.2], and in areas of high stress concentrations, e.g. in way of primary supporting member toes. See Figure 8 for typical lug arrangements.

5.1.5

At connection to shell envelope longitudinals below the scantling draught, T_{sc} and at connection to inner bottom longitudinals, a soft heel is to be provided in way of the heel of the primary supporting member web stiffeners when the calculated direct stress, σ_w, in the primary supporting member web stiffener according to [5.2] exceeds 80% of the permissible values. The soft heel is to have a keyhole, similar to that shown in item (c) in Figure 9.

A soft heel is not required at the intersection with watertight bulkheads and primary supporting members, where a back bracket is fitted or where the primary supporting member web is welded to the stiffener face plate.

5.1.6

In general, cut-outs are to have rounded corners and the corner radii, R, are to be as large as practicable, with a minimum of 20% of the breadth, b, of the cut-out or 25 mm, whichever is greater. The corner radii, R, does not need to be greater than 50 mm, see Figure 7. Consideration is to be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration.

Note 1: Except where specific dimensions are noted for the details of the keyhole in way of the soft heel, the details shown in this figure are only used to illustrate symbols and definitions and are not intended to represent design guidance or recommendations.

5.2 Connection of stiffeners to PSM

5.2.1 General

For connection of stiffeners to PSM in case of lateral pressure other than bottom slamming and bow impact loads, [5.2.2] and [5.2.3] are to be applied. In case of bottom slamming or bow impact loads, [5.2.4] is to be applied.

The cross sectional areas of the connections are to be determined from the proportion of load transmitted through each component in association with its appropriate permissible stress.

5.2.2

The load, W_1, in kN, transmitted through the shear connection is to be taken as follows.

- If the web stiffener is connected to the intersecting stiffener:

$$W_1 = W\left(\alpha_a + \frac{A_1}{4f_c\,A_w + A_1}\right)$$

- If the web stiffener is not connected to the intersecting stiffener:

$$W_1 = W$$

where:

W : Total load, in kN, transmitted through the stiffener connection to the PSM taken equal to:

$$W = \frac{P_1 s_1\left(S_1 - \frac{s_1}{2000}\right) + P_2 s_2\left(S_2 - \frac{s_2}{2000}\right)}{2}\,10^{-3}$$

P_1, P_2 : Design pressure applied on the stiffener for the design load set being considered, in kN/m^2, on each side of the considered connection.

S_1, S_2 : Spacing between the considered and the adjacent PSM on each side of the considered connection, in m.

s_1, s_2 : Spacing of the stiffener, in mm, on each side of the considered connection.

α_a : Panel aspect ratio, not to be taken greater than 0.25.

$$\alpha_a = \frac{s}{1000\ S}$$

$$S = \frac{S_1 + S_2}{2}$$

$$s = \frac{s_1 + s_2}{2}$$

A_1 : Effective net shear area, in cm^2, of the connection, to be taken equal to:

$A_1 = A_{1d} + A_{1c}$

In case of a slit type slot connections area, A_1, is given by:

$A_1 = 2\ A_{1d}$

In case of a typical double lug or collar plate connection area, A_1, is given by:

$A_1 = 2\ A_{1c}$

A_{1d} : Net shear connection area, in cm^2, excluding lug or collar plate, as given by:

$A_{1d} = \ell_d\ t_w\ 10^{-2}$

ℓ_d : Length of direct connection between stiffener and PSM web, in mm.

t_w : Net web thickness of the primary supporting member, in mm.

A_{1c} : Net shear connection area, in cm^2, with lug or collar plate, given by:

$A_{1c} = f_1\ \ell_c\ t_c\ 10^{-2}$

ℓ_c : Length of connection between lug or collar plate and PSM, in mm.

t_c : Net thickness of lug or collar plate, not to be taken greater than the net thickness of the adjacent PSM web, in mm.

f_1 : Shear stiffness coefficient, taken as:

$f_1 = 1.0$, for stiffeners of symmetrical cross section.

$f_1 = 140/w$, not to be taken greater than 1.0, for stiffeners of asymmetrical cross section.

w : Width of the cut-out for an asymmetrical stiffener, measured from the cut-out side of the stiffener web, in mm, as indicated in Figure 8.

A_w : Effective net cross sectional area, in cm^2, of the PSM web stiffener in way of the connection including backing bracket where fitted, as shown in Figure 9. If the PSM web stiffener incorporates a soft heel ending or soft heel and soft toe ending, A_w is to be measured at the throat of the connection, as shown in Figure 9.

f_c : Collar load factor taken equal to:

For intersecting stiffeners of symmetrical cross section:

$f_c = 1.85$ for $A_w \le 14$
$f_c = 1.85 - 0.0441(A_w - 14)$ for $14 < A_w \le 31$
$f_c = 1.1 - 0.013(A_w - 31)$ for $31 < A_w \le 58$
$f_c = 0.75$ for $A_w > 58$

For intersecting stiffeners of asymmetrical cross section:

$$f_c = 0.68 + 0.0172\frac{\ell_s}{A_w}$$

ℓ_s : Connection length equal to:

For a single lug or collar plate connection to the PSM:

$\ell_s = \ell_c$

For a single sided direct connection to the PSM:

$\ell_s = \ell_d$

In the case of a lug or collar plus a direct connection:

$\ell_s = 0.5\ (\ell_c + \ell_d)$

5.2.3

The load, W_2, in kN, transmitted through the PSM web stiffener is to be taken as:

- If the web stiffener is connected to the intersecting stiffener:

$$W_2 = W\left(1 - \alpha_a - \frac{A_1}{4 f_c A_w + A_1}\right)$$

- If the web stiffener is not connected to the intersecting stiffener:

$W_2 = 0$

The values of A_w, A_{wc} and A_1 are to be such that the calculated stresses satisfy the following criteria:

- For the connection to the PSM web stiffener not in way of the weld: $\sigma_w \le \sigma_{perm}$
- For the connection to the PSM web stiffener in way of the weld: $\sigma_{wc} \le \sigma_{perm}$
- For the shear connection to the PSM web: $\tau_w \le \tau_{perm}$

where:

W : Load, in kN, as defined in [5.2.2].

f_c : Collar load factor as defined in [5.2.2].

α_a : Panel aspect ratio, as defined in [5.2.2].

A_1 : Effective net shear area, in cm^2, as defined in [5.2.2].

A_w : Effective net cross sectional area, in cm^2, as defined in [5.2.2].

σ_w : Direct stress, in N/mm^2, in the PSM web stiffener at the minimum bracket area away from the weld connection:

$$\sigma_w = \frac{10 W_2}{A_w}$$

σ_{wc} : Direct stress, in N/mm^2, in the PSM web stiffener in way of the weld connection:

$$\sigma_{wc} = \frac{10\ W_2}{A_{wc}}$$

τ_w : Shear stress, in N/mm^2, in the shear connection to the PSM web:

$$\tau_{wc} = \frac{10\ W_1}{A_1}$$

A_{wc} : Effective net area, in cm^2, of the PSM web stiffener in way of the weld as shown in Figure 9.

σ_{perm} : Permissible direct stress given in Table 1 for AC-S and AC-SD, in N/mm^2.

τ_{perm} : Permissible shear stress given in Table 1 for AC-S and AC-SD, in N/mm^2.

5.2.4 Bottom slamming and bow impact loads

For bottom slamming or bow impact loads, the load W, in kN, transmitted through the PSM web stiffener is to comply with the following criteria instead of those defined in [5.2.2] and [5.2.3]:

$$0.9 W \le \frac{(A_1\ \tau_{perm} + A_w\ \sigma_{perm})}{10}$$

where:

W : Load, in kN, as defined in [5.2.2].

A_1 : Effective net shear area, in cm^2, as defined in [5.2.2].

A_w : Effective net cross sectional area, in cm^2, as defined in [5.2.2].

σ_{perm} : Permissible direct stress given in Table 1 for AC-I, in N/mm^2.

τ_{perm} : Permissible shear stress given in Table 1 for AC-I, in N/mm^2.

5.2.5

Where a backing bracket is fitted in addition to the PSM web stiffener, it is to be aligned with the web stiffener. The arm length of the backing bracket is not to be less than the depth of the web stiffener. The net cross sectional area through the throat of the bracket is to be included in the calculation of A_w as shown in Figure 9.

5.2.6

Lapped connections of PSM web stiffeners or tripping brackets to stiffeners are not permitted in the cargo hold region.

5.2.7

Where built-up stiffeners have their face plate welded to the side of the web, a symmetrical arrangement of connection to the PSM is to be fitted. This may be achieved by fitting backing brackets on the opposite side of the PSM or bulkhead. In way of the cargo hold region, the PSM web stiffener and backing brackets are to be butt welded to the intersecting stiffener web.

5.2.8

Where the web stiffener of the PSM is parallel to the web of the intersecting stiffener, but not connected to it, the offset PSM web stiffener is to be located in close proximity to the slot edge as shown in Figure 10. The ends of the offset web stiffeners are to be suitably tapered and softened.

Locations where the web stiffener of the PSM are not connected to the intersecting stiffeners as well as the detail arrangements are to be specially considered on the basis of their ability to transmit load with equivalent effectiveness to that of [5.2.2] through [5.2.7]. Details of calculations made and/or testing procedures and results are to be submitted.

Table 1 : Permissible stresses for connection between stiffeners and PSMs

Item	Direct stress, σ_{perm}, in N/mm^2			Shear stress, τ_{perm}, in N/mm^2		
	Acceptance criteria set			Acceptance criteria set		
	AC-S	AC-SD	AC-I	AC-S	AC-SD	AC-I
PSM web stiffener	$0.83R_{eH}$ (2)	R_{eH}	R_{eH}	-	-	-
PSM web stiffener to intersecting stiffener in way of weld connection:						
• Double continuous fillet	$0.58R_{eH}$ (2)	$0.70R_{eH}$ (2)	R_{eH}	-	-	-
• Partial penetration weld	$0.83R_{eH}$ (1) (2)	R_{eH} (1)	R_{eH}	-	-	-
PSM stiffener to intersecting stiffener in way of lapped welding	$0.50R_{eH}$	$0.60R_{eH}$	R_{eH}	-	-	-
Shear connection including lugs or collar plates:						
• Single sided connection	-	-	-	$0.71\ \tau_{eH}$	$0.85\ \tau_{eH}$	τ_{eH}
• Double sided connection	-	-	-	$0.83\ \tau_{eH}$	τ_{eH}	τ_{eH}

(1) The root face is not to be greater than one third of the gross thickness of the PSM stiffener.
(2) Permissible stresses may be increased by 5 percent where a soft heel is provided in way of the heel of the PSM web stiffener.

5.2.9

The size of the fillet welds is to be calculated according to Ch 12, Sec 3, [2.5] based on the weld factors given in Table 2. For the welding in way of the shear connection the size is not to be less than that required for the PSM web plate for the location under consideration.

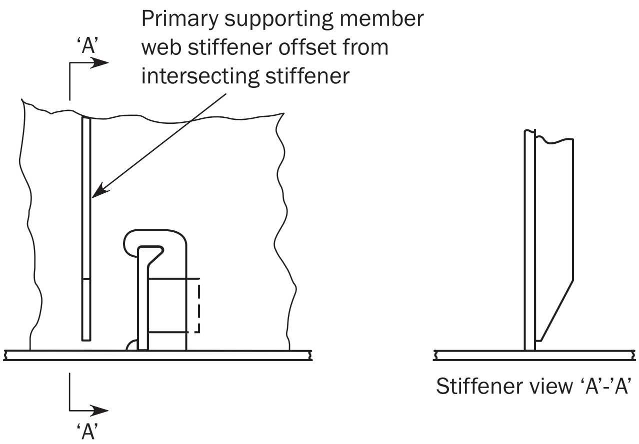
Table 2 : Weld factors for connection between stiffeners and PSMs

Item	Acceptance criteria	Weld factor
PSM stiffener to intersecting stiffener	AC-S AC-SD	$0.6\ \sigma_{wc}/\sigma_{perm}$ not to be less than 0.38
Shear connection inclusive of lug or collar plate	AC-S AC-SD	0.38
Shear connection inclusive of lug or collar plate, where the web stiffener of the PSM is not connected to the intersection stiffener	AC-S AC-SD	$0.6\ \tau_w/\tau_{perm}$ not to be less than 0.44
PSM stiffener to intersecting stiffener Shear connection inclusive of lug or collar plate	AC-I	$0.6\ \dfrac{9W}{A_1\ \tau_{perm} + A_w\ \sigma_{perm}}$

Note 1:

- τ_w : Shear stress, in N/mm², as defined in [5.2.3].
- σ_{wc} : Stress, in N/mm², as defined in [5.2.3].
- τ_{perm} : Permissible shear stress, in N/mm², see Table 1.
- σ_{perm} : Permissible direct stress, in N/mm², see Table 1.
- W : Load, in kN, as defined in [5.2.2].
- A_1 : Effective net shear area, in cm², as defined in [5.2.2].
- A_w : Effective net cross sectional area, in cm², as defined in [5.2.2].

Figure 10 : Offset PSM web stiffeners



6 OPENINGS

6.1 Openings and scallops in stiffeners

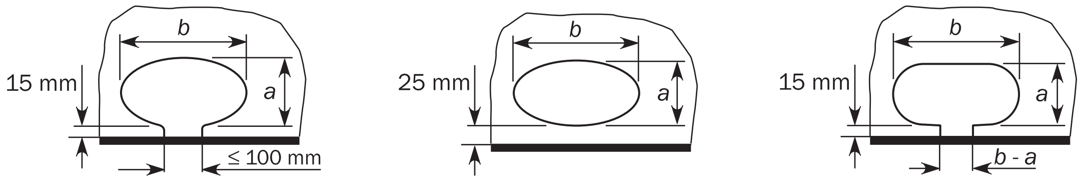
6.1.1

Figure 11 shows examples of air holes, drain holes and scallops. In general, the ratio of a/b, as defined in Figure 11, is to be between 0.5 and 1.0. In fatigue sensitive areas further consideration may be required with respect to the details and arrangements of openings and scallops.

6.1.2

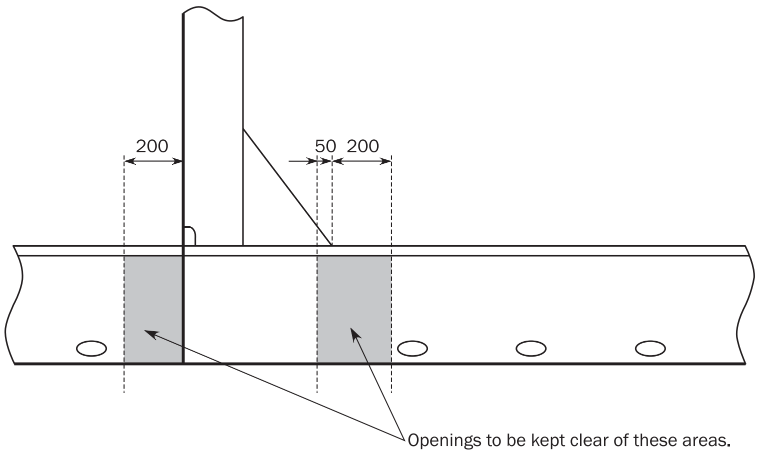
Openings and scallops are to be kept at least 200 mm clear of the toes of end brackets, end connections and other areas of high stress concentration, measured along the length of the stiffener toward the mid-span and 50 mm measured along the length in the opposite direction, see Figure 12. In areas where the shear stress is less than 60 percent of the permissible stress, alternative arrangements may be accepted.

Figure 11 : Examples of air holes, drain holes and scallops



The details shown in this figure are for guidance and illustration only.

Figure 12 : Location of air and drain holes



6.1.3

Closely spaced scallops or drain holes, i.e. where the distance between scallops/drain holes is less than twice the width *b* as shown in Figure 11, are not permitted in stiffeners contributing to the longitudinal strength. For other stiffeners, closely spaced scallops/drain holes are not permitted within 20% of the stiffener span measured from the end of the stiffener. Widely spaced air or drain holes may be permitted provided that they are of elliptical shape or equivalent to minimise stress concentration and are, in general, cut clear of the welds.

6.2 Openings in primary supporting members

6.2.1 General

Manholes, lightening holes and other similar openings are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are to be avoided in high stress areas unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

Examples of high stress areas include:

- Vertical or horizontal diaphragm plates in narrow cofferdams/double plate bulkheads within one-sixth of their length from either end.
- Floors or double bottom girders close to their span ends.
- Primary supporting member webs in way of end bracket toes.
- Above the heads and below the heels of pillars.

Where openings are arranged, the shape of openings is to be such that the stress concentration remains within acceptable limits.

Openings are to be well rounded with smooth edges.

6.2.2 Manholes and lightening holes

Web openings as indicated below do not require reinforcement

- In single skin sections, having depth not exceeding 25% of the web depth and located so that the edges are not less than 40% of the web depth from the faceplate.
- In double skin sections, having depth not exceeding 50% of the web depth and located so that the edges are well clear of cut outs for the passage of stiffeners.

The length of openings is not to be greater than:

- At the mid-span of primary supporting members: the distance between adjacent openings.
- At the ends of the span: 25% of the distance between adjacent openings.

For openings cut in single skin sections, the length of opening is not to be greater than the web depth or 60% of the stiffener spacing, whichever is greater.

The ends of the openings are to be equidistant from the cut outs for stiffeners.

Where lightening holes are cut in the brackets, the distance from the circumference of the hole to the free flange of brackets is not to be less than the diameter of the lightening hole.

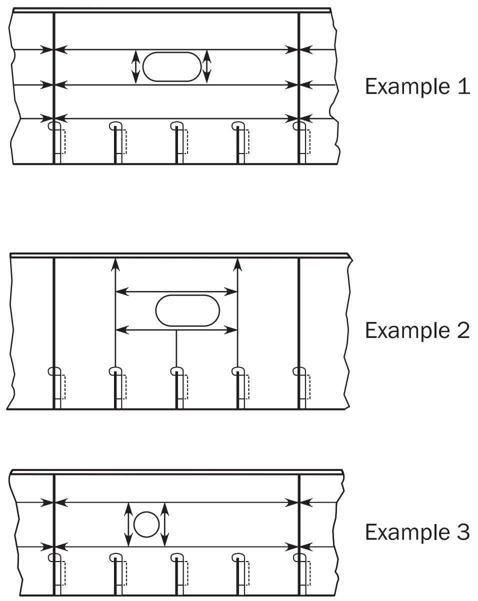
Openings not complying with this requirement are to be reinforced according to [6.2.3].

6.2.3 Reinforcements around openings

Manholes and lightening holes are to be stiffened according to this requirement, except where alternative arrangements are demonstrated as satisfactory, in accordance with the analysis methods described in Ch 7.

On members contributing to longitudinal strength, stiffeners are to be fitted along the free edges of the openings parallel to the vertical and horizontal axis of the opening. Stiffeners may be omitted in one direction if the shortest axis is less than 400 mm and in both directions if length of both axes is less than 300 mm. Edge reinforcement may be used as an alternative to stiffeners, see Figure 13.

Figure 13 : Web plate with openings



In the case of large openings in the web of PSMs (e.g. where a pipe tunnel is fitted in the double bottom), the secondary stresses in PSMs are to be considered for the reinforcement of these openings.

Where no FE analysis is performed, this may be carried out by assigning an equivalent net shear sectional area to the PSM obtained, in cm², according from the following formula:

$$A_{s-n50} = \frac{A_{1-n50}}{1 + \dfrac{32 l_{shr}^2 A_{1-n50}}{I_{1-n50}}} + \frac{A_{2-n50}}{1 + \dfrac{32 l_{shr}^2 A_{2-n50}}{I_{2-n50}}}$$

where:

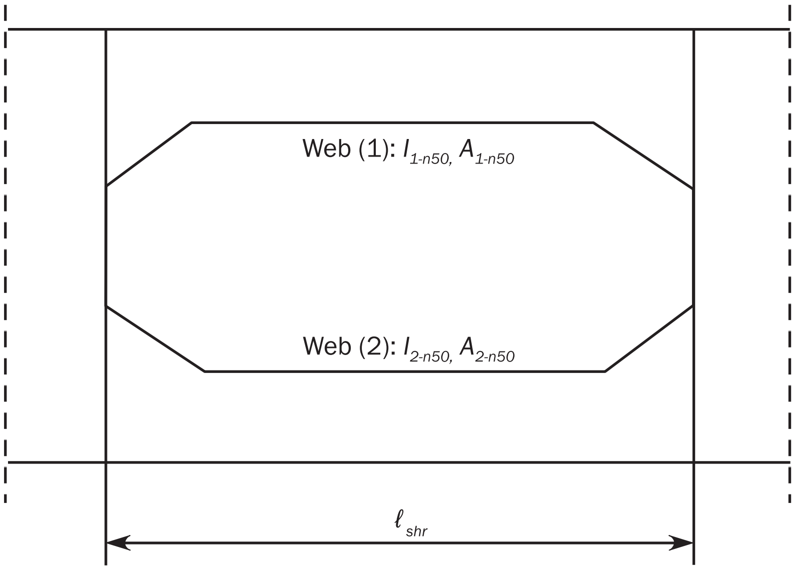
I_{1-n50}, I_{2-n50} : Net moments of inertia, in cm⁴, of deep webs (1) and (2), respectively, with attached plating around their neutral axes parallel to the plating.

A_{1-n50}, A_{2-n50} : Net shear sectional areas, in cm², of deep webs (1) and (2), respectively, taking account of the web height reduction by the depth of the cut out for the passage of the ordinary stiffeners, if any.

ℓ_{shr} : Shear span, in m, of deep webs (1) and (2) as defined in Ch 3, Sec 7, [1.1.2].

Deep web (1) and (2) are defined in Figure 14.

Figure 14 : Large openings in the web of primary supporting members



6.3 Openings in the strength deck

6.3.1 General

Openings in the strength deck are to be kept to a minimum and spaced as far as practicable from one another and from the ends of superstructures. Openings are to be located as far as practicable from high stress regions such as side shell platings, hatchway corners, or hatch side coamings.

6.3.2 Small opening location

Openings are generally to be located outside the limits as shown in Figure 15 in dashed area, defined by:

- The bent area of a rounded sheer strake, if any, or the side shell.
- $e = 0.25\ (B - b)$ from the edge of opening.
- $c = 0.07\ell + 0.1b$ or $0.25b$, whichever is greater.

where:

b : Width, in m, of the hatchway considered, measured in the transverse direction, see Figure 15.

ℓ : Width, in m, in way of the corner considered, of the cross deck strip between two consecutive hatchways, measured in the longitudinal direction, see Figure 15.

Transverse distance between the above limits and openings or between hatchways and openings as shown in Figure 15 is not to be less than:

- $g_2 = 2\, a_2$ for circular openings.
- $g_1 = a_1$ for elliptical openings.

Transverse distance between openings as shown in Figure 16 is not to be less than:

- $2\,(a_1 + a_2)$ for circular openings.
- $1.5\,(a_1 + a_2)$ for elliptical openings.

where:

a_1 : Transverse dimension of elliptical openings, or diameter of circular openings.

a_2 : Transverse dimension of elliptical openings, or diameter of circular openings.

a_3 : Longitudinal dimension of elliptical openings, or diameter of circular openings.

Longitudinal distance between openings is not to be less than:

- $(a_1 + a_3)$ for circular openings.
- $0.75\,(a_1 + a_3)$ for elliptical openings and for an elliptical opening in line with a circular one.

If the opening arrangements do not comply with these requirements, the hull girder longitudinal strength assessment is to be carried out by subtracting such opening areas, see Ch 5, Sec 1, [1.2.11].

Figure 15 : Position of openings in strength deck

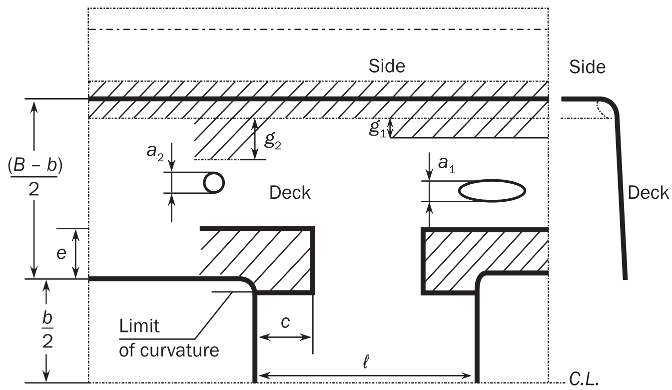
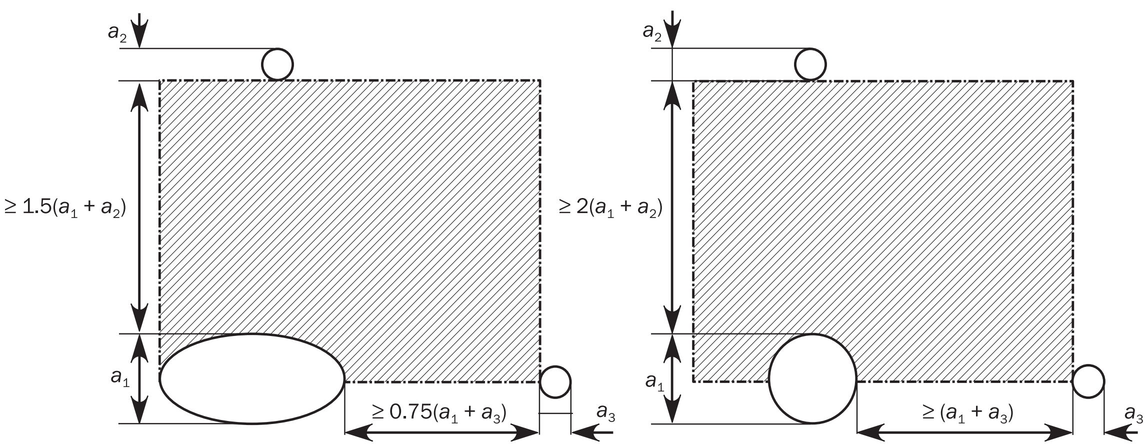


Figure 16 : Elliptical and circular openings in strength deck



7 DOUBLE BOTTOM STRUCTURE

7.1 General

7.1.1 Framing system

For ships greater than 120 m in length, the bottom shell, the inner bottom and the sloped bulkheads of hopper tanks, if any, are to be longitudinally framed within the cargo hold region. Where it is not practicable to apply the longitudinal framing system to fore and aft parts of the cargo hold region due to the hull form, transverse framing may be accepted on a case-by-case basis subject to appropriate brackets and other arrangements being incorporated to provide structural continuity in way of changes to the framing system.

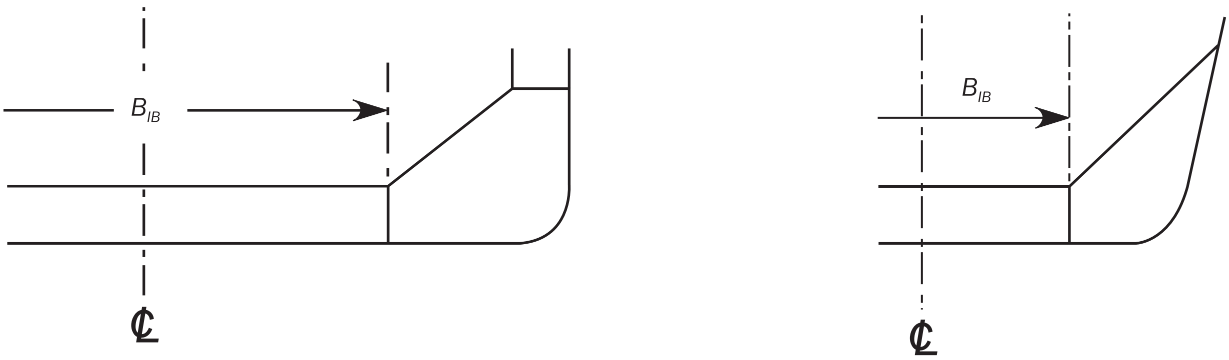
7.1.2 Variation in height of double bottom

Any variation in the height of the double bottom is generally to be made gradually and over an adequate length; the knuckles of inner bottom plating are to be located in way of plate floors. Where such arrangement is not possible, suitable longitudinal structures such as partial girders, longitudinal brackets, fitted across the knuckle are to be arranged.

7.1.3 Breadth of inner bottom

Breadth of inner bottom, in m, is to be measured at mid-length of the cargo hold as shown in Figure 17.

Figure 17 : Breadth of inner bottom



Ships with inclined slides

7.1.4 Drainage of tank top

For ships designed to carry solid cargoes, effective arrangements are to be provided for draining water from the tank top. Where wells are provided for the drainage, such wells are not to extend for more than one-half height of the double bottom.

7.1.5 Striking plate

Striking plates of adequate thickness or other equivalent arrangements are to be provided under sounding pipes to prevent the sounding rod from damaging the plating.

7.1.6 Duct keel

Where a duct keel is arranged, the centre girder may be replaced by two girders spaced, no more than 3 m apart. Otherwise, for a spacing wider than 3 m, the two girders are to be provided with support of adjacent structure and subject to the Society's approval.

The structures in way of the floors are to provide sufficient continuity of the latter.

7.2 Keel plate

7.2.1

Keel plating is to extend over the flat of bottom for the full length of the ship.

The width of the keel, in m, is not to be less than 0.8 + L/200, without being taken greater than 2.3 m.

7.3 Girders

7.3.1 Centre girder

When fitted, the centre girder is to extend within the cargo hold region and is to extend forward and aft as far as practicable. Structural continuity of the centre girder is to be maintained within the full length of the ship.

Where double bottom compartments are used for the carriage of fuel oil, fresh water or ballast water, the centre girder is to be watertight, except for the case such as narrow tanks at the end parts or when other watertight girders are provided within 0.25 B from the centreline.

7.3.2 Side girders

The side girders are to extend within the parallel part of the cargo hold region and are to extend forward and aft of the cargo hold region as far as practicable.

7.4 Floors

7.4.1 Web stiffeners

Floors are to be provided with web stiffeners in way of longitudinal ordinary stiffeners. Where the web stiffeners are not welded to the longitudinal stiffeners, design standard as given in Ch 9, Sec 6, [2] applies unless fatigue strength assessment for the cut out and connection of longitudinal stiffener is carried out.

7.5 Bilge keel

7.5.1 Material

The material of the bilge keel and ground bar is to be of the same yield stress as the material to which they are attached.

In addition, when the bilge keel extends over a length more than 0.15 L, the material of the bilge keel and ground bar is to be of the same grade as the material to which they are attached.

Figure 18 : Bilge keel construction

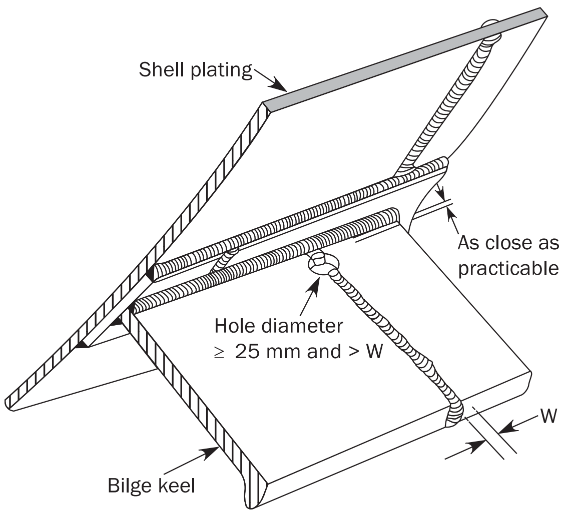


Figure 19 : Bilge keel end design

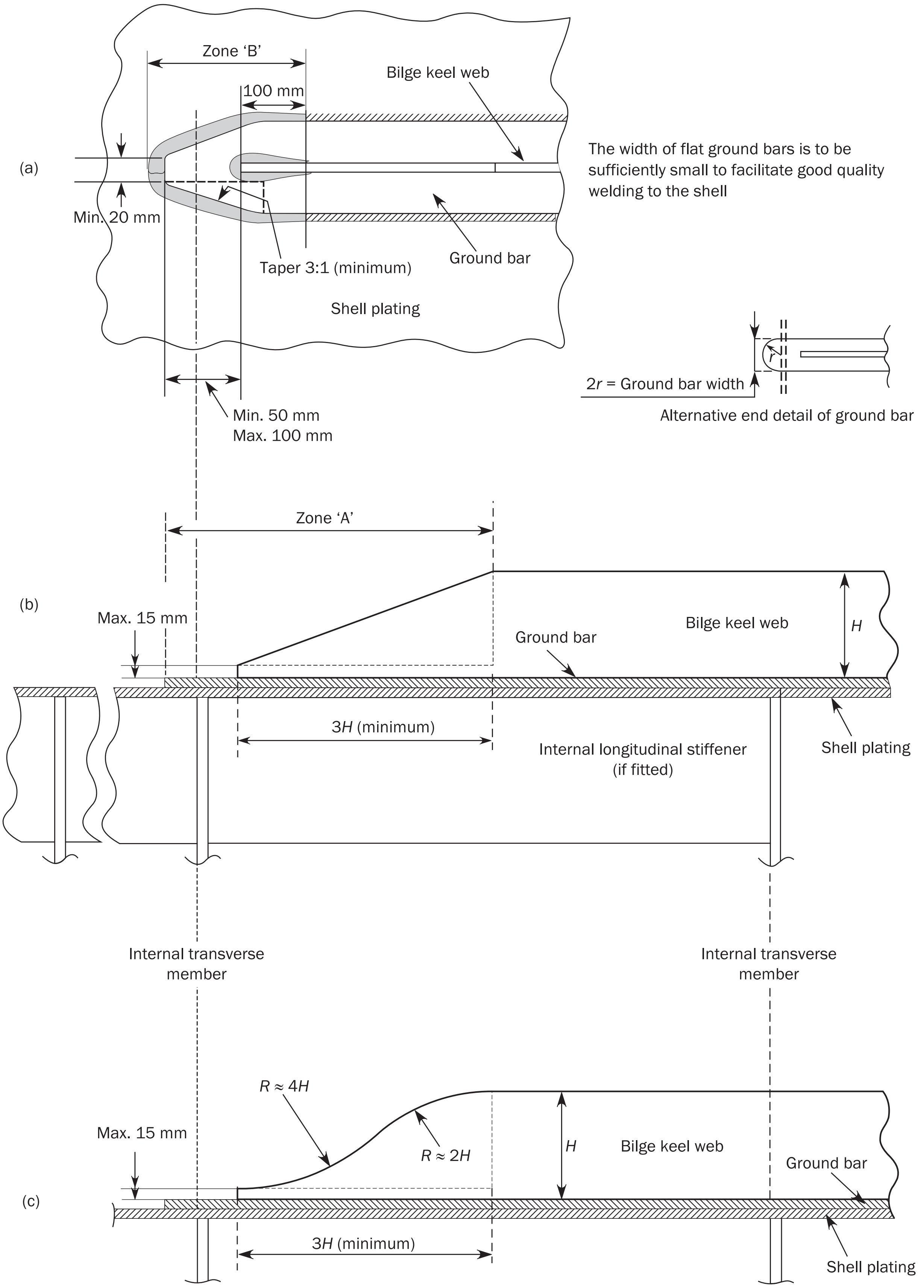
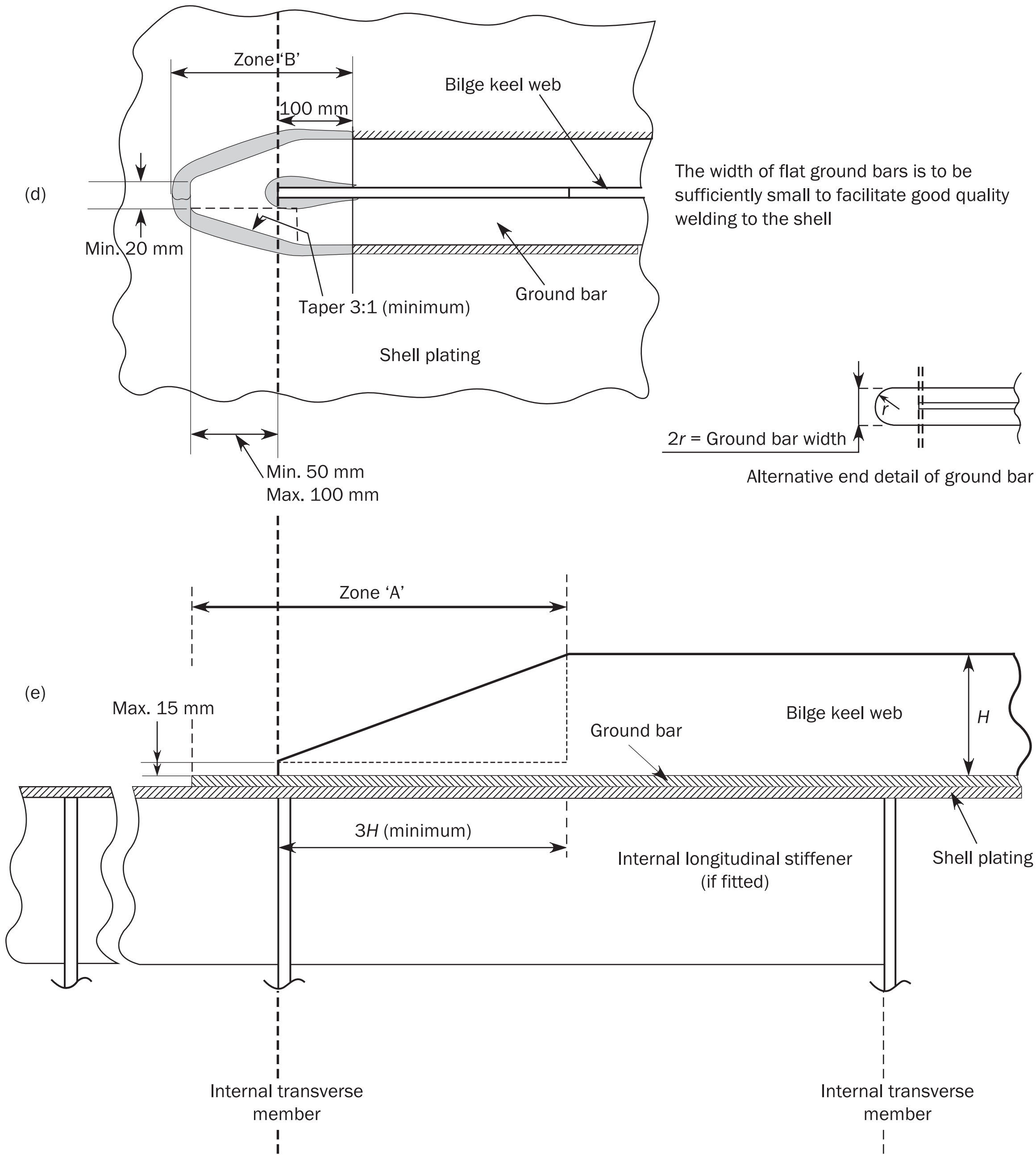


Figure 20 : Bilge keel end design (continued)



7.5.2 Design

The design of single web bilge keels is to be such that failure to the web occurs before failure of the ground bar. In general, this may be achieved by ensuring the web thickness of the bilge keel does not exceed that of the ground bar.

Bilge keels of a different design, from that shown in Figure 18, are to be specially considered by the Society.

7.5.3 Ground bars

Bilge keels are not to be welded directly to the shell plating. A ground bar, or doubler, is to be fitted on the shell plating as shown in Figure 18 and Figure 19. In general, the ground bar is to be continuous.

The gross thickness of the ground bar is not to be less than the gross thickness of the bilge strake or 14 mm, whichever is the lesser.

7.5.4 End details

The ground bar and bilge keel ends are to be tapered or rounded. Tapering is to be gradual with a minimum ratio of 3:1, see items (a), (b), (d) and (e) in Figure 19/Figure 20. Rounded ends are to be as shown in item (c) of Figure 19. Cut-outs on the bilge keel web, within zone 'A' (see items (b) and (e) of Figure 19/Figure 20) are not permitted.

The end of the bilge keel web is to be not less than 50 mm and not greater than 100 mm from the end of the ground bar, see items (a) and (d) of Figure 19/Figure 20.

Ends of the bilge keel and ground bar are to be supported by either transverse or longitudinal members inside the hull, as indicated as follows:

- Transverse support member is to be fitted at mid length between the end of the bilge keel web and the end of the ground bar, see items (a), (b) and (c) of Figure 19.
- Longitudinal stiffener is to be fitted in line with the bilge keel web, it is to extend to at least the nearest transverse member forward and aft of zone 'A' (see items (b) and (e) of Figure 19/Figure 20).

Alternative end arrangements may be accepted, provided that they are considered equivalent.

7.6 Docking

7.6.1 General

The drydocking arrangement itself is not covered in these Rules.

The bottom structure is to withstand the forces imposed by drydocking the ship.

7.6.2 Docking brackets

Docking brackets connecting the centreline girder to the bottom plating, are to be connected to the adjacent bottom longitudinals.

8 DOUBLE SIDE STRUCTURE

8.1 General

8.1.1

Side shell, inner hull bulkheads and longitudinal bulkheads are generally to be longitudinally framed. Where the side shell is longitudinally framed, the inner hull bulkheads are to be longitudinally framed. Alternative framing arrangements are to be specially considered by the Society.

8.1.2

Where the double side space of bulk carriers is void, the structural members bounding this space are to be structurally designed as a water ballast tank. In such a case the corresponding air pipe is considered as extending 0.76 m above the freeboard deck at side. For corrosion addition, the space is to be considered as a void space.

8.2 Structural arrangement

8.2.1 Primary supporting members

Double side web frames are to be fitted in line with web frames in hopper tanks. In addition, double side web frames are to be aligned with web frames or large brackets in topside tanks.

Vertical primary supporting members are to be fitted in way of hatch end beams of bulk carriers or similar large deck opening supporting transverse structure.

In general, horizontal side stringers are to be fitted aft of the collision bulkhead, up to 0.2 L aft of the fore end, in line with fore peak stringers.

8.2.2 Transverse stiffeners

Transverse stiffeners on side shell and inner side, where fitted, are to be continuous or fitted with bracket end connections within the height of the double side. The transverse stiffeners are to be effectively connected to stringers. At their upper and lower ends, shell and inner side transverse stiffeners are to be connected by brackets to supporting stringer plates.

8.2.3 Longitudinal stiffeners

Longitudinal stiffeners on side shell and inner side, where fitted, are to be continuous within the length of the parallel part of the cargo hold region. They are to be fitted with soft toe brackets in way of transverse bulkheads aligned with cargo hold bulkheads and are to be effectively connected to transverse web frames of the double side structure.

Longitudinal framing of the side shell is to extend outside the cargo hold region as far forward as practicable.

8.2.4 Sheer strake

Sheer strakes are to have breadths not less than 0.8 + L/200 m, measured vertically, but need not be greater than 1.8 m.

The sheer strake may be either welded to the stringer plate or rounded.

If the sheer strake is rounded, its radius, in mm, is to be not less than 17 t_s, where t_s is the net thickness, in mm, of the sheer strake.

The upper edge of the welded sheer strake is to be rounded smooth and free of notches. Fixtures such as bulwarks, eye plates are not to be directly welded on the upper edge of sheer strake, except in fore and aft parts. Drainage openings with a smooth transition in the longitudinal direction may be permitted.

Longitudinal seam welds of rounded sheer strake are to be located outside the bent area at a distance not less than 5 times the maximum net thicknesses of the sheer strake.

The welding of deck fittings to rounded sheer strakes is to be avoided within 0.6 L amidships.

The transition from a rounded sheer strake to an angled sheer strake associated with the arrangement of superstructures is to be designed to avoid any discontinuities.

8.2.5 Plating connection

Connection between the inner hull plating and the inner bottom plating is to be designed such that stress concentration is avoided.

The connections of hopper tanks plating with inner hull and with inner bottom are to be supported by a primary supporting member.

9 DECK STRUCTURE

9.1 Structural arrangement

9.1.1 Framing system

Deck areas contributing to the longitudinal strength are to be longitudinally framed.

9.1.2 Stringer plate

Stringer plates are to have breadths not less than 0.8 + L/200 m, measured parallel to the deck, but need not be greater than 1.8 m.

Rounded stringer plates, where adopted, are to comply with the requirements in [8.2.4].

9.1.3 Connection of deckhouses and superstructures

Connection of deckhouses and superstructures to the strength deck are to be designed such that loads are transmitted into the under deck supporting structure.

9.2 Deck scantlings

9.2.1

The web depth of deck stiffeners is not to be less than 60 mm.

The web depth of PSMs is not to be less than 10% and 7% of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2.5 times the depth of the slots if the slots are not closed. Unsupported span in bending is the bending span as defined in Ch 3, Sec 7 or in case of a grillage structure, the distance between connections to other PSMs.

10 BULKHEAD STRUCTURE

10.1 Application

10.1.1

The requirements of this article apply to longitudinal and transverse bulkheads, which may be plane or corrugated.

10.2 General

10.2.1

The web height of vertical PSMs on bulkheads may be gradually tapered from bottom to deck.

10.2.2

Bulkheads are to be stiffened in way of deck girders.

10.2.3

Bulkheads that support girders, or pillars and longitudinal bulkheads which are fitted in lieu of girders, are to be stiffened to provide supports not less effective than required for stanchions or pillars that would be located at the same position.

10.2.4

Where bulkheads are penetrated by cargo or ballast piping, the structural arrangements in way of the connection are to be adequate for the loads imparted to the bulkheads by the hydraulic forces in the pipes.

10.3 Plane bulkheads

10.3.1 General

Plane bulkheads may be horizontally or vertically stiffened.

Horizontally framed bulkheads are made of horizontal stiffeners supported by vertical primary supporting members.

Vertically framed bulkheads are made of vertical stiffeners supported by horizontal stringers, if needed.

The bulkhead stiffener webs of hopper and topside tank watertight bulkheads are to be aligned with the webs of longitudinal stiffeners of sloping plates of inner hull.

Floors are to be fitted in the double bottom in line with the plane transverse bulkhead.

10.3.2 End connection of stiffeners

The crossing of stiffeners through a watertight bulkhead is to be watertight.

End connections of stiffeners are to be bracketed. For isolated areas of the ship where bracketed end connections cannot be applied due to hull lines, other arrangements including sniped ends are acceptable.

10.3.3 Sniped end of stiffener

Sniped ends may be used on bulkheads subject to hydrostatic pressure provided they comply with [3.4].

10.4 Corrugated bulkheads

10.4.1 General

For bulk carriers of 190 m of length *L* and above and for oil tankers of 16 m moulded depth and above, the transverse vertically corrugated watertight bulkheads are to be fitted with a lower stool, and generally with an upper stool below deck. For bulk carriers having length *L* less than 190 m and for oil tankers having a moulded depth less than 16 m, corrugations may extend from inner bottom to deck.

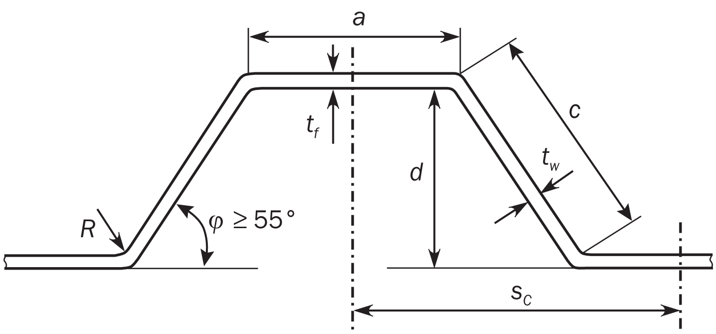
10.4.2 Construction

The main dimensions a, R, c, d, t_f, t_w, s_C of corrugated bulkheads are defined in Figure 21.

The corrugation angle φ is not to be less than 55°.

When welds in a direction parallel to the bend axis are provided in the zone of the bend, the welding procedures are to be submitted to the Society for approval.

Figure 21 : Dimensions of a corrugated bulkhead



10.4.3 Corrugated bulkhead depth

The depth of the corrugation, d, in mm, is not to be less than:

$$d = \frac{1000\ell_c}{C}$$

where:

ℓ_c : Mean span of considered corrugation, in m, as defined in [10.4.5].

C : Coefficient to be taken as:

C = 15 for tank and water ballast cargo hold bulkheads.

C = 18 for dry cargo hold bulkheads.

10.4.4 Actual section modulus of corrugations

The net section modulus of a corrugation may be obtained, in cm^3, from the following formula:

$$Z = \left[\frac{d(3at_f + ct_w)}{6}\right] 10^{-3}$$

where:

t_f, t_w : Net thickness of the plating of the corrugation, in mm, shown in Figure 21.

d, a, c : Dimensions of the corrugation, in mm, shown in Figure 21.

Where the web continuity is not ensured at ends of the bulkhead, the net section modulus of a corrugation is to be obtained, in cm^3, from the following formula:

$$Z = 0.5\ a\ t_f\ d\ 10^{-3}$$

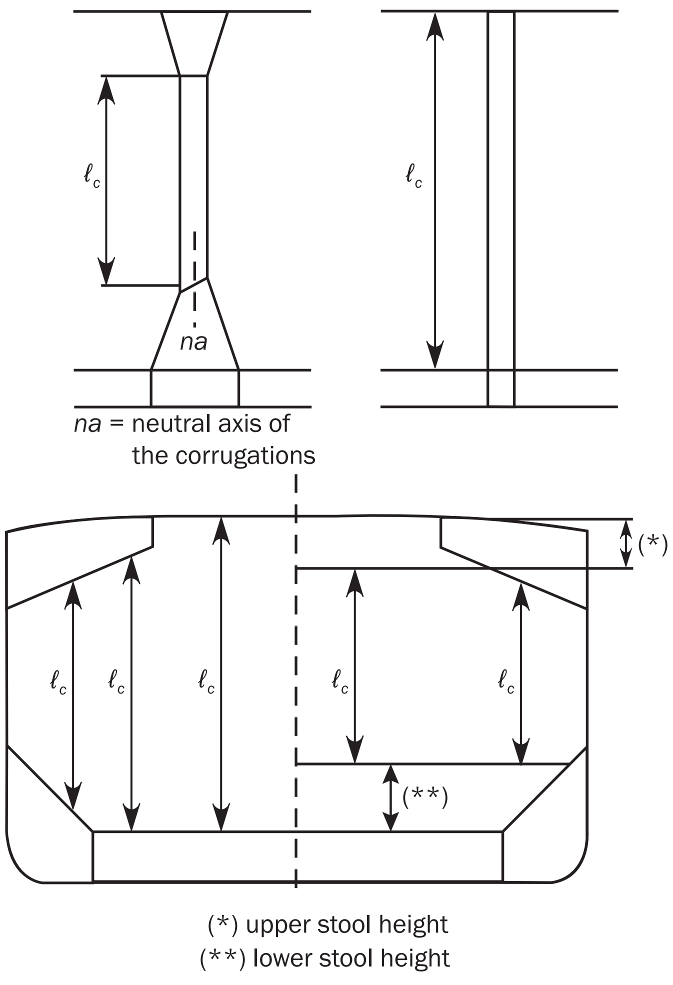
10.4.5 Span of corrugations

The span ℓ_C of the corrugations is to be taken as the distance shown in Figure 22.

For the definition of ℓ_C, the bottom of the upper stool is not to be taken more than a distance from the deck at the centre line equal to:

- 3 times the depth of corrugation, for non rectangular stool.
- 2 times the depth of corrugation, for rectangular stool.

Figure 22 : Span of the corrugations



10.4.6 Structural arrangements

Where corrugated bulkheads are cut in way of primary supporting members, corrugations on each side of the primary member are to be aligned with each other.

10.4.7 Bulkhead end supports

The strength continuity of corrugated bulkheads is to be maintained at the ends of corrugations.

Where a bulkhead is provided with a lower stool, floors or girders are to be fitted in line with both sides of the lower stool. Where a bulkhead is not provided with a lower stool, floors or girders are to be fitted in line with both flanges of the vertically corrugated transverse bulkhead.

The supporting floors or girders are to be connected to each other by suitably designed shear plates.

At deck, if no upper stool is fitted, transverse or longitudinal stiffeners are to be fitted in line with the corrugation flanges.

When the corrugation flange connected to the adjoining boundary structures (i.e. inner hull, side shell, longitudinal bulkhead, trunk, etc) is smaller than 50% of the width of the typical corrugation flange, an advanced analysis of the connection is required.

10.4.8 Bulkhead stools

Stool side plating is to be aligned with the corrugation flanges.

10.4.9 Lower stool

The lower stool, when fitted, is to have a height in general not less than:

- 3 corrugation depths, for bulk carriers.
- One corrugation depth, for oil tankers.

The ends of stool side ordinary stiffeners, when fitted in a vertical plane, are to be attached to brackets at the upper and lower ends of the stool. Lower stool side vertical stiffeners and their brackets in the stool are to be aligned with the inner bottom structures such as longitudinals or similar. Lower stool side plating is not to be knuckled anywhere between the inner bottom plating and the stool top plate.

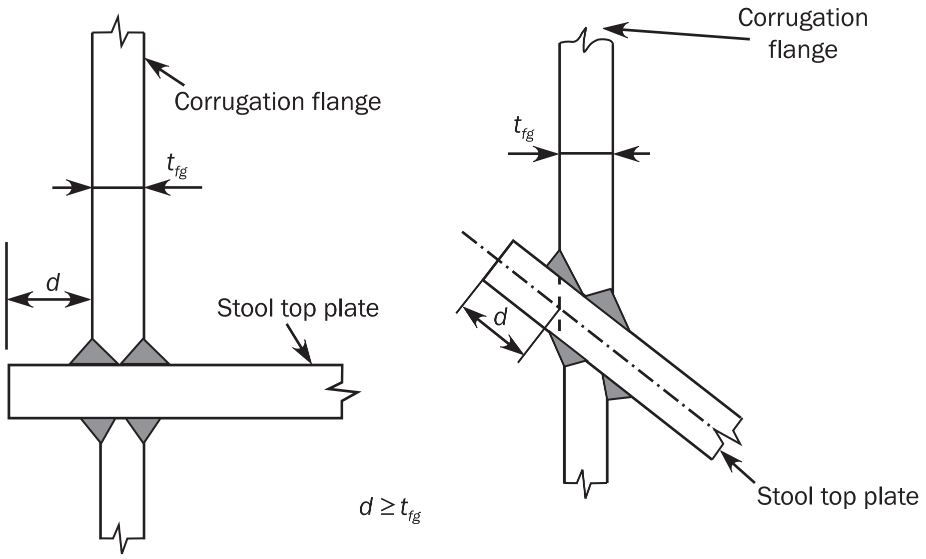
The distance *d* from the edge of the stool top plate to the surface of the corrugation flange is to be in accordance with Figure 23.

The lower part of the stool side plates is to be in line with double bottom floors or girders as the case may be, and the stool bottom is to have a width not less than:

- 2.5 corrugation depths, for bulk carriers.
- One corrugation depth, for oil tankers.

The stool is to be fitted with diaphragms in line with the longitudinal double bottom girders or floors. Scallops in the brackets and diaphragms in way of the connections to the stool top plate are to be avoided.

Figure 23 : Permitted distance, *d*, from the edge of the stool top plate to the surface of the corrugation flange



The stool side plating is to be connected to the stool top plate and the inner bottom plating by either full penetration or partial penetration welds. The supporting floors are to be connected to the inner bottom by either full penetration or partial penetration welds.

10.4.10 Upper stool

The upper stool, when fitted, is to have a height:

- Between two and three times the corrugation depth, for bulk carriers.
- At least one corrugation depth, for oil tankers.

Rectangular stools are to have a height in general equal to twice the depth of corrugations, measured from the deck level and at the hatch side girder. Brackets or deep webs are to be fitted to connect the upper stool to the deck transverse or hatch end beams.

The upper stool of a transverse bulkhead is to be properly supported by deck girders or deep brackets between the adjacent hatch end beams. The width of the upper stool bottom plate is generally to be the same as that of the lower stool top plate. The stool top of non-rectangular stools is to have a width not less than twice the depth of corrugations. The ends of stool side ordinary stiffeners when fitted in a vertical plane, are to be attached to brackets at the upper and lower end of the stool.

The stool is to be fitted with diaphragms in line with and effectively attached to longitudinal deck girders extending to the hatch end coaming girders or transverse deck primary supporting members. Scallops in the brackets and diaphragms in way of the connection to the stool bottom plate are to be avoided.

10.5 Non-tight bulkheads

10.5.1 General

In general, openings in wash bulkheads are to have generous radii and their aggregate area is not to be less than 10% of the area of the bulkhead.

10.5.2 Non-tight bulkheads not acting as pillars

In general, the maximum spacing of stiffeners fitted on non-tight bulkheads not acting as pillars is to be:

- 0.9 m, for transverse bulkheads.
- Two frame spacings, with a maximum of 1.5 m, for longitudinal bulkheads.

The net thickness of bulkhead stiffener, in mm, is not to be less than:

$t = 3 + 0.015\ L_2$

The depth of bulkhead stiffener of flat bar type is in general not to be less than 1/12 of stiffener length.

A smaller depth of stiffener may be accepted based on calculations showing compliance with Ch 6, Sec 5 and Ch 8.

10.5.3 Non-tight bulkheads acting as pillars

Non-tight bulkheads acting as pillars are to be provided with bulkhead stiffeners with a maximum spacing equal to:

- Two frame spacings, when the frame spacing does not exceed 0.75 m.
- One frame spacing, when the frame spacing is greater than 0.75 m.

Where non-tight bulkheads are corrugated, the depth of the corrugation is not to be less than 100 mm.

Each vertical stiffener, in association with a width of plating equal to 35 times the plating net thickness, 1/12 of stiffener length or the stiffener spacing, whichever is the smaller, is to comply with the applicable requirements in Ch 6, for the load being supported.

10.6 Watertight bulkheads of trunks and tunnels

10.6.1

Watertight trunks, tunnels, duct keels and ventilators are to be of the same strength as watertight bulkheads at corresponding levels. The means used for making them watertight, and the arrangements adopted for closing openings in them, are to be to the satisfaction of the Society.

11 PILLARS

11.1 General

11.1.1

Pillars are to be fitted in the same vertical line wherever possible. If not possible, effective means are to be provided for transmitting their loads to the supports below. Effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

11.1.2

Pillars are to be provided in line with the double bottom girder or as close thereto as practicable, and the structure above and below the pillars is to be of sufficient strength to provide effective distribution of the load. Where pillars connected to the inner bottom are not located in way of the intersection of floors and girders, partial floors or girders or equivalent structures are to be fitted as necessary to support the pillars.

11.1.3

Pillars provided in tanks are to be of solid or open section type.

Where the hydrostatic pressure may result in tensile stresses in the pillar, the tensile stress in the pillar and its end connections is not to exceed 45% of the specified minimum yield stress of the material.

11.2 Connections

11.2.1

Heads and heels of pillars are to be secured by thick doubling plates and brackets as necessary. Where the pillars are likely to be subjected to tensile loads, the head and heel of pillars are to be efficiently secured to withstand the tensile loads and the doubling plates replaced by insert plate.

In general, the net thickness of doubling plates is to be not less than 1.5 times the net thickness of the pillar. Pillars are to be attached at their heads and heels by continuous welding.

SECTION 7
STRUCTURAL IDEALISATION

SYMBOLS

Symbols

For symbols not defined in this section, refer to Ch 1, Sec 4.

φ_w : Angle, in deg, between the stiffener or primary supporting member web and the attached plating, see Figure 14. φ_w is to be taken equal to 90 deg if the angle is greater than or equal to 75 deg.

ℓ_{bdg} : Effective bending span, in m, as defined in [1.1.2] for stiffeners and [1.1.6] for primary supporting members.

ℓ_{shr} : Effective shear span, in m, as defined in [1.1.3] for stiffeners and [1.1.7] for primary supporting members.

ℓ : Full length of stiffener or of primary supporting member, in m, between their supports.

s : Stiffener spacing, in mm, as defined in [1.2].

S : Primary supporting member spacing, in m, as defined in [1.2].

a : Length, in mm, of EPP as defined in [2.1.1].

b : Breadth, in mm, of EPP as defined in [2.1.1].

h_{stf} : Stiffener height, including the face plate, in mm.

t_p : Net thickness of attached plate, in mm.

t_w : Net web thickness, in mm.

b_f : Breadth of flange, in mm, see Ch 3, Sec 2, Figure 2. For bulb profiles, see Table 1 and Table 2.

t_f : Net thickness of flange, in mm.

PSM : Primary Supporting Member.

EPP : Elementary Plate Panel.

LCP : Load Calculation Point.

1 STRUCTURAL IDEALISATION OF STIFFENERS AND PRIMARY SUPPORTING MEMBERS

1.1 Effective spans

1.1.1 General

Where arrangements differ from those defined in this article, span definition may be specially considered.

1.1.2 Effective bending span of stiffeners

The effective bending span ℓ_{bdg} of stiffeners is to be measured as shown in Figure 1 for single skin structures and Figure 2 for double skin structures.

If the web stiffener is sniped at the end or not attached to the stiffener under consideration, the effective bending span is to be taken as the full length between PSMs unless a backing bracket is fitted, see Figure 1.

The effective bending span may be reduced where brackets are fitted to the flange or free edge of the stiffener. Brackets fitted on the side opposite to that of the stiffener with respect to attached plating are not to be considered as effective in reducing the effective bending span.

In single skin structures, the effective bending span of a stiffener supported by a bracket or by a web stiffener on one side only of the primary supporting member web, is to be taken as the total span between primary supporting members as shown in item (a) of Figure 1. If brackets are fitted on both sides of the primary supporting member, the effective bending span is to be taken as in items (b), (c) and (d) of Figure 1.

Figure 1 : Effective bending span of stiffeners supported by web stiffeners (single skin construction)

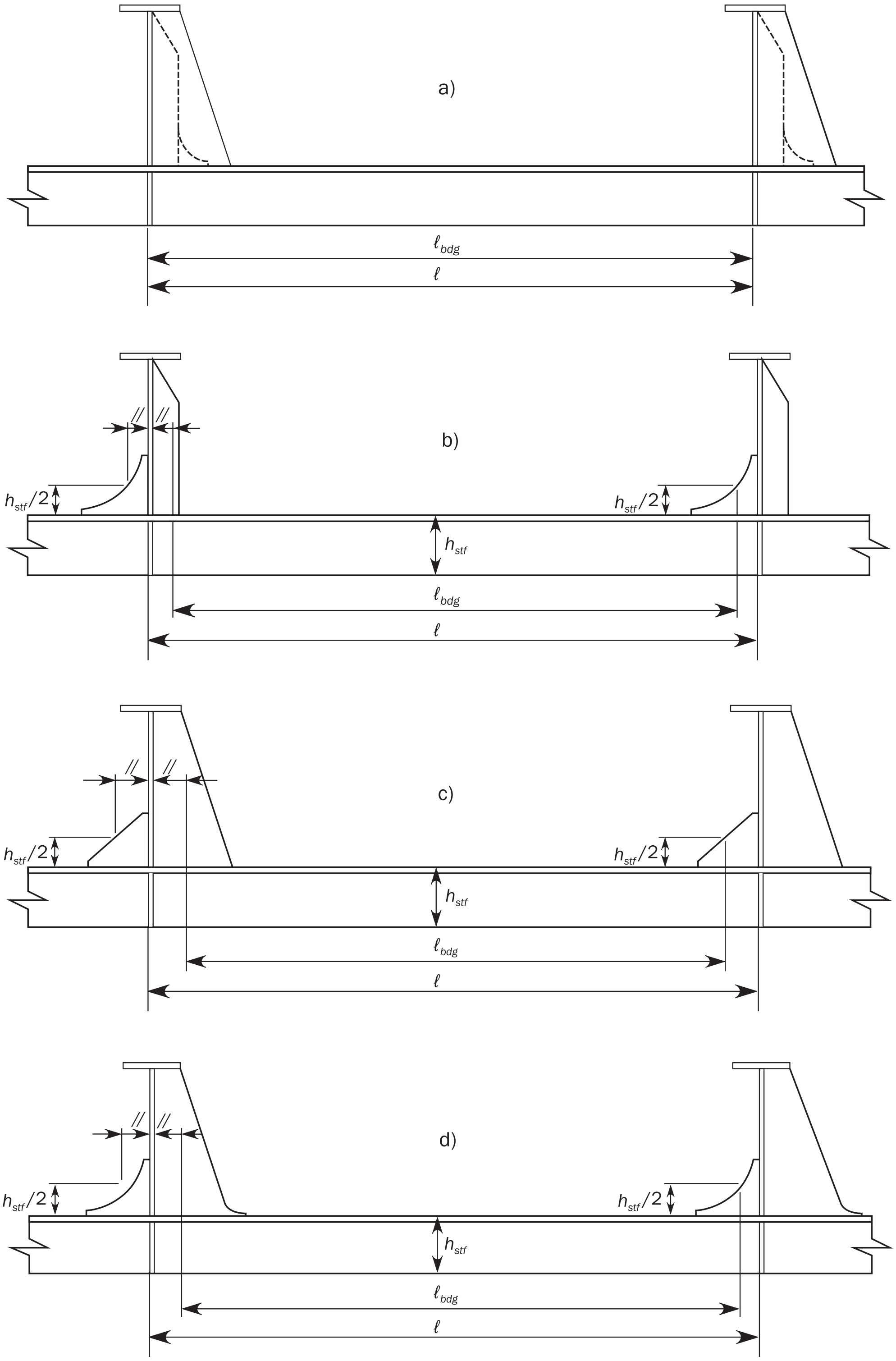
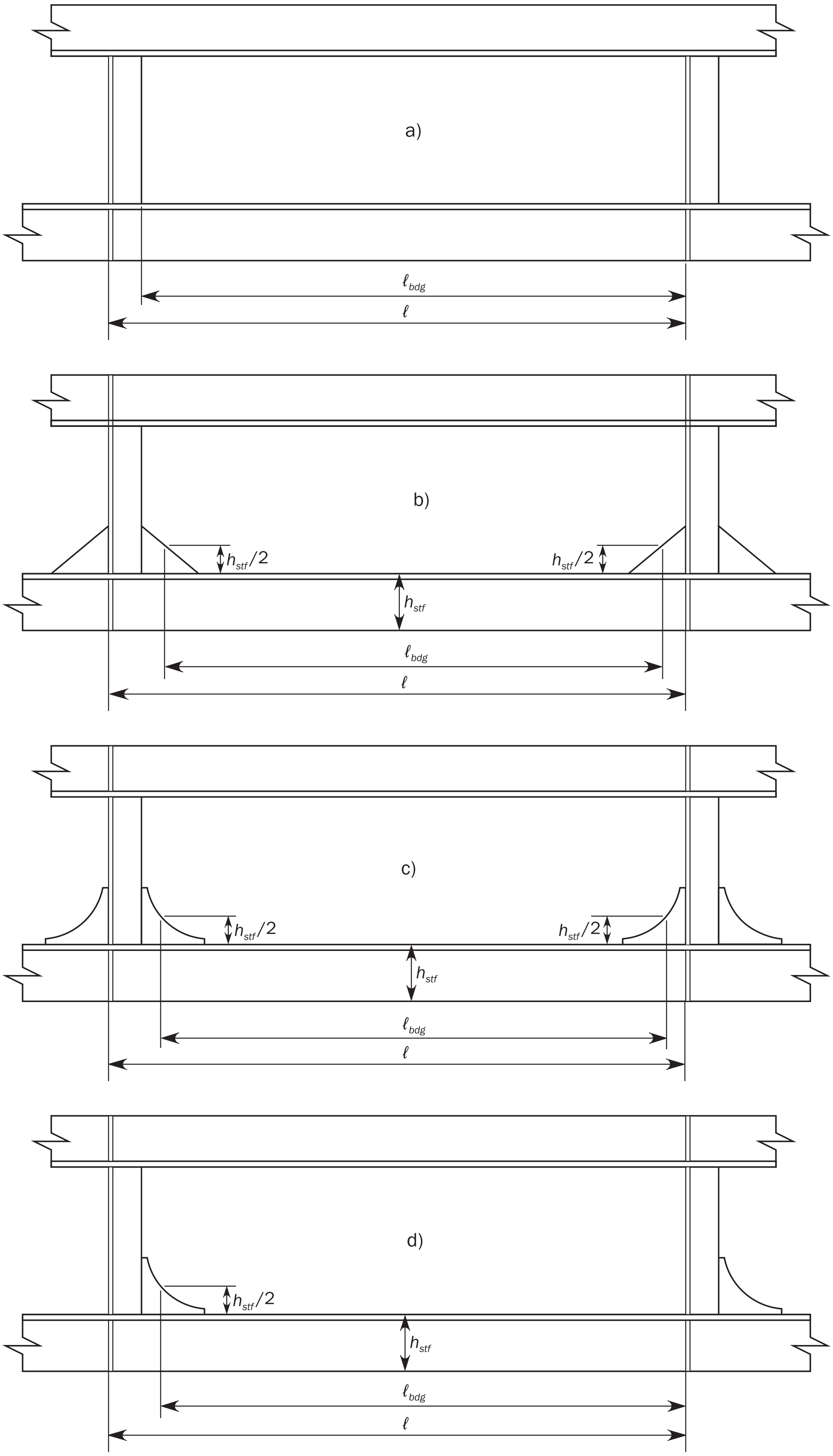
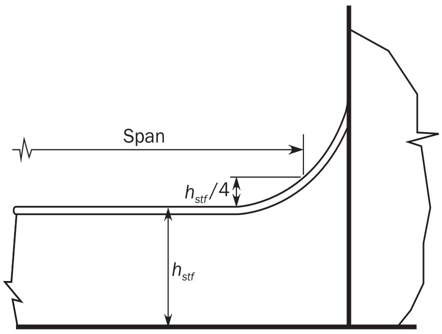


Figure 2 : Effective bending span of stiffeners supported by web stiffeners (double skin construction)



Where the face plate of the stiffener is continuous along the edge of the bracket, the effective bending span is to be taken to the position where the depth of the bracket is equal to one quarter of the depth of the stiffener, see Figure 3.

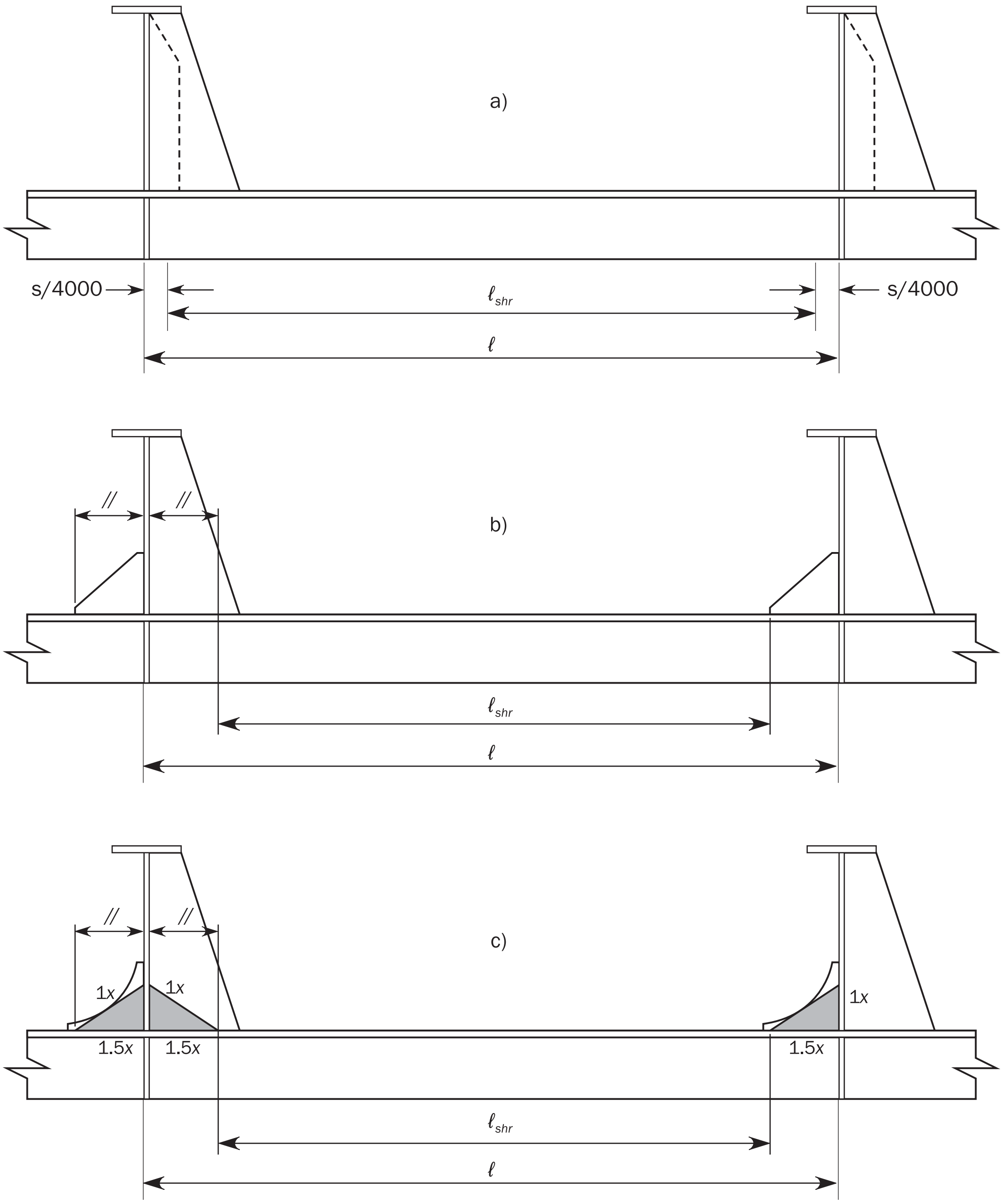
Figure 3 : Effective bending span for local support members with continuous face plate along bracket edge



1.1.3 Effective shear span of stiffeners

The effective shear span, ℓ_{shr} in m, of stiffeners is to be measured as shown in Figure 4 for single skin structures and Figure 5 for double skin structures.

Figure 4 : Effective shear span of stiffeners supported by web stiffeners (single skin construction)



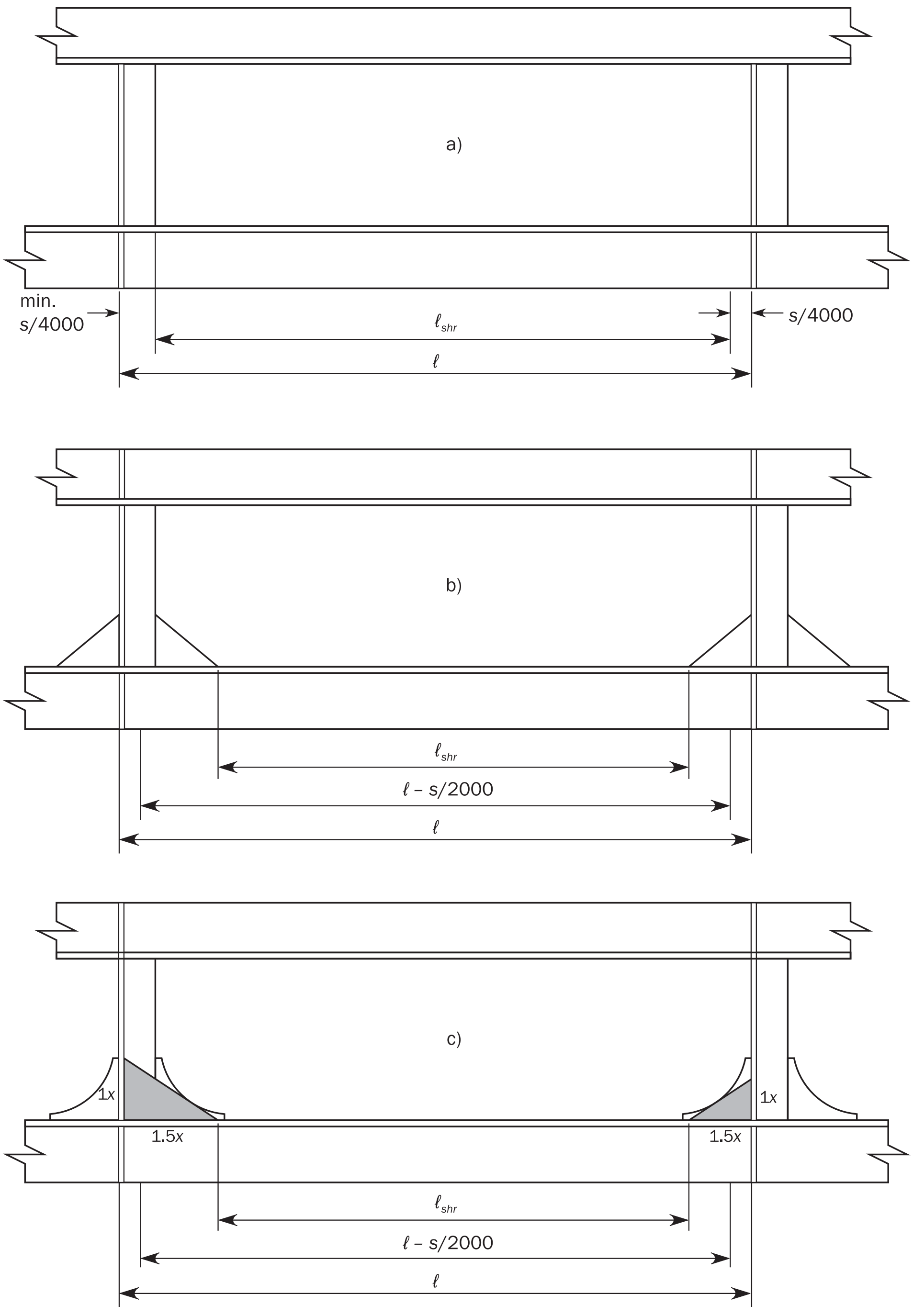
The effective shear span may be reduced for brackets fitted on either the flange or the free edge of the stiffener, or for brackets fitted to the attached plating on the side opposite to that of the stiffener.

If brackets are fitted at both the flange or free edge of the stiffener, and to the attached plating on the side opposite to the stiffener the effective shear span may be reduced using the longer effective bracket arm.

Regardless of support detail, the full length of the stiffener may be reduced by a minimum of s/4000 m at each end of the member, hence the effective shear span ℓ_{shr}, is not to be taken greater than:

$$\ell_{shr} \le \ell - \frac{s}{2000}$$

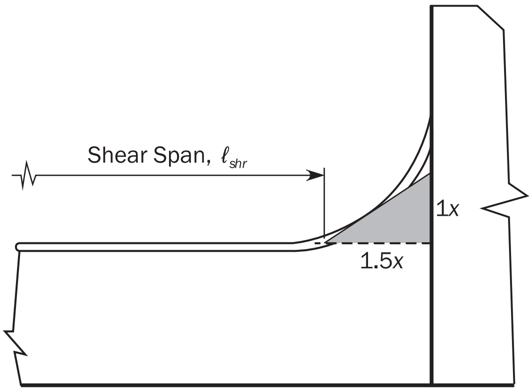
Figure 5 : Effective shear span of stiffeners supported by web stiffeners (double skin construction)



For curved and/or long brackets (high length/height ratio), the effective bracket length is to be taken as the maximum inscribed 1:1.5 triangle as shown in item (c) of both Figure 4 and Figure 5.

Where the face plate of the stiffener is continuous along the curved edge of the bracket, the bracket length to be considered for determination of the span point location is not to be taken greater than 1.5 times the length of the bracket arm as shown in Figure 6.

Figure 6 : Effective shear span for local support members with continuous face plate along bracket edge



1.1.4 Effect of hull form shape on span of stiffeners

For curved stiffeners, the span is defined as the chord length between span points to be measured at the flange for stiffeners with a flange, and at the free edge for flat bar stiffeners. The calculation of the effective span is to be in accordance with requirements given in [1.1.2] and [1.1.3].

1.1.5 Effective span of stiffeners supported by struts

The arrangement of stiffeners supported by struts is not allowed for ships over 120 m in length.

The span, ℓ of stiffeners supported by one strut fitted at mid distance of the primary supporting members is to be taken as $0.7\ell_2$.

In case where two struts are fitted at 1/3 and 2/3 length between primary supporting members, the span, ℓ of stiffeners is to be taken as $0.7\ell_2$.

ℓ_1 and ℓ_2 are the spans defined in Figure 7 and Figure 8.

Figure 7 : Span of stiffeners with one strut

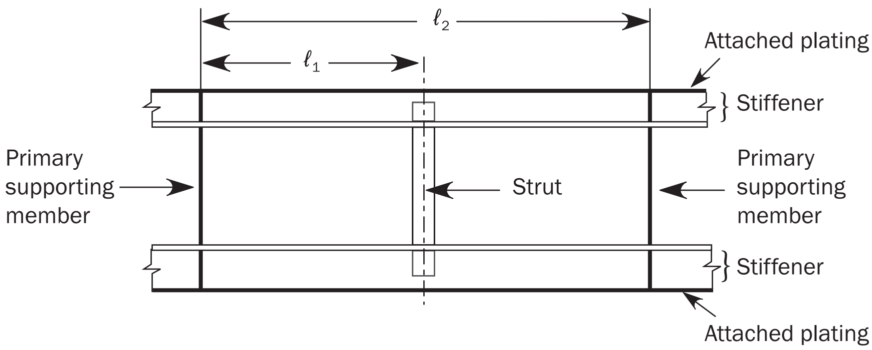


Figure 8 : Span of stiffeners with two struts

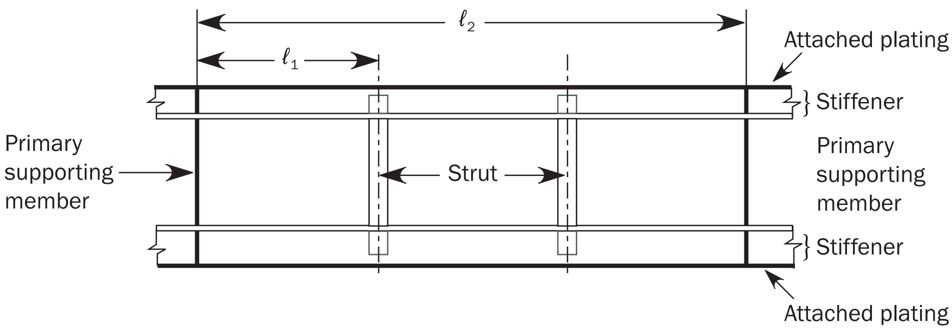


Figure 9 : Effective bending span of primary supporting member

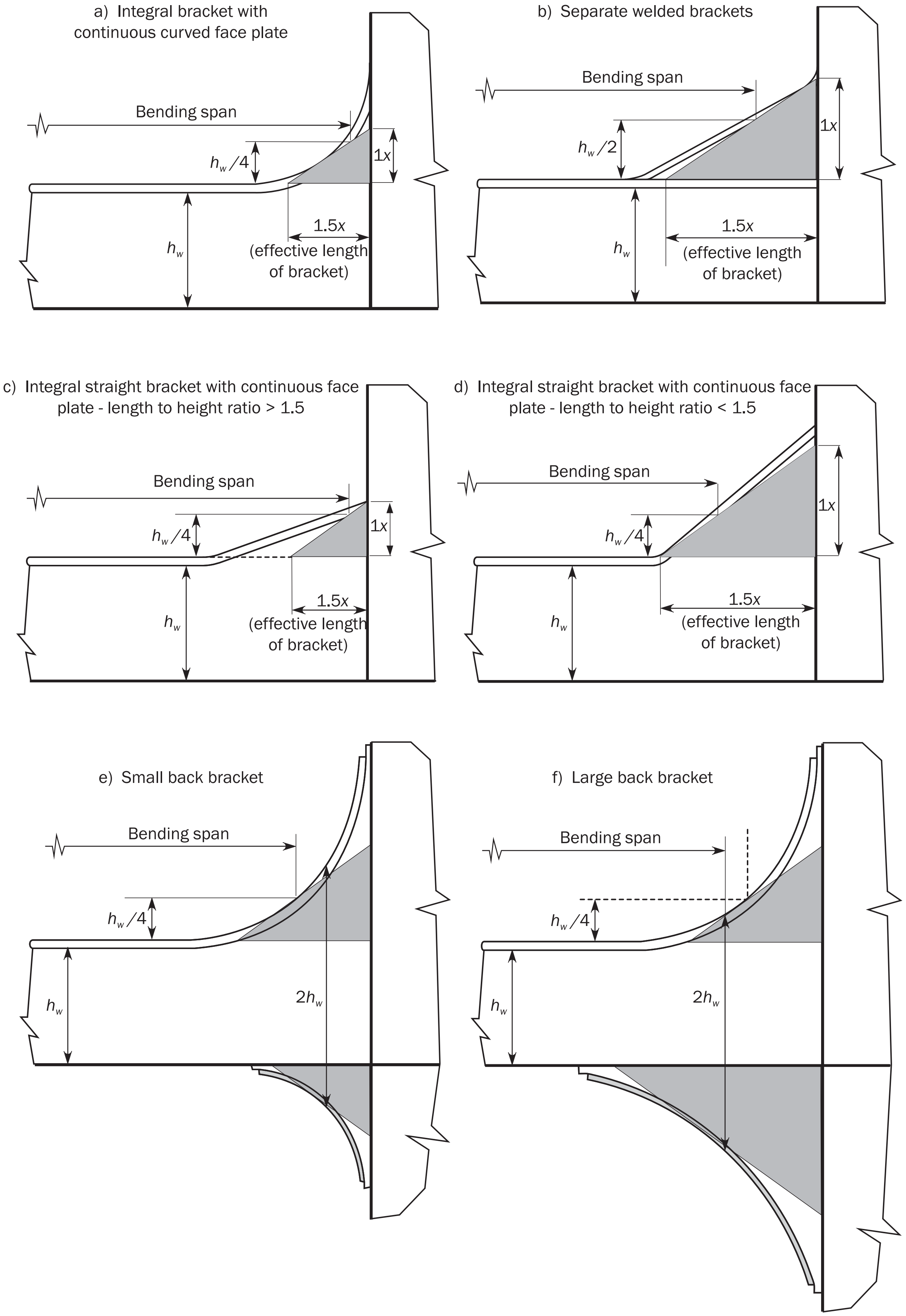
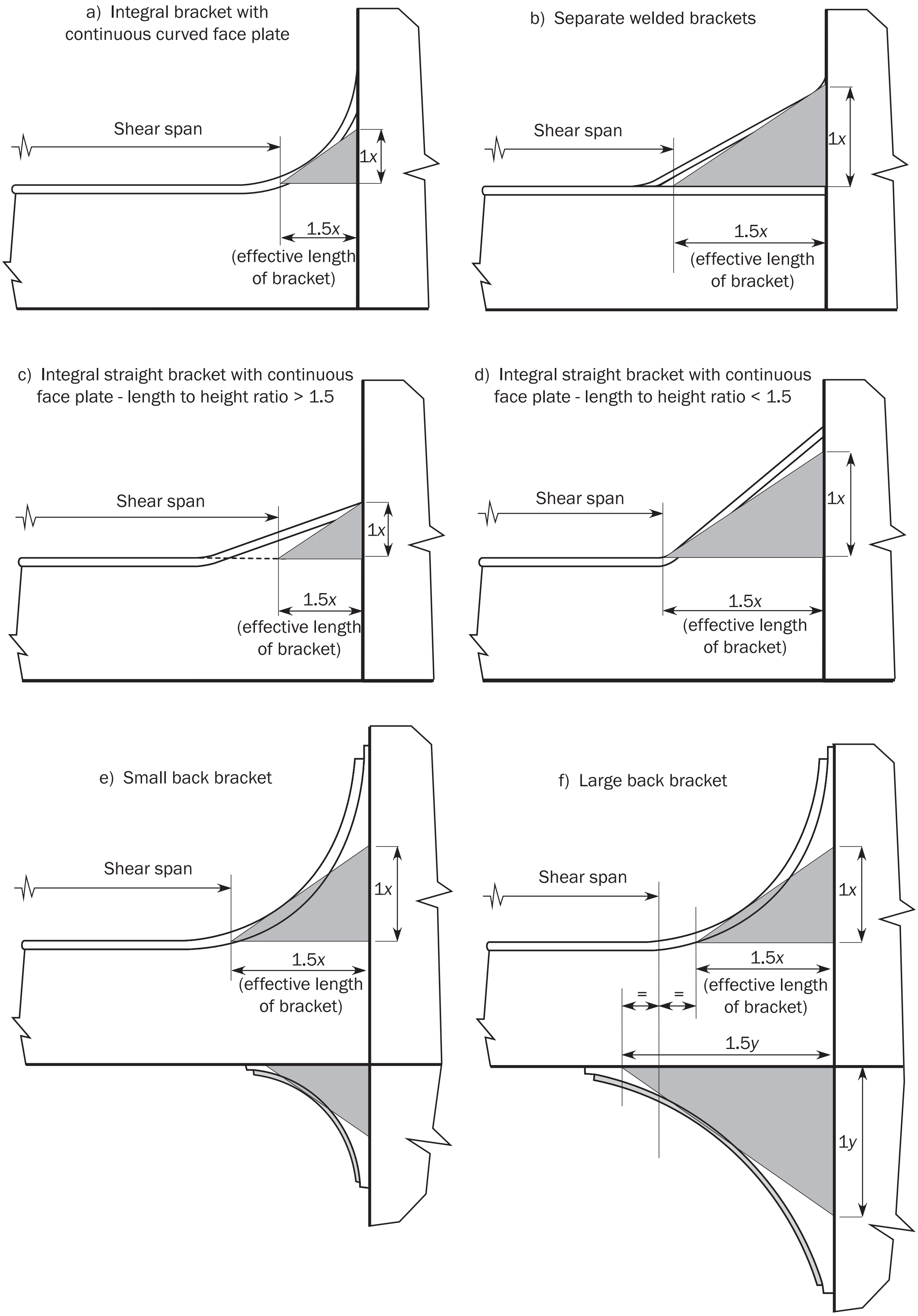


Figure 10 : Effective shear span of primary supporting member



1.1.6 Effective bending span of primary supporting members

The effective bending span, ℓ_{bdg}, in m, of a primary supporting member without end bracket is to be taken as the length of the member between supports.

The effective bending span, ℓ_{bdg}, of a primary supporting member may be taken as less than the full length of the member between supports provided that suitable end brackets are fitted.

The effective bending span ℓ_{bdg}, in m, of a primary supporting member with end brackets is taken between points where the depth of the bracket is equal to half the web height of the primary supporting member as shown in item (b) of Figure 9. The effective bracket used to define these span points is to be taken as given in [1.1.8].

In case of brackets where the face plate of the member is continuous along the face of the bracket, as shown in items (a), (c) and (d) of Figure 9, the effective bending span ℓ_{bdg}, in m, is taken between points where the depth of the bracket is equal to one quarter the web height of the primary supporting member. The effective bracket used to define these span points is to be taken as given in [1.1.8].

For straight brackets with a length to height ratio greater than 1.5, the span point is to be taken to the effective bracket; otherwise the span point is to be taken to the fitted bracket.

For curved brackets, for span positions above the tangent point between fitted bracket and effective bracket, the span point is to be taken to the fitted bracket; otherwise, the span point is to be taken to the effective bracket.

For arrangements where the primary supporting member face plate is carried on to the bracket and backing brackets are fitted; the span point need not be taken greater than to the position where the total depth reaches twice the depth of the primary supporting member. Arrangements with small and large backing brackets are shown in items (e) and (f) of Figure 9.

For arrangements where the height of the primary supporting member is maintained and the face plate width is increased towards the support; the effective bending span may be taken to a position where the face plate breadth reaches twice the nominal breadth.

1.1.7 Effective shear span of primary supporting members

The effective shear span of the primary supporting member may be reduced compared to effective bending span, and taken between the toes of the effective brackets supporting the member, where the toes of effective brackets are as shown in Figure 10. The effective bracket used to define the toe point is given in [1.1.8].

For arrangements where the effective backing bracket is larger than the effective bracket in way of face plate, the shear span is to be taken as the mean distance between toes of the effective brackets as shown in item (f) of Figure 10.

1.1.8 Effective bracket definition

The effective bracket is defined as the maximum size of triangular bracket with a length to height ratio of 1.5 that fits inside the fitted bracket. See Figure 9 for examples.

1.2 Spacing and load supporting breadth

1.2.1 Stiffeners

Stiffeners spacing, s, in mm, for the calculation of the effective attached plating of stiffeners is to be taken as the mean spacing between stiffeners and taken equal to, see Figure 11.

$$s = \frac{b_1 + b_2 + b_3 + b_4}{4}$$

where:

b_1, b_2, b_3, b_4: Spacings between stiffeners at ends, in mm.

In general, the loading breadth supported by stiffener is to be taken equal to s.

1.2.2 Primary supporting member

Primary supporting member spacing, *S*, for the calculation of the effective attached plating of primary supporting members is to be taken as the mean spacing between adjacent primary supporting members, and taken equal to, see Figure 11.

$$S = \frac{b_1 + b_2 + b_3 + b_4}{4}$$

where:

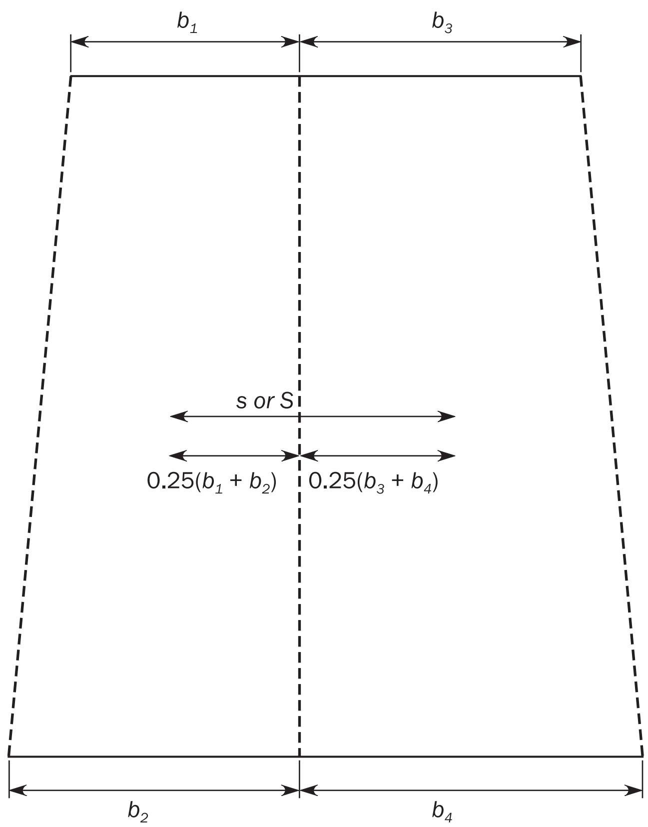
b_1, b_2, b_3, b_4 : Spacings between primary supporting members at ends.

In general, the loading breadth supported by a primary supporting member is to be taken equal to *S*.

1.2.3 Spacing of curved plating

For curved plating, the stiffener spacing, s or the primary supporting member spacing, *S* is to be measured on the mean chord between members.

Figure 11 : Spacing of plating



1.3 Effective breadth

1.3.1 Stiffeners

The effective breadth, b_{eff}, in mm, of the attached plating to be considered in the actual net section modulus for the yielding check of stiffeners is to be obtained from the following formulae:

- Where the plating extends on both sides of the stiffener:

  $b_{eff} = 200\ell$, or

  $b_{eff} = s$

  whichever is lesser.

- Where the plating extends on one side of the stiffener (i.e. stiffeners bounding openings):

  $b_{eff} = 100\ell$, or

  $b_{eff} = 0.5\ s$

  whichever is lesser.

However, where the attached plate net thickness is less than 8 mm, the effective breadth is not to be taken greater than 600 mm.

The effective breadth, b_{eff}, in mm, of the attached plating to be considered for the buckling check of stiffeners is given in Ch 8, Sec 5, [2.3.5].

1.3.2 Primary supporting members

The effective breadth of attached plating, b_{eff}, in m, for calculating the section modulus and/or moment of inertia of a primary supporting member is to be taken as:

$$b_{eff} = S \cdot \min\left[\frac{1.12}{1+\dfrac{1.75}{\left(\dfrac{\ell_{bdg}}{S\sqrt{3}}\right)^{1.6}}};1.0\right] \quad \text{for} \quad \frac{\ell_{bdg}}{S\sqrt{3}} \geq 1$$

$$b_{eff} = 0.407\frac{\ell_{bdg}}{\sqrt{3}} \quad \text{for} \quad \frac{\ell_{bdg}}{S\sqrt{3}} < 1$$

1.3.3 Effective area of curved face plate and attached plating of primary supporting members

The effective net area given in a) and b) is only applicable to curved face plates and curved attached plating of primary supporting members. This is not applicable for the area of web stiffeners parallel to the face plate.

The effective net area is applicable to primary supporting members for the following calculations:

- Actual net section modulus used for comparison with the scantling requirements in Ch 6.
- Actual effective net area of curved face plates, modelled by beam elements, used in Ch 7.

a) The effective net area, $A_{eff\text{-}n50}$, in mm^2, is to be taken as:

$A_{eff\text{-}n50} = C_f\, t_{f\text{-}n50}\, b_f$

where:

C_f : Flange efficiency coefficient taken equal to:

$$C_f = C_{f1}\frac{\sqrt{r_f\, t_{f-n50}}}{b_1} \quad \text{but not to be taken greater than 1.0.}$$

C_{f1} : Coefficient taken equal to:

- For symmetrical and unsymmetrical face plates,

$$C_{f1} = \frac{0.643\ (\sinh\beta\ \cosh\beta + \sin\beta\ \cos\beta)}{(\sinh\beta)^2 + \sin^2\beta}$$

- For attached plating of box girders with two webs,

$$C_{f1} = \frac{0.78\ (\sinh\beta + \sin\beta)\ (\cosh\beta - \cos\beta)}{(\sinh\beta)^2 + \sin^2\beta}$$

- For attached plating of box girders with multiple webs,

$$C_{f1} = \frac{1.56\ (\cosh\beta - \cos\beta)}{\sinh\beta + \sin\beta}$$

β : Coefficient calculated as:

$$\beta = \frac{1.285\ b_1}{\sqrt{r_f\ t_{f-n50}}}\text{, in rad.}$$

b_1 : Breadth, in mm, to be taken equal to:

- For symmetrical face plates, $b_1 = 0.5\ (b_f - t_{w\text{-}n50})$
- For unsymmetrical face plates, $b_1 = b_f$
- For attached plating of box girders, $b_1 = s_w - t_{w\text{-}n50}$

s_w : Spacing of supporting webs for box girders, in mm.

$t_{f\text{-}n50}$: Net flange thickness, in mm. For calculation of C_f and β of unsymmetrical face plates, $t_{f\text{-}n50}$ is not to be taken greater than $t_{w\text{-}n50}$.

$t_{w\text{-}n50}$: Net web plate thickness, in mm.

r_f : Radius of curved face plate or attached plating, in mm, see Figure 12 at mid thickness.

b_f : Breadth of face plate or attached plating, in mm, see Figure 12.

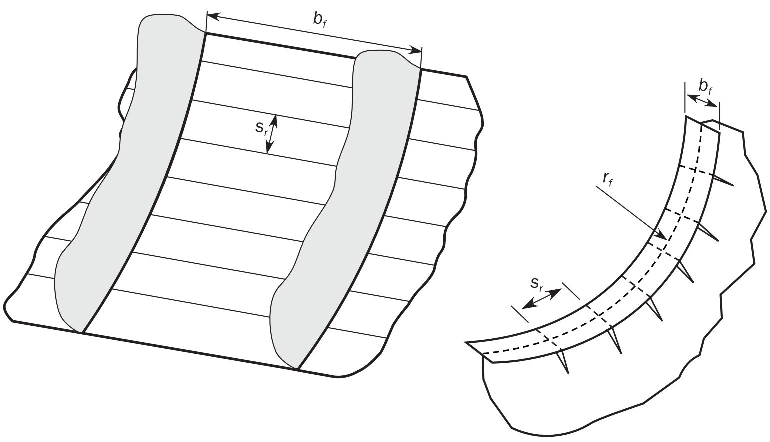
b) The effective net area, in mm², of curved face plates supported by radial brackets, or attached plating supported by cylindrical stiffeners, is given by:

$$A_{eff-n50} = \left(\frac{3r_f\ t_{f-n50} + C_f\ s_r^2}{3r_f\ t_{f-n50} + s_r^2}\right) t_{f-n50}\ b_f$$

where:

s_r : Spacing of tripping brackets or web stiffeners or stiffeners normal to the web plating, in mm, see Figure 12.

Figure 12 : Curved shell panel and face plate



1.4 Geometrical properties of stiffeners and primary supporting members

1.4.1 Stiffener profile with a bulb section

The properties of bulb profile sections are to be determined by direct calculations.

Where direct calculation of properties is not possible, a bulb section may be taken equivalent to a built-up section. The net dimensions of the equivalent built-up section are to be obtained, in mm, from the following formulae.

$$h_w = h'_w - \frac{h'_w}{9.2} + 2$$

$$b_f = \alpha\left(t'_w + \frac{h'_w}{6.7} - 2\right)$$

$$t_f = \frac{h'_w}{9.2} - 2$$

$$t_w = t'_w$$

where:

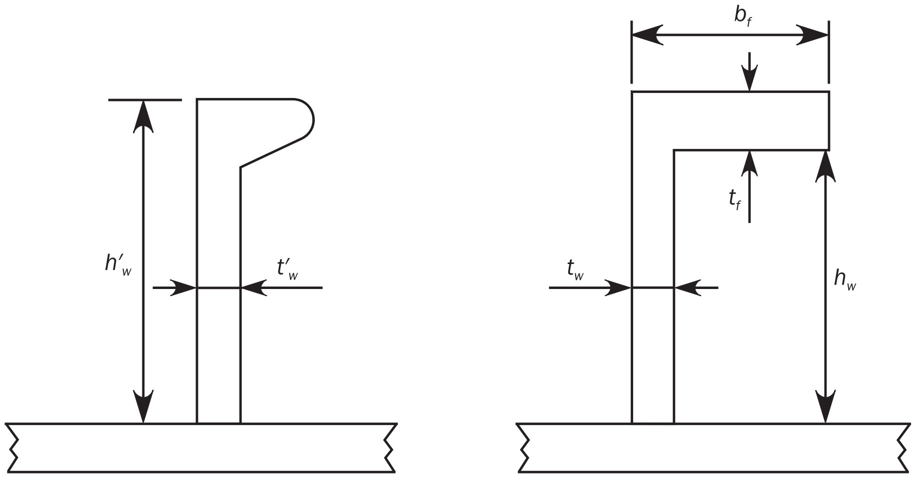
h'_w, t'_w : Net height and thickness of a bulb section, in mm, as shown in Figure 13.

α : Coefficient equal to:

$$\alpha = 1.1 + \frac{(120 - h'_w)^2}{3000} \quad \text{for } h'_w \le 120$$

$$\alpha = 1.0 \quad \text{for } h'_w > 120$$

Figure 13 : Dimensions of stiffeners



1.4.2 Net elastic shear area of stiffeners

The net elastic shear area, A_{shr}, in cm², of stiffeners is to be taken as:

$$A_{shr} = d_{shr}\, t_w\, 10^{-2}$$

d_{shr} : Effective shear depth of stiffener, in mm, as defined in [1.4.3].

t_w : Net web thickness of the stiffener, in mm, as defined in Ch 3, Sec 2, Figure 2.

1.4.3 Effective shear depth of stiffeners

The effective shear depth of stiffeners, d_{shr}, in mm, is to be taken as:

$$d_{shr} = (h_{stf} + t_p)\sin\varphi_w$$

where:

h_{stf} : Height of stiffener, in mm, as defined in Ch 3, Sec 2, Figure 2.

t_p : Net thickness of the stiffener attached plating, in mm, as defined in Ch 3, Sec 2, Figure 2.

φ_w : Angle, in deg, as defined in Figure 14.

1.4.4 Elastic net section modulus of stiffeners

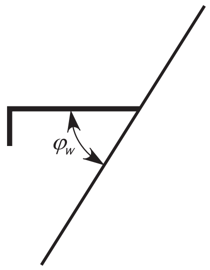
The elastic net section modulus, Z of stiffeners, in cm^3, is to be taken as:

$Z = Z_{stf} \sin \varphi_w$

where:

Z_{stf} : Net section modulus of the stiffener, in cm^3, considered perpendicular to its attached plate, i.e. with φ_w = 90 deg.

Figure 14 : Angle between stiffener web and attached plating



1.4.5 Effective net plastic shear area of stiffeners

The net plastic shear area, $A_{shr\text{-}pl}$, of stiffeners, in cm^2, which is used for assessment against impact loads is to be taken as:

$A_{shr\text{-}pl} = A_{shr}$

where:

A_{shr} : Net elastic shear area, in cm^2, as defined in [1.4.2].

1.4.6 Effective net plastic section modulus of stiffeners

The effective net plastic section modulus, Z_{pl}, of stiffeners, in cm^3, which is used for assessment against impact loads, is to be taken as:

$$Z_{pl} = \frac{f_w\, h_w^2\, t_w}{2000} + \frac{(2\gamma - 1)\, A_f\, h_{f-ctr}}{1000} \quad \text{for} \quad 75° \le \varphi_w \le 90°$$

$$Z_{pl} = \frac{f_w\, h_w^2\, t_w \sin\varphi_w}{2000} + \frac{(2\gamma - 1)\, A_f\, (h_{f-ctr} \sin\varphi_w - b_{f-ctr} \cos\varphi_w)}{1000} \quad \text{for} \quad \varphi_w < 75°$$

where:

f_w : Web shear stress factor, taken equal to:

- For flanged profile cross sections with n = 1 or 2, f_w = 0.75.
- For flanged profile cross sections with n = 0, f_w = 1.0.
- For flat bar stiffeners, f_w = 1.0.

n : Number of plastic hinges at end supports of each member, taken equal to: 0, 1 or 2.

A plastic hinge at end support may be considered where:

- The stiffener is continuous at the support.
- The stiffener passes through the support plate while it is connected at its termination point by a carling (or equivalent) to adjacent stiffeners.
- The stiffener is attached to an abutting stiffener effective in bending (not a buckling stiffener).
- The stiffener is attached to a bracket effective in bending. The bracket is assumed to be effective in bending when it is attached to another stiffener (not a buckling stiffener).

h_w : Depth of stiffener web, in mm, taken equal to:

- For T, L (rolled and built-up) and L2 profiles, as defined in Ch 3, Sec 2, Figure 2, $h_w = h_{stf} - t_{f\text{-}net}$.
- For flat bar and L3 profiles as defined in Ch 3, Sec 2, Figure 2, $h_w = h_{stf}$.
- For bulb profiles, to be taken as given in Table 1 and Table 2.

γ : Coefficient equal to:

$$\gamma = \frac{1 + \sqrt{3 + 12\beta}}{4}$$

β : Coefficient equal to:

- $\beta = \frac{t_w^2\, f_b\, \ell_{shr}^2}{80 b_f^2\, t_f\, h_{f-ctr}} 10^6 + \frac{t_w}{2 b_f}$ for L profiles without a mid-span tripping bracket,

but not to be taken greater than 0.5.

- $\beta = 0.5$ for other cases.

A_f : Net cross sectional area of flange, in mm^2:

- $A_f = 0$ for flat bar stiffeners.
- $A_f = b_f\, t_f$ for other stiffeners.

$b_{f\text{-}ctr}$: Distance from mid thickness of stiffener web to the centre of the flange area:

- $b_{f\text{-}ctr} = 0.5\,(b_f - t_{w\text{-}gr})$ for rolled angle profiles.
- $b_{f\text{-}ctr} = 0$ for T profiles.
- For bulb profiles as given in Table 1 and Table 2.

$h_{f\text{-}ctr}$: Height of stiffener measured to the mid thickness of the flange:

- $h_{f\text{-}ctr} = h_{stf} - 0.5\, t_f$ for profiles with flange of rectangular shape except for L3 profiles.
- $h_{f\text{-}ctr} = h_{stf} - d_e - 0.5\, t_f$ for L3 profiles as defined in Ch 3, Sec 2, Figure 2.
- For bulb profiles as given in Table 1 and Table 2.

d_e : Distance from upper edge of web to the top of the flange, in mm, for L3 profiles, see Ch 3, Sec 2, Figure 2.

f_b : Coefficient taken equal to:

- $f_b = 0.8$ for flanges continuous through the primary supporting member, with end bracket(s).
- $f_b = 0.7$ for flanges sniped at the primary supporting member or terminated at the support without aligned structure on the other side of the support, and with end bracket(s).
- $f_b = 1.0$ for other stiffeners.

t_f : Net flange thickness, in mm.

- $t_f = 0$ for flat bar stiffeners.
- For bulb profiles as given in Table 1 and Table 2.

Table 1 : Characteristic flange data for HP bulb profiles, see Figure 15

h_{stf} (mm)	d_w (mm)	$b_{f\text{-}gr}$ (mm)	$t_{f\text{-}gr}$ (mm)	$b_{f\text{-}ctr}$ (mm)	$h_{f\text{-}ctr}$ (mm)
200	171	40	14.4	10.9	188
220	188	44	16.2	12.1	206
240	205	49	17.7	13.3	225
260	221	53	19.5	14.5	244
280	238	57	21.3	15.8	263
300	255	62	22.8	16.9	281
320	271	65	25.0	18.1	300
340	288	70	26.4	19.3	318
370	313	77	28.8	21.1	346
400	338	83	31.5	22.9	374
430	363	90	33.9	24.7	402

Note 1: Characteristic flange data converted to net scantlings are given as:

$b_f \approx b_{f\text{-}gr} + 2\ t_w$

$t_f = t_{f\text{-}gr} - t_c$

$t_w = t_{w\text{-}gr} - t_c$

Table 2 : Characteristic flange data for JIS bulb profiles, see Figure 15

h_{stf} (mm)	d_w (mm)	$b_{f\text{-}gr}$ (mm)	$t_{f\text{-}gr}$ (mm)	$b_{f\text{-}ctr}$ (mm)	$h_{f\text{-}ctr}$ (mm)
180	156	34	11.9	9.0	170
200	172	39	13.7	10.4	188
230	198	45	15.2	11.7	217
250	215	49	17.1	12.9	235

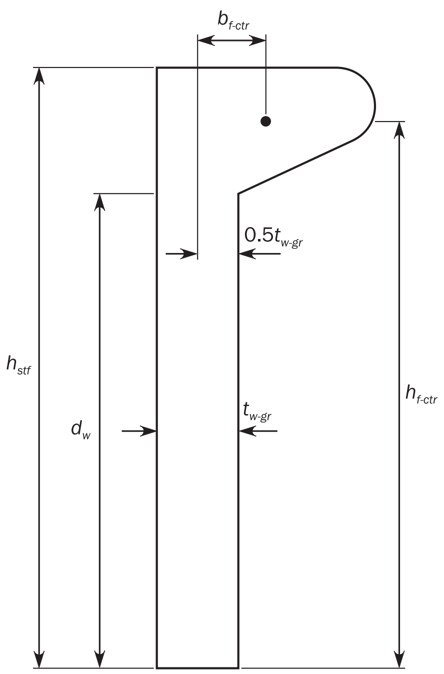
Note 1: Characteristic flange data converted to net scantlings are given as:

$b_f \approx b_{f\text{-}gr} + 2\ t_w$

$t_f = t_{f\text{-}gr} - t_c$

$t_w = t_{w\text{-}gr} - t_c$

Figure 15 : Characteristic data for bulb profiles



1.4.7 Primary supporting member web not perpendicular to attached plating

Where the primary supporting member web is not perpendicular to the attached plating, the actual net shear area, in cm², and the actual net section modulus, in cm³, can be obtained from the following formulae:

- Actual net shear area:

  $A_{sh-n50} = A_{sh-0-n50} \sin \varphi_w$ for $\varphi_w < 75°$
  $A_{sh-n50} = A_{sh-0-n50}$ for $75° \le \varphi_w \le 90°$

- Actual net section modulus:

  $Z_{n50} = Z_{perp-n50} \sin \varphi_w$ for $\varphi_w < 75°$
  $Z_{n50} = Z_{perp-n50}$ for $75° \le \varphi_w \le 90°$

where:

$A_{sh-0-n50}$: Actual net shear area, in cm², of the primary supporting member assumed to be perpendicular to the attached plating, to be taken equal to:

$$A_{sh-0-n50} = (h_w + t_{f-n50} + t_{p-n50})\, t_{w-n50}\, 10^{-2}$$

$Z_{perp-n50}$: Actual section modulus, in cm³, with its attached plating of the primary supporting member assumed to be perpendicular to the attached plating.

1.4.8 Shear area of primary supporting members with web openings

The effective web height, h_{eff}, in mm, to be considered for calculating the effective net shear area, A_{sh-n50} is to be taken as the lesser of:

$h_{eff} = h_w$

$h_{eff} = h_{w3} + h_{w4}$

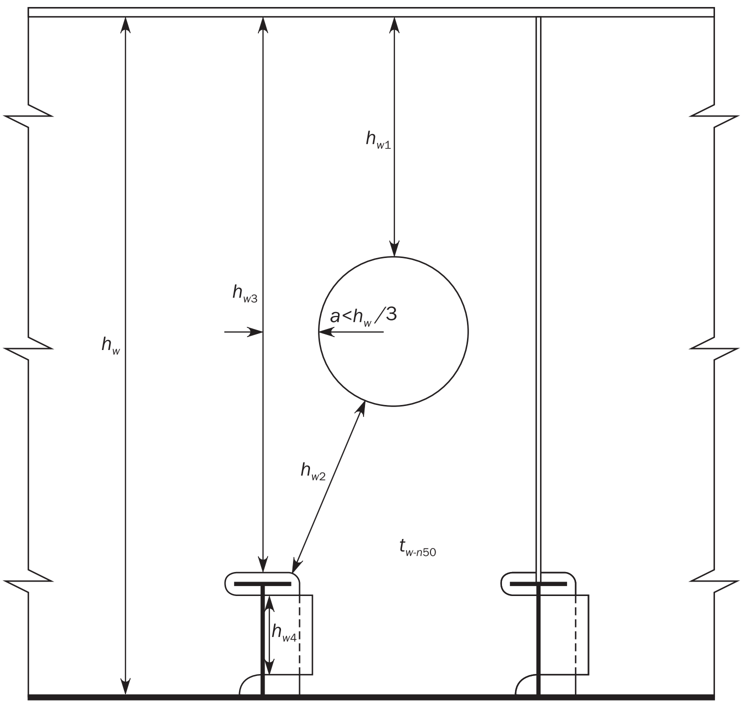
$h_{eff} = h_{w1} + h_{w2} + h_{w4}$

where:

h_w : Web height of primary supporting member, in mm.

h_{w1}, h_{w2}, h_{w3}, h_{w4} : Dimensions as shown in Figure 16.

Figure 16 : Effective shear area in way of web openings



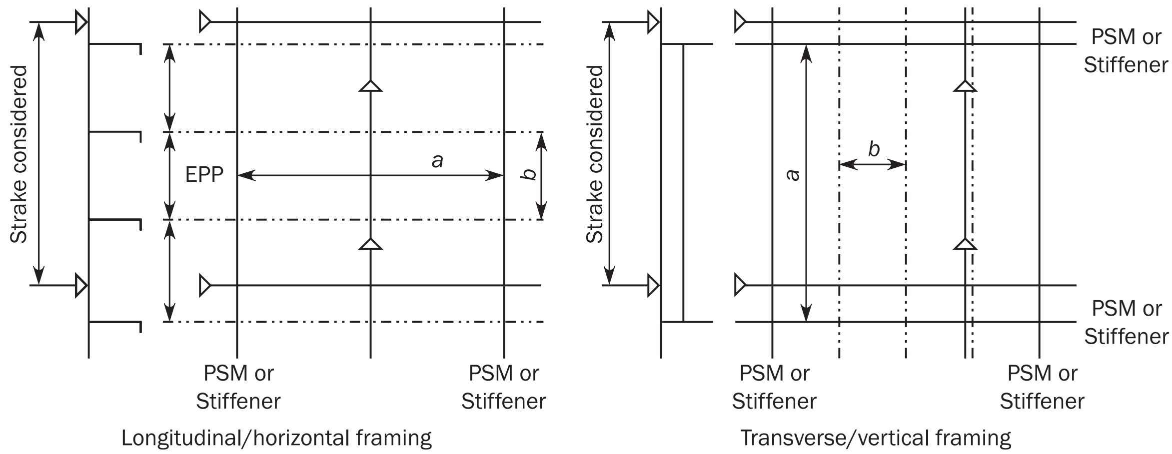
2 PLATES

2.1 Idealisation of EPP

2.1.1 EPP

An elementary plate panel (EPP) is the unstiffened part of the plating between stiffeners and/or primary supporting members. The plate panel length, *a*, and breadth, *b*, of the EPP are defined respectively as the longest and shortest plate edges, as shown in Figure 17.

Figure 17 : Elementary Plate Panel (EPP) definition



2.1.2 Strake required thickness

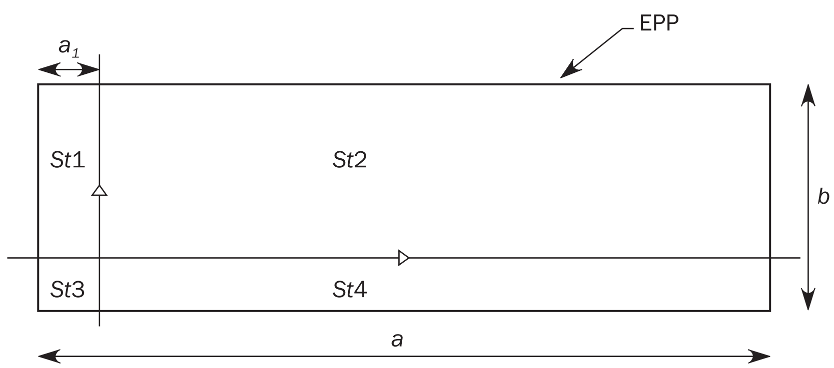
The required thickness of a plate strake is to be taken as the greatest value required for each EPP within that strake. The requirements given in Table 3 are to be applied for the selection of strakes to be considered as shown in Figure 18.

The maximum corrosion addition within a strake is to be applied according to Ch 3, Sec 3, [1.2.4].

Table 3 : Strake considered in a given EPP

	$a/b > 2$	$a/b \leq 2$
$a_1 > b/2$	All strakes (St1, St2, St3, St4)	All strakes (St1, St2, St3, St4)
$a_1 \leq b/2$	Strakes St2 and St4	All strakes (St1, St2, St3, St4)

Figure 18 : Strake considered in a given EPP



where:

a_1 : Distance, in mm, measured inside the considered strake in the direction of the long edge of the EPP, between the strake boundary weld seam and the EPP edge.

2.1.3

For direct strength assessment, the EPP is idealised with the mesh arrangement in the finite element model.

2.2 Load calculation point

2.2.1 Yielding

For the yielding check, the local pressure and hull girder stress, used for the calculation of the local scantling requirements are to be taken at the Load Calculation Point (LCP) having coordinates *x*, *y* and *z* as defined in Table 4.

Table 4 : LCP coordinates for yielding

LCP coordinates	General (1)		Horizontal plating		Vertical transverse structure and transverse stool plating	
	Longitudinal framing (Figure 19)	Transverse framing (Figure 20)	Longitudinal framing	Transverse framing	Horizontal framing (Figure 21)	Vertical framing (Figure 22)
x coordinate	Mid-length of the EPP		Mid-length of the EPP		Corresponding to *y* and *z* values	
y coordinate	Corresponding to *x* and *z* coordinates		Outboard *y* value of the EPP		Outboard *y* value of the EPP, taken at *z* level	
z coordinate	Lower edge of the EPP	The greater of lower edge of the EPP or lower edge of the strake	Corresponding to *x* and *y* values		Lower edge of the EPP	The greater of lower edge of the EPP or lower edge of the strake
(1) All structures other than horizontal platings or vertical transverse structures.						

Figure 19 : Load calculation point (LCP) for longitudinal framing

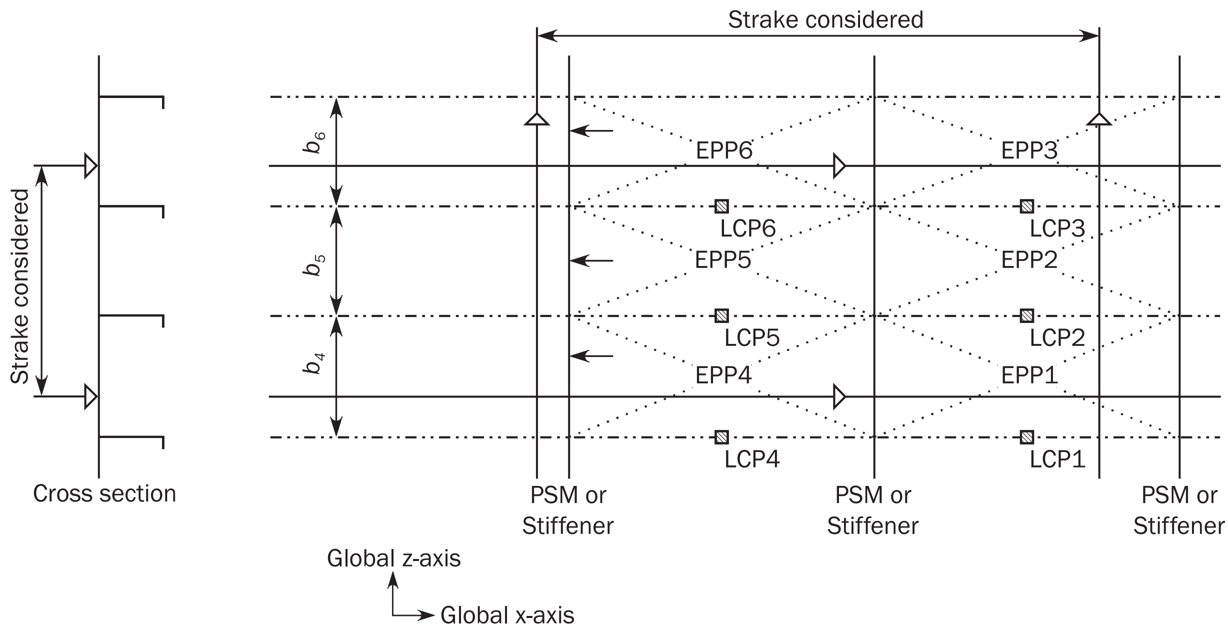


Figure 20 : Load calculation point for transverse framing

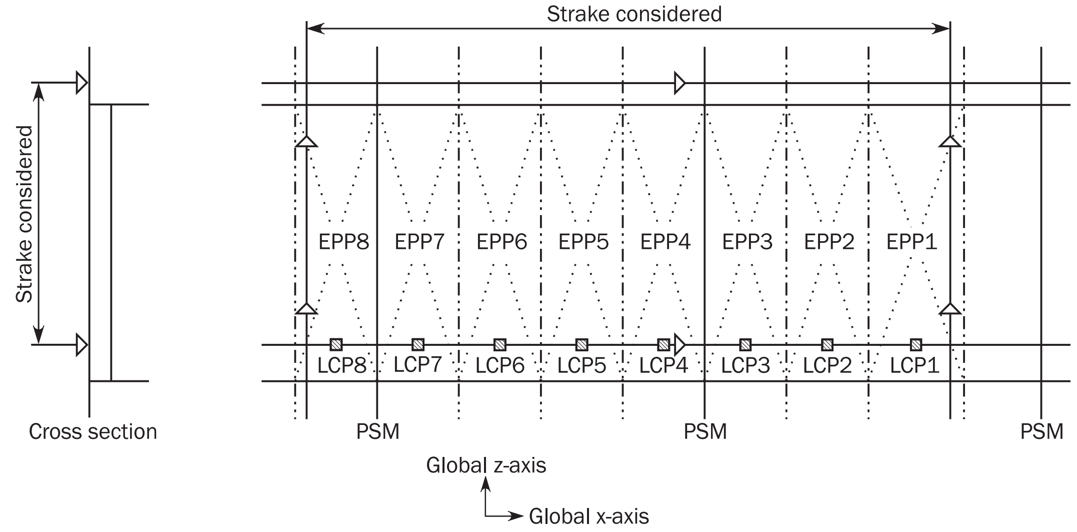


Figure 21 : Load calculation point for horizontal framing on transverse vertical structure

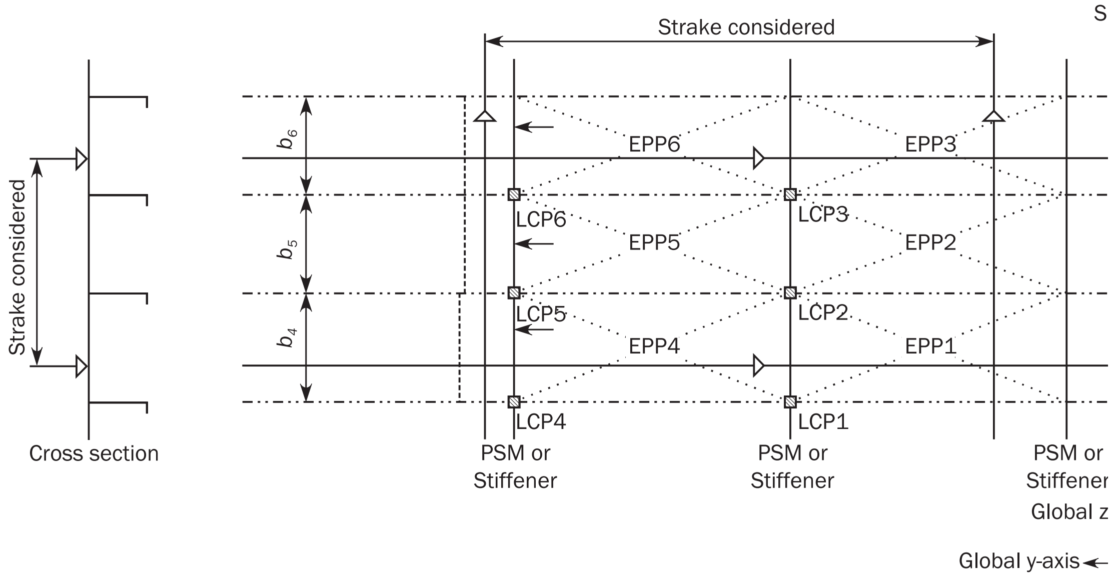
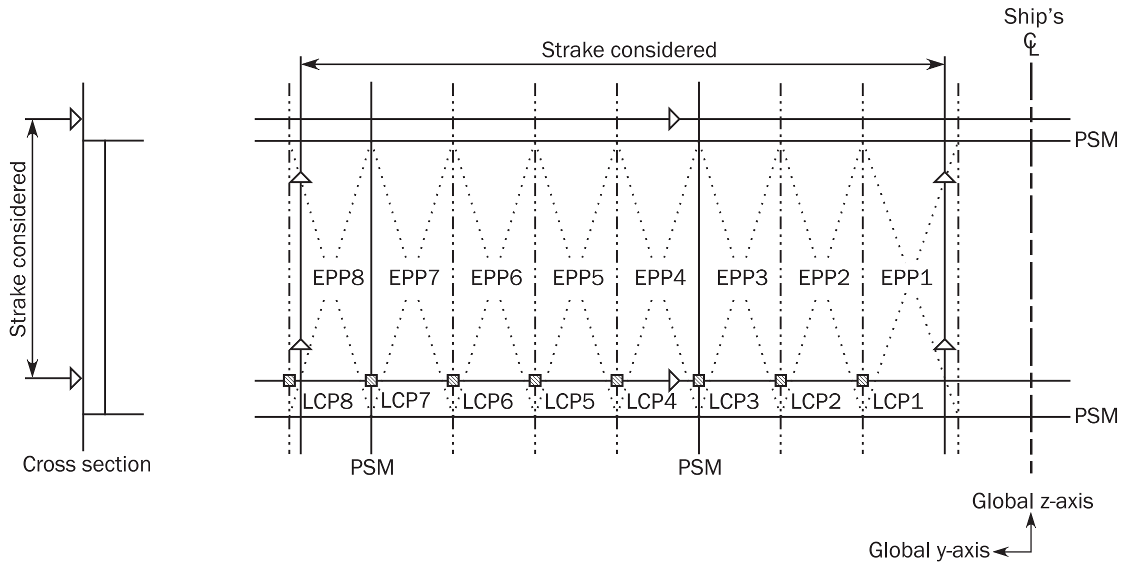


Figure 22 : Load calculation point for vertical framing on transverse vertical structure



2.2.2 Buckling

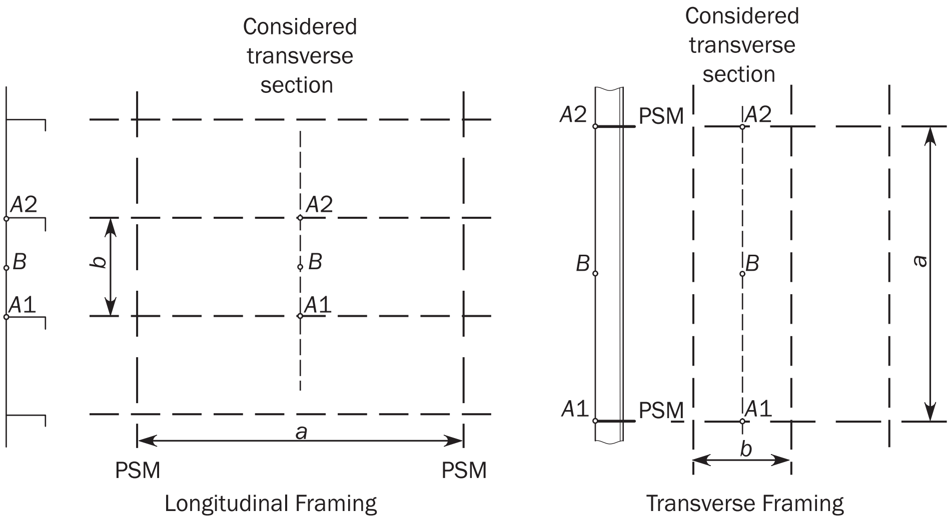
For the prescriptive buckling check of the EPP according to Ch 8, Sec 3, the LCP for the pressure and for the hull girder stresses are defined in Table 5.

For the FE buckling check, Ch 8, Sec 4 is applicable.

Table 5 : LCP coordinates for plate buckling

LCP coordinates	LCP for pressure	LCP for hull girder stresses (Figure 23)		
		Bending stresses		Shear stresses
		Non horizontal plate	Horizontal plate	
x coordinate	Same coordinates as LCP for yielding See Table 4	Mid-length of the EPP		
y coordinate		Both upper and lower ends of the EPP (points A1 and A2)	Outboard and inboard ends of the EPP (points A1 and A2)	Mid-point of EPP (point B)
z coordinate		Corresponding to *x* and *y* values		

Figure 23 : LCP for plate buckling – hull girder stresses



3 STIFFENERS

3.1 Reference point

3.1.1

The requirements of section modulus for stiffeners relate to the reference point giving the minimum section modulus. This reference point is generally located as shown in Figure 24 for typical profiles.

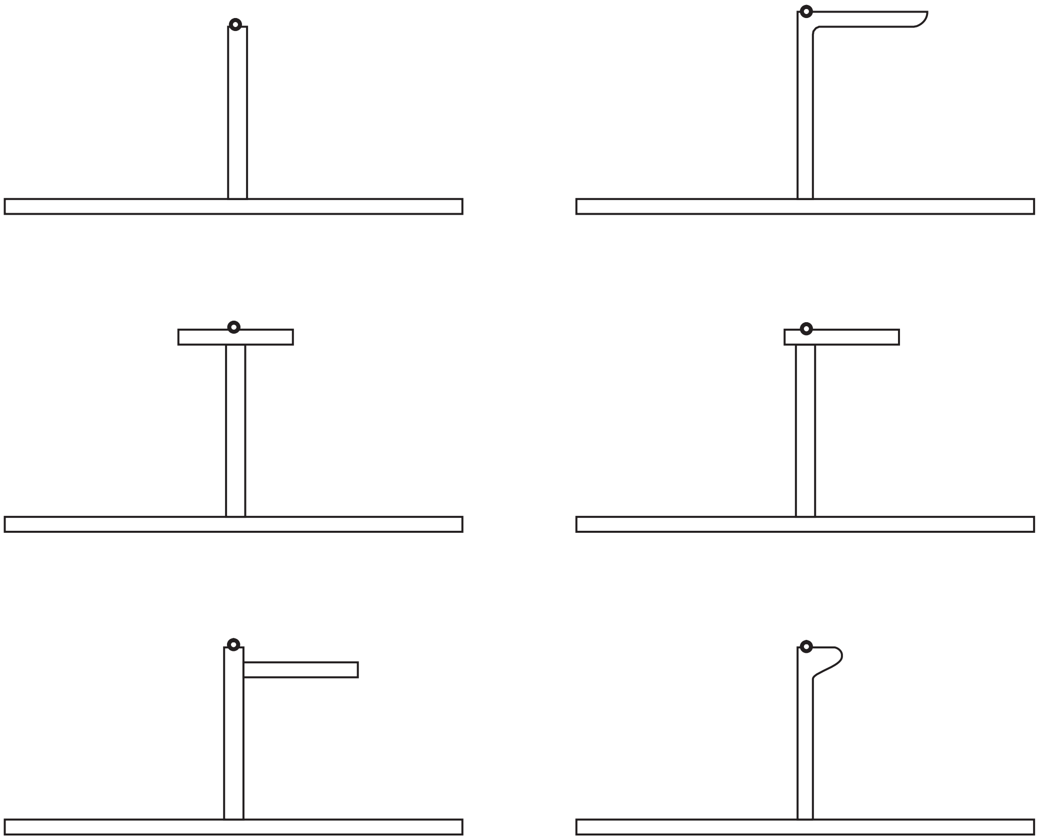
3.2 Load calculation points

3.2.1 LCP for Pressure

The load calculation point for the pressure is located at:

- Middle of the full length, ℓ, of the considered stiffener.
- The intersection point between the stiffener and its attached plate.

Figure 24 : Reference point for calculation of section modulus and hull girder stress for local scantling assessment



3.2.2 LCP for hull girder bending stress

The load calculation point for the hull girder bending stresses is defined as follows:

- For yielding verification according Ch 6:
  - At the middle of the full length, ℓ, of the considered stiffener.
  - At the reference point given in Figure 24.
- For prescriptive buckling requirements according to Ch 8:
  - At the middle of the full length, ℓ, of the considered stiffener.
  - At the intersection point between the stiffener and its attached plate.

3.2.3 Non-horizontal stiffeners

The lateral pressure, P is to be calculated as the maximum between the value obtained at middle of the full length, ℓ, and the value obtained from the following formulae:

$P = \frac{p_U + p_L}{2}$ when the upper end of the vertical stiffener is below the lowest zero pressure level.

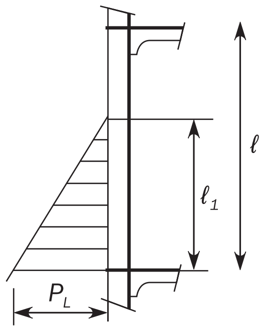
$P = \frac{\ell_1}{\ell}\frac{p_L}{2}$ when the upper end of the vertical stiffener is at or above the lowest zero pressure level, see Figure 25.

where:

ℓ_1 : Distance, in m, between the lower end of vertical stiffener and the lowest zero pressure level.

P_U, P_L : Lateral pressures at the upper and lower end of the vertical stiffener span ℓ, respectively.

Figure 25 : Definition of pressure for vertical stiffeners



4 PRIMARY SUPPORTING MEMBERS

4.1 Load calculation point

4.1.1

The load calculation point is located at the middle of the full length, *S*, at the attachment point of the primary supporting member with its attached plate.

PART 1 CHAPTER 4

LOADS

Table of Contents

SECTION 1
INTRODUCTION

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

S : Static load case.

S+D : Static plus dynamic load case.

1 GENERAL

1.1 Application

1.1.1 Scope

This chapter provides the design load for strength and fatigue assessments.

The load combinations are to be derived for the design load scenarios specified in Ch 4, Sec 7. This section uses the concept of design load scenarios to specify consistent design load sets which cover the appropriate operating modes of a bulk carrier or oil tanker.

1.1.2 Equivalent Design Wave EDW

The dynamic loads associated with each dynamic load case are based on the Equivalent Design Wave (EDW) concept. The EDW concept applies a consistent set of dynamic loads to the ship such that specified dominant load response is equivalent to the required long term response value.

1.1.3 Probability level for strength and fatigue assessments

In this chapter, the assessments are to be understood as follows:

- Strength assessment means the assessment for the strength criteria excluding fatigue, for the loads corresponding to the probability level of 10^{-8}, for the ballast water exchange, for harbour conditions and for flooded conditions.
- Fatigue assessment means the assessment for the fatigue criteria for the loads corresponding to the probability level of 10^{-2}.

1.1.4 Dynamic load components

All dynamic load components are to be concurrent values calculated for each dynamic load case.

1.1.5 Loads for strength assessment

The strength assessment is to be undertaken for all design load scenarios and the final assessment is to be made on the most onerous strength requirement.

Each design load scenario for strength assessment is composed of a Static (S) load case or a Static + Dynamic (S+D) load case, where the static and dynamic loads are dependent on the loading condition being considered.

The static loads are defined in the following sections:

- Still water hull girder loads in Ch 4, Sec 4.
- External loads in Ch 4, Sec 5.

- Internal loads in Ch 4, Sec 6.

The EDWs for the strength assessment and the dynamic load combination factors for global loads are listed in Ch 4, Sec 2, [2].

The dynamic load components are defined in the following sections:

- Dynamic hull girder load components in Ch 4, Sec 4.
- External loads in Ch 4, Sec 5.
- Internal loads in Ch 4, Sec 6.

1.1.6 Loads for fatigue assessment

Each design load scenario for fatigue assessment is composed of a Static + Dynamic (S+D) load case, where the static and dynamic loads are dependent on the loading condition being considered.

The static loads are defined in the following sections:

- Still water hull girder loads in Ch 4, Sec 4.
- External loads in Ch 4, Sec 5.
- Internal loads in Ch 4, Sec 6.

The EDWs for the fatigue assessment are listed in Ch 4, Sec 2, [3].

The dynamic load components are defined in the following sections:

- Dynamic hull girder load components in Ch 4, Sec 4.
- External loads in Ch 4, Sec 5.
- Internal loads in Ch 4, Sec 6.

1.2 Definitions

1.2.1 Coordinate system

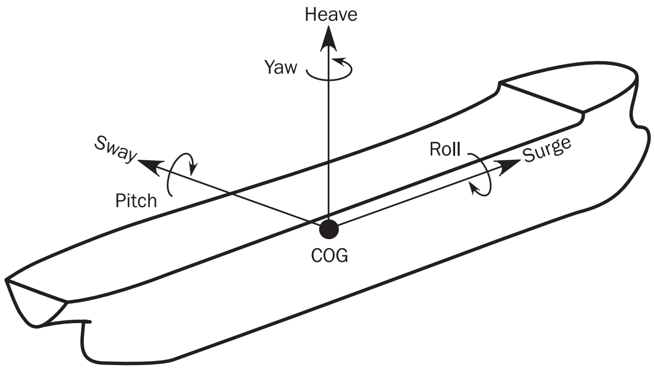
The coordinate system is defined in Ch 1, Sec 4, [3.6.1].

1.2.2 Sign convention for ship motions

The ship motions are defined with respect to the ship's centre of gravity (COG) as shown in Figure 1, where:

- Positive surge is translation in the *X*-axis direction (positive forward).
- Positive sway is translation in the *Y*-axis direction (positive towards port side of ship).
- Positive heave is translation in the *Z*-axis direction (positive upwards).
- Positive roll motion is positive rotation about a longitudinal axis through the COG (starboard down and port up).
- Positive pitch motion is positive rotation about a transverse axis through the COG (bow down and stern up).
- Positive yaw motion is positive rotation about a vertical axis through the COG (bow moving to port and stern to starboard).

Figure 1 : Definition of positive motions

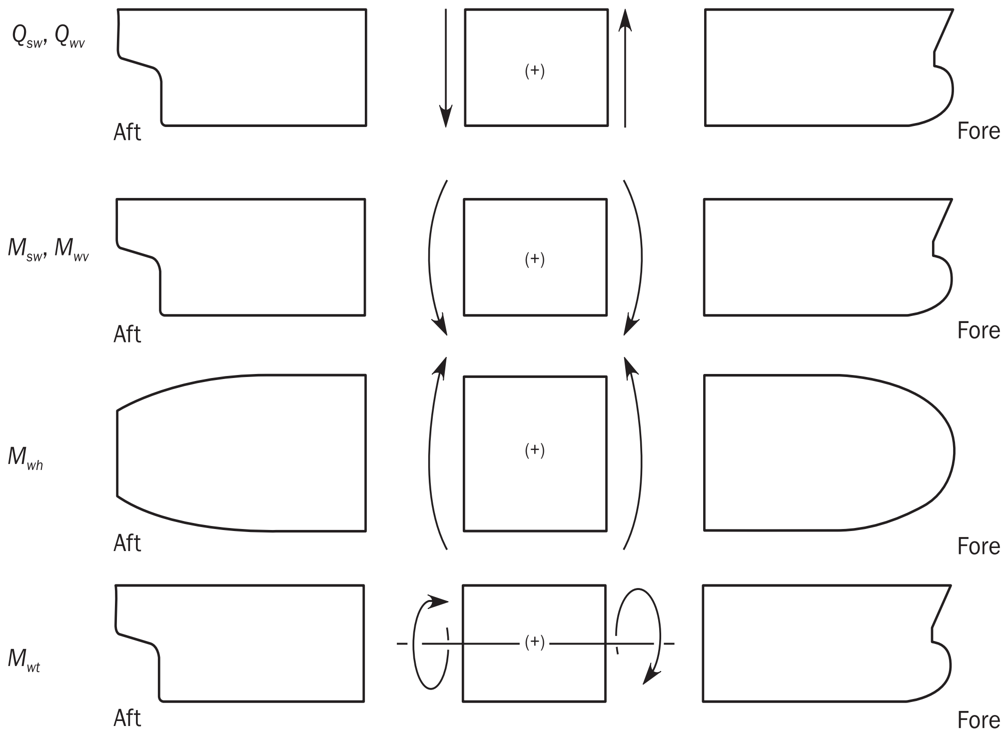


1.2.3 Sign convention for hull girder loads

The sign conventions of vertical bending moments, vertical shear forces, horizontal bending moments and torsional moments at any ship transverse section are as shown in Figure 2, namely:

- The vertical bending moments M_{sw} and M_{wv} are positive when they induce tensile stresses in the strength deck (hogging bending moment) and negative when they induce tensile stresses in the bottom (sagging bending moment).
- The vertical shear forces Q_{sw}, Q_{wv} are positive in the case of downward resulting forces acting aft of the transverse section and upward resulting forces acting forward of the transverse section under consideration.
- The horizontal bending moment M_{wh} is positive when it induces tensile stresses in the starboard side and negative when it induces tensile stresses in the port side.
- The torsional moment M_{wt} is positive in the case of resulting moment acting aft of the transverse section following negative rotation around the *X*-axis, and of resulting moment acting forward of the transverse section following positive rotation around the *X*-axis.

Figure 2 : Sign conventions for shear forces Q_{sw}, Q_{wv} and bending moments M_{sw}, M_{wv}, M_{wh} and M_{wt}



SECTION 2
DYNAMIC LOAD CASES

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

a_{surge}, $a_{pitch\text{-}x}$, a_{sway}, $a_{roll\text{-}y}$, a_{heave}, $a_{roll\text{-}z}$, $a_{pitch\text{-}z}$: Acceleration components, as defined in Ch 4, Sec 3.

f_{xL} : Ratio between X-coordinate of the load point and L, to be taken as:

$$f_{xL} = \frac{x}{L}$$, but not to be taken less than 0.0 or greater than 1.0.

f_T : Ratio between draught at a loading condition and scantling draught, as defined in Ch 4, Sec 3.

f_{lp} : Factor depending on longitudinal position along the ship, to be taken as:

$f_{lp} = 1.0$ for $x/L \le 0.5$
$f_{lp} = -1.0$ for $0.5 < x/L$

$f_{lp\text{-}OST}$: Factor for the longitudinal distribution of the torsional moment for the OST load case, to be taken as:

$f_{lp\text{-}OST} = 5\, f_{xL}$ for $x/L < 0.2$
$f_{lp\text{-}OST} = 1.0$ for $0.2 \le x/L < 0.4$
$f_{lp\text{-}OST} = -7.6\, f_{xL} + 4.04$ for $0.4 \le x/L < 0.65$
$f_{lp\text{-}OST} = -0.9$ for $0.65 \le x/L < 0.85$
$f_{lp\text{-}OST} = 6\, f_{xL} - 6$ for $0.85 \le x/L$

$f_{lp\text{-}OSA}$: Factor for the longitudinal distribution of the torsional moment for the OSA load case, to be taken as:

$f_{lp\text{-}OSA} = -(0.2 + 0.3\, f_T)$ for $x/L < 0.4$
$f_{lp\text{-}OSA} = -(0.2 + 0.3\, f_T)(5.6 - 11.5\, f_{xL})$ for $0.4 \le x/L < 0.6$
$f_{lp\text{-}OSA} = 1.3(0.2 + 0.3\, f_T)$ for $0.6 \le x/L$

WS : Weather side, side of the ship exposed to the incoming waves.

LS : Lee side, sheltered side of the ship away from the incoming waves.

M_{WV} : Vertical wave bending moment, in kNm, defined in Ch 4, Sec 4.

Q_{WV} : Vertical wave shear force, in kN, defined in Ch 4, Sec 4.

M_{WH} : Horizontal wave bending moment, in kNm, defined in Ch 4, Sec 4.

M_{WT} : Torsional wave bending moment, in kNm, defined in Ch 4, Sec 4.

C_{WV} : Load combination factor to be applied to the vertical wave bending moment.

C_{QW} : Load combination factor to be applied to the vertical wave shear force.

C_{WH} : Load combination factor to be applied to the horizontal wave bending moment.

C_{WT} : Load combination factor to be applied to the wave torsional moment.

C_{XS} : Load combination factor to be applied to the surge acceleration.

C_{XP} : Load combination factor to be applied to the longitudinal acceleration due to pitch.

C_{XG} : Load combination factor to be applied to the longitudinal acceleration due to pitch motion.

C_{YS} : Load combination factor to be applied to the sway acceleration.

C_{YR} : Load combination factor to be applied to the transverse acceleration due to roll.

C_{YG} : Load combination factor to be applied to the transverse acceleration due to roll motion.

C_{ZH} : Load combination factor to be applied to the heave acceleration.

C_{ZR} : Load combination factor to be applied to the vertical acceleration due to roll.

C_{ZP} : Load combination factor to be applied to the vertical acceleration due to pitch.

θ : Roll angle, in deg, as defined in Ch 4, Sec 3, [2.1.1].

φ : Pitch angle, in deg, as defined in Ch 4, Sec 3, [2.1.2].

1 GENERAL

1.1 Definition of dynamic load cases

1.1.1

The following Equivalent Design Waves (EDW) are to be used to generate the dynamic load cases for structural assessment:

- HSM load cases:

  HSM-1 and HSM-2: Head sea EDWs that minimise and maximise the vertical wave bending moment amidships respectively.

- HSA load cases:

  HSA-1 and HSA-2: Head sea EDWs that maximise and minimise the head sea vertical acceleration at FP respectively.

- FSM load cases:

  FSM-1 and FSM-2: Following sea EDWs that minimise and maximise the vertical wave bending moment amidships respectively.

- BSR load cases:

  BSR-1P and BSR-2P: Beam sea EDWs that minimise and maximise the roll motion downward and upward on the port side respectively with waves from the port side.

  BSR-1S and BSR-2S: Beam sea EDWs that maximise and minimise the roll motion downward and upward on the starboard side respectively with waves from the starboard side.

- BSP load cases:

  BSP-1P and BSP-2P: Beam sea EDWs that maximise and minimise the hydrodynamic pressure at the waterline amidships on the port side respectively.

  BSP-1S and BSP-2S: Beam sea EDWs that maximise and minimise the hydrodynamic pressure at the waterline amidships on the starboard side respectively.

- OST load cases:

  OST-1P and OST-2P: Oblique sea EDWs that minimise and maximise the torsional moment at 0.25*L* from the AE with waves from the port side respectively.

  OST-1S and OST-2S: Oblique sea EDWs that maximise and minimise the torsional moment at 0.25*L* from the AE with waves from the starboard side respectively.

- OSA load cases:

  OSA-1P and OSA-2P: Oblique sea EDWs that maximise and minimise the pitch acceleration with waves from the port side respectively.

  OSA-1S and OSA-2S: Oblique sea EDWs that maximise and minimise the pitch acceleration with waves from the starboard side respectively.

Note 1: 1 and 2 denote the maximum or the minimum dominate load component for each EDW.

Note 2: P and S denote that the weather side is on port side and on starboard side respectively.

HSA and OSA load cases are not to be used for fatigue assessment.

1.2 Application

1.2.1

The dynamic load cases described in this section are to be used for determining the dynamic loads required by the design load scenarios described in Ch 4, Sec 7. These dynamic load cases are to be applied to the following structural assessments:

a) Strength assessment:

- For plating, ordinary stiffeners and primary supporting members by prescriptive methods.
- For the direct strength method (FE analysis) assessment of structural members.

b) Fatigue assessment:

- For structural details covered by simplified stress analysis.
- For structural details covered by FE stress analysis.

2 DYNAMIC LOAD CASES FOR STRENGTH ASSESSMENT

2.1 Description of dynamic load cases

2.1.1

Table 1 to Table 3 describe the ship motions responses and the global loads corresponding to each dynamic load case to be considered for the strength assessment.

Table 1 : Ship responses for HSM, HSA and FSM load cases - Strength assessment

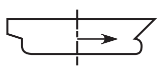
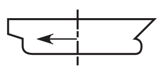
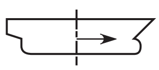
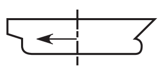
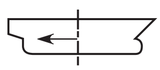
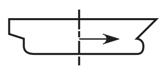
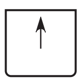
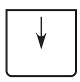
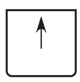
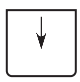
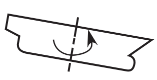
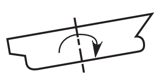
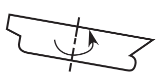
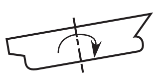
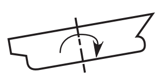
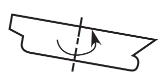
Loadcase	HSM-1	HSM-2	HSA-1	HSA-2	FSM-1	FSM-2
EDW	HSM		HSA		FSM	
Heading	Head		Head		Following	
Effect	Max. bending moment		Max. vertical acceleration		Max. bending moment	
VWBM	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging
VWSF	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore
HWBM	-	-	-	-	-	-
TM	-	-	-	-	-	-
Surge	To stern	To bow	To stern	To bow	To bow	To stern
a_{surge}						
Sway	-	-	-	-	-	-
a_{sway}	-	-	-	-	-	-
Heave	Down	Up	Down	Up	-	-
a_{heave}					-	-
Roll	-	-	-	-	-	-
a_{roll}	-	-	-	-	-	-
Pitch	Bow down	Bow up	Bow down	Bow up	Bow up	Bow down
a_{pitch}						

Table 2 : Ship responses for BSR and BSP load cases - Strength assessment

Load case	BSR-1P	BSR-2P	BSR-1S	BSR-2S	BSP-1P	BSP-2P	BSP-1S	BSP-2S
EDW	BSR		BSR		BSP		BSP	
Heading	Beam				Beam			
Effect	Max. roll				Max. pressure at waterline			
VWBM	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging
VWSF	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore
HWBM	Stbd tensile	Port tensile	Port tensile	Stbd tensile	Stbd tensile	Port tensile	Port tensile	Stbd tensile
TM	-	-	-	-	-	-	-	-
Surge	-	-	-	-	-	-	-	-
a_{surge}	-	-	-	-	-	-	-	-
Sway	To starboard	To portside	To portside	To starboard	To portside	To starboard	To starboard	To portside
a_{sway}	W.S L.S	W.S L.S	L.S W.S	L.S W.S	W.S L.S	W.S L.S	L.S W.S	L.S W.S
Heave	Down	Up	Down	Up	Down	Up	Down	Up
a_{heave}	W.S L.S	W.S L.S	L.S W.S	L.S W.S	W.S L.S	W.S L.S	L.S W.S	L.S W.S
Roll	Portside down	Portside up	Starboard down	Starboard up	Portside down	Portside up	Starboard down	Starboard up
a_{roll}	W.S L.S	W.S L.S	L.S W.S	L.S W.S	W.S L.S	W.S L.S	L.S W.S	L.S W.S
Pitch	-	-	-	-	Bow down	Bow up	Bow down	Bow up
a_{pitch}	-	-	-	-				

Table 3 : Ship responses for OST and OSA load cases - Strength assessment

Load case	OST-1P	OST-2P	OST-1S	OST-2S	OSA-1P	OSA-2P	OSA-1S	OSA-2S
EDW	OST				OSA			
Heading	Oblique				Oblique			
Effect	Max. torsional moment				Max. pitch acceleration			
VWBM	Sagging	Hogging	Sagging	Hogging	Hogging	Sagging	Hogging	Sagging
VWSF	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore
HWBM	Port tensile	Stbd tensile	Stbd tensile	Port tensile	Stbd tensile	Port tensile	Port tensile	Stbd tensile
TM								
Surge	To bow	To stern	To bow	To stern	To bow	To stern	To bow	To stern
a_{surge}								
Sway	-	-	-	-	To portside	To starboard	To starboard	To portside
a_{sway}	-	-	-	-	W.S L.S	W.S L.S	L.S W.S	L.S W.S
Heave	Down	Up	Down	Up	Up	Down	Up	Down
a_{heave}	W.S L.S	W.S L.S	L.S W.S	L.S W.S	W.S L.S	W.S L.S	L.S W.S	L.S W.S
Roll	Portside down	Portside up	Starboard down	Starboard up	Portside down	Portside up	Starboard down	Starboard up
a_{roll}	W.S L.S	W.S L.S	L.S W.S	L.S W.S	W.S L.S	W.S L.S	L.S W.S	L.S W.S
Pitch	Bow up	Bow down	Bow up	Bow down	Bow up	Bow down	Bow up	Bow down
a_{pitch}								

2.2 Load combination factors

2.2.1

The load combinations factors, LCFs for the global loads and inertia load components for strength assessment are defined in:

Table 4 : LCFs for HSM, HSA and FSM load cases.

Table 5 : LCFs for BSR and BSP load cases.

Table 6 : LCFs for OST and OSA load cases.

Table 4 : Load combination factors, LCFs for HSM, HSA and FSM load cases - Strength assessment

Load component		LCF	HSM-1	HSM-2	HSA-1	HSA-2	FSM-1	FSM-2
Hull girder loads	M_{WV}	C_{WV}	-1	1	-0.7	0.7	$-0.4f_T - 0.6$	$0.4f_T + 0.6$
	Q_{WV}	C_{QW}	$-1.0f_{lp}$	$1.0f_{lp}$	$-0.6f_{lp}$	$0.6f_{lp}$	$-1.0f_{lp}$	$1.0f_{lp}$
	M_{WH}	C_{WH}	0	0	0	0	0	0
	M_{WT}	C_{WT}	0	0	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	$0.3 - 0.2f_T$	$0.2f_T - 0.3$	0.2	-0.2	$0.2 - 0.4f_T$	$0.4f_T - 0.2$
	$a_{pitch-x}$	C_{XP}	-0.7	0.7	$-0.4f_T - 0.4$	$0.4f_T + 0.4$	0.15	-0.15
	$g\sin\varphi$	C_{XG}	0.6	-0.6	$0.4f_T + 0.4$	$-0.4f_T - 0.4$	-0.2	0.2
Transverse accelerations	a_{sway}	C_{YS}	0	0	0	0	0	0
	a_{roll-y}	C_{YR}	0	0	0	0	0	0
	$g\sin\theta$	C_{YG}	0	0	0	0	0	0
Vertical accelerations	a_{heave}	C_{ZH}	$0.5f_T - 0.15$	$0.15 - 0.5f_T$	$0.4f_T - 0.1$	$0.1 - 0.4f_T$	0	0
	a_{roll-z}	C_{ZR}	0	0	0	0	0	0
	$a_{pitch-z}$	C_{ZP}	-0.7	0.7	$-0.4f_T - 0.4$	$0.4f_T + 0.4$	0.15	-0.15

Table 5 : Load combination factors, LCFs for BSR and BSP load cases - Strength assessment

Load component		LCF	BSR-1P	BSR-2P	BSR-1S	BSR-2S
Hull girder loads	M_{WV}	C_{WV}	$0.1 - 0.2f_T$	$0.2f_T - 0.1$	$0.1 - 0.2f_T$	$0.2f_T - 0.1$
	Q_{WV}	C_{QW}	$(0.1 - 0.2f_T)\ f_{lp}$	$(0.2f_T - 0.1)\ f_{lp}$	$(0.1 - 0.2f_T)\ f_{lp}$	$(0.2f_T - 0.1)\ f_{lp}$
	M_{WH}	C_{WH}	$1.2 - 1.1f_T$	$1.1f_T - 1.2$	$1.1f_T - 1.2$	$1.2 - 1.1f_T$
	M_{WT}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	0	0	0	0
	$a_{pitch-x}$	C_{XP}	0	0	0	0
	$g\sin\varphi$	C_{XG}	0	0	0	0
Transverse accelerations	a_{sway}	C_{YS}	$0.2 - 0.2f_T$	$0.2f_T - 0.2$	$0.2f_T - 0.2$	$0.2 - 0.2f_T$
	a_{roll-y}	C_{YR}	1	-1	-1	1
	$g\sin\theta$	C_{YG}	-1	1	1	-1
Vertical accelerations	a_{heave}	C_{ZH}	$0.7 - 0.4f_T$	$0.4f_T - 0.7$	$0.7 - 0.4f_T$	$0.4f_T - 0.7$
	a_{roll-z}	C_{ZR}	1	-1	-1	1
	$a_{pitch-z}$	C_{ZP}	0	0	0	0

Load component		LCF	BSP-1P	BSP-2P	BSP-1S	BSP-2S
Hull girder loads	M_{WV}	C_{WV}	$0.3 - 0.8f_T$	$0.8f_T - 0.3$	$0.3 - 0.8f_T$	$0.8f_T - 0.3$
	Q_{WV}	C_{QW}	$(0.3 - 0.8f_T)\ f_{lp}$	$(0.8f_T - 0.3)\ f_{lp}$	$(0.3 - 0.8f_T)\ f_{lp}$	$(0.8f_T - 0.3)\ f_{lp}$
	M_{WH}	C_{WH}	$0.7 - 0.7f_T$	$0.7f_T - 0.7$	$0.7f_T - 0.7$	$0.7 - 0.7f_T$
	M_{WT}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	0	0	0	0
	$a_{pitch-x}$	C_{XP}	$0.1 - 0.3f_T$	$0.3f_T - 0.1$	$0.1 - 0.3f_T$	$0.3f_T - 0.1$
	$g\sin\varphi$	C_{XG}	$0.3f_T - 0.1$	$0.1 - 0.3f_T$	$0.3f_T - 0.1$	$0.1 - 0.3f_T$
Transverse accelerations	a_{sway}	C_{YS}	-0.9	0.9	0.9	-0.9
	a_{roll-y}	C_{YR}	0.3	-0.3	-0.3	0.3
	$g\sin\theta$	C_{YG}	-0.2	0.2	0.2	-0.2
Vertical accelerations	a_{heave}	C_{ZH}	1	-1	1	-1
	a_{roll-z}	C_{ZR}	0.3	-0.3	-0.3	0.3
	$a_{pitch-z}$	C_{ZP}	$0.1 - 0.3f_T$	$0.3f_T - 0.1$	$0.1 - 0.3f_T$	$0.3f_T - 0.1$

Table 6 : Load combination factors, LCFs for OST and OSA load cases - Strength assessment

Load component		LCF	OST-1P	OST-2P	OST-1S	OST-2S
Hull girder loads	M_{WV}	C_{WV}	$-0.3 - 0.2f_T$	$0.3 + 0.2f_T$	$-0.3 - 0.2f_T$	$0.3 + 0.2f_T$
	Q_{WV}	C_{QW}	$(-0.35-0.2f_T)\ f_{lp}$	$(0.35+0.2f_T)\ f_{lp}$	$(-0.35-0.2f_T)\ f_{lp}$	$(0.35+0.2f_T)\ f_{lp}$
	M_{WH}	C_{WH}	-0.9	0.9	0.9	-0.9
	M_{WT}	C_{WT}	$-f_{lp-OST}$	f_{lp-OST}	f_{lp-OST}	$-f_{lp-OST}$
Longitudinal accelerations	a_{surge}	C_{XS}	$0.1f_T - 0.15$	$0.15 - 0.1f_T$	$0.1f_T - 0.15$	$0.15 - 0.1f_T$
	$a_{pitch-x}$	C_{XP}	$0.7 - 0.3f_T$	$0.3f_T - 0.7$	$0.7 - 0.3f_T$	$0.3f_T - 0.7$
	$g\sin\varphi$	C_{XG}	$0.2f_T - 0.45$	$0.45 - 0.2f_T$	$0.2f_T - 0.45$	$0.45 - 0.2f_T$
Transverse accelerations	a_{sway}	C_{YS}	0	0	0	0
	a_{roll-y}	C_{YR}	$0.4f_T - 0.25$	$0.25 - 0.4f_T$	$0.25 - 0.4f_T$	$0.4f_T - 0.25$
	$g\sin\theta$	C_{YG}	$0.1 - 0.2f_T$	$0.2f_T - 0.1$	$0.2f_T - 0.1$	$0.1 - 0.2f_T$
Vertical accelerations	a_{heave}	C_{ZH}	$0.2f_T - 0.05$	$0.05 - 0.2f_T$	$0.2f_T - 0.05$	$0.05 - 0.2f_T$
	a_{roll-z}	C_{ZR}	$0.4f_T - 0.25$	$0.25 - 0.4f_T$	$0.25 - 0.4f_T$	$0.4f_T - 0.25$
	$a_{pitch-z}$	C_{ZP}	$0.7 - 0.3f_T$	$0.3f_T - 0.7$	$0.7 - 0.3f_T$	$0.3f_T - 0.7$

Load component		LCF	OSA-1P	OSA-2P	OSA-1S	OSA-2S
Hull girder loads	M_{WV}	C_{WV}	$0.75 - 0.5f_T$	$-0.75 + 0.5f_T$	$0.75 - 0.5f_T$	$-0.75 + 0.5f_T$
	Q_{WV}	C_{QW}	$(0.6-0.4f_T)\ f_{lp}$	$(-0.6+0.4f_T)\ f_{lp}$	$(0.6-0.4f_T)\ f_{lp}$	$(-0.6+0.4f_T)\ f_{lp}$
	M_{WH}	C_{WH}	$0.55 + 0.2f_T$	$-0.55 - 0.2f_T$	$-0.55 - 0.2f_T$	$0.55 + 0.2f_T$
	M_{WT}	C_{WT}	$-f_{lp-OSA}$	f_{lp-OSA}	f_{lp-OSA}	$-f_{lp-OSA}$
Longitudinal accelerations	a_{surge}	C_{XS}	$0.1f_T - 0.45$	$0.45 - 0.1f_T$	$-0.45 + 0.1f_T$	$0.45 - 0.1f_T$
	$a_{pitch-x}$	C_{XP}	1.0	- 1.0	1.0	- 1.0
	$g\sin\varphi$	C_{XG}	- 1.0	1.0	- 1.0	1.0
Transverse accelerations	a_{sway}	C_{YS}	$-0.2 - 0.1f_T$	$0.2 + 0.1f_T$	$0.2 + 0.1f_T$	$-0.2 - 0.1f_T$
	a_{roll-y}	C_{YR}	$0.3 - 0.2f_T$	$0.2f_T - 0.3$	$0.2f_T - 0.3$	$0.3 - 0.2f_T$
	$g\sin\theta$	C_{YG}	$0.1f_T - 0.2$	$0.2 - 0.1f_T$	$0.2 - 0.1f_T$	$0.1f_T - 0.2$
Vertical accelerations	a_{heave}	C_{ZH}	$-0.2f_T$	$0.2f_T$	$-0.2f_T$	$0.2f_T$
	a_{roll-z}	C_{ZR}	$0.3 - 0.2f_T$	$0.2f_T - 0.3$	$0.2f_T - 0.3$	$0.3 - 0.2f_T$
	$a_{pitch-z}$	C_{ZP}	1.0	- 1.0	1.0	- 1.0

3 DYNAMIC LOAD CASES FOR FATIGUE ASSESSMENT

3.1 Description of dynamic load cases

3.1.1

Table 7 to Table 9 define the ship motions responses and the global loads corresponding to each dynamic load case to be considered for fatigue assessment.

Table 7 : Ship responses for HSM and FSM load cases - Fatigue assessment

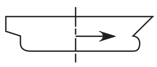
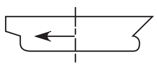
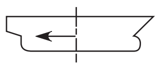
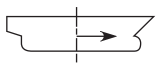
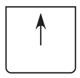
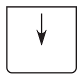
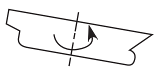
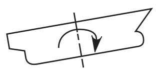
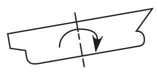
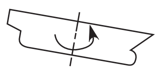
Load case	HSM-1	HSM-2	FSM-1	FSM-2
EDW	HSM		FSM	
Heading	Head		Following	
Effect	Max. bending moment		Max. bending moment	
VWBM	Sagging	Hogging	Sagging	Hogging
VWSF	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore
HWBM	-	-	-	-
TM	-	-	-	-
Surge	To stern	To bow	To bow	To stern
a_{surge}				
Sway	-	-	-	-
a_{sway}	-	-	-	-
Heave	Down	Up	-	-
a_{heave}			-	-
Roll	-	-	-	-
a_{roll}	-	-	-	-
Pitch	Bow down	Bow up	Bow up	Bow down
a_{pitch}				

Table 8 : Ship responses for BSR and BSP load cases - Fatigue assessment

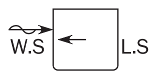
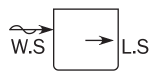
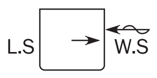
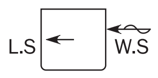
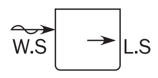
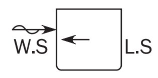
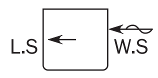
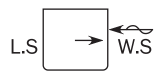
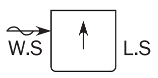
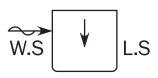
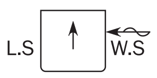
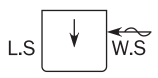
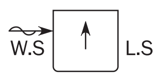
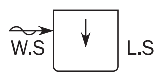
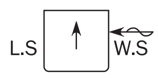
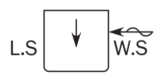
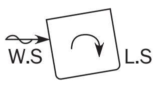
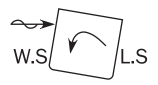
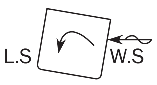
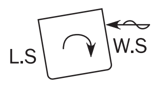
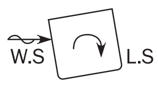
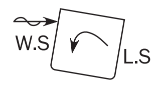
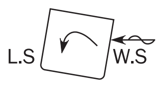
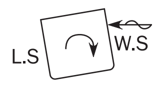
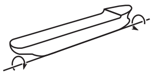
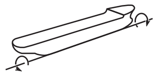
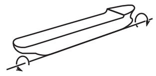
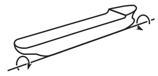
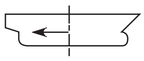
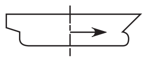
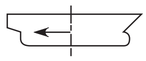
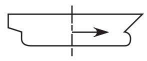
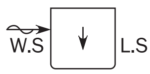
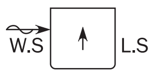
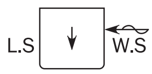
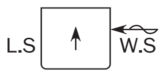
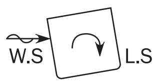
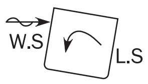
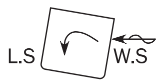
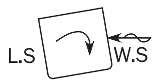
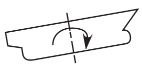
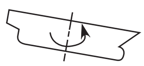
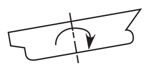
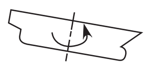
Load case	BSR-1P	BSR-2P	BSR-1S	BSR-2S	BSP-1P	BSP-2P	BSP-1S	BSP-2S
EDW	BSR		BSR		BSP		BSP	
Heading	Beam				Beam			
Effect	Max. roll				Max. pressure at waterline			
VWBM	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging
VWSF	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore
HWBM	Stbd tensile	Port tensile	Port tensile	Stbd tensile	Stbd tensile	Port tensile	Port tensile	Stbd tensile
TM	-	-	-	-	-	-	-	-
Surge	-	-	-	-	-	-	-	-
a_{surge}	-	-	-	-	-	-	-	-
Sway	To starboard	To portside	To portside	To starboard	To portside	To starboard	To starboard	To portside
a_{sway}								
Heave	Down	Up	Down	Up	Down	Up	Down	Up
a_{heave}								
Roll	Portside down	Portside up	Starboard down	Starboard up	Portside down	Portside up	Starboard down	Starboard up
a_{roll}								
Pitch	-	-	-	-	-	-	-	-
a_{pitch}	-	-	-	-	-	-	-	-

Table 9 : Ship responses for OST load cases - Fatigue assessment

Load case	OST-1P	OST-2P	OST-1S	OST-2S
EDW	OST			
Heading	Oblique			
Effect	Max. torsional moment			
VWBM	Sagging	Hogging	Sagging	Hogging
VWSF	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore
HWBM	Port tensile	Stbd tensile	Stbd tensile	Port tensile
TM				
Surge	To bow	To stern	To bow	To stern
a_{surge}				
Sway	-	-	-	-
a_{sway}	-	-	-	-
Heave	Up	Down	Up	Down
a_{heave}				
Roll	Portside down	Portside up	Starboard down	Starboard up
a_{roll}				
Pitch	Bow up	Bow down	Bow up	Bow down
a_{pitch}				

3.2 Load combination factors

3.2.1

The load combinations factors, LCFs for the global loads and inertial load components for fatigue assessment are defined in:

Table 10: LCFs for HSM and FSM load cases.

Table 11: LCFs for BSR and BSP load cases.

Table 12: LCFs for OST load case.

Table 10 : Load combination factors, LCFs for HSM and FSM load cases - Fatigue assessment

Load component		LCF	HSM-1	HSM-2	FSM-1	FSM-2
Hull girder loads	M_{WV}	C_{WV}	-1	1	$-0.75 - 0.2f_T$	$0.75 + 0.2f_T$
	Q_{WV}	C_{QW}	$-1.0\ f_{lp}$	$1.0\ f_{lp}$	$(-0.75-0.2f_T)\ f_{lp}$	$(0.75+0.2f_T)\ f_{lp}$
	M_{WH}	C_{WH}	0	0	0	0
	M_{WT}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	$0.3 - 0.2f_T$	$0.2f_T - 0.3$	$-0.4f_T + 0.2$	$0.4f_T - 0.2$
	$a_{pitch-x}$	C_{XP}	-0.9	0.9	0.1	-0.1
	$g\sin\varphi$	C_{XG}	$0.4f_T + 0.4$	$-0.4f_T - 0.4$	-0.15	0.15
Transverse accelerations	a_{sway}	C_{YS}	0	0	0	0
	a_{roll-y}	C_{YR}	0	0	0	0
	$g\sin\theta$	C_{YG}	0	0	0	0
Vertical accelerations	a_{heave}	C_{ZH}	$0.8f_T - 0.15$	$0.15 - 0.8f_T$	0	0
	a_{roll-z}	C_{ZR}	0	0	0	0
	$a_{pitch-z}$	C_{ZP}	-0.9	0.9	0.1	-0.1

Table 11 : Load combination factors, LCFs for BSR and BSP load cases - Fatigue assessment

Load component		LCF	BSR-1P	BSR-2P	BSR-1S	BSR-2S
Hull girder loads	M_{WV}	C_{WV}	$0.1 - 0.2f_T$	$0.2f_T - 0.1$	$0.1 - 0.2f_T$	$0.2f_T - 0.1$
	Q_{WV}	C_{QW}	$(0.1 - 0.2f_T)\ f_{lp}$	$(0.2f_T - 0.1)\ f_{lp}$	$(0.1 - 0.2f_T)\ f_{lp}$	$(0.2f_T - 0.1)\ f_{lp}$
	M_{WH}	C_{WH}	$1.1 - f_T$	$f_T - 1.1$	$f_T - 1.1$	$1.1 - f_T$
	M_{WT}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	0	0	0	0
	$a_{pitch-x}$	C_{XP}	0	0	0	0
	$g\sin\varphi$	C_{XG}	0	0	0	0
Transverse accelerations	a_{sway}	C_{YS}	$0.2 - 0.2f_T$	$0.2f_T - 0.2$	$0.2f_T - 0.2$	$0.2 - 0.2f_T$
	a_{roll-y}	C_{YR}	1	-1	-1	1
	$g\sin\theta$	C_{YG}	-1	1	1	-1
Vertical accelerations	a_{heave}	C_{ZH}	$0.7 - 0.4f_T$	$0.4f_T - 0.7$	$0.7 - 0.4f_T$	$0.4f_T - 0.7$
	a_{roll-z}	C_{ZR}	1	-1	-1	1
	$a_{pitch-z}$	C_{ZP}	0	0	0	0

Load component		LCF	BSP-1P	BSP-2P	BSP-1S	BSP-2S
Hull girder loads	M_{WV}	C_{WV}	$0.3 - 0.8f_T$	$0.8f_T - 0.3$	$0.3 - 0.8f_T$	$0.8f_T - 0.3$
	Q_{WV}	C_{QW}	$(0.3 - 0.8f_T)\ f_{lp}$	$(0.8f_T - 0.3)\ f_{lp}$	$(0.3 - 0.8f_T)\ f_{lp}$	$(0.8f_T - 0.3)\ f_{lp}$
	M_{WH}	C_{WH}	$0.6 - 0.6f_T$	$0.6f_T - 0.6$	$0.6f_T - 0.6$	$0.6 - 0.6f_T$
	M_{WT}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	0	0	0	0
	$a_{pitch-x}$	C_{XP}	0	0	0	0
	$g\sin\varphi$	C_{XG}	0	0	0	0
Transverse accelerations	a_{sway}	C_{YS}	-0.95	0.95	0.95	-0.95
	a_{roll-y}	C_{YR}	0.3	-0.3	-0.3	0.3
	$g\sin\theta$	C_{YG}	-0.2	0.2	0.2	-0.2
Vertical accelerations	a_{heave}	C_{ZH}	1	-1	1	-1
	a_{roll-z}	C_{ZR}	0.3	-0.3	-0.3	0.3
	$a_{pitch-z}$	C_{ZP}	0	0	0	0

Table 12 : Load combination factors, LCFs for OST load cases - Fatigue assessment

Load component		LCF	OST-1P	OST-2P	OST-1S	OST-2S
Hull girder loads	M_{WV}	C_{WV}	-0.4	0.4	-0.4	0.4
	Q_{WV}	C_{QW}	-0.4 f_{lp}	0.4 f_{lp}	-0.4 f_{lp}	0.4 f_{lp}
	M_{WH}	C_{WH}	-0.9	0.9	0.9	-0.9
	M_{WT}	C_{WT}	$-f_{lp\text{-}OST}$	$f_{lp\text{-}OST}$	$f_{lp\text{-}OST}$	$-f_{lp\text{-}OST}$
Longitudinal accelerations	a_{surge}	C_{XS}	$-0.25 + 0.2f_T$	$0.25 - 0.2f_T$	$-0.25 + 0.2f_T$	$0.25 - 0.2f_T$
	$a_{pitch\text{-}x}$	C_{XP}	$0.4 - 0.2f_T$	$-0.4 + 0.2f_T$	$0.4 - 0.2f_T$	$-0.4 + 0.2f_T$
	$g\sin\varphi$	C_{XG}	$-0.4 + 0.2f_T$	$0.4 - 0.2f_T$	$-0.4 + 0.2f_T$	$0.4 - 0.2f_T$
Transverse accelerations	a_{sway}	C_{YS}	0	0	0	0
	$a_{roll\text{-}y}$	C_{YR}	$-0.4 + 0.6f_T$	$0.4 - 0.6f_T$	$0.4 - 0.6f_T$	$-0.4 + 0.6f_T$
	$g\sin\theta$	C_{YG}	$0.2 - 0.3f_T$	$-0.2 + 0.3f_T$	$-0.2 + 0.3f_T$	$0.2 - 0.3f_T$
Vertical accelerations	a_{heave}	C_{ZH}	-0.05	0.05	-0.05	0.05
	$a_{roll\text{-}z}$	C_{ZR}	$-0.4 + 0.6f_T$	$0.4 - 0.6f_T$	$0.4 - 0.6f_T$	$-0.4 + 0.6f_T$
	$a_{pitch\text{-}z}$	C_{ZP}	$0.4 - 0.2f_T$	$-0.4 + 0.2f_T$	$0.4 - 0.2f_T$	$-0.4 + 0.2f_T$

SECTION 3
SHIP MOTIONS AND ACCELERATIONS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

a_0 : Acceleration parameter, to be taken as:

$$a_0 = (1.58 - 0.47C_B)\left(\frac{2.4}{\sqrt{L}} + \frac{34}{L} - \frac{600}{L^2}\right)$$

T_θ : Roll period, in s, as defined in [2.1.1].

θ : Roll angle, in deg, as defined in [2.1.1].

T_φ : Pitch period, in s, as defined in [2.1.2].

φ : Pitch angle, in deg, as defined in [2.1.2].

R : Vertical coordinate, in m, of the ship rotation centre, to be taken as:

$$R = \min\left(\frac{D}{4} + \frac{T_{LC}}{2}, \frac{D}{2}\right)$$

C_{XG}, C_{XS}, C_{XP}, C_{YG}, C_{YS}, C_{YR}, C_{ZH}, C_{ZR}, *and* C_{ZP}: Load combination factors, as defined in Ch 4, Sec 2.

$a_{roll\text{-}y}$: Transverse acceleration due to roll, in m/s^2, as defined in [3.3.2].

$a_{pitch\text{-}x}$: Longitudinal acceleration due to pitch, in m/s^2, as defined in [3.3.1].

$a_{roll\text{-}z}$: Vertical acceleration due to roll, in m/s^2, as defined in [3.3.3].

$a_{pitch\text{-}z}$: Vertical acceleration due to pitch, in m/s^2, as defined in [3.3.3].

f_T : Ratio between draught at a loading condition and scantling draught, to be taken as:

$$f_T = \frac{T_{LC}}{T_{SC}}$$ but is not to be taken less than 0.5.

T_{LC} : Draught, in m, amidships for the considered load case

x, y, z : X, Y and Z coordinates, in m, of the considered point with respect to the coordinate system, as defined in Ch 4, Sec 1, [1.2.1].

f_{ps} : Coefficient for strength assessments which is dependant on the applicable design load scenario specified in Ch 4, Sec 7, and to be taken as:

f_{ps} = 1.0 for extreme sea loads design load scenario.

f_{ps} = 0.8 for the ballast water exchange design load scenario.

f_{ps} = 0.8 for the accidental flooded design load scenario at sea.

f_{ps} = 0.4 for the harbour/sheltered water design load scenario.

f_{fa} : Fatigue coefficient to be taken as:

f_{fa} = 0.9

1 GENERAL

1.1 Definition

1.1.1

The ship motions and accelerations are assumed to be sinusoidal. The motion values defined by the formulae in this section are single amplitudes, i.e. half of the 'crest to trough' height.

2 SHIP MOTIONS AND ACCELERATIONS

2.1 Ship motions

2.1.1 Roll motion

The roll period T_θ, in s, to be taken as:

$$T_\theta = \frac{2.3\pi\ k_r}{\sqrt{g\ GM}}$$

The roll angle θ, in deg, to be taken as:

$$\theta = \frac{9000\,(1.25 - 0.025T_\theta)\ f_p\ f_{BK}}{(B + 75)\pi}$$

where:

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = f_{fa}(0.23 - 4f_T\ B \times 10^{-4})$ for fatigue assessment.

f_{BK} : To be taken as:

$f_{BK} = 1.2$ for ships without bilge keel.

$f_{BK} = 1.0$ for ships with bilge keel.

k_r : Roll radius of gyration, in m, in the considered loading condition. The values in Table 1 or Table 2 are to be adopted.

GM : Metacentric height, in m, in the considered loading condition. The values in Table 1 or Table 2 are to be adopted.

Table 1 : k_r and GM values for oil tankers

Loading condition (1) (2)	T_{LC}	k_r	GM
Full load condition	T_{SC}	$0.35B$	$0.12B$
Optional conditions that have a draught greater than $0.9T_{SC}$	Actual draught but ≥ $0.9T_{SC}$	$0.35B$	$0.12B$
Partial load condition	$\leq 0.6T_{SC}$	$0.40B$	$0.24B$
Ballast condition	T_{BAL}	$0.45B$	$0.33B$

(1) For optional loading conditions or gale/emergency ballast conditions with draught between $0.6T_{SC}$ and $0.9T_{SC}$, the values of k_r and GM, unless provided in the loading manual, are to be obtained by linear interpolation between the optional condition at $0.9T_{SC}$ and the partial load condition at $0.6T_{SC}$ based on the actual draught.

(2) For flooded loading conditions, the values of k_r and GM, unless provided in the loading manual, are to be taken as those for the full load condition.

Table 2 : k_r and GM values for bulk carriers

Loading condition (1) (2) (4)		Application	T_{LC}	k_r	GM
Full load condition	Homogeneous loading	All bulk carriers	T_{SC}	0.35B	0.12B
	Alternate heavy cargo	BC-A		0.40B	0.20B
	Alternate light cargo	BC-A		0.35B	0.12B
	Homogeneous heavy cargo	BC-B, BC-A		0.42B	0.25B
Steel coil loading (3)		All bulk carriers designated for the carriage of steel products		0.42B	0.25B
Heavy ballast condition		All bulk carriers	T_{BAL-H}	0.40B	0.25B
Normal ballast condition		All bulk carriers	T_{BAL}	0.45B	0.33B

(1) For Multi-port (MP) loading conditions with draught greater than or equal to $0.9T_{SC}$, the values of k_r and GM, unless provided in the loading manual, are to be taken as those from the most appropriate full load condition.
For Multi-port (MP) loading conditions with draught between T_{BAL-H} and $0.9T_{SC}$, the values of k_r and GM, unless provided in the loading manual, are to be obtained by linear interpolation, based on the draught, between the heavy ballast condition and the most appropriate full load condition.
For Multi-port (MP) loading conditions with a draught below T_{BAL-H}, the values of k_r and GM for the heavy ballast condition are to be used.

(2) For flooded loading conditions, the values of k_r and GM, unless provided in the loading manual, are to be taken as those for the full load condition.

(3) When steel coil loading condition is provided by the designer according to Ch 1, Sec 2, [3.6] in the loading manual, this condition is to be assessed with draught, k_r and GM values given in this table.

(4) Block Loading conditions are to be assessed with draught, k_r and GM values given in this table for Homogeneous heavy cargo loading condition.

2.1.2 Pitch motion

The pitch period T_φ, in s, is to be taken as:

$$T_\varphi = \sqrt{\frac{2\pi\lambda_\varphi}{g}}$$

where:

$$\lambda_\varphi = 0.6\,(1 + f_T)\,L$$

The pitch angle φ, in deg, is to be taken as:

$$\varphi = 1350\,f_p\,L^{-0.94}\left\{1.0 + \left(\frac{2.57}{\sqrt{gL}}\right)^{1.2}\right\}$$

where:

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = f_{fa}[(0.27 - 0.02f_T) - (13 - 5f_T)\,L \times 10^{-5}]$ for fatigue assessment.

2.2 Ship accelerations at the centre of gravity

2.2.1 Surge acceleration

The longitudinal acceleration due to surge, in m/s^2, is to be taken as:

$$a_{surge} = 0.2\,f_p\,a_0\,g$$

where:

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = f_{fa}[0.27 - (15 + 4f_T)\ L \times 10^{-5}]$ for fatigue assessment.

2.2.2 Sway acceleration

The transverse acceleration due to sway, in m/s^2, is to be taken as:

$$a_{sway} = 0.3\ f_p\ a_0\ g$$

where:

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = f_{fa}[0.24 - (6 - 2f_T)\ B \times 10^{-4}]$ for fatigue assessment.

2.2.3 Heave acceleration

The vertical acceleration due to heave, in m/s^2, is to be taken as:

$$a_{heave} = f_p\ a_0\ g$$

where:

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = f_{fa}[(0.27 + 0.02f_T) - 17L \times 10^{-5}]$ for fatigue assessment.

2.2.4 Roll acceleration

The roll acceleration, a_{roll}, in rad/s^2, is to be taken as:

$$a_{roll} = f_p\ \theta\ \frac{\pi}{180}\left(\frac{2\pi}{T_\theta}\right)^2$$

where:

θ : Roll angle using f_p equal to 1.0.

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = f_{fa}[0.23 - 4f_T\ B \times 10^{-4}]$ for fatigue assessment.

2.2.5 Pitch acceleration

The pitch acceleration, a_{pitch}, in rad/s^2, is to be taken as:

$$a_{pitch} = f_p\left(\frac{3.1}{\sqrt{gL}} + 1.0\right)\varphi\ \frac{\pi}{180}\left(\frac{2\pi}{T_\varphi}\right)^2$$

where:

φ : Pitch angle using f_p equal to 1.0.

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = f_{fa}[0.28 - (5 + 6f_T)\ L \times 10^{-5}]$ for fatigue assessment.

3 ACCELERATIONS AT ANY POSITION

3.1 General

3.1.1

The accelerations used to derive the inertial loads at any position are defined with respect to the ship fixed coordinate system. Hence the acceleration values defined in [3.2] and [3.3] include the gravitational acceleration components due to the instantaneous roll and pitch angles.

3.1.2

The accelerations to be applied for the dynamic load cases defined in Ch 4, Sec 2 are given in [3.2].

3.1.3

The envelope accelerations as defined in [3.3] are provided for advisory purposes and may be used for other design purpose when the maximum design acceleration values are required, for example, crane foundations, machinery foundations, etc.

3.2 Accelerations for dynamic load cases

3.2.1 General

The accelerations to be applied for the dynamic load cases defined in Ch 4, Sec 2 are given in [3.2.2] to [3.2.4].

3.2.2 Longitudinal acceleration

The longitudinal acceleration at any position for each dynamic load case, in m/s², is to be taken as:

$$a_X = -C_{XG}\, g\, \sin\varphi + C_{XS}\, a_{surge} + C_{XP}\, a_{pitch}(z-R)$$

3.2.3 Transverse acceleration

The transverse acceleration at any position for each dynamic load case, in m/s², is to be taken as:

$$a_Y = C_{YG}\, g\, \sin\theta + C_{YS}\, a_{sway} - C_{YR}\, a_{roll}(z-R)$$

3.2.4 Vertical acceleration

The vertical acceleration at any position for each dynamic load case, in m/s², is to be taken as:

$$a_Z = C_{ZH}\, a_{heave} + C_{ZR}\, a_{roll}\, y - C_{ZP}\, a_{pitch}\, (x - 0.45L)$$

3.3 Envelope accelerations

3.3.1 Longitudinal acceleration

The envelope longitudinal acceleration, $a_{x\text{-}env}$, in m/s², at any position, is to be taken as:

$$a_{x-env} = 0.7\sqrt{a_{surge}^{\ 2} + \left[\frac{L}{325}\,(g\sin\varphi + a_{pitch-x})\right]^2}$$

where:

$a_{pitch\text{-}x}$: Longitudinal acceleration due to pitch, in m/s²

$$a_{pitch-x} = a_{pitch}\,(z-R)$$

3.3.2 Transverse acceleration

The envelope transverse acceleration, $a_{y\text{-}env}$, in m/s^2, at any position, is to be taken as:

$$a_{y-env} = \sqrt{a_{sway}{}^2 + (g\ \sin\theta + a_{roll-y})^2}$$

where:

$a_{roll\text{-}y}$: Transverse acceleration due to roll, in m/s^2.

$$a_{roll-y} = a_{roll}\ (z - R)$$

3.3.3 Vertical acceleration

The envelope vertical acceleration, $a_{z\text{-}env}$, in m/s^2, at any position, is to be taken as:

$$a_{z-env} = \sqrt{a_{heave}{}^2 + \left(\left(0.3 + \frac{L}{325}\right) a_{pitch-z}\right)^2 + (1.2 a_{roll-z})^2}$$

where:

$a_{picth\text{-}z}$: Vertical acceleration due to pitch, in m/s^2.

$$a_{pitch-z} = a_{pitch}\ (x - 0.45L)$$

$a_{roll\text{-}z}$: Vertical acceleration due to roll, in m/s^2.

$$a_{roll-z} = a_{roll}\ y$$

SECTION 4
HULL GIRDER LOADS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

x : X coordinate, in m, of the calculation point with respect to the reference coordinate system defined in Ch 4, Sec 1, [1.2.1].

C_w : Wave coefficient, in m, to be taken as:

$$C_w = 10.75 - \left(\frac{300 - L}{100}\right)^{1.5} \quad \text{for } 90 \leq L \leq 300$$

$$C_w = 10.75 \quad \text{for } 300 < L \leq 350$$

$$C_w = 10.75 - \left(\frac{L - 350}{150}\right)^{1.5} \quad \text{for } 350 < L \leq 500$$

f_β : Heading correction factor, to be taken as:

- For strength assessment:

  f_β = 0.8 for BSR and BSP load cases for the extreme sea loads design load scenario.

  f_β = 1.0 for HSM, HSA, FSM, OST and OSA load cases for the extreme sea loads design load scenario.

  f_β = 1.0 for ballast water exchange at sea, harbour/sheltered water and accidental flooded design load scenarios.

- For fatigue assessment:

  f_β = 1.0.

f_{ps} : Coefficient, as defined in Ch 4, Sec 3.

BSR, *BSP*, *HSM*, *HSA*, *FSM*, *OST*, *OSA* : Dynamic load cases, as defined in Ch 4, Sec 2.

1 APPLICATION

1.1 General

1.1.1

The hull girder loads for the static (S) design load scenarios is to be taken as the still water loads defined in [2].

1.1.2

The total hull girder loads for the static plus dynamic (S+D) design load scenarios are to be derived for each dynamic load case and are to be taken as the sum of the still water loads defined in [2] and the dynamic loads defined in [3.5].

2 VERTICAL STILL WATER HULL GIRDER LOADS

2.1 General

2.1.1 Seagoing and harbour/sheltered water conditions

The designer is to provide the permissible still water bending moment and shear force for seagoing and harbour/sheltered water operations.

The permissible still water hull girder loads are to be given at each transverse bulkhead in the cargo hold region, at the middle of cargo compartments, at the collision bulkhead, at the engine room forward bulkhead and at the mid-point between the forward and aft engine room bulkheads. The permissible hull girder bending moments and shear forces at any other position may be obtained by linear interpolation.

Note 1: It is recommended that, for initial design, the permissible hull girder hogging and sagging still water bending moments are at least 5% above the maximum still water bending moment from loading conditions in the loading manual, and the permissible hull girder shear forces are at least 10% above the maximum still water shear force from loading condition in the loading manual, to account for growth and design margins during the design and construction phase of the ship.

2.1.2 Flooded condition

The designer is to provide the envelope of permissible still water bending moment and shear force in flooded condition.

2.1.3 Still water loads for the fatigue assessment

The still water bending moment and shear force values and distribution to be used for the fatigue assessment are to be taken as the most typical values applicable for the loading conditions that the ship will operate in for most of its life. Typically, these conditions will be the normal ballast condition and full homogeneously loaded condition for double hull oil tankers. For bulk carriers, these will be the normal ballast condition, heavy ballast condition, full homogeneously loaded condition and full alternate loaded condition; note the latter is only applicable to BC-A bulk carriers. The definition of loading conditions to use is specified in Ch 9.

2.2 Vertical still water bending moment

2.2.1 Minimum still water bending moment

The minimum still water bending moment, $M_{sw\text{-}h\text{-}min}$ and $M_{sw\text{-}s\text{-}min}$, in kNm, in hogging and sagging condition, respectively is to be taken as:

Hogging conditions:

$$M_{sw-h-min} = f_{sw}\ (171 C_w\ L^2\ B(C_B + 0.7)\ 10^{-3} - M_{wv-h-mid})$$

Sagging conditions:

$$M_{sw-s-min} = -0.85 f_{sw}\ (171 C_w\ L^2\ B(C_B + 0.7)\ 10^{-3} + M_{wv-s-mid})$$

where:

$M_{wv\text{-}h\text{-}mid}$: Vertical wave bending moment for strength assessment in hogging condition, as defined in [3.1.1] using f_p and f_m equal to 1.0.

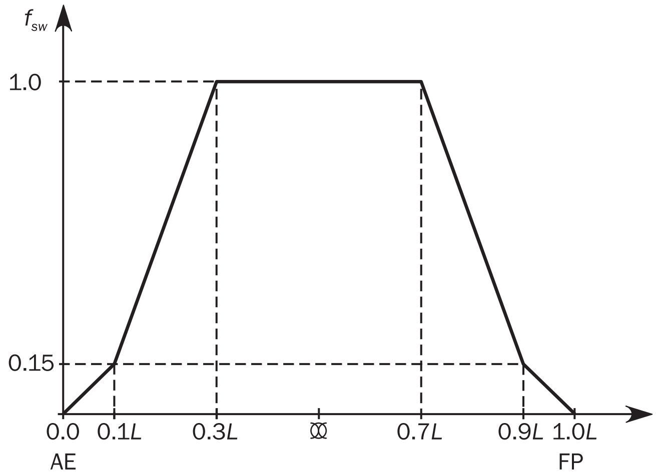
$M_{wv\text{-}s\text{-}mid}$: Vertical wave bending moment for strength assessment in sagging condition, as defined in [3.1.1] using f_p and f_m equal to 1.0.

f_{sw} : Distribution factor along the ship length. To be taken as, see Figure 1:

$f_{sw} = 0.0$ for $x \le 0$
$f_{sw} = 0.15$ at $x = 0.1\,L$
$f_{sw} = 1.0$ for $0.3\,L \le x \le 0.7\,L$
$f_{sw} = 0.15$ at $x = 0.9\,L$
$f_{sw} = 0.0$ for $x \ge L$

Intermediate values of f_{sw} are to be obtained by linear interpolation.

Figure 1 : Distribution factor f_{sw}



2.2.2 Permissible vertical still water bending moment in seagoing condition

The permissible vertical still water bending moments, $M_{sw\text{-}h}$ and $M_{sw\text{-}s}$ in seagoing condition at any longitudinal position are to envelop:

- The most severe still water bending moments calculated, in hogging and sagging conditions, respectively, for the seagoing loading conditions defined in Ch 4, Sec 8.
- The most severe still water bending moments for the seagoing loading conditions defined in the loading manual.
- The minimum still water bending moment defined in [2.2.1]

2.2.3 Permissible vertical still water bending moment in harbour/sheltered water and tank testing condition

The permissible vertical still water bending moments in the harbour/sheltered water and tank testing condition $M_{sw\text{-}p\text{-}h}$ and $M_{sw\text{-}p\text{-}s}$ at any longitudinal position are to envelop:

- The most severe still water bending moments, in hogging and sagging conditions, respectively, for the harbour/sheltered water loading conditions defined in Ch 4, Sec 8.
- The most severe still water bending moments for the harbour/sheltered water loading conditions defined in the loading manual.
- The permissible still water bending moment defined in [2.2.2].
- The minimum still water bending moment defined in [2.2.1] increased by 25%.

2.2.4 Permissible vertical still water bending moment in flooded condition at sea

The permissible vertical still water bending moments in flooded condition $M_{sw\text{-}f}$ at any longitudinal position are to envelop:

- The most severe still water bending moments, in hogging and sagging conditions, respectively, for the intact and flooded seagoing loading conditions defined in Ch 4, Sec 8.
- The most severe still water bending moments for the intact and flooded seagoing loading conditions defined in the loading manual.
- The permissible still water bending moment defined in [2.2.2] increased by 10%.

2.3 Vertical still water shear force

2.3.1 Minimum still water shear force in seagoing conditions for oil tankers

The minimum hull girder positive and negative vertical still water shear force, Q_{sw-min} in kN, in way of transverse bulkheads between cargo tanks in the seagoing condition is to be taken as:

a) For oil tankers with three cargo tanks across the breadth of the ship:

$$Q_{sw-min} = \pm max \begin{cases} 0.225\rho g\ B_{local}\ \ell_{tk}\ T_{SC} \\ 0.5\rho g\ [0.98\ (V_{CT} + 2V_{ST}) - 0.7B_{local}\ \ell_{tk}\ T_{SC}] \end{cases}$$

and is to be taken as the maximum value of Q_{sw-min} calculated for cargo/ballast tanks forward and aft of the transverse bulkhead.

b) For oil tankers with two cargo tanks across the breadth of the ship:

$$Q_{sw-min} = \pm 0.4\rho g\ B_{local}\ \ell_{tk}\ T_{SC}$$

and is to be taken as maximum value of Q_{sw-min} calculated for cargo/ballast tanks forward and aft of the transverse bulkhead.

where:

B_{local} : Local breadth, in m, at T_{SC} at the middle length of the tank under consideration.

ℓ_{tk} : Length of cargo tank under consideration, in m, taken at the forward or aft side of the transverse bulkhead under consideration, in m.

V_{CT} : Volume of centre cargo tank, in m^3, taken for the cargo tank on the forward or aft side of the transverse bulkhead under consideration.

V_{ST} : Volume of side cargo tank, in m^3, taken for the cargo tank on the forward or aft side of the transverse bulkhead under consideration.

2.3.2 Minimum still water shear force in harbour/sheltered water conditions for oil tankers

The minimum hull girder positive and negative vertical still water shear force, $Q_{sw-p-min}$ in kN in the harbour/sheltered water condition in way of transverse bulkheads between cargo tanks are to be taken as:

a) For oil tankers with three cargo tanks across the breadth of the ship:

$$Q_{sw-p-min} = \pm max \begin{cases} 0.275\rho g\ B_{local}\ \ell_{tk}\ T_{SC} \\ 0.5\rho g\ [0.98\ (V_{CT} + 2V_{ST}) - 0.6B_{local}\ \ell_{tk}\ T_{SC}] \end{cases}$$

and is to be taken as the maximum value of $Q_{sw-p-min}$ calculated for cargo/ballast tanks forward and aft of the transverse bulkhead.

b) For oil tankers with two cargo tanks across the breadth of the ship:

$$Q_{sw-min} = \pm 0.45\rho g\ B_{local}\ \ell_{tk}\ T_{SC}$$

and is to be taken as maximum value of $Q_{sw-p-min}$ calculated for cargo/ballast tanks forward and aft of the transverse bulkhead.

2.3.3 Permissible still water shear force in seagoing condition

The permissible vertical still water shear forces, Q_{sw} for oil tankers and bulk carriers, in seagoing condition at any longitudinal position are to envelop:

- The most severe still water shear forces, positive or negative, for the seagoing loading conditions defined in Ch 4, Sec 8 after shear force correction in case of bulk carrier.
- The most severe still water shear forces for the seagoing loading conditions defined in the loading manual after shear force correction in case of bulk carrier.
- For oil tankers, the minimum still water shear forces for seagoing conditions defined in [2.3.1].

2.3.4 Permissible still water shear force in harbour/sheltered water and tank testing condition

The permissible vertical still water shear forces, Q_{sw-p} for oil tankers and bulk carriers, in the harbour/sheltered water and tank testing condition at any longitudinal position are to envelop:

- The most severe still water shear forces, positive or negative, for the harbour/sheltered water loading conditions defined in Ch 4, Sec 8 after shear force correction in case of bulk carrier.
- The most severe still water shear forces for the harbour/sheltered water loading conditions defined in the loading manual after shear force correction in case of bulk carrier.
- For oil tankers, the minimum still water shear forced for harbour/sheltered water conditions defined in [2.3.2].

The following value may be used as guidance at preliminary design stage:

$$Q_{sw-p} = Q_{sw} + 0.6Q_{wv}$$

where:

Q_{sw} : Permissible still water shear force Q_{sw}, as defined in [2.3.3].

Q_{wv} : Vertical wave shear force for strength assessment Q_{wv-pos} and Q_{wv-neg}, as defined in [2.3.1] using f_p equal to 1.0.

2.3.5 Permissible still water shear force in flooded condition at sea

The permissible vertical still water shear forces, Q_{sw-f} for oil tankers and bulk carriers, in flooded condition at any longitudinal position are to envelop:

- The most severe still water shear forces, positive or negative, for the flooded seagoing loading conditions defined in Ch 4, Sec 8 after shear force correction in case of bulk carrier.
- The most severe still water shear forces for the flooded seagoing loading conditions defined in the loading manual after shear force correction in case of bulk carrier.
- The permissible still water shear force is defined in [2.3.3].

3 DYNAMIC HULL GIRDER LOADS

3.1 Vertical wave bending moment

3.1.1

The vertical wave bending moments at any longitudinal position, in kNm, are to be taken as:

Hogging condition:

$$M_{wv-h} = 0.19 f_{nl-vh} f_m f_p C_w L^2 BC_B$$

Sagging condition:

$$M_{wv-s} = -0.19 f_{nl-vs} f_m f_p C_w L^2 BC_B$$

where:

$f_{nl\text{-}vh}$: Coefficient considering nonlinear effects applied to hogging, to be taken as:

$f_{nl\text{-}vh} = 1.0$ for strength and fatigue assessment.

$f_{nl\text{-}vs}$: Coefficient considering nonlinear effects applied to sagging, to be taken as:

$f_{nl\text{-}vs} = 0.58\left(\frac{C_B + 0.7}{C_B}\right)$ for strength assessment.

$f_{nl\text{-}vs} = 1.0$ for fatigue assessment.

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = 0.9[0.27 - (6 + 4f_T)\ L \times 10^{-5}]$ for fatigue assessment.

f_m : Distribution factor for vertical wave bending moment along the ship's length, to be taken as:

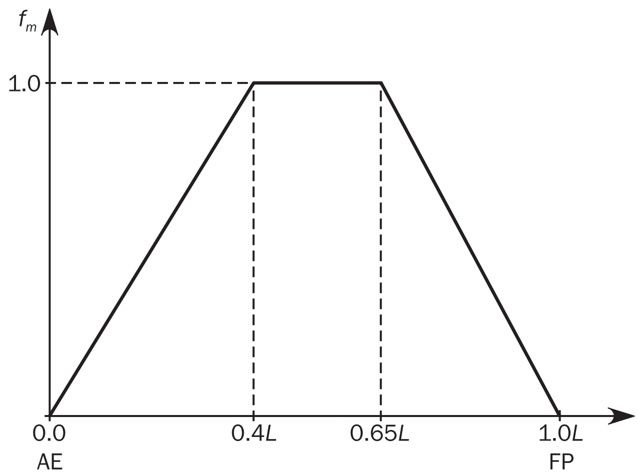
$f_m = 0.0$ for $x \le 0$

$f_m = 1.0$ for $0.4\ L \le x \le 0.65\ L$

$f_m = 0.0$ for $x \ge L$

Intermediate values of f_m are to be obtained by linear interpolation (see Figure 2).

Figure 2 : Distribution factor f_{mm}



3.2 Vertical wave shear force

3.2.1

The vertical wave shear forces at any longitudinal position, in kN, are to be taken as:

$$Q_{wv-pos} = 0.52 f_{q-pos}\ f_p\ C_w\ LBC_B$$

$$Q_{wv-neg} = -0.52 f_{q-neg}\ f_p\ C_w\ LBC_B$$

where:

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = 0.9[0.27 - (17 - 8f_T)\ L \times 10^{-5}]$ for fatigue assessment.

$f_{q\text{-}pos}$: Distribution factor along the ship length for positive wave shear force, to be taken as:

$f_{q\text{-}pos}$ = 0.0 for $x \le 0$
$f_{q\text{-}pos}$ = 0.92 f_{nl-vh} for 0.2 $L \le x \le 0.3$ L
$f_{q\text{-}pos}$ = 0.7 for 0.4 $L \le x \le 0.6$ L
$f_{q\text{-}pos}$ = 1.0 f_{nl-vs} for 0.7 $L \le x \le 0.85$ L
$f_{q\text{-}pos}$ = 0.0 for $x \ge L$

Intermediate values of $f_{q\text{-}pos}$ are to be obtained by linear interpolation (see Figure 3).

$f_{q\text{-}neg}$: Distribution factor along the ship length for negative wave shear force, to be taken as:

$f_{q\text{-}neg}$ = 0.0 for $x \le 0$
$f_{q\text{-}neg}$ = 0.92 f_{nl-vs} for $0.2L \le x \le 0.3$ L
$f_{q\text{-}neg}$ = 0.7 for $0.4L \le x \le 0.6$ L
$f_{q\text{-}neg}$ = 1.0 f_{nl-vh} for $0.7L \le x \le 0.85$ L
$f_{q\text{-}neg}$ = 0.0 for $x \ge L$

Intermediate values of $f_{q\text{-}neg}$ are to be obtained by linear interpolation, see Figure 4.

$f_{nl\text{-}vh}$, $f_{nl\text{-}vs}$: Coefficient considering nonlinear effects defined in [3.1.1].

Figure 3 : Distribution factor of positive vertical shear force $f_{q\text{-}pos}$

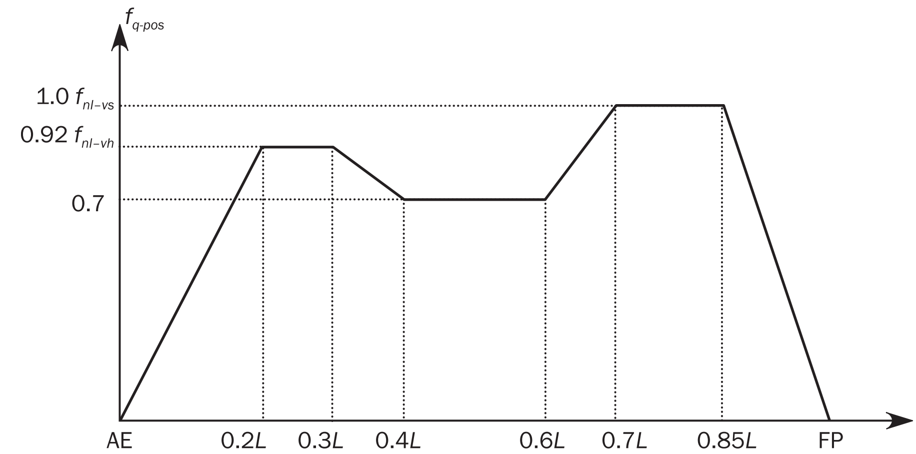
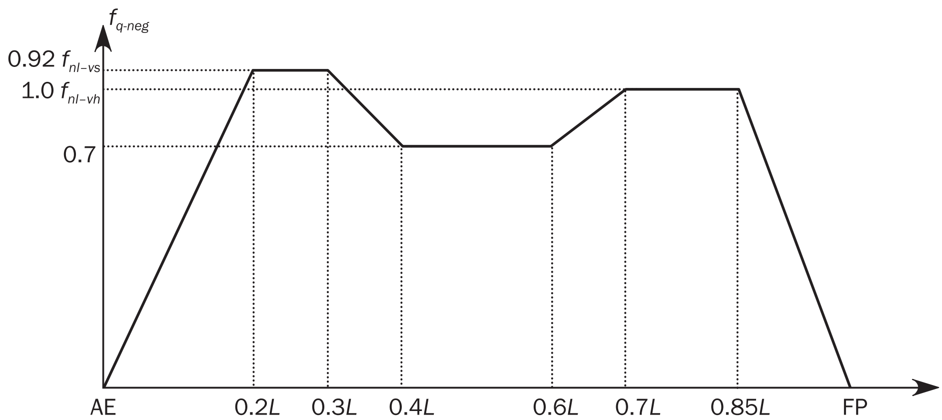


Figure 4 : Distribution factor of negative vertical shear force $f_{q\text{-}neg}$



3.3 Horizontal wave bending moment

3.3.1

The horizontal wave bending moment at any longitudinal position, in kNm, is to be taken as:

$$M_{wh} = f_{nlh} f_p \left(0.31 + \frac{L}{2800}\right) f_m \, C_w \, L^2 \, T_{LC} \, C_B$$

where:

f_{nlh} : Coefficient considering nonlinear effect to be taken as:

f_{nlh} = 0.9 for strength assessment

f_{nlh} = 1.0 for fatigue assessment

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = 0.9 \cdot [(0.2 + 0.04 f_T) + (11 - 8 f_T) \, L \times 10^{-5}]$ for fatigue assessment.

f_m : Distribution factor defined in [3.1.1].

3.4 Wave torsional moment

3.4.1

The wave torsional moment at any longitudinal position with respect to the ship baseline, in kNm, is to be taken as:

$$M_{wt} = f_p (M_{wt1} + M_{wt2})$$

where:

$$M_{wt1} = 0.4 f_{t1} \, C_w \sqrt{\frac{L}{T_{LC}}} \, B^2 \, D C_B$$

$$M_{wt2} = 0.22 f_{t2} \, C_w \, L B^2 \, C_B$$

f_{t1}, f_{t2} : Distribution factors, taken as:

$f_{t1} = 0$ for $x < 0$

$f_{t1} = \left|\sin\left(\frac{2\pi x}{L}\right)\right|$ for $0 \le x \le L$

$f_{t1} = 0$ for $x > L$

$f_{t2} = 0$ for $x < 0$

$f_{t2} = sin^2\left(\frac{\pi x}{L}\right)$ for $0 \le x \le L$

$f_{t2} = 0$ for $x > L$

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = 0.9[0.24 + (6 f_T - 5) \, B \times 10^{-4}]$ for fatigue assessment.

3.5 Hull girder loads for dynamic load cases

3.5.1 General

The dynamic hull girder loads to be applied for the dynamic load cases defined in Ch 4, Sec 2, are given in [3.5.2] to [3.5.5].

3.5.2 Vertical wave bending moment

The vertical wave bending moment, $M_{wv\text{-}LC}$, in kNm, to be used for each dynamic load case in Ch 4, Sec 2, is defined in Table 1.

Table 1 : Vertical wave bending moment for dynamic load cases

Load combination factor	M_{wv-LC}
$C_{WV} \geq 0$	$f_\beta \; C_{WV} \; M_{wv-h}$
$C_{WV} < 0$	$f_\beta \; C_{WV} \; \lvert M_{wv-s} \rvert$

where:

C_{WV} : Load combination factor for vertical wave bending moment, to be taken as specified in Ch 4, Sec 2.

M_{wv-h}, M_{wv-s}: Hogging and sagging vertical wave bending moment taking account of the considered design load scenario, as defined in [3.1.1].

3.5.3 Vertical wave shear force

The vertical wave shear force, Q_{wv-LC}, in kN, to be used for each dynamic load case in Ch 4, Sec 2, is defined in Table 2.

Table 2 : Vertical wave shear force for dynamic load cases

Load combination factor	Q_{wv-LC}
$C_{QW} \geq 0$	$f_\beta \; C_{QW} \; Q_{wv-pos}$
$C_{QW} < 0$	$f_\beta \; C_{QW} \; \lvert Q_{wv-neg} \rvert$

where:

C_{QW} : Load combination factor for vertical wave shear force, to be taken as specified in Ch 4, Sec 2.

Q_{wv-pos}, Q_{wv-neg} : Positive and negative vertical wave shear force taking account of the considered design load scenario, as defined in [3.2.1].

3.5.4 Horizontal wave bending moment

The horizontal wave bending moment, M_{wh-LC}, in kNm, to be used for each dynamic load case defined in Ch 4, Sec 2, is to be taken as:

$$M_{wh-LC} = f_\beta \; C_{WH} \; M_{wh}$$

where:

C_{WH} : Load combination factor for horizontal wave bending moment, to be taken as specified in Ch 4, Sec 2.

M_{wh} : Horizontal wave bending moment taking account of the appropriate design load scenario, as defined in [3.3.1].

3.5.5 Wave torsional moment

The wave torsional moment, M_{wt-LC}, in kNm, to be used for each dynamic load case defined in Ch 4, Sec 2, is to be taken as:

$$M_{wt-LC} = f_\beta \; C_{WT} \; M_{wt}$$

where:

C_{WT} : Load combination factor for wave torsional moment, to be taken as specified in Ch 4, Sec 2.

M_{wt} : Wave torsional moment taking account of the appropriate design load scenario, as defined in [3.4.1].

SECTION 5

EXTERNAL LOADS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

λ : Wave length, in m.

B_x : Moulded breadth at the waterline, in m, at the considered cross section.

x, y, z : X, Y and Z coordinates, in m, of the load point with respect to the reference coordinate system defined in Ch 4, Sec 1, [1.2.1].

f_{xL} : Ratio as defined in Ch 4, Sec 2.

f_{yB} : Ratio between Y-coordinate of the load point and B_x, to be taken as:

$$f_{yB} = \frac{|2y|}{B_x} \text{, but not greater than 1.0.}$$

$f_{yB} = 0$ when $B_x = 0$.

f_{yB1} : Ratio between Y-coordinate of the load point and B, to be taken as:

$$f_{yB1} = \frac{|2y|}{B} \text{, but not greater than 1.0}$$

C_w : Wave coefficient defined in Ch 4, Sec 4.

f_T : Ratio as defined in Ch 4, Sec 3.

$P_{W,WL}$: Wave pressure at the waterline, kN/m^2, for the considered dynamic load case.

$$P_{W,WL} = P_W \text{ for } z = T_{LC}$$

h_W : Water head equivalent to the pressure at waterline, in m, to be taken as:

$$h_W = \frac{P_{W,WL}}{\rho g}$$

f_{ps} : Coefficient for strength assessment, as defined in Ch 4, Sec 3.

θ : Roll angle, in deg, as defined in Ch 4, Sec 3, [2.1.1].

T_θ : Roll period, in s, as defined in Ch 4, Sec 3, [2.1.1].

f_{fa} : Coefficient defined in Ch 4, Sec 3.

f_β : Coefficient defined in Ch 4, Sec 4.

1 SEA PRESSURE

1.1 Total pressure

1.1.1

The external pressure P_{ex} at any load point of the hull, in kN/m^2, for the static (S) design load scenarios, is to be taken as:

$P_{ex} = P_S$ but not less than 0.

The total pressure P_{ex} at any load point of the hull for the static plus dynamic (S+D) design load scenarios, is to be derived from each dynamic load case and is to be taken as:

$P_{ex} = P_S + P_W$ but not less than 0.

where:

P_S : Hydrostatic pressure, in kN/m^2, defined in [1.2].

P_W : Wave pressure, in kN/m^2, is defined in [1.3].

1.2 Hydrostatic pressure

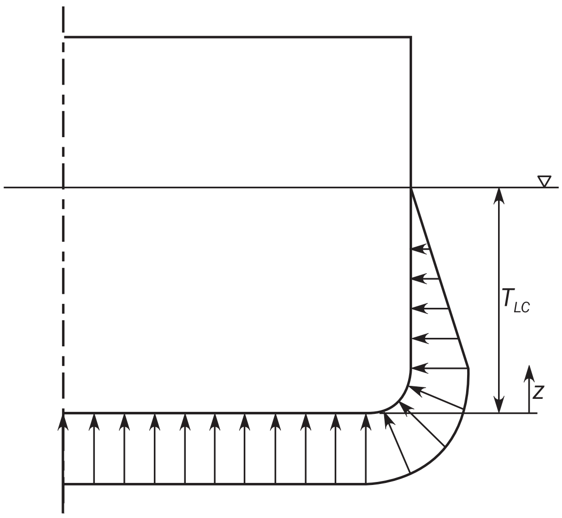
1.2.1

The hydrostatic pressure, P_S at any load point, in kN/m^2, is obtained from Table 1. See also Figure 1.

Table 1 : Hydrostatic pressure, P_S

Location	Hydrostatic Pressure, P_S, in kN/m^2
$z \le T_{LC}$	$\rho\, g\, (T_{LC} - z)$
$z > T_{LC}$	0

Figure 1 : Hydrostatic pressure, P_S



1.3 External dynamic pressures for strength assessment

1.3.1 General

The hydrodynamic pressures for each dynamic load case defined in Ch 4, Sec 2, [2] are defined in [1.3.2] to [1.3.8].

1.3.2 Hydrodynamic pressures for HSM load cases

The hydrodynamic pressures, P_W, for HSM-1 and HSM-2 load cases, at any load point, in kN/m², are to be obtained from Table 2. See also Figure 2 and Figure 3.

Table 2 : Hydrodynamic pressures for HSM load cases

	Wave pressure, in kN/m²		
Load case	$z \le T_{LC}$	$T_{LC} < z \le h_W + T_{LC}$	$z > h_W + T_{LC}$
HSM-1	$P_W = max\ (-P_{HS}, \rho g\ (z - T_{LC}))$	$P_W = P_{W,WL} - \rho g(z - T_{LC})$	$P_W = 0.0$
HSM-2	$P_W = max\ (P_{HS}, \rho g\ (z - T_{LC}))$		

where:

$$P_{HS} = f_{ps}\ f_{nl}\ f_h\ k_a\ k_p\ f_{yz}\ C_W \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{nl} : Coefficient considering non-linear effects, to be taken as:

- For extreme sea loads design load scenario:

  $f_{nl} = 0.7$ at $f_{xL} = 0$

  $f_{nl} = 0.9$ at $f_{xL} = 0.3$

  $f_{nl} = 0.9$ at $f_{xL} = 0.7$

  $f_{nl} = 0.6$ at $f_{xL} = 1$

- For ballast water exchange design load scenario:

  $f_{nl} = 0.85$ at $f_{xL} = 0$

  $f_{nl} = 0.95$ at $f_{xL} = 0.3$

  $f_{nl} = 0.95$ at $f_{xL} = 0.7$

  $f_{nl} = 0.80$ at $f_{xL} = 1$

Intermediate values are obtained by linear interpolation.

f_{yz} : Girth distribution coefficient, to be taken as:

$$f_{yz} = \frac{z}{T_{LC}} + f_{yB} + 1$$

f_h : Coefficient to be taken as:

$$f_h = 3.0(1.21 - 0.66\ f_T)$$

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be taken as:

$$k_a = (0.5 + f_T)\left\{(3 - 2\sqrt{f_{yB}}) - \frac{20}{9}f_{xL}(7 - 6\sqrt{f_{yB}})\right\} + \frac{2}{3}(1 - f_T) \quad \text{for } f_{xL} < 0.15$$

$$k_a = 1.0 \quad \text{for } 0.15 \le f_{xL} < 0.7$$

$$k_a = 1 + (f_{xL} - 0.7)\left\{\left(\frac{40}{3}f_T - 5\right) + 2(1 - f_{yB})\left[\frac{18}{C_B}f_T(f_{xL} - 0.7) - 0.25(2 - f_T)\right]\right\} \quad \text{for } f_{xL} \ge 0.7$$

λ : Wave length of the dynamic load case, in m, to be taken as:

$$\lambda = 0.6(1 + f_T)L$$

k_p : Phase coefficient to be obtained from Table 3. Intermediate values are to be interpolated.

Table 3 : k_p values for HSM load cases

f_{xL}	0	$0.3 - 0.1\ f_T$	$0.35 - 0.1\ f_T$	$0.8 - 0.2\ f_T$	$0.9 - 0.2\ f_T$	1.0
k_p	$-0.25\ f_T\ (1 + f_{yB})$	-1	1	1	-1	-1

Figure 2 : Transverse distribution amidships of dynamic pressure for HSM-1, HSA-1 and FSM-1 load cases

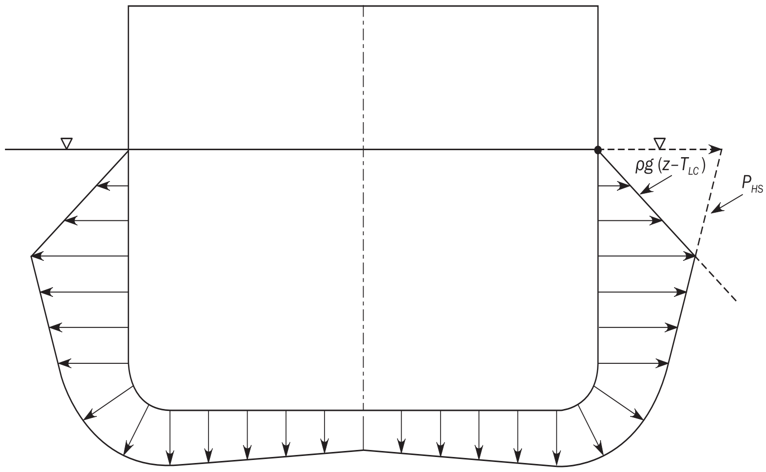
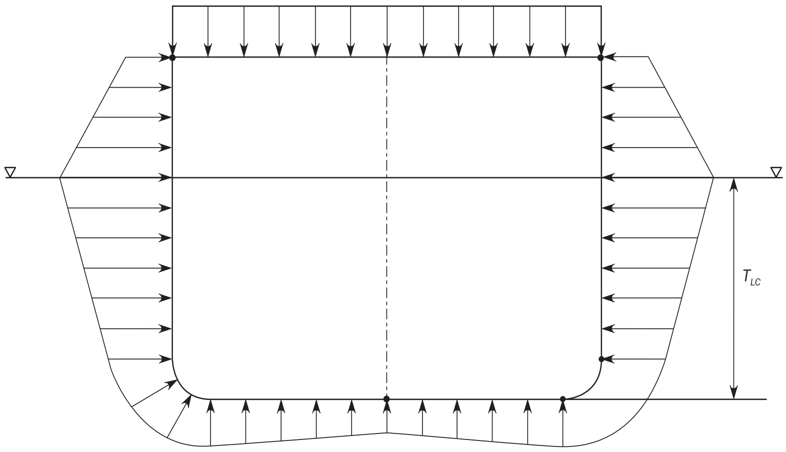


Figure 3 : Transverse distribution amidships of dynamic pressure for HSM-2, HSA-2 and FSM-2 load cases



1.3.3 Hydrodynamic pressures for HSA load cases

The hydrodynamic pressures, P_W, for HSA-1 and HSA-2 load cases at any load point, in kN/m², are to be obtained from Table 4. See also Figure 2 and Figure 3.

Table 4 : Hydrodynamic pressures for HSA load cases

	Wave pressure, in kN/m²		
Load case	$z \le T_{LC}$	$T_{LC} < z \le h_W + T_{LC}$	$z > h_W + T_{LC}$
HSA-1	$P_W = max(-P_{HS},\ \rho g(z - T_{LC}))$	$P_W = P_{W,WL} - \rho g(z - T_{LC})$	$P_W = 0.0$
HSA-2	$P_W = max(P_{HS},\ \rho g(z - T_{LC}))$		

where:

$$P_{HS} = f_{ps}\ f_{nl}\ f_h\ k_a\ k_p\ f_{yz}\ C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{nl} : Coefficient considering non-linear effects, to be taken as defined in [1.3.2].

f_{yz} : Girth distribution coefficient, to be taken as:

$$f_{yz} = \frac{z}{T_{LC}} + f_{yB} + 1$$

f_h : Coefficient to be taken as:

$$f_h = 2.4(1.21 - 0.66\ f_T)$$

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be taken as defined in [1.3.2].

λ : Wave length of the dynamic load case, in m, to be taken as:

$$\lambda = 0.6(1 + f_T)L$$

k_p : Phase coefficient to be obtained from Table 5. Intermediate values are to be interpolated.

Table 5 : k_p values for HSA load cases

f_{xL}	0	$0.3 - 0.1\ f_T$	$0.5 - 0.2\ f_T$	$0.8 - 0.2\ f_T$	$0.9 - 0.2\ f_T$	1.0
k_p	$1.5 - f_T - 0.5\ f_{yB}$	-1	1	1	-1	-1

1.3.4 Hydrodynamic pressures for FSM load cases

The hydrodynamic pressures, P_W, for FSM-1 and FSM-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 6. See also Figure 2 and Figure 3.

Table 6 : Hydrodynamic pressures for FSM load cases

	Wave pressure, in kN/m^2		
Load case	$z \le T_{LC}$	$T_{LC} < z \le h_W + T_{LC}$	$z > h_W + T_{LC}$
FSM-1	$P_W = max(-P_{FS},\ \rho g(z - T_{LC}))$	$P_W = P_{W,WL} - \rho g(z - T_{LC})$	$P_W = 0.0$
FSM-2	$P_W = max(P_{FS},\ \rho g(z - T_{LC}))$		

where:

$$P_{FS} = f_{ps}\ f_{nl}\ f_h\ k_a\ k_p\ f_{yz}\ C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{nl} : Coefficient considering non-linear effects, to be taken as:

$f_{nl} = 0.9$ for extreme sea loads design load scenario.

$f_{nl} = 0.95$ for ballast water exchange design load scenarios.

f_{yz} : Girth distribution coefficient, to be taken as:

$$f_{yz} = \frac{z}{T_{LC}} + f_{yB} + 1$$

f_h : Coefficient to be taken as:

$f_h = 2.6$

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be taken as:

$$k_a = 1 + (3.75 - 2\ f_T)(1 - 5\ f_{xL})(1 - f_{yB}) \quad \text{for} \quad f_{xL} < 0.2$$
$$k_a = 1.0 \quad \text{for} \quad 0.2 \le f_{xL} < 0.9$$
$$k_a = 1 + 20(1 - f_{yB})\ (f_{xL} - 0.9) \quad \text{for} \quad f_{xL} \ge 0.9$$

λ : Wave length of the dynamic load case, in m, to be taken as:

$$\lambda = 0.6(1 + 2/3\ f_T)L$$

k_p : Phase coefficient to be obtained from Table 7. Intermediate values are to be interpolated.

Table 7 : k_p values for FSM load cases

f_{xL}	0	$0.35 - 0.1\ f_T$	$0.5 - 0.2\ f_T$	0.75	0.8	1.0
k_p	$-0.75 - 0.25\ f_{yB}$	-1	1	1	-1	$-0.75 - 0.25\ f_{yB}$

1.3.5 Hydrodynamic pressures for BSR load cases

The wave pressures, P_W, for BSR-1 and BSR-2 load cases, at any load point, in kN/m², are to be obtained from Table 8. See also Figure 4 and Figure 5.

Table 8 : Hydrodynamic pressures for BSR load cases

<table>
<tr><th></th><th colspan="3">Wave pressure, in kN/m²</th></tr>
<tr><th>Load case</th><th>$z \le T_{LC}$</th><th>$T_{LC} < z \le h_W + T_{LC}$</th><th>$z > h_W + T_{LC}$</th></tr>
<tr><td>BSR-1P</td><td>$P_W = \max(P_{BSR}, \rho g\ (z - T_{LC}))$</td><td rowspan="4">$P_W = P_{W,WL} - \rho g\ (z - T_{LC})$</td><td rowspan="4">$P_W = 0.0$</td></tr>
<tr><td>BSR-2P</td><td>$P_W = \max(-P_{BSR}, \rho g\ (z - T_{LC}))$</td></tr>
<tr><td>BSR-1S</td><td>$P_W = \max(P_{BSR}, \rho g\ (z - T_{LC}))$</td></tr>
<tr><td>BSR-2S</td><td>$P_W = \max(-P_{BSR}, \rho g\ (z - T_{LC}))$</td></tr>
</table>

where:

- For BSR-1P and BSR-2P load cases.

$$P_{BSR} = f_\beta\, f_{nl}\left(10 y \sin\theta + 0.88\, f_{ps}\, C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}\,(f_{yB1} + 1)\right)$$

- For BSR-1S and BSR-2S load cases.

$$P_{BSR} = f_\beta\, f_{nl}\left(-10 y \sin\theta + 0.88\, f_{ps}\, C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}\,(f_{yB1} + 1)\right)$$

f_{nl} : Coefficient considering non-linear effect, to be taken as:

$f_{nl} = 1$ for extreme sea loads design load scenario.

$f_{nl} = 1$ for ballast water exchange design load scenarios.

λ : Wave length of the dynamic load case, in m, to be taken as:

$$\lambda = \frac{g}{2\pi}\,T_\theta^2$$

Figure 4 : Transverse distribution of dynamic pressure for BSR-1P (left) and BSR-1S (right) load cases

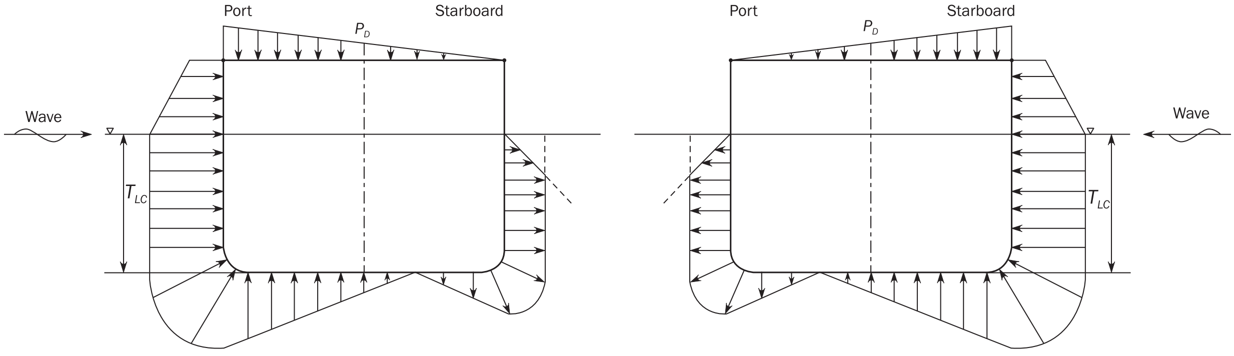
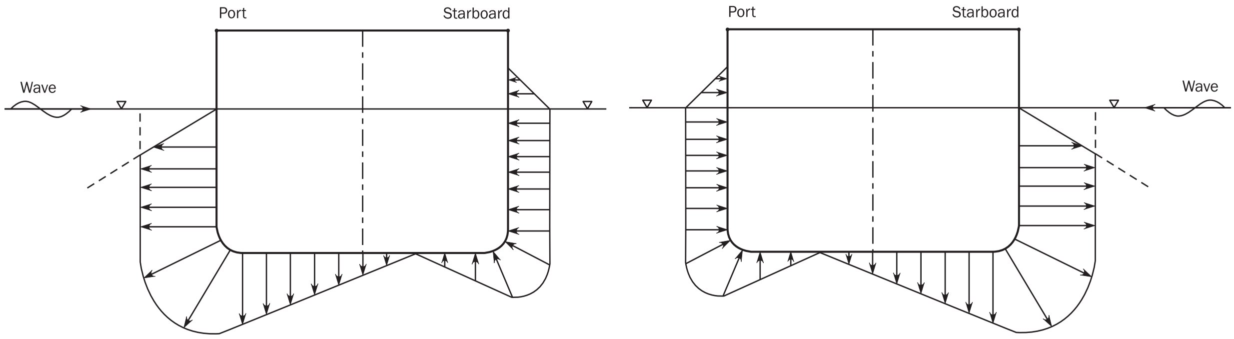


Figure 5 : Transverse distribution of dynamic pressure for BSR-2P (left) and BSR-2S (right) load cases



1.3.6 Hydrodynamic pressures for BSP load cases

The wave pressures, P_W, for BSP-1 and BSP-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 9. See also Figure 6 and Figure 7.

Table 9 : Hydrodynamic pressures for BSP load cases

	Wave pressure, in kN/m²		
Load case	$z \le T_{LC}$	$T_{LC} < z \le h_W + T_{LC}$	$z > h_W + T_{LC}$
BSP-1P	$P_W = \max(P_{BSP}, \rho g\,(z - T_{LC}))$	$P_W = P_{W,WL} - \rho g\,(z - T_{LC})$	$P_W = 0.0$
BSP-2P	$P_W = \max(-P_{BSP}, \rho g\,(z - T_{LC}))$		
BSP-1S	$P_W = \max(P_{BSP}, \rho g\,(z - T_{LC}))$		
BSP-2S	$P_W = \max(-P_{BSP}, \rho g\,(z - T_{LC}))$		

where:

$$P_{BSP} = 4.5\, f_\beta\, f_{ps}\, f_{nl}\, f_{yz}\, C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

λ : Wave length of the dynamic load case, in m, to be taken as:

$$\lambda = 0.2(1 + 2\, f_T)L$$

f_{yz} : Girth distribution coefficient, to be obtained from Table 10.

Table 10 : Girth distribution coefficient, f_{yz} for BSP load cases

Transverse position	BSP-1P - BSP-2P	BSP-1S - BSP-2S
$y \ge 0$	$f_{yz} = 2\frac{z}{T_{LC}} + 2.5\, f_{yB1} + 0.5$	$f_{yz} = \frac{2}{3}\frac{z}{T_{LC}} + \frac{1}{2} f_{yB1} + 0.5$
$y < 0$	$f_{yz} = \frac{2}{3}\frac{z}{T_{LC}} + \frac{1}{2} f_{yB1} + 0.5$	$f_{yz} = 2\frac{z}{T_{LC}} + 2.5\, f_{yB1} + 0.5$

f_{nl} : Coefficient considering non-linear effect, to be taken as:

- For extreme sea loads design load scenario:

  $f_{nl} = 0.6$ at $f_{xL} = 0$

  $f_{nl} = 0.8$ at $f_{xL} = 0.3$

  $f_{nl} = 0.8$ at $f_{xL} = 0.7$

  $f_{nl} = 0.6$ at $f_{xL} = 1$

- For ballast water exchange design load scenario:

  f_{nl} = 0.6 at f_{xL} = 0

  f_{nl} = 0.8 at f_{xL} = 0.3

  f_{nl} = 0.8 at f_{xL} = 0.7

  f_{nl} = 0.6 at f_{xL} = 1

Intermediate values are obtained by linear interpolation.

Figure 6 : Transverse distribution of dynamic pressure for BSP-1P (left) and BSP-1S (right) load cases

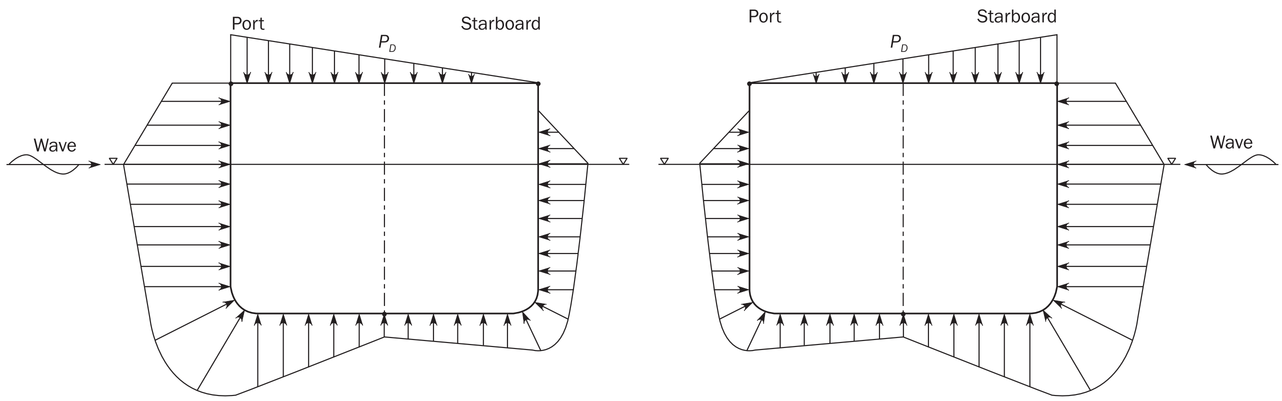
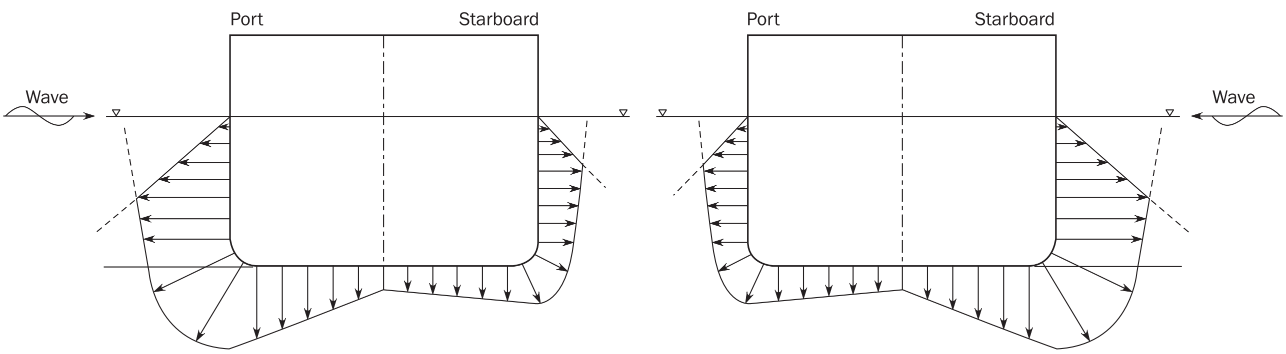


Figure 7 : Transverse distribution of dynamic pressure for BSP-2P (left) and BSP-2S (right) load cases



1.3.7 Hydrodynamic pressures for OST load cases

The wave pressures, P_W, for OST-1 and OST-2 load cases, at any load point are to be obtained, in kN/m^2, from Table 11. See also Figure 8 and Figure 9.

Figure 8 : Transverse distribution of dynamic pressure amidships for OST-1P (left) and OST-1S (right) load cases

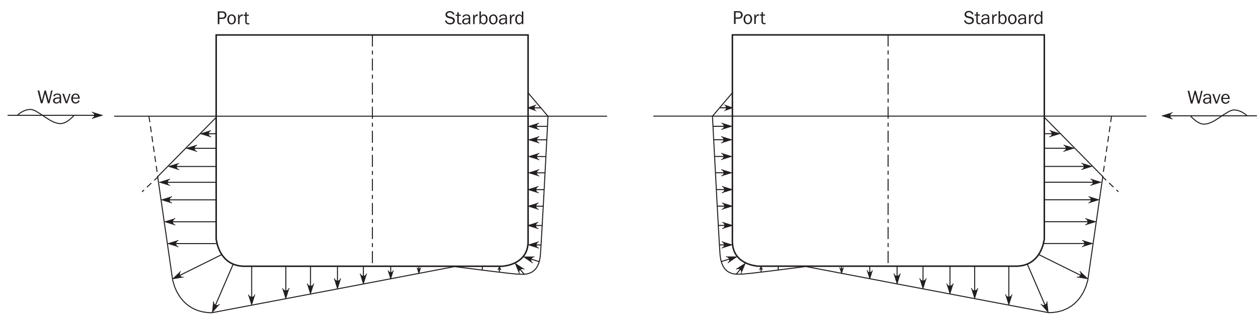


Figure 9 : Transverse distribution of dynamic pressure amidships for OST-2P (left) and OST-2S (right) load cases

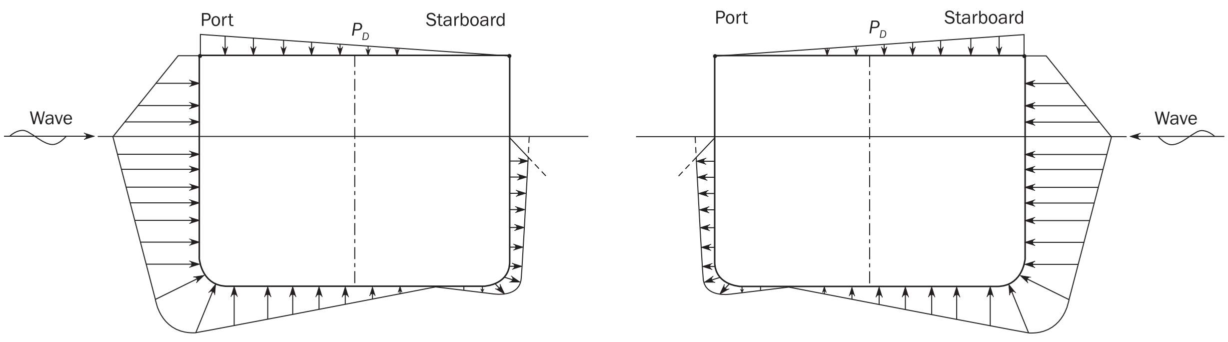


Table 11 : Hydrodynamic pressures for OST load cases

	Wave pressure, in kN/m²		
Load case	$z \le T_{LC}$	$T_{LC} < z \le h_W + T_{LC}$	$z > h_W + T_{LC}$
OST-1P	$P_W = \max\,(P_{OST}, \rho g\,(z - T_{LC}))$	$P_W = P_{W,WL} - \rho g(z - T_{LC})$	$P_W = 0.0$
OST-2P	$P_W = \max\,(-P_{OST}, \rho g\,(z - T_{LC}))$		
OST-1S	$P_W = \max\,(P_{OST}, \rho g\,(z - T_{LC}))$		
OST-2S	$P_W = \max\,(-P_{OST}, \rho g\,(z - T_{LC}))$		

where:

$$P_{OST} = 1.38\, f_{ps}\, f_{nl}\, k_a\, k_p\, f_{yz}\, C_W \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{yz} : Girth distribution coefficient, to be obtained from Table 12.

f_{nl} : Coefficient considering non-linear effect, to be taken as:

$f_{nl} = 0.8$ for extreme sea loads design load scenario.

$f_{nl} = 0.9$ for ballast water exchange design load scenarios.

λ : Wave length of the dynamic load case, in m, to be taken as:

$$\lambda = 0.45\, L$$

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be obtained from Table 13.

k_p : Phase coefficient to be obtained from Table 14. Intermediate values are to be interpolated.

Table 12 : Girth distribution coefficient, f_{yz} for OST load cases

Transverse position	OST-1P - OST-2P	OST-1S - OST-2S
$y \ge 0$	$5\,\dfrac{z}{T_{LC}} + 3.5\, f_{yB} + 1.5$	$1.5\,\dfrac{z}{T_{LC}} + 1.5$
$y < 0$	$1.5\,\dfrac{z}{T_{LC}} + 1.5$	$5\,\dfrac{z}{T_{LC}} + 3.5\, f_{yB} + 1.5$

Table 13 : k_a values for OST load cases

Transverse position	Longitudinal Position	OST-1P - OST-2P	OST-1S - OST-2S
$y \geq 0$	$f_{xL} \leq 0.2$	$1.0 + 3.5(1 - f_{yB})(1 - 5\ f_{xL})$	$1.0 + [3.5 - (4f_T - 0.5)f_{yB}](1 - 5\ f_{xL})$
	$0.2 < f_{xL} \leq 0.8$	1.0	1.0
	$f_{xL} > 0.8$	1.0	$1.0 + 4\ (1 - f_T)\ (5\ f_{xL} - 4)\ f_{yB}$
$y < 0$	$f_{xL} \leq 0.2$	$1.0 + [3.5 - (4\ f_T - 0.5)\ f_{yB}]\ (1 - 5\ f_{xL})$	$1.0 + 3.5(1 - f_{yB})(1 - 5\ f_{xL})$
	$0.2 < f_{xL} \leq 0.8$	1.0	1.0
	$f_{xL} > 0.8$	$1.0 + 4(1 - f_T)(5\ f_{xL} - 4)\ f_{yB}$	1.0

Table 14 : k_p values for OST load cases

Transverse position	f_{xL}	OST-1P - OST-2P	OST-1S - OST-2S
$y \geq 0$	0.0	1.0	1.0
	0.2	1.0	$1.0 + (0.75 - 1.5\ f_T)\ f_{yB}$
	0.4	-1.0	$-1.0 + (1.75 - 0.5\ f_T)\ f_{yB}$
	0.5	-1.0	$-1.0 + (1.75 - 0.5\ f_T)\ f_{yB}$
	0.7	$-0.1 + (1.6\ f_T - 1.5)\ f_{yB}$	$-0.1 + (0.25 - 0.3\ f_T)\ f_{yB}$
	0.9	$0.8 + 0.2\ f_{yB}$	$0.8 - (0.9\ f_T + 0.85)\ f_{yB}$
	1.0	$-1.0 + f_{yB}$	$-1.0 + (0.5 - 0.5\ f_T)\ f_{yB}$
$y < 0$	0.0	1.0	1.0
	0.2	$1.0 + (0.75 - 1.5\ f_T)\ f_{yB}$	1.0
	0.4	$-1.0 + (1.75 - 0.5\ f_T)\ f_{yB}$	-1.0
	0.5	$-1.0 + (1.75 - 0.5\ f_T)\ f_{yB}$	-1.0
	0.7	$-0.1 + (0.25 - 0.3\ f_T)\ f_{yB}$	$-0.1 + (1.6f_T - 1.5)f_{yB}$
	0.9	$0.8 - (0.9\ f_T + 0.85)\ f_{yB}$	$0.8 + 0.2\ f_{yB}$
	1.0	$-1.0 + (0.5 - 0.5\ f_T)\ f_{yB}$	$-1.0 + f_{yB}$

1.3.8 Hydrodynamic pressures for OSA load cases

The wave pressures, P_W, for OSA-1 and OSA-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 15. See also Figure 10 and Figure 11.

Table 15 : Hydrodynamic pressures for OSA load cases

	Wave pressure, in kN/m^2		
Load case	$z \leq T_{LC}$	$T_{LC} < z \leq h_W + T_{LC}$	$z > h_W + T_{LC}$
OSA-1P	$P_W = \max\ (P_{OSA}, \rho g\ (z - T_{LC}))$	$P_W = P_{W,WL} - \rho g\ (z - T_{LC})$	$P_W = 0.0$
OSA-2P	$P_W = \max\ (- P_{OSA}, \rho g\ (z - T_{LC}))$		
OSA-1S	$P_W = \max\ (P_{OSA}, \rho g\ (z - T_{LC}))$		
OSA-2S	$P_W = \max\ (- P_{OSA}, \rho g\ (z - T_{LC}))$		

where:

$$P_{OSA} = 0.81\ f_{ps}\ f_{nl}\ k_a\ k_p\ f_{yz}\ C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}\ (1 + 0.5\ f_T)$$

λ : Wave length of the dynamic load case, in m, to be taken as:

$$\lambda = 0.70\ L$$

f_{nl} : Coefficient considering non-linear effect, to be taken as:

- For extreme sea loads design load scenario:

  $f_{nl} = 0.5$ at $f_{xL} = 0$

  $f_{nl} = 0.8$ at $f_{xL} = 0.3$

  $f_{nl} = 0.8$ at $f_{xL} = 0.7$

  $f_{nl} = 0.6$ at $f_{xL} = 1$

- For ballast water exchange design load scenario:

  $f_{nl} = 0.75$ at $f_{xL} = 0$

  $f_{nl} = 0.9$ at $f_{xL} = 0.3$

  $f_{nl} = 0.9$ at $f_{xL} = 0.7$

  $f_{nl} = 0.8$ at $f_{xL} = 1$

Intermediate values are obtained by linear interpolation.

f_{yz} : Girth distribution coefficient, to be obtained from Table 16.

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be obtained from Table 17.

k_p : Phase coefficient to be obtained from Table 18. Intermediate values are to be interpolated.

Table 16 : Girth distribution coefficient, f_{yz} for OSA load cases

Transverse position	OSA-1P - OSA-2P	OSA-1S - OSA-2S
$y \geq 0$	$5.5\ \frac{z}{T_{LC}} + 5.3\ f_{yB} + 2.2$	$0.9\ \frac{z}{T_{LC}} + 0.4\ f_{yB} + 2.2$
$y < 0$	$0.9\ \frac{z}{T_{LC}} + 0.4\ f_{yB} + 2.2$	$5.5\frac{z}{T_{LC}} + 5.3\ f_{yB} + 2.2$

Table 17 : k_a values for OSA load cases

Transverse position	Longitudinal position	OSA-1P - OSA-2P	OSA-1S - OSA-2S
$y \geq 0$	$f_{xL} \leq 0.2$	$1.0 + 3\ (2 - f_T)\ (1 - 5\ f_{xL})\ (1 - f_{yB})$	$1.0 + 3\ (2 - f_T)\ (1 - 5\ f_{xL}) + \{(28\ f_{xL} - 5) + 3\ f_T(1 - 5\ f_{xL})\}\ f_{yB}$
	$0.2 < f_{xL} \leq 0.5$	1.0	$1.0 + (1 - 2\ f_{xL})\ f_{yB}$
	$0.5 < f_{xL} \leq 0.8$	1.0	$1.0 + 1.5(2\ f_{xL} - 1)\ f_{yB}$
	$f_{xL} > 0.8$	$1.0 + (f_{xL} - 0.8)\ (1 - f_{yB})\ A$	$1.0 + \{1.5(2\ f_{xL} - 1) - (f_{xL} - 0.8)\ A\}f_{yB} + (f_{xL} - 0.8)\ A$
$y < 0$	$f_{xL} \leq 0.2$	$1.0 + 3\ (2 - f_T)\ (1 - 5\ f_{xL}) + \{(28\ f_{xL} - 5) + 3\ f_T(1 - 5\ f_{xL})\}\ f_{yB}$	$1.0 + 3\ (2 - f_T)\ (1 - 5\ f_{xL})\ (1 - f_{yB})$
	$0.2 < f_{xL} \leq 0.5$	$1.0 + (1 - 2\ f_{xL})\ f_{yB}$	1.0
	$0.5 < f_{xL} \leq 0.8$	$1.0 + 1.5(2\ f_{xL} - 1)\ f_{yB}$	1.0
	$f_{xL} > 0.8$	$1.0 + \{1.5(2\ f_{xL} - 1) - (f_{xL} - 0.8)\ A\}f_{yB} + (f_{xL} - 0.8)\ A$	$1.0 + (f_{xL} - 0.8)\ (1 - f_{yB})\ A$
where: $A = 22 - 15f_T + 3[22(f_{xL} - 0.8) - 0.25(2 - f_T)]$			

Figure 10 : Transverse distribution of dynamic pressure amidships for OSA-1P (left) and OSA-1S (right) load cases

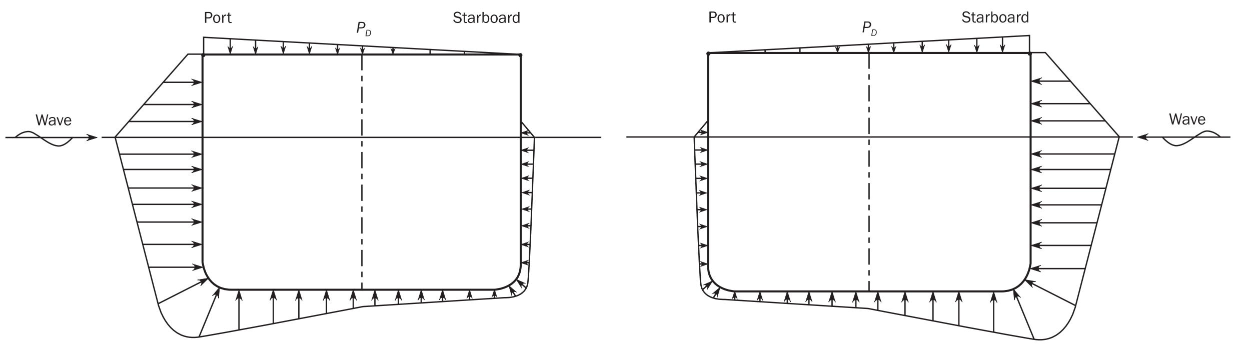


Figure 11 : Transverse distribution of dynamic pressure amidships for OSA-2P (left) and OSA-2S (right) load cases

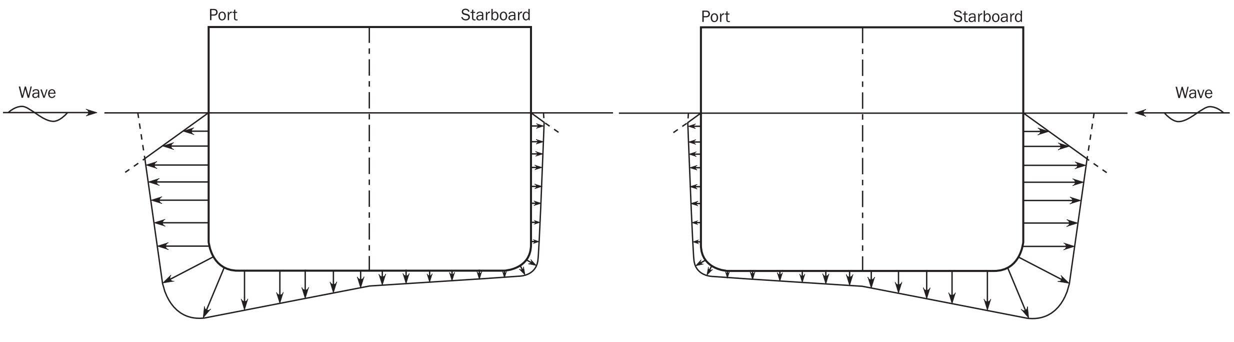


Table 18 : k_p values for OSA load cases

Transverse position	f_{xL}	OSA-1P; OSA-2P	OSA-1S; OSA-2S
$y \geq 0$	0.0	$0.75 - 0.5\ f_{yB}$	0.75
	0.2	$f_T - 0.25 + (1.25 - f_T)\ f_{yB}$	$f_T - 0.25 + (0.35\ f_T - 0.47)\ f_{yB}$
	0.4	1.0	$1.0 + (2.7\ f_T - 3.2)\ f_{yB}$
	0.5	$1.25 - 0.5\ f_T + (0.5\ f_T - 0.25) f_{yB}$	$1.25 - 0.5\ f_T + (2.7\ f_T - 3.2)\ f_{yB}$
	0.6	$1.5 - f_T + (f_T - 1.07)\ f_{yB}$	$1.5 - f_T + (2.68\ f_T - 3.19)\ f_{yB}$
	0.85	$0.5\ f_T - 1.25 + (0.25 - 0.5\ f_T)\ f_{yB}$	$0.5\ f_T - 1.25 + (0.2 - 0.1\ f_T)\ f_{yB}$
	1.0	$0.5\ f_T - 1.25 + (0.25 - 0.5\ f_T)\ f_{yB}$	$0.5\ f_T - 1.25 + (0.2 - 0.1\ f_T)\ f_{yB}$
$y < 0$	0.0	0.75	$0.75 - 0.5\ f_{yB}$
	0.2	$f_T - 0.25 + (0.35\ f_T - 0.47)\ f_{yB}$	$f_T - 0.25 + (1.25 - f_T)\ f_{yB}$
	0.4	$1.0 + (2.7\ f_T - 3.2)\ f_{yB}$	1.0
	0.5	$1.25 - 0.5\ f_T + (2.7\ f_T - 3.2)\ f_{yB}$	$1.25 - 0.5\ f_T + (0.5\ f_T - 0.25) f_{yB}$
	0.6	$1.5 - f_T + (2.68\ f_T - 3.19)\ f_{yB}$	$1.5 - f_T + (f_T - 1.07)\ f_{yB}$
	0.85	$0.5\ f_T - 1.25 + (0.2 - 0.1\ f_T)\ f_{yB}$	$0.5\ f_T - 1.25 + (0.25 - 0.5\ f_T)\ f_{yB}$
	1.0	$0.5\ f_T - 1.25 + (0.2 - 0.1\ f_T)\ f_{yB}$	$0.5\ f_T - 1.25 + (0.25 - 0.5\ f_T)\ f_{yB}$

1.3.9 Envelope of dynamic pressure

The envelope of dynamic pressure at any point, $P_{ex\text{-}max}$, is to be taken as the greatest pressure obtained from any of the load cases determined by [1.3.2] to [1.3.8].

1.4 External dynamic pressures for fatigue assessments

1.4.1 General

The external pressure P_{ex} at any load point of the hull for the fatigue static plus dynamic (F:S+D) design load scenario, is to be derived for each fatigue dynamic load case and is to be taken as:

$P_{ex} = P_S + P_W$ but not less than 0.

where:

P_S : Hydrostatic pressure, in kN/m^2, defined in[1.2].

P_W : Hydrodynamic pressure, in kN/m^2, is defined in [1.4.2] to [1.4.6].

1.4.2 Hydrodynamic pressures for HSM load cases

The hydrodynamic pressures, P_W, for load cases HSM-1 and HSM-2, at any load point, in kN/m^2, are to be obtained from Table 19.

Table 19 : Hydrodynamic pressures for HSM load cases

	Wave pressure, in kN/m^2		
Load case	$z \leq T_{LC}$	$T_{LC} < z \leq 2h_w + T_{LC}$	$z > 2h_w + T_{LC}$
HSM-1	$P_w = max\ (-P_{HS}, \rho g(z - T_{LC}))$	$P_w = P_{w,wL} - \frac{1}{2}\rho g\ (z - T_{LC})$	$P_W = 0.0$
HSM-2	$P_w = max\ (P_{HS}, \rho g(z - T_{LC}))$		

where:

$$P_{HS} = f_p\, f_h\, k_a\, k_p\, f_{yz}\, C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{yz} : Girth distribution coefficient, to be taken as:

$$f_{yz} = \frac{z}{T_{LC}} + f_{yB} + 1$$

f_h : Coefficient to be taken as:

$$f_h = 2.75\,(1.21 - 0.66\, f_T)$$

f_p : Coefficient to be taken as:

$$f_p = f_{fa}[(0.21 + 0.02\, f_T) + (6 - 4\, f_T)\, L \times 10^{-5}]$$

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be taken as:

$$k_a = 1 + 3\, f_T - (1 + f_T)\, f_{yB} + [5\,(1 + f_T)\, f_{yB} - 15\, f_T]\, f_{xL} \quad \text{for} \quad f_{xL} < 0.2$$

$$k_a = 1.0 \quad \text{for} \quad 0.2 \le f_{xL} < 0.6$$

$$k_a = 1 + (f_{xL} - 0.6)\,[(13.5 - 3.5\, f_T)\, f_{yB} + (14.5\, f_T - 17) + 40(1 - f_{yB})\,(f_{xL} - 0.6)] \quad \text{for} \quad f_{xL} \ge 0.6$$

λ : Wave length of the dynamic load case, in m, to be taken as:

$$\lambda = 0.6\,(1 + f_T)\, L$$

k_p : Phase coefficient to be obtained from Table 20. Intermediate values are to be interpolated.

Table 20 : k_p values for HSM load cases

f_{xL}	k_P
0	$(1.0 - f_T) + (0.5 - f_T)\, f_{yB}$
$0.3 - 0.1\, f_T$	-1
$0.5 - 0.2\, f_T$	1
$0.9 - 0.4\, f_T$	1
$0.9 - 0.2\, f_T$	-1
1.0	-1

1.4.3 Hydrodynamic pressures for FSM load cases

The hydrodynamic pressures, P_W, for FSM-1 and FSM-2 load cases, at any load point, in kN/m², are to be obtained from Table 21.

Table 21 : Hydrodynamic pressures for FSM load cases

	Wave pressure, in kN/m²		
Load case	$z \le T_{LC}$	$T_{LC} < z \le 2\, h_W + T_{LC}$	$z > 2\, h_W + T_{LC}$
FSM-1	$P_w = max(-P_{FS},\, \rho g(z - T_{LC}))$	$P_W = P_{W,WL} - \frac{1}{2}\, \rho g\,(z - T_{LC})$	$P_W = 0.0$
FSM-2	$P_W = max(P_{FS},\, \rho g(z - T_{LC}))$		

where:

$$P_{FS} = f_p\, f_h\, k_a\, k_p\, f_{yz}\, C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{yz} : Girth distribution coefficient, to be taken as:

$$f_{yz} = \frac{z}{T_{LC}} + f_{yB} + 1$$

f_h : Coefficient to be taken as:
$f_h = 2.6$

f_p : Coefficient to be taken as:

$$f_p = f_{fa}[(0.21 + 0.02\,f_T) + (6 - 4\,f_T)\,L \times 10^{-5}]$$

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be taken as:

$k_a = 1 + (3.5 - 2\,f_T)(1 - 5\,f_{xL})(1 - f_{yB})$ for $f_{xL} < 0.2$

$k_a = 1.0$ for $0.2 \le f_{xL} < 0.9$

$k_a = 1 + 15(1 - f_{yB})(f_{xL} - 0.9)$ for $f_{xL} \ge 0.9$

λ : Wave length of the dynamic load case, in m, to be taken as:

$$\lambda = 0.6\left(1 + \frac{2}{3}\,f_T\right)L$$

k_p : Phase coefficient to be obtained from Table 22. Intermediate values are to be interpolated.

Table 22 : k_p values for HSM load cases

f_{xL}	k_P
0	$-0.75 - 0.25\,f_{yB}$
$0.35 - 0.1\,f_T$	-1
$0.5 - 0.2\,f_T$	1
0.75	1
$0.9 - 0.1\,f_T$	-1
1.0	$-0.5 - 0.5\,f_{yB}$

1.4.4 Hydrodynamic pressures for BSR load cases

The hydrodynamic pressures, P_W, for BSR-1 and BSR-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 23.

Table 23 : Hydrodynamic pressures for BSR load cases

	Wave pressure, in kN/m^2		
Load case	$z \le T_{LC}$	$T_{LC} < z \le 2\,h_W + T_{LC}$	$z > 2\,h_W + T_{LC}$
BSR-1P	$P_W = \max\,(P_{BSR}, \rho g(z - T_{LC}))$	$P_W = P_{W,WL} - \frac{1}{2}\rho g\,(z - T_{LC})$	$P_W = 0.0$
BSR-2P	$P_W = \max\,(-P_{BSR}, \rho g(z - T_{LC}))$		
BSR-1S	$P_W = \max\,(P_{BSR}, \rho g(z - T_{LC}))$		
BSR-2S	$P_W = \max\,(-P_{BSR}, \rho g(z - T_{LC}))$		

where:

- For BSR-1P and BSR-2P load cases.

$$P_{BSR} = 10y\sin\theta + 0.88 f_p\,C_w\sqrt{\frac{L_0 + \lambda - 125}{L}}(f_{yB1} + 1)$$

- For BSR-1S and BSR-2S load cases.

$$P_{BSR} = -10y\sin\theta + 0.88 f_p\, C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}(f_{yB1} + 1)$$

f_p : Coefficient to be taken as:

$$f_p = f_{fa}[(0.21 + 0.04\, f_T) - (12\, f_T - 2)\, B \times 10^{-4}]$$

λ : Wave length of the dynamic load case, in m, to be taken as:

$$\lambda = \frac{g}{2\pi} T_\theta^2$$

1.4.5 Hydrodynamic pressures for BSP load cases

The wave pressures, P_W, for BSP-1 and BSP-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 24.

Table 24 : Hydrodynamic pressures for BSP load cases

	Wave pressure, in kN/m^2		
Load case	$z \le T_{LC}$	$T_{LC} < z \le 2\, h_w + T_{LC}$	$z > 2\, h_w + T_{LC}$
BSP-1P	$P_W = \max(P_{BSP}, \rho g(z - T_{LC}))$	$P_W = P_{W,WL} - \frac{1}{2}\rho g(z - T_{LC})$	$P_W = 0.0$
BSP-2P	$P_W = \max(-P_{BSP}, \rho g(z - T_{LC}))$		
BSP-1S	$P_W = \max(P_{BSP}, \rho g(z - T_{LC}))$		
BSP-2S	$P_W = \max(-P_{BSP}, \rho g(z - T_{LC}))$		

where:

$$P_{BSP} = 4.5\, f_p\, f_{yz}\, C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

λ : Wave length of the dynamic load case, in m, to be taken as:

$$\lambda = 0.2(1 + 2\, f_T)L$$

f_p : Coefficient to be taken as:

$$f_p = f_{fa}[0.2 + (8 + 16\, f_T) \times 10^{-3}]$$

f_{yz} : Girth distribution coefficient, to be obtained from Table 25.

Table 25 : Girth distribution coefficient, f_{yz} for BSP load cases

Transverse position	BSP-1P - BSP-2P	BSP-1S - BSP-2S
$y \ge 0$	$f_{yz} = 2\frac{z}{T_{LC}} + 2.5\, f_{yB1} + 0.5$	$f_{yz} = \frac{2}{3}\frac{z}{T_{LC}} + \frac{1}{2} f_{yB1} + 0.5$
$y < 0$	$f_{yz} = \frac{2}{3}\frac{z}{T_{LC}} + \frac{1}{2} f_{yB1} + 0.5$	$f_{yz} = 2\frac{z}{T_{LC}} + 2.5\, f_{yB1} + 0.5$

1.4.6 Hydrodynamic pressures for OST load cases

The wave pressures, P_W, for OST-1 and OST-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 26.

Table 26 : Hydrodynamic pressures for OST load cases

	Wave pressure, in kN/m²		
Load case	$z \leq T_{LC}$	$T_{LC} < z \leq 2\ h_W + T_{LC}$	$z > 2h_W + T_{LC}$
OST-1P	$P_W = \max(P_{OST}, \rho g(z - T_{LC}))$	$P_W = P_{W,WL} - \frac{1}{2}\rho g(z - T_{LC})$	$P_W = 0.0$
OST-2P	$P_W = \max(-P_{OST}, \rho g(z - T_{LC}))$		
OST-1S	$P_W = \max(P_{OST}, \rho g(z - T_{LC}))$		
OST-2S	$P_W = \max(-P_{OST}, \rho g(z - T_{LC}))$		

where:

$$P_{OST} = 1.38\ f_p\ k_a\ k_p\ f_{yz}\ C_w\ \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{yz} : Girth distribution coefficient, to be obtained from Table 27.

Table 27 : Girth distribution coefficient, f_{yz} for OST load cases

Transverse position	OST-1P - OST-2P	OST-1S - OST-2S
$y \geq 0$	$5\frac{z}{T_{LC}} + 3.3\ f_{yB} + 1.7$	$\frac{z}{T_{LC}} + 0.3\ f_{yB} + 1.7$
$y < 0$	$\frac{z}{T_{LC}} + 0.3\ f_{yB} + 1.7$	$5\frac{z}{T_{LC}} + 3.3\ f_{yB} + 1.7$

f_p : Coefficient to be taken as:

$$f_p = f_{fa}[(0.25 - 0.02\ f_T) + (12\ f_T - 9)\ B \times 10^{-4}]$$

λ : Wave length of the dynamic load case, in m, to be taken as:

$$\lambda = 0.45\ L$$

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be obtained from Table 28.

k_p : Phase coefficient to be obtained from Table 29. Intermediate values are to be interpolated.

Table 28 : k_a values for OST load cases

Transverse position	Longitudinal Position	OST-1P - OST-2P	OST-1S - OST-2S
$y \geq 0$	$f_{xL} \leq 0.2$	$1.0 + \{(3.5 - 2\ f_T) + (10\ f_T - 17.5)f_{xL}\}(1 - f_{yB})$	$1.0 + (3.5 - 2\ f_T - 1.5\ f_{yB}) + (10\ f_T - 17.5 + 7.5\ f_{yB})f_{xL}$
	$0.2 < f_{xL} \leq 0.8$	1.0	1.0
	$f_{xL} > 0.8$	1.0	$1.0 + 2(1 - f_T)(5f_{xL} - 4)f_{yB}$
$y < 0$	$f_{xL} \leq 0.2$	$1.0 + (3.5 - 2\ f_T - 1.5\ f_{yB}) + (10\ f_T - 17.5 + 7.5\ f_{yB})f_{xL}$	$1.0 + \{(3.5 - 2\ f_T) + (10\ f_T - 17.5)f_{xL}\}(1 - f_{yB})$
	$0.2 < f_{xL} \leq 0.8$	1.0	1.0
	$f_{xL} > 0.8$	$1.0 + 2(1 - f_T)(5f_{xL} - 4)f_{yB}$	1.0

Table 29 : k_p values for OST load cases

Transverse position	f_{xL}	OST-1P - OST-2P	OST-1S - OST-2S
$y \geq 0$	0.0	1.0	$1.0 + (0.5 - f_T)\ f_{yB}$
	0.2	1.0	$1.0 + 3(0.5 - f_T)f_{yB}$
	0.4	-1.0	$(2.7 - 2.4\ f_T)\ f_{yB} - 1$
	0.5	-1.0	$(2.8 - 2.6\ f_T)\ f_{yB} - 1$
	0.7	$(f_T - 0.62)\ f_{yB} - 0.38$	$(2.38 - 3\ f_T)\ f_{yB} - 0.38$
	0.9	$0.24 + 0.76\ f_{yB}$	$0.24 - (0.24 + f_T)\ f_{yB}$
	1.0	$-1.0 + 0.5\ f_{yB}$	-1.0
$y = 0$	0.0	$1.0 + (0.5 - f_T)\ f_{yB}$	1.0
	0.2	$1.0 + 3(0.5 - f_T)f_{yB}$	1.0
	0.4	$(2.7 - 2.4\ f_T)\ f_{yB} - 1$	-1.0
	0.5	$(2.8 - 2.6\ f_T)\ f_{yB} - 1$	-1.0
	0.7	$(2.38 - 3\ f_T)\ f_{yB} - 0.38$	$(f_T - 0.62)\ f_{yB} - 0.38$
	0.9	$0.24 - (0.24 + f_T)\ f_{yB}$	$0.24 + 0.76\ f_{yB}$
	1.0	-1.0	$-1.0 + 0.5\ f_{yB}$

2 EXTERNAL PRESSURES ON EXPOSED DECKS

2.1 Application

2.1.1

The external pressures and forces on exposed decks are only to be applied for strength assessment.

2.1.2

The green sea pressures defined in [2.2] for exposed decks are to be considered independently of the pressures due to distributed cargo or other equipment loads and any concentrated forces due to cargo or other unit equipment loads, defined in [2.3.1] and [2.3.2] respectively.

2.2 Green sea loads

2.2.1 Pressure on exposed deck

The external dynamic pressure due to green sea loading, P_D, at any point of an exposed deck, in kN/m^2, for the static plus dynamic (S+D) design load scenarios is to be derived for each dynamic load case and is to be taken as defined in [2.2.3] to [2.2.4]

The external dynamic pressure due to green sea loading, P_D, at any point of an exposed deck for the static (S) design load scenarios is zero.

2.2.2

If a breakwater is fitted on the exposed deck, no reduction in the green sea pressure is allowed for the area of the exposed deck located aft of the breakwater.

2.2.3 HSM, HSA and FSM load cases

The external pressure, P_D, for HSM, HSA and FSM load cases, at any load point of an exposed deck is to be obtained, in kN/m^2, from the following formula, see Figure 2 and Figure 3:

$$P_D = \chi \, P_W$$

where:

$P_W = P_{W,D}$, but not to be taken less than $P_{D\text{-}min}$.

$P_{W,D}$: Pressure, in kN/m^2, obtained at side of the exposed deck for HSM, HSA and FSM load cases as defined in [1.3].

$P_{D\text{-}min}$: Minimum exposed deck pressure, in kN/m^2, to be taken as:

- For cargo hold analysis according to Ch 7: $P_{D\text{-}min} = 0$.
- For other cases: $P_{D\text{-}min}$ as defined in Table 30.

χ : Coefficient defined in Table 31.

Table 30 : Minimum pressures on exposed decks for HSM, HSA, FSM load cases

Location	Minimum pressure on exposed deck, $P_{D\text{-}min}$, in kN/m^2	
	$L_{LL} \geq 100$m	$L_{LL} < 100$m
$x_{LL}/L_{LL} \leq 0.75$	34.3	$14.9 + 0.195\, L_{LL}$
$x_{LL}/L_{LL} > 0.75$	$34.3 + (14.8 + a(L_{LL} - 100))\left(4\dfrac{x_{LL}}{L_{LL}} - 3\right)$	$12.2 + \dfrac{L_{LL}}{9}\left(5\dfrac{x_{LL}}{L_{LL}} - 2\right) + 3.6\dfrac{x_{LL}}{L_{LL}}$

a : Coefficient taken equal to:
$a = 0.356$ for Type A, Type B-60 and Type B-100 freeboard ships
$a = 0.0726$ for Type B freeboard ships.

x_{LL} : *X*-coordinate of the load point measured from the aft end of the freeboard length L_{LL}.

Table 31 : Coefficient for pressure on exposed decks

Exposed deck location	χ
Freeboard deck	1.00
Superstructure deck including forecastle deck	0.75
1st tier of deckhouse	0.56
2nd tier of deckhouse	0.42
3rd tier of deckhouse	0.32
4th tier of deckhouse	0.25
5th tier of deckhouse	0.20
6th tier of deckhouse	0.15
7th tier of deckhouse and above	0.10

2.2.4 BSR, BSP, OST and OSA load cases

The external pressure, P_D, for BSR, BSP, OST and OSA load cases at any load point of an exposed deck is to be obtained, in kN/m^2, by linear interpolation between the pressures at the port and starboard deck edges (see also Figure 4, Figure 6, Figure 9 and Figure 10):

$$P_{D,stb} = \chi \, P_{W,D-stb}$$

$$P_{D,pt} = \chi \, P_{W,D-pt}$$

where:

$P_{W,D\text{-}stb}$: Pressure obtained at starboard deck edge for BSR, BSP, OST or OSA load cases as defined in [1.3], as appropriate.

$P_{W,D\text{-}pt}$: Pressure obtained at port deck edge for BSR, BSP, OST and OSA load cases as defined in [1.3], as appropriate.

χ : Coefficient defined in Table 31.

2.2.5 Envelope of dynamic pressures on exposed deck

The envelope of dynamic pressure at any point of an exposed deck, $P_{D\text{-}max}$, is to be taken as the greatest pressure obtained from any of the load cases determined by [2.2.3] and [2.2.4].

2.3 Load carried on exposed deck

2.3.1 Pressure due to distributed load

If a distributed load is carried on an exposed deck, for example deck cargo or other equipment, the static and dynamic pressures due to this distributed load are to be considered.

The total pressure, P_{dl}, in kN/m^2, due to this distributed load for the static (S) design load scenario is to be taken as:

$$P_{dl} = P_{dl-s}$$

The pressure P_{dl}, in kN/m^2, due to this distributed load for the static plus dynamic (S+D) design load scenario is to be derived for each dynamic load case and is to be taken as:

$$P_{dl} = P_{dl-s} + P_{dl-d}$$

where:

$P_{dl\text{-}s}$: Static pressure, in kN/m^2, due to the distributed load, to be defined by the Designer and, in general, but not less than 10 kN/m^2.

$P_{dl\text{-}d}$: Dynamic pressure, in kN/m^2, due to the distributed load, in kN/m^2, to be taken as:

$$P_{dl-d} = f_\beta \frac{a_Z}{g} P_{dl-s}$$

a_Z : Vertical acceleration, in m/s^2, at the centre of gravity of the distributed load, for the considered load case, to be obtained according to Ch 4, Sec 3, [3.2.4].

2.3.2 Concentrated force due to unit load

If a unit load, for example deck cargo, is carried on an exposed deck, the static and dynamic forces due to the unit load carried are to be considered.

The force F_U, in kN, due to this concentrated load for the static (S) design load scenarios, is to be taken as:

$$F_U = F_{U-s}$$

The force F_U, in kN, due to this concentrated load for the static plus dynamic (S+D) design load scenarios is to be derived for each dynamic load case and is to be taken as:

$$F_U = F_{U-s} + F_{U-d}$$

where:

$F_{U\text{-}s}$: Static force, in kN, due to the unit load to be taken equal to:

$$F_{U-s} = m_U\, g$$

$F_{U\text{-}d}$: Dynamic force, in kN, due to unit load to be taken equal to:

$$F_{U-d} = m_U\, f_\beta\, a_Z$$

m_U : Mass of the unit load carried, in t.

a_Z : Vertical acceleration, in m/s^2, at the centre of gravity of the unit load carried for the considered load case, to be obtained according to Ch 4, Sec 3, [3.2.4].

3 EXTERNAL IMPACT PRESSURES FOR THE BOW AREA

3.1 Application

3.1.1

The impact pressures for the bow area are only to be applied for strength assessment.

3.2 Bottom slamming pressure

3.2.1

The bottom slamming pressure P_{SL}, in kN/m^2, for the bottom slamming design load scenario is to be evaluated for the following two cases:

Case 1: An empty ballast tank or a void space in way of the bottom shell.

$$P_{SL} = 10\, g\sqrt{L}\, f_{SL}\, c_{SL-et} \quad \text{for } L < 170 \text{ m}$$

$$P_{SL} = 130\, g\, f_{SL}\, c_{SL-et}\, e^{c_1} \quad \text{for } L \geq 170 \text{ m}$$

Case 2: A full ballast tank in way of the bottom shell.

$$P_{SL} = 10\, g\sqrt{L}\, f_{SL}\, c_{SL-ft} - 1.25\, \rho g(z_{top} - z) \quad \text{for } L < 170 \text{ m}$$

$$P_{SL} = 130\, g\, f_{SL}\, c_{SL-ft}\, e^{c_1} - 1.25\, \rho g(z_{top} - z) \quad \text{for } L \geq 170 \text{ m}$$

where:

c_1 : Coefficient to be taken as:

$$c_1 = 0 \quad \text{for } L \leq 180 \text{ m}$$

$$c_1 = -0.0125(L - 180)^{0.705} \quad \text{for } L > 180 \text{ m}$$

$c_{SL\text{-}et}$: Slamming coefficient for case with an empty ballast tank or void space:

$$c_{SL-et} = 5.95 - 10.5\left(\frac{T_{F-e}}{L}\right)^{0.2}$$

$c_{SL\text{-}ft}$: Slamming coefficient for case with a full ballast tank:

$$c_{SL-ft} = 5.95 - 10.5\left(\frac{T_{F-f}}{L}\right)^{0.2}$$

f_{SL} : Longitudinal slamming distribution factor, to be taken as:

$$f_{SL} = 0 \quad \text{for } x/L \leq 0.5$$

$$f_{SL} = 1.0 \quad \text{for } x/L = 0.5 + c_2$$

$$f_{SL} = 1.0 \quad \text{for } x/L = 0.65 + c_2$$

$$f_{SL} = 0.5 \quad \text{for } x/L \geq 1$$

Intermediate values of f_{SL} are to be obtained by linear interpolation.

c_2 : Coefficient to be taken as:

$$c_2 = 0.33\, C_B + \frac{L}{2500} \quad \text{but not to be taken greater than 0.35.}$$

$T_{F\text{-}e}$: Design slamming draught at the FP to be provided by the Designer. $T_{F\text{-}e}$ is not to be greater than the minimum draught at the FP indicated in the loading manual for all seagoing conditions where any of the ballast tanks within the bottom slamming region are empty. This includes all loading conditions with tanks inside the bottom slamming region that use the 'sequential' ballast water exchange method.

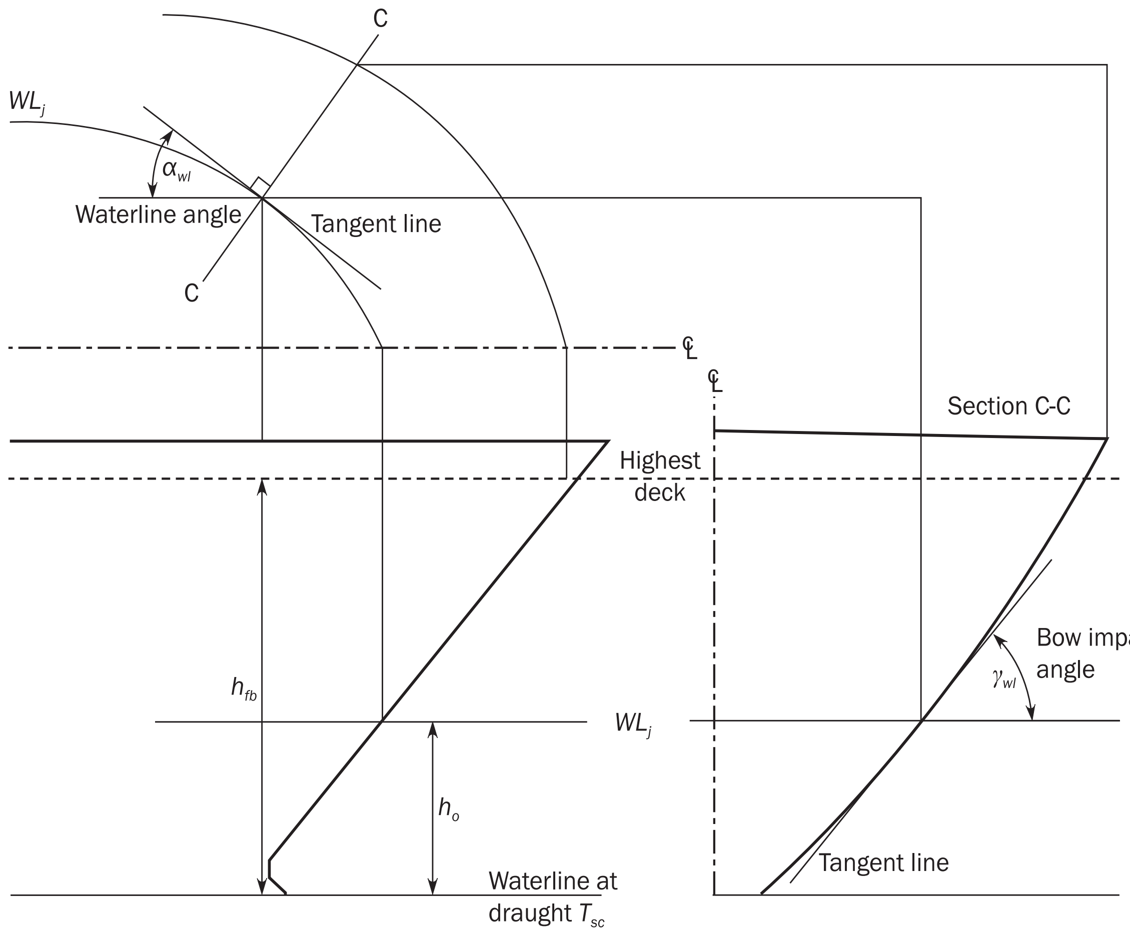
$T_{F\text{-}f}$: Design slamming draught at the FP to be provided by the Designer. $T_{F\text{-}f}$ is not to be greater than the minimum draught at the FP indicated in the loading manual for all seagoing conditions where all ballast tanks within the bottom slamming region are full. This includes all loading conditions with tanks inside the bottom slamming region that use the 'flow-through' ballast water exchange method.

z_{top} : Z-coordinate of the highest point of the tank, excluding small hatchways, in m.
For strength assessment of double bottom floors and girders, z_{top} is not to be taken greater than the double bottom height.

3.2.2 Loading manual information

The loading guidance information is to clearly state the design slamming draughts and the ballast water exchange method used for each ballast tank.

Figure 12 : Definition of bow geometry



3.3 Bow impact pressure

3.3.1 Design pressures

The bow impact pressure P_{FB}, in kN/m^2, to be considered for the bow impact design load scenario is to be taken as:

$$P_{FB} = 1.025\ f_{FB}\ c_{FB}\ V_{im}^2\ \sin\gamma_{wl}$$

where:

f_{FB} : Longitudinal bow flare impact pressure distribution factor. To be taken as:

$$f_{FB} = 0.55 \quad \text{for } x/L \le 0.9$$
$$f_{FB} = 4\,(x/L - 0.9) + 0.55 \quad \text{for } 0.9 < x/L \le 0.9875$$
$$f_{FB} = 8(x/L - 0.9875) + 0.9 \quad \text{for } 0.9875 < x/L \le 1.0$$
$$f_{FB} = 1.0 \quad \text{for } x/L > 1.0$$

V_{im} : Impact speed, in knots, to be taken as:

$$V_{im} = 0.514\ V_{ref}\ \sin\alpha_{wl} + \sqrt{L}$$

V_{ref} : Forward speed, in knots, to be taken as:

$$V_{ref} = 0.75\ V \quad \text{but not less than 10.}$$

α_{wl} : Local waterline angle, in deg, at the considered position, but not less than 35 deg. See Figure 12.

γ_{wl} : Local bow impact angle, in deg, measured in a vertical plane containing the normal to the shell, from the horizontal to the tangent line at the considered position but not less than 50 deg, as shown in Figure 12. Where this value is not available, it may be taken as:

$$\gamma_{wl} = \tan^{-1}\left(\frac{\tan\beta_{pl}}{\cos\alpha_{wl}}\right)$$

β_{pl} : Local body plan angle, in deg, at the considered position from the horizontal to the tangent line, but not less than 35 deg.

c_{FB} : Coefficient to be taken as:

$$c_{FB} = 1.0 \quad \text{for positions between draughts } T_{BAL} \text{ and } T_{SC}.$$
$$c_{FB} = \sqrt{1.0 + \cos^2\left[90\ \frac{(h_{fb} - 2h_0)}{h_{fb}}\right]} \quad \text{for positions above draught } T_{SC}.$$

h_{fb} : Vertical distance, in m, from the waterline at the draught T_{SC} to the highest deck at side. See Figure 12.

h_0 : Vertical distance, in m, from the waterline at the draught T_{SC} to the considered position. See Figure 12.

4 EXTERNAL PRESSURES ON SUPERSTRUCTURE AND DECKHOUSES

4.1 Application

4.1.1

The external pressures on superstructure and deckhouses are only to be applied for strength assessment.

These pressures are to be considered as dynamic pressures and are to be applied to the appropriate structure without any static pressure load component.

4.1.2

The dynamic load case concept is not to be applied for external pressures on superstructures and deckhouses.

4.2 Exposed wheel house tops

4.2.1

The lateral pressure for exposed wheel house tops, P_D, in kN/m^2, is to be taken as:

$$P_D = 12.5$$

4.3 Sides of superstructures

4.3.1

The design pressure for the external sides of superstructures, P_{SI}, in kN/m^2, is to be taken as:

where:

$$P_{SI} = 2.1\ C_W\ c_F\ (C_B + 0.7)\ \frac{20}{10 + z - T_{LC}}$$

c_F : Distribution factor according to Table 32.

Table 32 : Distribution factor c_F

Location	c_F
$x/L < 0.2$	$1.0 + \frac{5}{C_B}\left(0.2 - \frac{x}{L}\right)$ without taking x/L less than 0.1
$x/L \geq 0.2$	1.0

4.4 End bulkheads of superstructures and deckhouse walls

4.4.1

The external pressure for the aft and forward external bulkheads of superstructures and deckhouse walls, in kN/m^2, is to be taken as:

$$P_A = f_n\ f_c\ [f_b\ f_d - (z - T_{SC})]$$

but is not to be less than $P_{A\text{-}min}$.

where:

f_n : Coefficient defined in Table 33.

f_c : Coefficient, to be taken as:

$$f_c = 0.3 + 0.7\ \frac{b_1}{B_1} \quad \text{but not less than 0.475.}$$

For exposed parts of machinery casings, f_c is not to be taken less than 1.0.

f_d : Coefficient, to be taken as:

$$f_d = \frac{L}{10}\ e^{-(L/300)} - \left(1 - \left(\frac{L}{150}\right)^2\right) \quad \text{for } L < 150 \text{ m}$$

$$f_d = \frac{L}{10}\ e^{-(L/300)} \quad \text{for } 150 \text{ m} \leq L < 300 \text{ m}$$

$$f_d = 11.03 \quad \text{for } L \geq 300 \text{ m}$$

b_1 : Breadth of deckhouse at the position considered.

B_1 : Actual breadth of ship on the exposed weather deck at the position considered.

f_b : Coefficient defined in Table 34.

$P_{A\text{-}min}$: Minimum lateral pressure, in kN/m^2, as defined in Table 35.

5 EXTERNAL PRESSURES ON HATCH COVERS

5.1 Application

5.1.1

The external pressures on hatch covers are only to be applied for strength assessment.

5.2 Green sea loads

5.2.1

The green sea loads at any load point of a hatch cover, P_{HC}, in kN/mm^2, is to be taken as follows:

- For cargo hold analysis according to Ch 7:

  $P_{HC} = P_D - \rho\ g\ (z_{HC} - D)$ without being less than 0.

- For other cases: $P_{HC} = P_{D,min}$ as defined in Table 30.

P_D : Green sea pressure, in kN/mm^2, on the deck in way of the hatch cover obtained according to [2.2], considering χ equal to 1.0.

z_{HC} : z coordinate of the top of the hatch cover, in m.

5.3 Load carried on hatch covers

5.3.1

If a distributed load or a unit load is carried on a hatch cover, the pressure is to be obtained according to [2.3].

Table 33 : Coefficient f_n

Type of bulkhead	Location	f_n
Unprotected front bulkhead (1)	Lowest tier (2)	$20 + \frac{L_2}{12}$
	Second tier	$10 + \frac{L_2}{12}$
	Third tier and above	$5 + \frac{L_2}{15}$
Protected front bulkhead (1)	All tiers	$5 + \frac{L_2}{15}$
Side bulkheads	All tiers	$5 + \frac{L_2}{15}$
Aft end bulkheads	Abaft amidships	$7 + \frac{L_2}{100} - 8\frac{x}{L_2}$
	Forward of amidships	$5 + \frac{L_2}{100} - 4\frac{x}{L_2}$

(1) The front bulkhead of a superstructure or deckhouse may be considered as protected when it is located less than B_x behind another superstructure or deckhouse, and the width of the front bulkhead being considered is less than the width of the aft bulkhead of the superstructure or deckhouse forward of it. B_x is the local breadth of the ship at the front bulkhead.

(2) The lowest tier is normally that tier which is directly situated above the uppermost continuous deck to which the moulded depth D is measured. However, when (D - T_{SC}) exceeds the minimum non-corrected tabular freeboard (according to ICLL as amended) by at least one standard superstructure height (as defined in Ch 1, Sec 4, [3.3]), then this tier may be defined as the 2nd tier and the tier above as the 3rd tier.

Table 34 : Coefficient f_b

Location of bulkhead (1)	f_b
$\frac{x}{L} < 0.45$	$1.0 + \left(\frac{x/L - 0.45}{C_{B1} + 0.2}\right)^2$
$\frac{x}{L} \geq 0.45$	$1.0 + 1.5\left(\frac{x/L - 0.45}{C_{B1} + 0.2}\right)^2$

where:

C_{B1} : Block coefficient, but not less than 0.60 nor greater than 0.80. For aft deckhouse bulkheads located forward of amidships, C_{B1} may be taken as 0.80.

(1) For deckhouse sides, the deckhouse is to be subdivided into parts of approximately equal length, not exceeding 0.15*L* each, and *x* is to be taken as the *X*-coordinate of the centre of each part considered.

Table 35 : Minimum lateral pressure, P_{A-min}

	P_{A-min}, in kN/m²	
L	Lowest tier of unprotected fronts	Elsewhere (1)
$90 < L \leq 250$	$25 + \frac{L}{10}$	$12.5 + \frac{L}{20}$
$L > 250$	50	25

(1) For the 4th tier and above, P_{A-min} is to be taken equal to 12.5 kN/m².

SECTION 6
INTERNAL LOADS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4

a_X, a_Y, a_Z: Longitudinal, transverse and vertical accelerations, in m/s^2, at x_G, y_G, z_G, as defined in Ch 4, Sec 3, [3.2].

B_H : Breadth of the cargo hold, in m, measured at mid-length of the cargo hold and at the mid height between the top of hopper tank and the bottom of topside tank, see Figure 1.

B_{IB} : Breadth of inner bottom, in m, measured at mid-length of the cargo hold, see Figure 1.

D_1 : Distance, in m, from the baseline to the freeboard deck at side amidships.

d_{sc} : Diameter, in m, of a steel coil.

f_{cd} : Factor for joint probability of occurrence of liquid cargo density and maximum sea state in 25 years design life, to be taken as:

- For strength assessment with FE analysis of cargo tanks filled with liquid cargo:

  $f_{cd} = 1.0$ for $\rho_L > 1.025$ t/m^3.

  $f_{cd} = 0.88$ for $\rho_L = 1.025$ t/m^3.

- For other cases:

  $f_{cd} = 1.0$.

f_{dc} : Dry cargo factor taken as:

- $f_{dc} = 1.0$ for strength assessment,
- $f_{dc} = 0.5$ for fatigue assessment.

f_β : Coefficient defined in Ch 4, Sec 4.

h_{air} : Height of air pipe or overflow pipe above the top of the tank, in m.

h_C : Height of bulk cargo, in m, from the inner bottom to the upper surface of bulk cargo, as defined in [2.3.1] or [2.3.2].

h_{DB} : Height, in m, of the double bottom at the centreline, measured at mid-length of the cargo hold, see Figure 1.

h_{HPL} : Vertical distance, in m, from the inner bottom at centreline to the upper intersection of hopper tank and side shell or inner side for double side bulk carriers, determined at mid length of the considered cargo hold, as shown in Figure 1.

$h_{HPL} = 0$ if there is no hopper tank.

h_{HPU} : Vertical distance, in m, from the inner bottom at centreline to the lower intersection of topside tank and side shell or inner side for double side bulk carriers, determined at mid length of the cargo hold at midship, as shown in Figure 1.

h_{LS} : Mean height, in m, of the lower stool, measured from the inner bottom.

h_{max} : Maximum permissible filling level, in m, taken as:

- For ballast tanks: maximum tank height,
- For cargo tanks with cargo density equal to ρ_L: maximum tank height

- For cargo tanks with heavy liquid cargo density equal to ρ_{part} associated with a partially filled cargo tank: h_{part} as defined in Ch 10, Sec 4, [1.2.1].

K_C : Coefficient taken equal to:

$K_C = \cos^2\alpha + (1 - \sin\Psi)\sin^2\alpha$ for inner bottom, hopper tank, transverse and longitudinal bulkheads, lower stool, vertical upper stool, inner side and side shell.

$K_C = 0$ for topside tank, main deck and sloped upper stool.

$K_{C\text{-}f}$: Coefficient taken equal to:

$$K_{C-f} = \tan^2\left(45 - \frac{\Psi}{2}\right)$$

ℓ : Distance, in m, between floors.

ℓ_H : Length of the cargo hold, in m, at the centreline between the transverse bulkheads. This is to be measured to the mid-depth of the corrugated bulkhead(s) if fitted.

ℓ_{lp} : Distance, in m, between outermost dunnage per EPP in the ship X direction, see Figure 10.

ℓ_{st} : Length, in m, of a steel coil.

M : Mass, in t, of the bulk cargo being considered.

M_{Full} : Cargo mass, in t, in a cargo hold corresponding to the volume up to the top of the hatch coaming with a density of the greater of M_H/V_{Full} or 1.0 t/m^3.

$M_{Full} = 1.0\ V_{Full}$ but not less than M_H.

M_H : Cargo mass, in t, in a cargo hold that corresponds to the homogeneously loaded condition at maximum draught with 50% consumables.

M_{HD} : Maximum allowable cargo mass, in t, in a cargo hold according to design loading conditions with specified holds empty at maximum draught with 50% consumables.

$M_{sc\text{-}ib}$: Equivalent mass of a steel coil, in t, on inner bottom, as defined in [4.3.1]

$M_{sc\text{-}hs}$: Equivalent mass of a steel coil, in t, on hopper side, as defined in [4.3.2].

n_1 : Number of tiers of steel coils.

n_2 : Number of load points per EPP of the inner bottom, see [4.1.3].

n_3 : Number of dunnages supporting one row of steel coils.

P_{drop} : Overpressure, in kN/m^2, due to sustained liquid flow through air pipe or overflow pipe in case of overfilling or filling during flow through ballast water exchange. It is to be defined by the designer, but not to be less than 25 kN/m^2.

P_{PV} : Setting of pressure relief valve, in kN/m^2, if fitted, but not less than 25 kN/m^2.

perm : Permeability of cargo, to be taken as:

perm = 0.3 for iron ore, coal cargoes and cement.

perm = 0 for steel coils.

R : Vertical coordinate of the ship rotation centre, defined in Ch 4, Sec 3.

s_C : Spacing of corrugations, in m, as defined in Ch 3, Sec 6, [10.4.2].

T_θ : Roll period, in s, as defined in Ch 4, Sec 3, [2.1.1].

V_{Full} : Volume, in m^3, of cargo hold up to top of the hatch coaming, taken as:

$V_{Full} = V_H + V_{HC}$.

V_H : Volume, in m^3, of cargo hold up to level of the intersection of the main deck with the hatch coaming excluding the volume enclosed by hatch coaming, see Figure 1.

V_{HC} : Volume, in m^3, of the hatch coaming, from the level of the intersection of the main deck with the hatch side coaming to the top of the hatch coaming, determined for the cargo hold at midship, as shown in Figure 1.

V_{TS} : Total volume, in m^3, of the portion of the lower bulkhead stools within the cargo hold length ℓ_H and inboard of the hopper tanks.

W : Mass, in t, of a steel coil.

x, y, z : X, Y and Z coordinates, in m, of the load point with respect to the reference coordinate system defined in Ch 4, Sec 1, [1.2.1].

x_G, y_G, z_G: X, Y and Z coordinates, in m, of the volumetric centre of gravity of the tank or fully filled cargo hold, i.e. V_{Full}, considered with respect to the reference coordinate system defined in Ch 4, Sec 1, [1.2].

In case of partially filled cargo hold, x_G, y_G, z_G to be taken as follows:

x_G, y_G: Volumetric centre of gravity of the cargo hold.

$z_G = h_{DB} + h_{C\text{-}cl} / 2$

z_{top} : Z coordinate of the highest point of tank, excluding small hatchways, in m.

z_C : Height of the upper surface of the cargo above the baseline in way of the load point, in m, to be taken as:

$z_C = h_{DB} + h_C$.

α : Angle, in deg, between panel considered and the horizontal plane.

φ : Pitch angle, in deg, defined in Ch 4, Sec 3, [2.1.2].

ψ : Assumed angle of repose, in deg, of bulk cargo (considered drained and removed); to be taken as:

$\psi = 30°$ in general.
$\psi = 35°$ for iron ore.
$\psi = 25°$ for cement.

ρ_c : Density of bulk cargo, in t/m^3, as defined in [2.3.3].

ρ_L : Density of liquid in the tank and ballast hold, in t/m^3, but not less than:

- For strength assessment:

  $\rho_L = 1.025$ for all liquids including oil cargoes. If a tank filled at 98% is intended to carry heavier liquid cargoes than 1.025 (i.e. $\rho_{max\text{-}LM} > 1.025$), then $\rho_L = \rho_{max\text{-}LM}$.

- For fatigue assessment:

  $\rho_L = 0.9$ for liquid cargoes.

  $\rho_L = 1.025$ for all other liquids.

$\rho_{max\text{-}LM}$: Maximum liquid cargo density in t/m^3, associated with a full tank at 98%, from any loading condition in the ship's loading manual or value specified by the designer.

ρ_{part} : Maximum permissible high liquid cargo density, in t/m^3, associated with a partially filled cargo tank but not taken less than ρ_L considered for strength assessment.

ρ_{slh} : Liquid density, in t/m^3, to be used for sloshing assessment, taken as:

$\rho_{slh} = \rho_{part}$ for heavy liquid cargo density associated with partial filling of cargo tank
$\rho_{slh} = \rho_L$ for all other cases

ρ_{ST} : Density of steel, in t/m^3, to be taken as 7.8.

θ : Roll angle, in deg, defined in Ch 4, Sec 3, [2.1.1].

θ_h : Angle, in deg, between inner bottom plate and hopper sloping plate. in general θ_h is such that:

$$\tan\theta_h = \frac{2h_{HPL}}{B_H - B_{IB}}$$

1 PRESSURES DUE TO LIQUIDS

1.1 Application

1.1.1 Pressures for the strength and fatigue assessments of intact conditions

The internal pressure due to liquid acting on any load point of a tank and ballast hold boundary, in kN/m^2, for the static (S) design load scenarios, given in Ch 4, Sec 7, is to be taken as:

$P_{in} = P_{ls}$ but not less than 0.

The internal pressure due to liquid acting on any load point of a tank and ballast hold boundary, in kN/m^2, for the static plus dynamic (S+D) design load scenarios is to be derived for each dynamic load case and is to be taken as:

$P_{in} = P_{ls} + P_{ld}$ but not less than 0.

where:

P_{ls} : Static pressure due to liquid in tanks and ballast holds, in kN/m^2, as defined in [1.2].

P_{ld} : Dynamic inertial pressure due to liquid in tanks and ballast holds, in kN/m^2, as defined in [1.3].

1.1.2 Pressures for the strength assessments of flooded conditions

The internal pressure in flooded condition, in kN/m^2, acting on any load point of the watertight boundary of a hold, tank or other space for the flooded static (S) design load scenarios, given in Ch 4, Sec 7, is to be taken as:

$P_{in} = P_{fs}$ but not less than $\rho g d_0$

The internal pressure in flooded condition, in kN/m^2, acting on any load point of the watertight boundary of a hold, tank or other space for the flooded static plus dynamic (S+D) design load scenarios, is to be derived for each dynamic load case and is to be taken as:

$P_{in} = P_{fs} + P_{fd}$ but not less than $\rho g d_0$

where:

P_{fs} : Static pressure of seawater in flooded condition in the compartment, in kN/m^2, as defined in [1.4].

P_{fd} : Dynamic inertial pressure of seawater in flooded condition in the compartment, in kN/m^2, as defined in [1.5].

d_0 : Distance, in m, to be taken as:

$d_0 = 0.02 L$ for $L < 120$ m.

$d_0 = 2.4$ for $L \geq 120$ m.

For corrugations of vertically corrugated bulkheads of bulk carrier cargo holds, the flooded pressures and forces specified in [3] for bulk cargoes are to be applied.

For cargo holds carrying steel products, the requirements for pressures and forces in [4] are to be applied.

1.2 Static liquid pressure

1.2.1 Normal operations at sea

The static pressure due to liquid in tanks and ballast holds, P_{ls} during normal operations at sea, in kN/m^2, is to be taken as:

$P_{ls} = f_{cd}\, \rho_L\, g\, (Z_{top} - Z) + P_{PV}$ for cargo tanks filled with liquid cargo.

$P_{ls} = \rho_L\, g\, (z_{top} - z + 0.5\, h_{air})$ for other cases.

1.2.2 Harbour/sheltered water operations

The static pressure, P_{ls} due to liquid in tanks and ballast holds for harbour/sheltered water operations, in kN/m^2, is to be taken as:

$P_{ls} = \rho_L\ g\ (z_{top} - z + h_{air}) + P_{drop}$ for ballast tanks

$P_{ls} = \rho_L\ g\ (z_{top} - z) + P_{PV}$ for cargo tanks filled with liquid cargo

$P_{ls} = \rho_L\ g\ (z_{top} - z + 0.5\ h_{air})$ for other cases

1.2.3 Sequential ballast water exchange

The static pressure, P_{ls} due to liquid in ballast tanks associated with sequential ballast water exchange operations, in kN/m^2, is to be taken as:

$P_{ls} = \rho_L\ g\ (z_{top} - z + 0.5\ h_{air})$

1.2.4 Flow through ballast water exchange

The static pressure, P_{ls} due to liquid in ballast tanks associated with flow through ballast water exchange operations, in kN/m^2, is to be taken as:

$P_{ls} = \rho_L\ g\ (z_{top} - z + h_{air}) + P_{drop}$

1.2.5 Ballasting using ballast water treatment system

The static pressure, P_{ls} due to liquid in tanks and ballast holds associated with ballasting operations using a ballast water treatment system is to be taken as defined for sequential ballast exchange in [1.2.3]. The ship designer has to inform the Society if the ballast water treatment system implies additional pressure to be considered as P_{drop}, etc in addition to the pressure defined in [1.2.3].

1.2.6 Static liquid pressure for the fatigue assessment

The static pressure due to liquid in tanks and ballast holds, P_{ls} to be used for the fatigue assessment, in kN/m^2, is to be taken as:

$P_{ls} = \rho_L\ g\ (z_{top} - z)$ for all tanks (cargo and water ballast tanks, ballast hold and other tanks).

1.3 Dynamic liquid pressure

1.3.1

The dynamic pressure, P_{ld} due to liquid in tanks and ballast holds, in kN/m^2 is to be taken as:

$P_{ld} = f_\beta f_{cd} \rho_L [a_Z (z_0 - z) + f_{ull-l}\, a_X (x_0 - x) + f_{ull-t}\, a_Y (y_0 - y)]$

where:

f_{ull-l} : Longitudinal acceleration correction factor for the ullage space above the liquid in tanks and ballast holds, taken as:

- For strength assessment:

  f_{ull-l} = 0.62 for cargo tanks filled with any liquids including water ballast.

  f_{ull-l} = 1.0 for other cases.

- For fatigue assessment:

  $f_{ull-l} = 0.5 + \dfrac{|z_0 - z|}{\ell_{fs}} \dfrac{180}{\varphi\pi}$ for cargo tanks and ballast holds.

  f_{ull-l} = 1.0 for other cases.

  f_{ull-l} is not to be less than 0.0 nor greater than 1.0

ℓ_{fs} : Cargo tank length at the top of the tank or length of the ballast hold hatch coaming, in m.

f_{ull-t} : Transverse acceleration correction factor to account for the ullage space above the liquid in tanks and ballast holds, taken as:

- For strength assessment:

  f_{ull-t} = 0.67 for cargo tanks filled with any liquids including water ballast.

  f_{ull-t} = 1.0 for other cases.

- For fatigue assessment:

  $$f_{ull-t} = 0.5 + \frac{|z_0 - z|}{b_{top}} \frac{180}{\theta\pi} \quad \text{for cargo tanks and ballast holds.}$$

  f_{ull-t} = 1.0 for other cases.

  f_{ull-t} is not to be less than 0.0 nor greater than 1.0

b_{top} : Cargo tank breadth at the top of the tank or breadth of the ballast hold hatch coaming, in m, determined at mid length of the tank or ballast hold hatch coaming.

x_0 : X coordinate, in m, of the reference point.

y_0 : Y coordinate, in m, of the reference point.

z_0 : Z coordinate, in m, of the reference point.

The reference point is to be taken as the point with the highest value of V_j, calculated for all points that define the upper boundary of the tank or ballast hold as follows:

$$V_j = a_X (x_j - x_G) + a_Y (y_j - y_G) + (a_Z + g)(z_j - z_G)$$

where:

x_j : X coordinate, in m, of the point j on the upper boundary of the tank or ballast hold.

y_j : Y coordinate, in m, of the point j on the upper boundary of the tank or ballast hold.

z_j : Z coordinate, in m, of the point j on the upper boundary of the tank or ballast hold.

1.4 Static pressure in flooded conditions

1.4.1 Static pressure in flooded compartments

The static pressure, P_{fs} in kN/m², for watertight boundaries of flooded compartments is to be taken as:

$$P_{fs} = \rho g (z_{FD} - z) \quad \text{but not less than 0.}$$

where:

z_{FD} : Z coordinate, in m, of the freeboard deck at side in way of the transverse section considered or the deepest equilibrium waterline in the damaged condition whichever is the greater.

1.5 Dynamic pressure in flooded conditions

1.5.1 Dynamic pressure in flooded compartments

The dynamic pressure, P_{fd}, in kN/m², for watertight boundaries of flooded compartments is to be taken as:

$$P_{fd} = f_\beta\ \rho\, [a_Z (z_{0FD} - z) + f_{ull-l}\, a_X (x_0 - x) + f_{ull-t}\, a_Y (y_0 - y)]$$

where:

z_{0FD} : Z coordinate of the effective reference point, in m, for a flooded compartment taken as:

When $z_{FD} > z_0,\ z_{0FD} = z_0$

When $z_{FD} \le z_0,\ z_{0FD} = z_{FD}$

f_{ull-l}, f_{ull-t} : Longitudinal and transverse acceleration correction factors:

When $z_{FD} > z_0$, f_{ull-l} and f_{ull-t} are to be taken as defined in [1.3.1].

When $z_{FD} \leq z_0$, f_{ull-l} = 1.0 and f_{ull-t} = 1.0.

2 PRESSURES AND FORCES DUE TO DRY BULK CARGO

2.1 Application

2.1.1

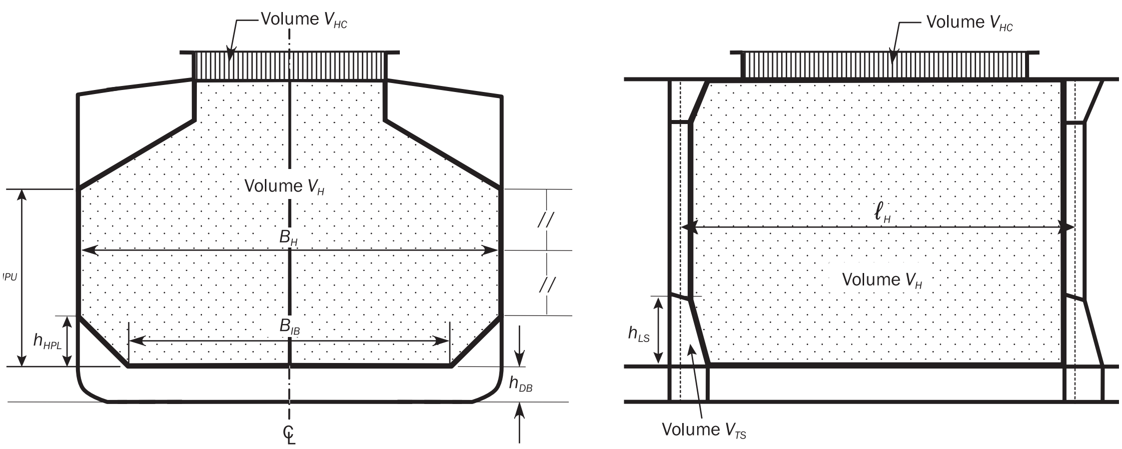
The pressures and forces due to dry cargo in bulk in a cargo hold are to be determined both for fully and partially filled cargo holds according to [2.4] and [2.5].

2.2 Hold definitions

2.2.1 Geometrical characteristics

Figure 1 gives the main geometrical elements of a bulk carrier cargo hold.

Figure 1 : Definition of cargo hold parameters for bulk carrier



2.2.2 Fully and partially filled cargo holds

The definitions of a fully and partially filled dry bulk cargo holds are as follow:

a) Fully filled hold:
The dry bulk cargo density is such that the cargo hold is filled up to the top of the hatch coaming, as shown in Figure 2.

The upper surface of the cargo and its effective height in the hold h_C are to be determined in accordance with [2.3.1].

b) Partially filled hold:
The cargo density is such that the cargo hold is not filled up to the top of the hatch coaming, as shown in Figure 3 or Figure 4.

The upper surface of the cargo and its effective height in the hold h_C are to be determined in accordance with [2.3.2].

2.3 Dry cargo characteristics

2.3.1 Definition of the upper surface of dry bulk cargo for full cargo holds

For a fully filled cargo hold as defined in [2.2.2], including non-prismatic holds, the effective upper surface of the cargo is an equivalent horizontal surface at h_C, in m, above inner bottom at centreline as shown in Figure 2.

The value of h_C is to be calculated at mid length of the cargo hold at the midship, is to be kept constant over the cargo hold region area and is determined as follows:

$$h_C = h_{HPU} + h_0$$

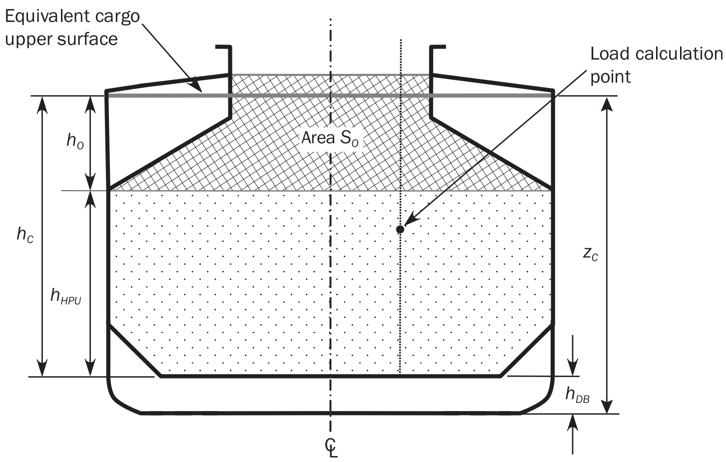
where:

$$h_0 = \frac{S_A}{B_H}$$

$$S_A = S_0 + \frac{V_{HC}}{\ell_H}$$

S_0 : Shaded area, in m^2, above the lower intersection of topside tank and side shell or inner side, as the case may be, and up to the level of the intersection of the main deck with the hatch coaming, determined for the cargo hold at the midship as shown in Figure 2.

Figure 2 : Definition of effective upper surface of cargo for a full cargo hold



2.3.2 Definition of upper surface of dry bulk cargo for partially filled cargo holds

For any partially filled cargo hold, as defined in [2.2.2], including non-prismatic holds, the effective upper surface of the cargo is to be made of three parts:

- One central horizontal surface of breadth $B_H/2$, in m, at a height $h_{C\text{-}CL}$, in m, above the inner bottom
- A sloped surface at each side with an angle $\psi/2$, in degrees, between the central horizontal surface, and the side shell or inner hull, as shown in Figure 3, or the hopper plating, as shown in Figure 4, as the case may be.

The height of cargo surface h_C, in m, is to be calculated at mid length of the considered cargo hold and is to be taken as constant over the length of the hold as follows:

For $|y| \le \frac{B_H}{4}$: $h_C = h_{C\text{-}CL}$

For $\frac{B_H}{4} < |y| \le \frac{B_2}{2}$: $h_C = h_{C-CL} - \left(|y| - \frac{B_H}{4}\right) \tan\frac{\Psi}{2}$

For $|y| > \frac{B_2}{2}$: $h_C = 0$

where:

h_1 : Height, in m, to be taken as:

$$h_1 = \frac{M}{\rho_C \cdot B_H\ \ell_H} - \left(\frac{B_H + B_{IB}}{2B_H}\right) h_{HPL} - \frac{3}{16} B_H \tan\frac{\psi}{2} + \frac{V_{TS}}{B_H\ \ell_H}$$

- For $h_1 \geq 0$ as shown in Figure 3:

$$h_{C-CL} = h_{HPL} + h_1 + h_2$$

$$h_2 = \frac{B_H}{4} \tan\frac{\psi}{2}$$

$$B_2 = B_H$$

- For $h_1 < 0$ as shown in Figure 4

$$h_{C-CL} = h_{11} + h_{22}$$

$$h_{11} = h_{HPL}\left(\frac{B_2 - B_{IB}}{B_H - B_{IB}}\right)$$

$$h_{22} = \left(\frac{B_2}{2} - \frac{B_H}{4}\right) \tan\frac{\psi}{2}$$

$$B_2 = \sqrt{\frac{\frac{1}{\ell_H}\left(\frac{M}{\rho_C} + V_{TS}\right) + \frac{1}{2}\left(\frac{h_{HPL} \cdot B_{IB}^2}{B_H - B_{IB}}\right) + \frac{B_H^2}{16}\tan\frac{\psi}{2}}{\frac{1}{2}\left[\left(\frac{h_{HPL}}{B_H - B_{IB}}\right) + \frac{1}{2}\tan\frac{\psi}{2}\right]}}$$

h_{C-CL} : Height, in m, of the cargo surface at the centreline, as shown in Figure 3 and Figure 4

B_2 : Maximum breadth of the cargo, in m, as shown in Figure 3 and Figure 4

Figure 3 : Definition of the effective upper surface of cargo for a partially filled cargo hold when $h_1 \geq 0$

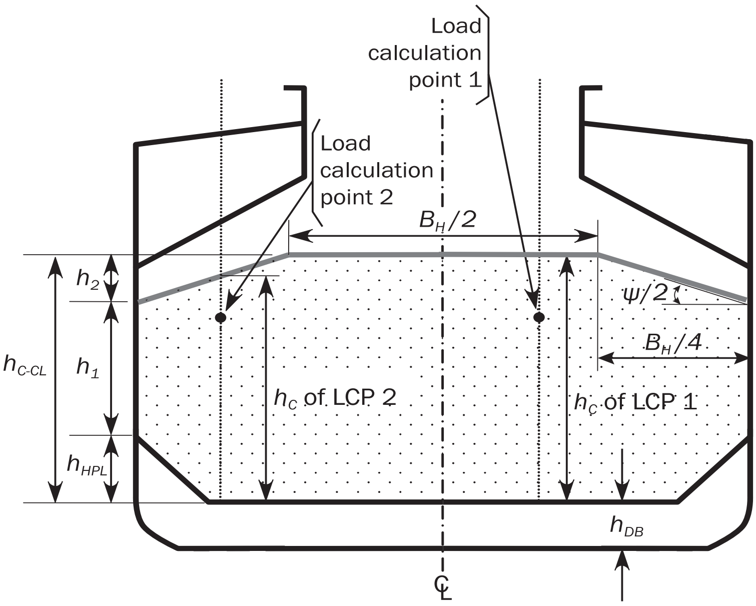
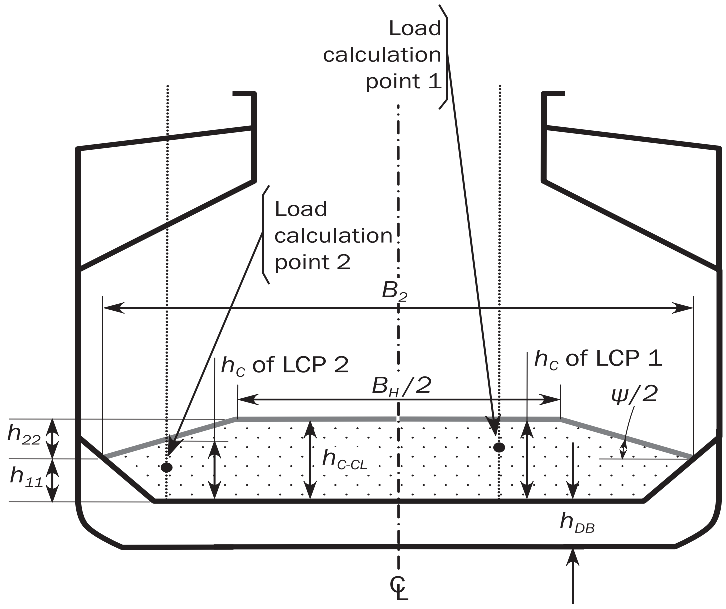


Figure 4 : Definition of the effective upper surface of cargo for a partially filled cargo hold when $h_1 < 0$



2.3.3 Mass and density

The dry cargo mass and the density of the cargo are to be taken as follows:

- For strength assessment in intact condition: the values defined in Table 1
- For fatigue assessment: the values defined in Table 2
- For strength assessment in flooded condition: the values defined in Table 3

Table 1 : Dry bulk cargo mass and density for strength assessment in intact condition

Ship type	Cargo mass Cargo density	Homogeneous loading condition		Alternate loading condition	
		Fully filled hold	Partially filled hold	Fully filled hold	Partially filled hold
No BC notation	M	$M = M_{Full}$	N/A	N/A	
	ρ_C	Maximum value specified in the loading manual			
BC-C	M	$M = M_{Full}$	N/A	N/A	
	ρ_C	$\rho_C = \dfrac{M_{Full}}{V_{Full}}$ but not less than 1.0			
BC-B	M	$M = M_{Full}$	$M = M_H$	N/A	
	ρ_C	$\rho_C = \dfrac{M_{Full}}{V_{Full}}$ but not less than 1.0	$\rho_C = 3.0$ (1)		
BC-A	M	$M = M_{Full}$	$M = M_H$	$M = M_{HD} + 0.1M_H$	$M = M_{HD} + 0.1M_H$
	ρ_C	$\rho_C = \dfrac{M_{Full}}{V_{Full}}$ but not less than 1.0	$\rho_C = 3.0$ (1)	$\rho_C = \dfrac{M_{HD} + 0.1\,M_H}{V_{Full}}$	$\rho_C = 3.0$ (1)

(1) To be taken as 3.0 unless an alternative maximum cargo density is specified in the loading manual.

Table 2 : Dry bulk cargo mass and density for fatigue assessment

Ship type	Cargo mass Cargo density	Homogeneous loading condition (Fully filled hold)	Alternate loading condition (Partially filled hold)
No BC notation	M	$M = M_H$	N/A
	ρ_C	ρ_C = maximum value specified in the loading manual	
BC-C	M	$M = M_H$	
	ρ_C	$\rho_C = \left(\frac{M_H}{V_{Full}}\right)$	
BC-B	M	$M = M_H$	
	ρ_C	$\rho_C = \left(\frac{M_H}{V_{Full}}\right)$	
BC-A	M	$M = M_H$	$M = M_{HD}$
	ρ_C	$\rho_C = \left(\frac{M_H}{V_{Full}}\right)$	$\rho_C = 3.0$ **(1)**

(1) To be taken as 3.0 unless an alternative maximum cargo density is specified in the loading manual.

Table 3 : Dry bulk cargo mass and density for strength assessment in flooded condition

Ship type	Cargo mass Cargo density	Homogeneous loading condition		Alternate loading condition		
		Fully filled hold	Partially filled hold	Fully filled hold	Partially filled hold	Hold loaded with $\rho_C \leq 1.78$ t/m^3 **(2)**
No BC notation	M	$M = M_H$	N/A	N/A		
	ρ_C	ρ_C = maximum value specified in the loading manual				
BC-C	M	$M = M_H$	N/A	N/A		
	ρ_C	$\rho_C = \left(\frac{M_H}{V_{Full}}\right)$				
BC-B	M	$M = M_H$	$M = M_H$	N/A		
	ρ_C	$\rho_C = \left(\frac{M_H}{V_{Full}}\right)$	$\rho_C = 3.0$ **(1)**			
BC-A	M	$M = M_H$	$M = M_H$	$M = M_{HD}$	$M = M_{HD}$	$M = M_{HD}$
	ρ_C	$\rho_C = \left(\frac{M_H}{V_{Full}}\right)$	$\rho_C = 3.0$ **(1)**	$\rho_C = \left(\frac{M_{HD}}{V_{Full}}\right)$	$\rho_C = 3.0$ **(1)**	$\rho_C = 1.78$

(1) To be taken as 3.0 unless an alternative maximum cargo density is specified in the loading manual.

(2) To be applied for bulk carriers that are required to carry cargoes with a density less than or equal to 1.78 t/m^3.

2.3.4 FE application

The following process is to be applied for the bulk cargo pressure loads used in FE analysis:

a) Determine h_c according to [2.3.1] for fully filled cargo hold or [2.3.2] for partially filled cargo hold.

b) Determine the corresponding static pressure as defined in [2.4.2] and static shear pressure as defined in [2.5.2] using ρ_c and apply them in the FE model.

c) Calculate the actual mass of cargo, M_{actual}, in t.

d) Determine the effective cargo density, in t/m^3:

$$\rho_{eff} = \frac{M}{M_{actual}} \rho_c$$

e) Calculate the final pressure distribution and shear load using ρ_{eff} instead of ρ_c.

2.4 Dry bulk cargo pressures

2.4.1 Total pressure

The total pressure due to dry bulk cargo acting on any load point of a cargo hold boundary, in kN/m^2, is to be taken as:

$P_{in} = P_{bs}$	For strength assessment of intact conditions for static (S) design load scenarios, given in Ch 4, Sec 7
$P_{in} = P_{bs} + P_{bd}$	For strength assessment of intact conditions and fatigue assessment for static plus dynamic (S+D) design load scenarios, given in Ch 4, Sec 7

but not less than 0.

where:

P_{bs} : Static pressure due to dry bulk cargo, in kN/m^2, as defined in [2.4.2].

P_{bd} : Dynamic inertial pressure due to dry bulk cargo in cargo holds, in kN/m^2, as defined in [2.4.3].

Static and dynamic pressures as defined in [2.4.2] and [2.4.3] for FE analysis are to be determined using ρ_{eff} instead of ρ_c.

2.4.2 Static pressure

The dry bulk cargo static pressure P_{bs}, in kN/m^2, is to be taken as:

$$P_{bs} = \rho_C \, g K_C \, (z_C - z) \quad \text{but not less than 0.}$$

2.4.3 Dynamic pressure

The dry bulk cargo dynamic pressure P_{bd}, in kN/m^2, for each load case is to be taken as:

$$P_{bd} = f_\beta \, \rho_C \, [0.25 \, a_X \, (x_G - x) + 0.25 \, a_Y \, (y_G - y) + f_{dc} K_C \, a_Z \, (z_C - z)] \quad \text{for } z \le z_c$$

$$P_{bd} = 0 \quad \text{for } z > z_c$$

2.5 Shear load

2.5.1 Application

For FE strength assessment, the following shear load pressures are to be considered in addition to the dry bulk cargo pressures defined in [2.4] when the load point elevation, z, is lower or equal to z_c:

- For static (S) design load scenarios, given in Ch 4, Sec 7: Static shear load, $P_{bs\text{-}s}$, due to gravitational forces acting on hopper tanks and lower stools plating, as defined in [2.5.2].

- For static plus dynamic (S+D) design load scenarios, given in Ch 4, Sec 7: The following dynamic shear load pressures:

  $P_{bs\text{-}s}$ + $P_{bs\text{-}d}$ for the hopper tank and the lower stool plating, as defined in [2.5.3].

  $P_{bs\text{-}dx}$ for the inner bottom plating in the longitudinal direction, as defined in [2.5.4].

  $P_{bs\text{-}dy}$ for the inner bottom plating in the transverse direction, as defined in [2.5.4].

Shear loads as defined in [2.5.2] to [2.5.4] for FE analysis are to be determined using ρ_{eff} instead of ρ_c.

2.5.2 Static shear load on the hopper tank and lower stool plating

The static shear load pressure, $P_{bs\text{-}s}$ (positive downward to the plating) due to dry bulk cargo gravitational forces acting on hopper tank and lower stool plating, in kN/m^2, is to be taken as:

$$P_{bs-s} = \rho_C\, g\, \frac{(1-K_C)\,(z_C - z)}{\tan\alpha}$$

2.5.3 Dynamic shear load on the hopper tank and lower stool plating

The dynamic shear load pressure, $P_{bs\text{-}d}$ (positive downward to the plating) due to dry bulk cargo forces on the hopper tank and lower stool plating, in kN/m^2, for each dynamic load case is to be taken as:

$$P_{bs-d} = f_\beta\, \rho_C\, a_z\, \frac{(1-K_C)\,(z_C - z)}{\tan\alpha}$$

2.5.4 Dynamic shear load along the inner bottom plating for FE analyses

The dynamic shear load pressures, $P_{bs\text{-}dx}$ in the longitudinal direction (positive to bow) due to dry bulk cargo forces acting along the inner bottom plating, in kN/m^2, for each dynamic load case is to be taken respectively as:

$$P_{bs-dx} = -0.75\, f_\beta\, \rho_C\, a_X\, h_C$$

The dynamic shear load pressures, $P_{bs\text{-}dy}$ in the transverse direction (positive to port) due to dry bulk cargo forces acting along the inner bottom plating, in kN/m^2, for each dynamic load case is to be taken respectively as

$$P_{bs-dy} = -0.75\, f_\beta\, \rho_C\, a_y\, h_C$$

The dynamic shear load pressures $P_{bs\text{-}dx}$ and $P_{bs\text{-}dy}$ are only used for FE strength assessment.

3 PRESSURES AND FORCES DUE TO DRY CARGOES IN FLOODED CONDITIONS

3.1 Vertically corrugated transverse watertight bulkheads

3.1.1 Application

The pressure defined in this sub-article applies to vertically corrugated transverse watertight bulkheads of the cargo holds of bulk carriers for the assessment in flooded conditions.

Each cargo hold is to be considered individually flooded, see Figure 5, Figure 6 and Figure 7.

3.1.2 General

The loads to be considered as acting on each bulkhead are those given by the combination of loads induced by cargo loads with those induced by the flooded loads of one hold adjacent to the bulkhead under examination. In any case, the pressure due to the flooded loads without cargo is also to be considered.

The most severe combinations of cargo induced loads and flooded loads are to be used for the check of the scantlings of each bulkhead, depending on the loading conditions included in the loading manual considering the individual flooded condition of both loaded and empty holds:

- Homogeneous loading conditions;
- Non-homogeneous loading conditions;

For the purpose of this article, the following items are defined as:

- Design load limits:

  The specified design load limits for the cargo holds are to be represented by loading conditions defined by the designer in the loading manual.

- Maximum cargo mass to consider:

  Unless the ship is intended to carry, in non-homogeneous conditions, only iron ore or cargo having bulk density equal to or greater than 1.78 t/m^3, the maximum mass of cargo which may be carried in the hold is also to be considered to fill that hold up to the top of the hatch coaming.

- Homogeneous loading conditions:

  Homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling level, evaluated for each hold, does not exceed 1.20, to be corrected for different cargo densities.

- Packed cargoes:

  Holds carrying packed cargoes (such as steel mill products) are to be considered as empty.

- Unconsidered loading conditions:

  Non-homogeneous part loading conditions associated with multi-port loading and unloading operations for homogeneous loading conditions do not need to be considered for the verification of these requirements.

3.1.3 Flooded level

The flooded level z_F is the distance, in m, measured vertically from the baseline with the ship in the upright position, and obtained from Table 4.

Table 4 : Flooded level z_F, in m, for vertically corrugated transverse bulkheads

Bulk carrier type	Vertically corrugated transverse bulkhead position	
	Foremost	Others
Bulk carriers less than 50,000 t deadweight with Type B freeboard	$z_F = 0.95\ D_1$	$z_F = 0.85\ D_1$
	$z_F = 0.9\ D_1$ **(1)**	$z_F = 0.8\ D_1$ **(1)**
Other bulk carriers	$z_F = D_1$	$z_F = 0.9\ D_1$
	$z_F = 0.95\ D_1$ **(1)**	$z_F = 0.85\ D_1$ **(1)**
(1) For ships carrying cargoes having bulk density less than 1.78 t/m^3 in non-homogeneous loading conditions.		

3.1.4 Flooded patterns

Three different flooded patterns are to be considered:

- The flooded level is below the upper surface of the cargo, (see Figure 5: $z_C > z_F$)
- The flooded level is above the upper surface of the cargo, (see Figure 6: $z_C \le z_F$)
- The flooded hold is empty, (see Figure 7: $z_C = h_{DB}$)

Figure 5 : Flooded level below upper surface of bulk cargo

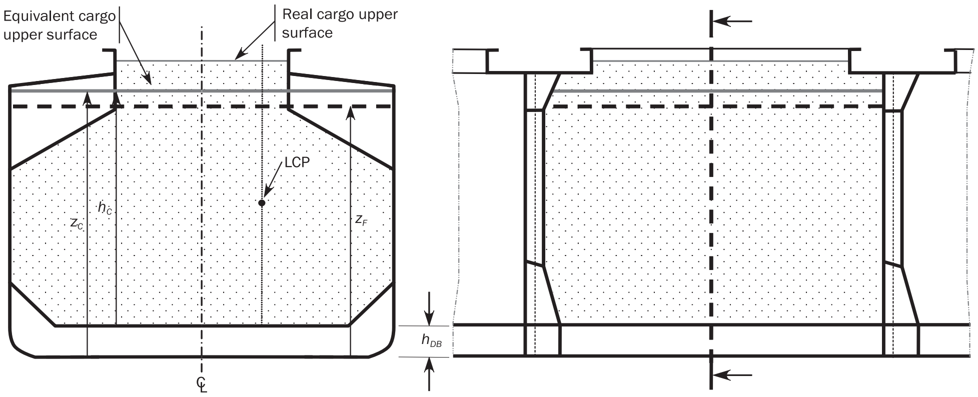


Figure 6 : Flooded level above upper surface of bulk cargo

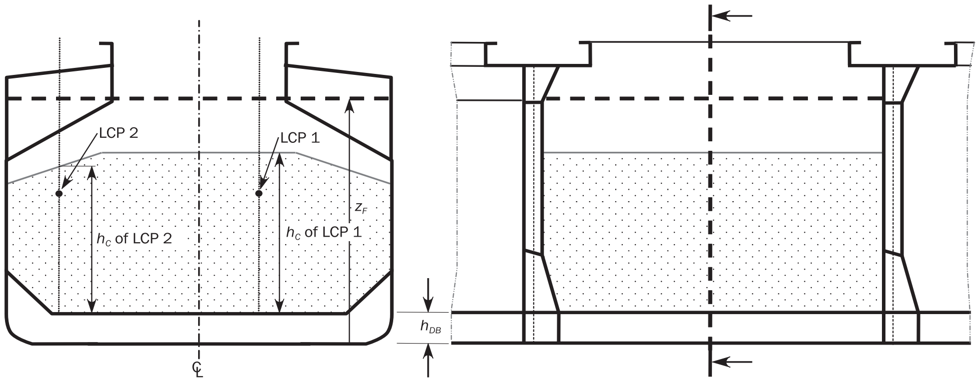
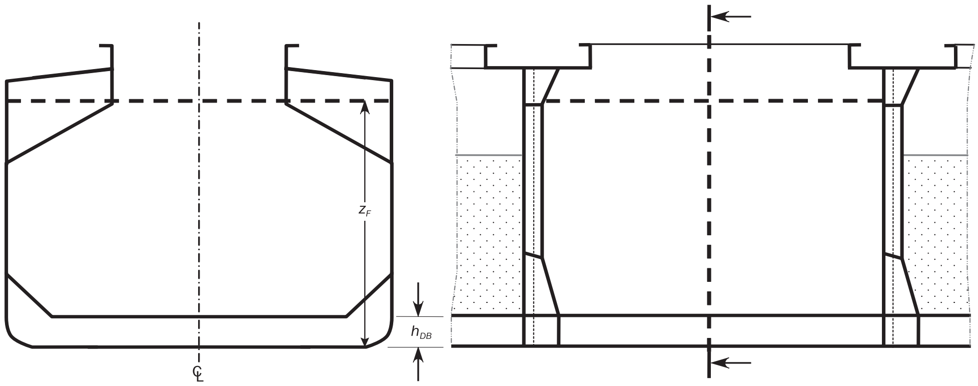


Figure 7 : Flooded cargo hold without cargo



3.1.5 Pressures and forces on vertically corrugated transverse bulkheads of flooded cargo holds

The static pressure $P_{bf\text{-}s}$, in kN/m^2, at any point of the vertically corrugated transverse bulkhead located at a level z from the baseline is given in Table 5 for each flooded pattern defined in [3.1.4].

The force $F_{bf\text{-}s}$, in kN, acting on a corrugation of a transverse bulkhead is given by Table 6 for each flooded pattern defined in [3.1.4].

where:

$P_{bf\text{-}s\text{-}LE}$: Static pressure calculated according to Table 5 for $z = h_{LS} + h_{DB}$.

Table 5 : Static pressure on vertically corrugated transverse bulkhead of a flooded cargo hold P_{bf-s}

Flooded case	Load point position	Pressure P_{bf-s}, in kN/m²
$z_C > z_F$	$z > z_C$	$P_{bf-s} = 0$
	$z_C \geq z \geq z_F$	$P_{bf-s} = \rho_C\, g\, (z_C - z)\, K_{C-f}$
	$z_F > z \geq h_{DB}$	$P_{bf-s} = \rho g\, (z_F - z) + [\rho_C\, (z_C - z) - \rho\, (1 - perm)\, (z_F - z)]\, g K_{C-f}$
$h_{DB} \leq z_C \leq z_F$	$z > z_F$	$P_{bf-s} = 0$
	$z_F \geq z \geq z_C$	$P_{bf-s} = \rho g\, (z_F - z)$
	$z_C > z \geq h_{DB}$	$P_{bf-s} = \rho g\, (z_F - z) + [\rho_C - \rho\, (1 - perm)]\, g\, (z_C - z)\, K_{C-f}$

Table 6 : Force acting on a corrugation in the flooded cargo holds F_{bf-s}

Flooded case	Force F_{bf-s}, in kN
$z_C > z_F$	$F_{bf-s} = s_C \left\{ \rho_C\, g\, \dfrac{(z_C - z_F)^2}{2}\, K_{C-f} + \left[\dfrac{\rho_C\, g\, (z_C - z_F)\, K_{C-f} + P_{bf-s-LE}}{2}\right] (z_F - h_{DB} - h_{LS}) \right\}$
$z_F \geq z_C$	$F_{bf-s} = s_C \left\{ \rho g\, \dfrac{(z_F - z_C)^2}{2} + \left[\dfrac{\rho g\, (z_F - z_C) + P_{bf-s-LE}}{2}\right] (z_C - h_{DB} - h_{LS}) \right\}$

3.1.6 Pressures and forces on vertically corrugated transverse bulkheads of non-flooded cargo holds

The static pressure P_{bs}, in kN/m², at a point of the vertically corrugated transverse bulkhead located, located at the level z from the baseline, due to dry bulk cargo of a non-flooded cargo hold acting on the intact side of the transverse bulkhead which is flooded on the other side is to be taken as:

$P_{bs} = \rho_C\, g\, K_{C-f}\, (z_C - z)$ but not less than 0.

The resultant force F_{bs}, in kN, acting on a corrugation is to be taken as:

$$F_{bs} = \rho_C\, g s_C\, \frac{(z_C - h_{DB} - h_{LS})^2}{2}\, K_{C-f}$$

3.1.7 Resultant pressures and forces on vertically corrugated transverse bulkheads of flooded cargo holds

The resultant pressure P_R, in kN/m², at each point of the bulkhead, and the resultant force F_R, in kN, acting on a corrugation, given in Table 7, are to be considered for the assessment in flooded conditions of vertically corrugated transverse bulkhead structures, where:

P_{bf-s} : Pressure in the flooded cargo holds, in kN/m², as defined in [3.1.5].

P_{bs} : Pressure in the non-flooded cargo holds, in kN/m², as defined in [3.1.6].

F_{bf-s} : Force acting on a corrugation in the flooded cargo holds, in kN, as defined in [3.1.5].

F_{bs} : Force acting on a corrugation in the non-flooded cargo holds, in kN, as defined in [3.1.6].

Table 7 : Resultant pressure P_R and resultant force F_R on vertically corrugated transverse bulkhead in flooded condition

Loading condition	Resultant pressure P_R, in kN/m^2	Resultant force F_R, in kN	Application
Homogeneous	$P_R = P_{bf\text{-}s} - 0.8\ P_{bs}$	$F_R = F_{bf\text{-}s} - 0.8\ F_{bs}$	All bulk carriers
Alternate	$P_R = P_{bf\text{-}s}$	$F_R = F_{bf\text{-}s}$	BC-A bulk carriers

3.2 Double bottom in cargo hold region of bulk carrier in flooded conditions

3.2.1 Application

Each cargo hold is to be considered individually flooded.

3.2.2 General

The loads to be considered as acting on the double bottom are those given by the external sea pressures and the combination of the cargo loads with those induced by the flooding of the hold to which the double bottom belongs.

The most severe combinations of cargo induced loads and flooded loads are to be used, depending on the loading conditions included in the loading manual:

- Homogeneous loading conditions.
- Non-homogeneous loading conditions.
- Packed cargo conditions (such as in the case of steel mill products).

For each loading condition, the maximum dry bulk cargo density to be carried is to be considered in calculating the allowable hold loading.

3.2.3 Flooded level

The flooded level z_F is the distance, in m, measured vertically from the baseline with the ship in the upright position, and obtained from Table 8.

Table 8 : Flooded level z_F, for double bottom in cargo hold region of bulk carrier

Bulk carrier type	Cargo hold	
	Foremost	Others
Bulk carriers less than 50,000 t deadweight with Type-B freeboard	$z_F = 0.95\ D_1$	$z_F = 0.85\ D_1$
Other bulk carriers	$z_F = D_1$	$z_F = 0.9\ D_1$

4 STEEL COIL LOADS IN CARGO HOLDS OF BULK CARRIERS

4.1 General

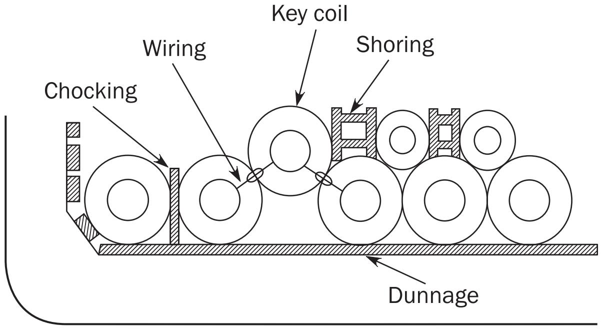
4.1.1 Application

The provision is determined by assuming Figure 8 as the standard means of securing steel coils loaded on wooden dunnage.

It is assumed that all the steel coils have the same characteristics.

In cases where steel coils are lined up in two or more tiers, formulae in [4.1.3] and [4.2] can be applied assuming that only the lowest tier of steel coils is in contact with hopper sloping plate or inner side plate. In other cases, scantling requirements are to be determined on a case-by-case basis.

Figure 8 : Inner bottom loaded by steel coils



4.1.2 Arrangement of steel coils on inner bottom

The two following arrangements of steel coils on the inner bottom are considered:

- The steel coils are positioned without respect to the location of the inner bottom floors, as shown in Figure 9.
- The steel coils are positioned with respect to the location of the inner bottom floors, as shown in Figure 10.

Figure 9 : Steel coils loaded independently of inner bottom floors locations

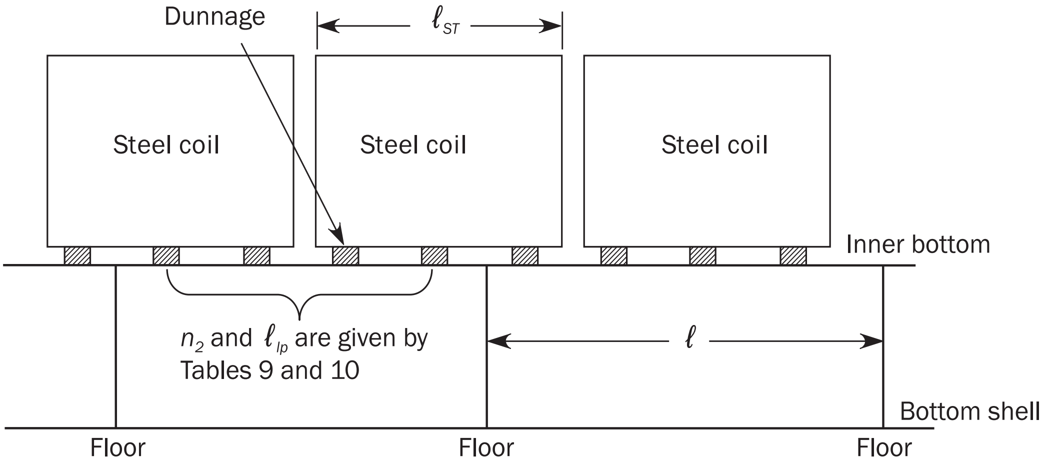
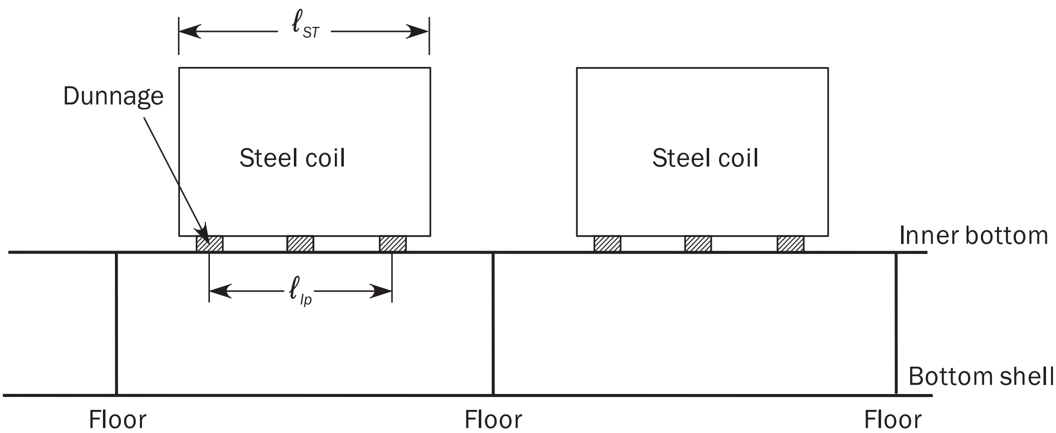


Figure 10 : Steel coils loaded between inner bottom floors



4.1.3 Arrangement of steel coils independently of the floor locations

For steel coils loaded without respect to the location of floors in the inner bottom, see Figure 9:

The number n_2 of load point dunnages per elementary plate panels is to be found in comply with Table 9.

The distance ℓ_{lp}, in m, between outermost load point dunnages per elementary plate panel is to be found in comply with Table 10.

Table 9 : Number n_2 of load point dunnages per elementary plate panel

n_2	n_3			
	2	3	4	5
1	$0 < \frac{\ell}{\ell_{st}} \le 0.5$	$0 < \frac{\ell}{\ell_{st}} \le 0.33$	$0 < \frac{\ell}{\ell_{st}} \le 0.25$	$0 < \frac{\ell}{\ell_{st}} \le 0.2$
2	$0.5 < \frac{\ell}{\ell_{st}} \le 1.2$	$0.33 < \frac{\ell}{\ell_{st}} \le 0.67$	$0.25 < \frac{\ell}{\ell_{st}} \le 0.5$	$0.2 < \frac{\ell}{\ell_{st}} \le 0.4$
3	$1.2 < \frac{\ell}{\ell_{st}} \le 1.7$	$0.67 < \frac{\ell}{\ell_{st}} \le 1.2$	$0.5 < \frac{\ell}{\ell_{st}} \le 0.75$	$0.4 < \frac{\ell}{\ell_{st}} \le 0.6$
4	$1.7 < \frac{\ell}{\ell_{st}} \le 2.4$	$1.2 < \frac{\ell}{\ell_{st}} \le 1.53$	$0.75 < \frac{\ell}{\ell_{st}} \le 1.2$	$0.6 < \frac{\ell}{\ell_{st}} \le 0.8$
5	$2.4 < \frac{\ell}{\ell_{st}} \le 2.9$	$1.53 < \frac{\ell}{\ell_{st}} \le 1.87$	$1.2 < \frac{\ell}{\ell_{st}} \le 1.45$	$0.8 < \frac{\ell}{\ell_{st}} \le 1.2$
6	$2.9 < \frac{\ell}{\ell_{st}} \le 3.6$	$1.87 < \frac{\ell}{\ell_{st}} \le 2.4$	$1.45 < \frac{\ell}{\ell_{st}} \le 1.7$	$1.2 < \frac{\ell}{\ell_{st}} \le 1.4$
7	$3.6 < \frac{\ell}{\ell_{st}} \le 4.1$	$2.4 < \frac{\ell}{\ell_{st}} \le 2.73$	$1.7 < \frac{\ell}{\ell_{st}} \le 1.95$	$1.4 < \frac{\ell}{\ell_{st}} \le 1.6$
8	$4.1 < \frac{\ell}{\ell_{st}} \le 4.8$	$2.73 < \frac{\ell}{\ell_{st}} \le 3.07$	$1.95 < \frac{\ell}{\ell_{st}} \le 2.4$	$1.6 < \frac{\ell}{\ell_{st}} \le 1.8$
9	$4.8 < \frac{\ell}{\ell_{st}} \le 5.3$	$3.07 < \frac{\ell}{\ell_{st}} \le 3.6$	$2.4 < \frac{\ell}{\ell_{st}} \le 2.65$	$1.8 < \frac{\ell}{\ell_{st}} \le 2.0$
10	$5.3 < \frac{\ell}{\ell_{st}} \le 6.0$	$3.6 < \frac{\ell}{\ell_{st}} \le 3.93$	$2.65 < \frac{\ell}{\ell_{st}} \le 2.9$	$2.0 < \frac{\ell}{\ell_{st}} \le 2.4$

Table 10 : Distance between outermost load point dunnages per elementary plate panel, ℓ_{lp}, in m

n_2	n_3			
	2	3	4	5
1	Actual breadth of dunnages			
2	$0.5\ell_{st}$	$0.33\ell_{st}$	$0.25\ell_{st}$	$0.2\ell_{st}$
3	$1.2\ell_{st}$	$0.67\ell_{st}$	$0.50\ell_{st}$	$0.4\ell_{st}$
4	$1.7\ell_{st}$	$1.20\ell_{st}$	$0.75\ell_{st}$	$0.6\ell_{st}$
5	$2.4\ell_{st}$	$1.53\ell_{st}$	$1.20\ell_{st}$	$0.8\ell_{st}$
6	$2.9\ell_{st}$	$1.87\ell_{st}$	$1.45\ell_{st}$	$1.2\ell_{st}$
7	$3.6\ell_{st}$	$2.40\ell_{st}$	$1.70\ell_{st}$	$1.4\ell_{st}$
8	$4.1\ell_{st}$	$2.73\ell_{st}$	$1.95\ell_{st}$	$1.6\ell_{st}$
9	$4.8\ell_{st}$	$3.07\ell_{st}$	$2.40\ell_{st}$	$1.8\ell_{st}$
10	$5.3\ell_{st}$	$3.60\ell_{st}$	$2.65\ell_{st}$	$2.0\ell_{st}$

4.1.4 Arrangement of steel coils between floors

For steel coils loaded with respect to the locations of floors in the inner bottom, see Figure 10:

- The number n_2 of load point dunnages per elementary plate panels is to be taken as: $n_2 = n_3$
- The distance ℓ_{lp} between outermost load point dunnages per elementary plate panel is to be taken as the distance between the outermost dunnage supporting one row of steel coils.

4.1.5 Centre of gravity of steel coil cargo

The centre of gravity of the steel coil cargo of the considered cargo hold is to be taken at the following position:

a) Longitudinal position

x_{Gsc} is the X coordinate, in m, of the volumetric centre of gravity of the considered cargo hold with respect to the reference coordinate system defined in Ch 4, Sec 1, [1.2.1].

b) Transverse position

$$y_{Gsc} = \varepsilon \frac{B_H}{4}$$

c) Vertical position

$$z_{Gsc} = h_{DB} + \left[1 + (n_1 - 1)\frac{\sqrt{3}}{2}\right]\frac{d_{sc}}{2}$$

where:

ε : Coefficient to be taken as:

ε = 1.0 when a port side structural member is assessed.

ε = -1.0 when a starboard side structural member is assessed.

4.2 Total loads

4.2.1 Total load on the inner bottom

The total load F_{sc-ib}, in kN, due to steel coil cargoes on the inner bottom is to be taken as:

$$F_{sc-ib} = \cos(C_{XG}\,\varphi)\,\cos(C_{YG}\,\theta)\,F_{sc-ib-s} + F_{sc-ib-d} \text{ but not less than 0}$$

where:

$F_{sc-ib-s}$: Static load, in kN, on the inner bottom, given in [4.3.1].

$F_{sc-ib-d}$: Dynamic load, in kN, on the inner bottom, given in [4.4.2].

C_{XG}, C_{YG} : Load combination factors, as defined in Ch 4, Sec 2, [2.2].

4.2.2 Total load on the hopper side

The total load F_{sc-hs}, in kN, due to steel coil cargoes on the hopper side is to be taken as:

$$F_{sc-hs} = \frac{\cos(\theta_h + \varepsilon\,C_{YG}\,\theta)\,\cos(C_{XG}\,\varphi)}{\cos\theta_h}F_{sc-hs-s} + F_{sc-hs-d} \text{ but not less than 0}$$

where:

$F_{sc-hs-s}$: Static load, in kN, on the hopper side, given in [4.3.2].

$F_{sc-hs-d}$: Dynamic load, in kN, on the hopper, given in [4.4.3].

C_{XG}, C_{YG} : Load combination factors, as defined in Ch 4, Sec 2, [2.2].

4.3 Static loads

4.3.1 Static loads on the inner bottom

The static load $F_{sc-ib-s}$, in kN, on the inner bottom due to steel coils is to be taken as:

$$F_{sc-ib-s} = M_{sc-ib} g$$

where:

M_{sc-ib} : Equivalent mass of steel coils, in t, to be taken as:

$$M_{sc-ib} = K_S\, W \frac{n_1\, n_2}{n_3} \quad \text{for} \quad n_2 \le 10 \quad \text{and} \quad n_3 \le 5$$

$$M_{sc-ib} = K_S\, W n_1 \frac{\ell}{\ell_{st}} \quad \text{for} \quad n_2 > 10 \quad \text{or} \quad n_3 > 5$$

K_S : Coefficient to be taken as:

K_S = 1.4 when steel coils are lined up in one tier with a key coil.

K_S= 1.0 in other cases.

4.3.2 Static load on the hopper side

The static load $F_{sc-hs-s}$, in kN, on the hopper side due to steel coils is to be taken as:

$$F_{sc-hs-s} = \cos\theta_h M_{sc-hs} \cdot g$$

where:

M_{sc-hs} : Equivalent mass of steel coils, in t, to be taken as:

$$M_{sc-hs} = C_k\, W \frac{n_2}{n_3} \quad \text{for} \quad n_2 \le 10 \quad \text{and} \quad n_3 \le 5$$

$$M_{sc-hs} = C_k\, W \frac{\ell}{\ell_{st}} \quad \text{for} \quad n_2 > 10 \quad \text{or} \quad n_3 > 5$$

C_k : Coefficient to be taken as:

C_k = 3.2 when steel coils are lined up two or more tiers, or when steel coils are lined up one tier and key coil is located second or 3rd from hopper sloping plate or inner hull plate.

C_k = 2.0 for other cases.

4.4 Dynamic loads

4.4.1 Tangential roll acceleration

The tangential roll acceleration a_R, in m/s^2, is to be taken as:

$$a_R = \theta \frac{\pi}{180} \left(\frac{2\pi}{T_\theta}\right)^2 \sqrt{y_{Gsc}^2 + (R - z_{Gsc})^2}$$

where:

y_{Gsc} : Y coordinate, in m, of the centre of gravity of the steel coil cargo of the considered cargo hold, given in [4.1.5].

z_{Gsc} : Z coordinate, in m, of the centre of gravity of the steel coil cargo of the considered cargo hold, given in [4.1.5].

4.4.2 Dynamic load on the inner bottom

The dynamic load $F_{sc\text{-}ib\text{-}d}$, in kN, on the inner bottom due to steel coils is to be taken as:

$$F_{sc-ib-d} = M_{sc-ib}\, a_z$$

where:

a_z : Vertical acceleration, in m/s^2, as defined in Ch 4, Sec 3, [3.2.4], calculated at the centre of gravity of the steel coil cargo of the considered cargo hold, given in [4.1.5].

4.4.3 Dynamic load on the hopper side

The dynamic load $F_{sc\text{-}hs\text{-}d}$, in kN, on the hopper side due to steel coils is to be taken as:

$$F_{sc-hs-d} = \varepsilon M_{sc-hs}\left[C_{YR}\, a_R\, \sin\left(\tan^{-1}\left|\frac{y_{Gsc}}{R - z_{Gsc}}\right| - \theta_h\right) - C_{YS}\, a_{sway}\, \sin\theta_h\right]$$

where:

C_{YS}, C_{YR} : Load combination factors, defined in Ch 4, Sec 2, [2.2].

a_{sway} : Sway acceleration, in m/s^2, as defined in Ch 4, Sec 3, [2.2.2].

a_R : Tangential acceleration, in m/s^2, as defined in [4.4.1].

y_{Gsc} : Y coordinate, in m, of the centre of gravity of the steel coil cargo of the considered cargo hold, given in [4.1.5].

z_{Gsc} : Z coordinate, in m, of the centre of gravity of the steel coil cargo of the considered cargo hold, given in [4.1.5].

5 LOADS ON NON-EXPOSED DECKS AND PLATFORMS

5.1 Application

5.1.1 General

The loads defined in [5.2] and [5.3] are applicable to non-exposed decks, accommodation decks and platforms.

5.2 Pressure due to distributed load

5.2.1

If a distributed load is carried on a deck, the static and dynamic pressures due to this distributed load are to be considered.

The static distributed load is to be defined by the designer without being less than 3 kN/m^2 for accommodation decks and 10 kN/m^2 for other decks and platforms.

The pressure P_{dl}, in kN/m^2, due to this distributed load for the static (S) design load scenarios, given in Ch 4, Sec 7, is to be taken as:

$$P_{dl} = P_{dl-s}$$

The pressure P_{dl}, in kN/m^2, due to this distributed load for the static plus dynamic (S+D) design load scenarios, is to be derived for the envelope of dynamic load cases and is to be taken as:

$$P_{dl} = P_{dl-s} + P_{dl-d} \quad \text{but not less than 0.}$$

where:

$P_{dl\text{-}s}$: Static pressure, in kN/m^2, due to the distributed load.

P_{dl-d} : Dynamic pressure, in kN/m^2, due to the distributed load, in kN/m^2, to be taken as:

$$P_{dl-d} = f_\beta \frac{a_{Z-env}}{g} P_{dl-s}$$

a_{z-env} : Envelope of vertical acceleration, in m/s^2, at the load position being considered, for the dynamic load cases, given in Ch 4, Sec 3, [3.3.3].

5.3 Concentrated force due to unit load

5.3.1

If a unit load is carried on an internal deck, the static and dynamic forces due to the unit load carried are to be considered.

The force F_U, in kN, due to this concentrated load for the static (S) design load scenarios, given in Ch 4, Sec 7, is to be taken as:

$$F_U = F_{U-s}$$

The force F_U, in kN, due to this concentrated load for the static plus dynamic (S+D) design load scenarios, is to be derived for the envelope of dynamic load cases and is to be taken as:

$F_U = F_{U-s} + F_{U-d}$ but not less than 0.

where:

F_{U-s} : Static force, in kN, due to the unit load to be taken as:

$$F_{U-s} = m_U g$$

F_{U-d} : Dynamic force, in kN, due to unit load to be taken as:

$$F_{U-d} = m_U f_\beta a_{z-env}$$

m_U : Mass of the unit load carried, in t.

a_{z-env} : Envelope of vertical acceleration, in m/s^2, at the centre of gravity of the unit load carried for the dynamic load cases, given in Ch 4, Sec 3, [3.3.3].

6 SLOSHING PRESSURES IN TANKS

6.1 General

6.1.1 Application

This article applies to all liquid cargo, ballast tanks and other tanks with volume exceeding 100 m^3, but does not apply to the water ballast cargo hold of bulk carriers.

6.1.2

The sloshing pressures defined in this article do not include the effect of impact pressures due to high velocity impacts with tank boundaries or internal structures. For tanks with a maximum effective sloshing breadth, b_{slh}, see [6.4.2], greater than 0.56 B or a maximum effective sloshing length, ℓ_{slh}, see [6.3.2], greater than 0.13 L at any filling level from 0.05 h_{max} to 0.95 h_{max}, see [6.3.3], a separate impact assessment is to be carried out in accordance with the Society procedures.

6.1.3 Sloshing pressure on tank boundaries and internal divisions

The sloshing pressure due to liquid motions in a tank P_{slh} acting on any load point of a tank boundary or internal divisions, in kN/m^2, for the sloshing design load scenario, given in Ch 4, Sec 7, is to be taken as follows, without being less than $P_{slh\text{-}min}$, as given in [6.2]:

- $P_{slh} = P_{slh\text{-}lng}$ for transverse bulkheads, as defined in [6.3.3].
- $P_{slh} = P_{slh\text{-}wf}$ for web frames and transverse stringers, as defined in [6.3.4].
- $P_{slh} = P_{slh\text{-}t}$ for longitudinal bulkheads, as defined in [6.4.3].
- $P_{slh} = P_{slh\text{-}grd}$ for longitudinal girders and stringers, see [6.4.4].

6.2 Minimum sloshing pressure

6.2.1

The minimum sloshing pressure, $P_{slh\text{-}min}$, for tanks of cellular construction, i.e. double hull construction with internal structures restricting the fluid motion, is to be taken as 12 kN/m^2.

The minimum sloshing pressure, $P_{slh\text{-}min}$, for cargo and all other tanks is to be taken as 20 kN/m^2.

6.3 Sloshing pressure due to longitudinal liquid motion

6.3.1 Application

The sloshing pressure due to longitudinal liquid motion, $P_{slh\text{-}lng}$, is to be taken as a constant value over the full tank depth and is to be taken as the greater of the sloshing pressures calculated for filling levels from 0.05 h_{max} to 0.95 h_{max}, in 0.05 h_{max} increments.

6.3.2 Effective sloshing length

The effective sloshing length, ℓ_{slh}, in m, is to be taken as defined in Table 11.

Table 11 : Effective sloshing length ℓ_{slh}

Type of transverse bulkhead	ℓ_{slh}
Transverse tight bulkheads	$\ell_{slh} = \dfrac{(1 + n_{WT}\,\alpha_{WT})\,(1 + f_{wf}\,\alpha_{wf})\ell_{tk-h}}{(1 + n_{WT})\,(1 + f_{wf})}$
Transverse wash bulkheads	$\ell_{slh} = \dfrac{[1 + (n_{WT} - 1)\,\alpha_{WT}]\,(1 + f_{wf}\,\alpha_{wf})\ell_{tk-h}}{(1 + n_{WT})\,(1 + f_{wf})}$

where:

n_{WT} : Number of transverse wash bulkheads in the tank.

α_{WT} : Transverse wash bulkhead coefficient, to be taken as (see Figure 11):

$$\alpha_{WT} = \frac{A_{OWT}}{A_{tk-t-h}}$$

α_{wf} : Transverse web frame coefficient, to be taken as (see Figure 12):

$$\alpha_{wf} = \frac{A_{O-wf-h}}{A_{tk-t-h}}$$

For tanks with changing shape along the length and/or with web frames of different shape the transverse web frame coefficient, α_{wf}, may be taken as the weighted average of all web frame locations in the tank given as:

$$\alpha_{wf} = \frac{\sum_{i=1}^{n_{wf}} \frac{A_{O-wf-h_i}}{A_{tk-t-h_i}}}{n_{wf}}$$

A_{OWT} : Total area of openings, in m^2, in the transverse section in way of the wash bulkhead below the considered filling height.

$A_{tk\text{-}t\text{-}h}$: Total transverse cross sectional area, in m^2, of the tank below the considered filling height.

$A_{O\text{-}wf\text{-}h}$: Total area of openings, in m^2, in the transverse section in way of the web frame below the considered filling height.

f_{wf} : Factor to account for number of transverse web frames and transverse wash bulkheads in the tank, to be taken as:

$$f_{wf} = \frac{n_{wf}}{1 + n_{WT}}$$

n_{wf} : Number of transverse web frames, excluding wash bulkheads, in the tank.

$\ell_{tk\text{-}h}$: Length of cargo tank, in m, at considered filling height.

Figure 11 : Transverse wash bulkhead coefficient

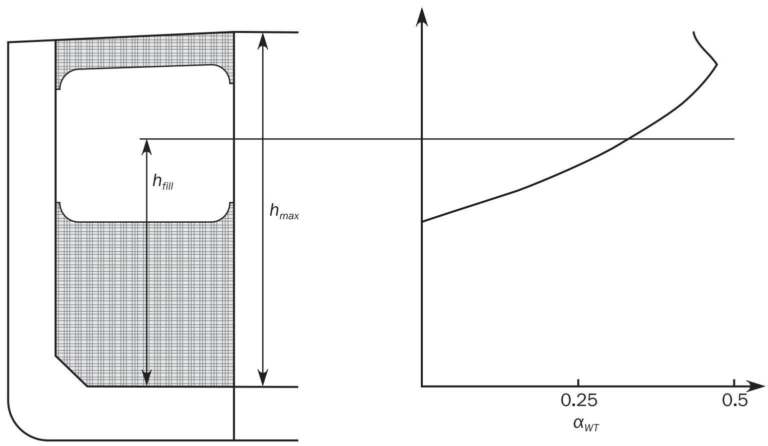
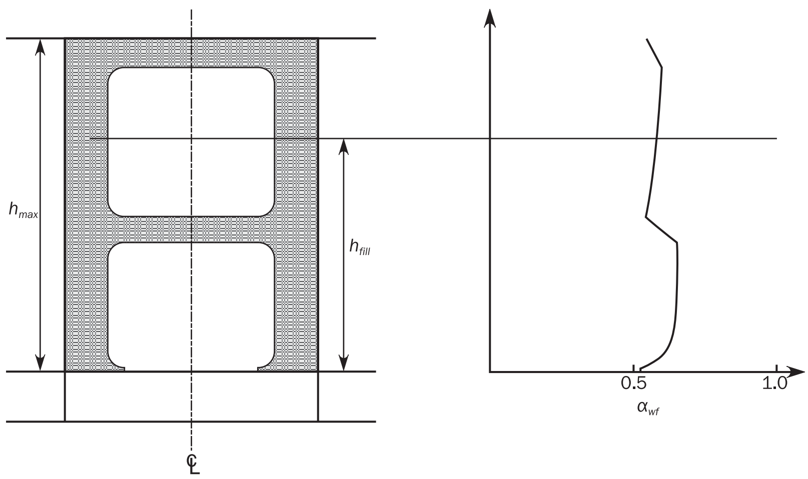


Figure 12 : Transverse web frame coefficient



6.3.3 Sloshing pressure in way of transverse bulkheads

The sloshing pressure in way of transverse bulkheads including wash bulkheads due to longitudinal liquid motion, $P_{slh-lng}$, in kN/m², for a particular filling level, is to be taken as:

$$P_{slh-\ln g} = \rho_{slh}\, g\ell_{slh}\, f_{slh}\left[0.4 - \left(0.39 - \frac{1.7\ \ell_{slh}}{L}\right)\frac{L}{350}\right]$$

where:

ℓ_{slh} : Effective sloshing length, in m, as defined in [6.3.2].

f_{slh} : Coefficient taken as:

$$f_{slh} = 1 - 2\left(0.7 - \frac{h_{fill}}{h_{max}}\right)^2$$

h_{fill} : Filling height, measured from tank bottom, in m, see Figure 11.

6.3.4 Sloshing pressure on internal web frames or transverse stringers adjacent to a transverse bulkhead

For tanks with internal web frames the sloshing pressure acting on a web frame or transverse stringer adjacent to transverse bulkheads or transverse wash bulkheads due to longitudinal liquid motion, P_{slh-wf}, in kN/m², provided it is located within 0.25 ℓ_{slh} from the bulkhead, is to be taken as:

$$P_{slh-wf} = P_{slh-\ln g}\left(1 - \frac{s_{wf}}{\ell_{slh}}\right)^2$$

where:

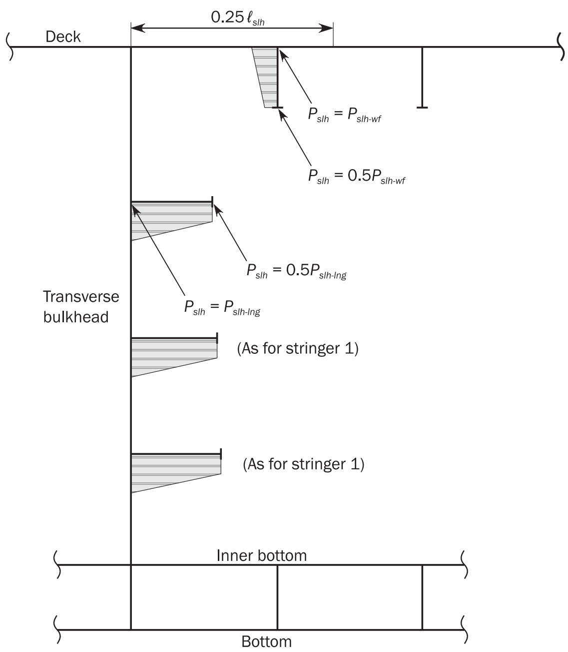
ℓ_{slh} : Effective sloshing length, in m, as defined in [6.3.2].

$P_{slh-lng}$: Sloshing pressure due to longitudinal liquid motion acting on transverse bulkhead, as defined in [6.3.3].

s_{wf} : Distance from transverse bulkhead to web frame under consideration, in m.

The distribution of pressure across web frames and transverse stringers is given in Figure 13.

Figure 13 : Sloshing pressure distribution on transverse stringers and web frames



6.4 Sloshing pressure due to transverse liquid motion

6.4.1 Application

The sloshing pressure due to transverse liquid motion, $P_{slh\text{-}t}$, is to be taken constant as a constant value over the full tank depth and is to be taken as the greater of the sloshing pressures calculated for filling levels from 0.05 h_{max} to 0.95 h_{max}, in 0.05 h_{max} increments.

6.4.2 Effective sloshing breadth

The effective sloshing breadth, b_{slh}, in m, is to be taken as in Table 12, but not less than 0.3B.

Table 12 : Effective sloshing breadth b_{slh}

Type of longitudinal bulkhead	b_{slh}
Longitudinal tight bulkheads	$b_{slh} = \dfrac{(1 + n_{WL}\ \alpha_{WL})\ (1 + f_{grd}\ \alpha_{grd})\ b_{tk-h}}{(1 + n_{WL})\ (1 + f_{grd})}$
Longitudinal wash bulkheads	$b_{slh} = \dfrac{[1 + (n_{WL} - 1)\ \alpha_{WL}]\ (1 + f_{grd}\ \alpha_{grd})\ b_{tk-h}}{(1 + n_{WL})\ (1 + f_{grd})}$

where:

n_{WL} : Number of longitudinal wash bulkheads in the tank.

α_{WL} : Longitudinal wash bulkhead coefficient:

$$\alpha_{WL} = \frac{A_{OWL}}{A_{tk-L-h}}$$

α_{grd} : Girder coefficient, to be taken as:

$$\alpha_{grd} = \frac{A_{O-grd-h}}{A_{tk-L-h}}$$

A_{OWL} : Total area of openings, in m^2, in the longitudinal section in way of the wash bulkhead below the considered filling height.

$A_{tk\text{-}L\text{-}h}$: Total longitudinal cross sectional area, in m^2, of the tank below the considered filling height.

$A_{O\text{-}grd\text{-}h}$: Total area of openings, in m^2, in the longitudinal section in way of the web frame below the considered filling height.

f_{grd} : Factor to account for number of longitudinal girders and longitudinal wash bulkheads in the tank, to be taken as:

$$f_{grd} = \frac{n_{grd}}{1 + n_{WL}}$$

n_{grd} : Number of longitudinal girders, excluding longitudinal wash bulkheads, in the tank.

$b_{tk\text{-}h}$: Breadth of cargo tank, in m, at considered filling height.

6.4.3 Sloshing pressure in way of longitudinal bulkheads

The sloshing pressure in way of longitudinal bulkheads including wash bulkheads due to transverse liquid motion, $P_{slh\text{-}t}$, in kN/m^2, for a particular filling level, is to be taken as:

$$P_{slh-t} = 7\ \rho_{slh}\ g f_{slh} \left(\frac{b_{slh}}{B} - 0.3\right)\ GM^{0.75}$$

where:

b_{slh} : Effective sloshing breadth defined in [6.4.2].

GM : Metacentric height, given in Ch 4, Sec 3, [2.1.1].

For the calculation of sloshing pressure in ballast tanks the 'ballast condition' is to be used for oil tankers and the 'normal ballast condition' for bulk carriers.

For the calculations of sloshing pressure in cargo tanks of oil tankers, the 'partial load condition' is to be used.

6.4.4 Sloshing pressure on internal girders or longitudinal stringers adjacent to longitudinal bulkheads

For tanks with internal girders or stringers, the sloshing pressure acting on the girder/web frame adjacent to longitudinal bulkheads and longitudinal wash bulkhead, $P_{slh\text{-}grd}$, in kN/m², provided it is located within 0.25 b_{slh} from the bulkhead, is to be taken as:

$$P_{slh-grd} = P_{slh-t}\left(1 - \frac{s_{grd}}{b_{slh}}\right)^2$$

where:

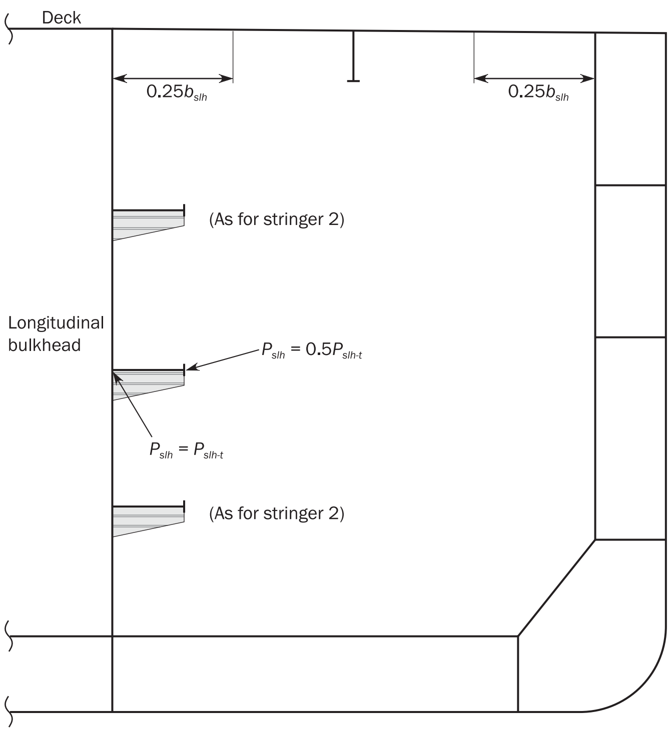
b_{slh} : Effective sloshing breadth defined in [6.4.2].

$P_{slh\text{-}t}$: Sloshing pressure due to transverse liquid motion acting on longitudinal bulkhead, as defined in [6.4.3].

s_{grd} : Distance from longitudinal bulkhead to girder under consideration, in m.

The distribution of pressure across stringers is given in Figure 14. The distribution of pressure across longitudinal girders is similar to the deck web frame shown in Figure 13.

Figure 14 : Sloshing pressure distribution on longitudinal stringers and girders



7 DESIGN PRESSURE FOR TANK TESTING

7.1 Definition

7.1.1

The actual strength testing is to be carried out in accordance with Ch 1, Sec 2, [3.8.4]. In order to assess the structure, static design pressures are to be applied.

The design pressure for tank testing, P_{ST}, in kN/m^2, is to be taken as:

$$P_{ST} = 10\ (z_{ST} - z)$$

where:

z_{ST} : Design testing load height, in m, as defined in Table 13.

Table 13 : Design testing load height z_{ST}

Compartment	z_{ST}
Double bottom tanks (1)	The greater of the following: $z_{ST} = z_{top} + h_{air}$ $z_{ST} = z_{bd}$
Hopper side tanks, topside tanks, double side tanks, fore and aft peaks used as tank, cofferdams	The greater of the following: $z_{ST} = z_{top} + h_{air}$ $z_{ST} = z_{top} + 2.4$
Tank bulkheads, deep tanks, fuel oil bunkers	The greater of the following: $z_{ST} = z_{top} + h_{air}$ $z_{ST} = z_{top} + 2.4$ $z_{ST} = z_{top} + 0.1\ P_{PV}$
Ballast hold	$z_{ST} = z_h + 0.9$
Chain locker (if aft of collision bulkhead)	$z_{ST} = z_{top}$
Independent tanks	The greater of the following: $z_{ST} = z_{top} + h_{air}$ $z_{ST} = z_{top} + 0.9$
Ballast ducts	Testing load height corresponding to ballast pump maximum pressure

where:

z_{bd} : Z coordinate, in m, of the bulkhead deck.

z_h : Z coordinate, in m, of the top of hatch coaming.

(1) For double bottom tanks connected with hopper side tanks, topside tanks or double side tanks, z_{ST} corresponding to "Hopper side tanks, topside tanks, double side tanks, fore and aft peaks used as tank, cofferdams" is applicable.

SECTION 7
DESIGN LOAD SCENARIOS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

VBM : Design vertical bending moment, in kNm.

M_{sw} : Permissible hull girder hogging and sagging still water bending moment for seagoing operation, in kNm, as defined in Ch 4, Sec 4, [2.2.2].

M_{sw-p} : Permissible hull girder hogging and sagging still water bending moment for harbour/sheltered water operation, in kNm, as defined in Ch 4, Sec 4, [2.2.3].

M_{sw-f} : Permissible hull girder hogging or sagging still water bending moment M_{sw-f} for seagoing operation in the flooded condition, in kNm, as defined in Ch 4, Sec 4, [2.2.4].

M_{wv-LC} : Vertical wave bending moment for a considered dynamic load case, in kNm, as defined in Ch 4, Sec 4, [3.5.2].

HBM : Design horizontal bending moment, in kNm.

M_{wh-LC} : Horizontal wave bending moment for a considered dynamic load case, in kNm, as defined in Ch 4, Sec 4, [3.5.4].

TM : Design torsional moment, in kNm.

M_{wt-LC} : Wave torsional moment for a considered dynamic load case, in kNm, as defined in Ch 4, Sec 4, [3.5.5].

VSF : Design vertical shear force, in kN.

Q_{sw} : Permissible hull girder positive and negative still water shear force limits for seagoing operation, in kN, as defined in Ch 4, Sec 4, [2.3.1] or Ch 4, Sec 4, [2.3.3].

Q_{sw-p} : Permissible hull girder positive and negative still water shear force limits for harbour/sheltered water operation, in kN, as defined in Ch 4, Sec 4, [2.3.2] or Ch 4, Sec 4, [2.3.4].

Q_{sw-f} : Permissible hull girder positive and negative still water shear force for seagoing operation in the flooded condition, in kN, as defined in Ch 4, Sec 4, [2.3.5].

Q_{wv-LC} : Vertical wave shear force for a considered dynamic load case, in kN, as defined in Ch 4, Sec 4, [3.5.3].

P_{ex} : Design external pressure, in kN/m^2.

P_S : Static sea pressure at considered draught, in kN/m^2, as defined in Ch 4, Sec 5, [1.2.1].

P_W : Dynamic pressure for a considered dynamic load case, in kN/m^2, as defined in Ch 4, Sec 5, [1.3.2] to Ch 4, Sec 5, [1.3.8].

P_D : Green sea load for a considered dynamic load case, in kN/m^2, as defined in Ch 4, Sec 5, [2.2.3] and Ch 4, Sec 5, [2.2.4].

P_{in} : Design internal pressure, in kN/m^2.

P_{ST} : Tank testing pressure, in kN/m^2, see Ch 4, Sec 6, [7.1.1].

P_{ls} : Static liquid pressure in tank, in kN/m^2, as defined in Ch 4, Sec 6, [1.2].

P_{ld} : Dynamic liquid pressure in tank for a considered dynamic load case, in kN/m^2, as defined in Ch 4, Sec 6, [1.3].

P_{bs} : Dry bulk cargo static pressure, in kN/m^2, as defined in Ch 4, Sec 6, [2.5.2].

P_{bd} : Dry bulk cargo dynamic pressure for a considered dynamic load case, in kN/m^2, as defined in Ch 4, Sec 6, [2.5.3].

P_{fs} : Static pressure in compartments and tanks in flooded condition, in kN/m^2, as defined in Ch 4, Sec 6, [1.4.1].

P_{fd} : Dynamic pressure in compartments and tanks in flooded condition, in kN/m^2, as defined in Ch 4, Sec 6, [1.5.1]

$P_{dl\text{-}s}$: Static pressure on non-exposed decks and platforms, in kN/m^2, as defined in Ch 4, Sec 6, [5.2.1].

$P_{dl\text{-}d}$: Dynamic pressure on non-exposed decks and platforms for a considered dynamic load case, in kN/m^2, as defined in Ch 4, Sec 6, [5.2.1]

$F_{U\text{-}s}$: Static load acting on supporting structures and securing systems for heavy units or cargo, equipment or structural components, in kN, as defined in Ch 4, Sec 5, [2.3.2].

$F_{U\text{-}d}$: Dynamic load acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, in kN, as defined in Ch 4, Sec 5, [2.3.2].

P_{SL} : Bottom slamming pressure, in kN/m^2, as defined in Ch 4, Sec 5, [3.2].

P_{FB} : Bow impact pressure, in kN/m^2, as defined in Ch 4, Sec 5, [3.3].

P_{slh} : Sloshing pressure, in kN/m^2, as defined in Ch 4, Sec 6, [6].

1 GENERAL

1.1 Application

1.1.1

This section gives the design load scenarios that are to be used for:

- Strength assessment by prescriptive and direct analysis (Finite Element Method, FEM) methods, as given in [2].
- Fatigue assessment by prescriptive and direct analysis (FEM) methods, as given in [3].

1.1.2

For the strength assessment, the principal design load scenarios consist of either S (Static) loads or S+D (Static + Dynamic) loads. In some cases, the letter 'A' prefixes the S or S+D to denote that this is an accidental design load scenario. There are some additional design load scenarios to be considered which relate to impact (I) loads, sloshing (SL) loads and fatigue (F) load.

2 DESIGN LOAD SCENARIOS FOR STRENGTH ASSESSMENT

2.1 Principal design load scenarios

2.1.1

The principal design load scenarios are given in Table 1.

Table 1 : Principal design load scenarios

Design load scenario			Harbour and sheltered water and testing	Seagoing conditions with extreme sea loads	Ballast water exchange (4)	Accidental flooded conditions (4)	
Load components			Static (S)	Static + Dynamic (S+D)	Static + dynamic (S+D)	Static (A: S)	Static + dynamic (A: S+D)
Hull Girder	VBM		M_{sw-p}	$M_{sw} + M_{wv-LC}$	$M_{sw} + M_{wv-LC}$	M_{sw-f} (2)	$M_{sw-f} + M_{wv-LC}$ (3)
	HBM		-	M_{wh-LC}	M_{wh-LC}	-	M_{wh-LC} (3)
	VSF		Q_{sw-p}	$Q_{sw} + Q_{wv-LC}$	$Q_{sw} + Q_{wv-LC}$	-	$Q_{sw-f} + Q_{wv-LC}$ (3)
	TM		-	M_{wt-LC}	M_{wt-LC}	-	-
Local Loads	P_{ex}	External deck for green sea	-	P_D	-	-	-
		Hull envelope	P_S	$P_S + P_W$	$P_S + P_W$	-	-
	P_{in}	Ballast tanks (1)	Max (P_{ls}, P_{ST})	$P_{ls} + P_{ld}$	$P_{ls} + P_{ld}$	-	-
		Liquid cargo tanks			-	-	
		Other tanks			-	-	
		Watertight boundaries	-	-	-	P_{fs}	$P_{fs} + P_{fd}$
		Cargo holds	P_{bs}	$P_{bs} + P_{bd}$	-		
	P_{dk}	Internal decks for dry spaces	P_{dl-s}	$P_{dl-s} + P_{dl-d}$	-	-	-
		External deck for distributed loads	P_{dl-s}	$P_{dl-s} + P_{dl-d}$	-	-	-
		External deck for heavy units	F_{U-s}	$F_{U-s} + F_{U-d}$	-	-	-

(1) WB cargo hold is considered as ballast tank except for design load scenario 'ballast water exchange'.
(2) M_{swf} used for hull local scantling of watertight bulkhead
(3) Hull girder strength check is performed according to Ch 5, Sec 1 for bulk carriers having a length L of 150 m or above
(4) Applicable to prescriptive assessment only

2.2 Additional design load scenarios

2.2.1

The design load scenarios to be considered for sloshing, bottom slamming and bow impact are given in Table 2.

Table 2 : Design load scenarios for impact and sloshing conditions

Design load scenario / Load components			Bow impact Impact (I)	Bottom slamming Impact (I)	Sloshing Sloshing (SL)
Hull Girder	VBM		-	-	M_{sw}
	HBM		-	-	-
	VSF		-	-	-
	TM		-	-	-
Local Loads	P_{ex}	External deck for green sea	-	-	-
		Hull envelope	P_{FB}	P_{SL}	-
	P_{in}	Ballast tanks	-	-	P_{slh}
		Liquid cargo tanks			
		Other tanks			
		Watertight boundaries		-	-
		Cargo holds (1)	-	-	-
	P_{dk}	Internal decks for dry spaces	-	-	-
		External deck for distributed loads	-	-	-
		External deck for heavy units	-	-	-

(1) Sloshing assessment is not to be considered for water ballast cargo holds of bulk carriers.

3 DESIGN LOAD SCENARIOS FOR FATIGUE ASSESSMENT

3.1 Design load scenarios

3.1.1

The design load scenarios for fatigue assessment are given in Table 3.

Table 3 : Design load scenarios for fatigue assessment

Design load scenario / Load components			Fatigue: Static + Dynamic (F: S+D)
Hull Girder	VBM		$M_{sw} + M_{wv\text{-}LC}$
	HBM		$M_{wh\text{-}LC}$
	VSF		$Q_{sw} + Q_{wv\text{-}LC}$
	TM		$M_{wt\text{-}LC}$
Local Loads	P_{ex}	External deck for green sea	-
		Hull envelope	$P_S + P_W$
	P_{in}	Ballast tanks (1)	$P_{ls} + P_{ld}$
		Liquid cargo tanks	
		Other tanks designed for liquid filling	
		Watertight boundaries	-
		Cargo holds	$P_{bs} + P_{bd}$
	P_{dk}	Internal decks for dry spaces	-
		External deck for distributed loads	-
		External deck for heavy units	-

(1) WB cargo hold is considered as ballast tank except for design load scenario ‘ballast water exchange’.

SECTION 8
LOADING CONDITIONS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

ℓ : Distance from propeller centreline to the waterline, in m.

D_p : Propeller diameter, in m.

M_{Full} : Cargo mass, in t, as defined in Ch 4, Sec 6.

M_H : Cargo mass, in t, as defined in Ch 4, Sec 6.

M_{HD} : Cargo mass, in t, as defined in Ch 4, Sec 6.

M_{BLK} : Maximum cargo mass in cargo holds in block loading conditions, in t, as defined in Ch 4, App 1.

$C_{BM\text{-}LC}$: Coefficient taken as the percentage of permissible SWBM, defined in Table 2 to Table 9 and Table 12 to Table 21.

$C_{SF\text{-}LC}$: Coefficient taken as the percentage of permissible SWSF, defined in Table 2 to Table 9 and Table 12 to Table 21.

$x_{b\text{-}aft}$, $x_{b\text{-}fwd}$: Longitudinal position, in m, of respectively the aft and forward bulkhead of the mid-hold of the FE model.

EA : Empty hold in alternate loading condition.

FA : Full hold in alternate loading condition.

T_{H1}, T_{H2}, T_{H3}, T_{H4}: Minimum permissible draught, in m, in harbour condition as defined in Ch 4, App 1.

1 APPLICATION

1.1 Ships having a length *L* of 150m or above

1.1.1

The requirements in [2] to [5] are applicable to ships having a length *L* of 150 m or above.

1.1.2 Design loading conditions for strength assessment

Design loading conditions for strength assessment are given in [2] to [4]. The design loading conditions common to both oil tankers and bulk carriers are given in [2]. Specific design loading conditions for oil tankers and bulk carriers are given in [3] and [4] respectively.

Unless otherwise specified, each of the design seagoing conditions is to be investigated for the arrival and departure conditions.

1.1.3

These requirements are not intended to prevent conditions to be included in the loading manual for which calculations are to be submitted. It is not intended to replace in any way the required loading manual/instrument.

1.1.4

Loading conditions from the loading manual, which are not covered in [2] to [4], if any, are to be considered.

1.1.5 Standard design load conditions for fatigue assessment

The standard design loading conditions for fatigue assessment are given in [5].

1.2 Bulk carriers having a length *L* less than 150 m

1.2.1

The severest loading condition from the loading manual, midship section drawing or otherwise specified by the Designer are to be considered for the longitudinal strength given in Ch 5 and for local strength check of plating, ordinary stiffeners and primary supporting members given in Ch 6 and Pt 2, Ch 1, Sec 3 and Pt 2, Ch 1, Sec 4.

The requirements in [2] are applicable to ships having a length *L* less than 150 m.

1.3 Dynamic load cases

1.3.1 Seagoing conditions

Unless otherwise specified, each of the design seagoing conditions are to be investigated for all dynamic load cases.

1.3.2 Beam and oblique sea dynamic load cases

For FE load analysis, the beam sea and oblique sea dynamic load cases calculated for port and starboard sides are to be applied on the model to obtain the results for both model sides.

For ship with structure symmetrical about the centreline, the beam sea and oblique sea dynamic load cases calculated for portside may be applied only to the model (i.e. dynamic load cases on starboard side may be omitted) provided the results (yield and buckling) are mirrored.

2 COMMON DESIGN LOADING CONDITIONS

2.1 Definitions

2.1.1

In general, the design cargo and ballast loading conditions, based on the amount of bunker, fresh water and stores at departure and arrival, are to be considered for the still water bending moment and shear force calculations. Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted in addition to those for departure and arrival conditions. Also, where any ballasting and/or deballasting is intended during voyage, calculations of the intermediate condition just before and just after ballasting and/or deballasting are to be submitted and included in the loading manual.

2.1.2 Departure conditions

The departure conditions are to be based on bunker tanks not taken less than 95% full and other consumables taken at 100% capacity.

2.1.3 Arrival conditions

The arrival conditions are to be based on 10% of the maximum capacity of bunker, fresh water and stores.

2.2 Partially filled ballast tanks

2.2.1 Partially filled ballast tanks in ballast loading conditions

Ballast loading conditions involving partially filled peak and/or other ballast tanks in any departure, arrival or intermediate condition are not permitted to be used as design loading conditions unless:

- Stress levels are within the Rule acceptance criteria for loading conditions with the considered tanks full, empty and partially filled at intended level in any departure, arrival or intermediate condition.
- For bulk carriers having a length L of 150 m or above, longitudinal strength of hull girder in flooded condition given in Ch 5, Sec 1 is to comply with loading conditions with the considered tanks full, empty and partially filled at intended level in any departure, arrival or intermediate condition.

The corresponding full, empty and partially filled tank conditions are to be considered as design conditions for calculation of the still water bending moment and shear force, but these do not need to comply with propeller immersion and trim requirements as specified in [2.3.1], [3.1.1] or [4.1.1].

Where multiple tanks are intended to be partially filled, all combinations of empty, full and partially filled at intended levels for those tanks are to be investigated. These requirements are not applicable to ballast water exchange using the sequential method.

2.2.2 Partially filled ballast tanks in cargo loading conditions

In cargo loading conditions, the requirement in [2.2] applies to peak ballast tanks only.

2.3 Seagoing conditions

2.3.1

The following seagoing loading conditions are to be included, as a minimum, in the loading manual:

a) Homogeneous cargo loading condition including a condition at the scantling draught. Homogeneous loading conditions are to not include filling of ballast tanks in departure conditions.

b) Ballast condition where the ballast tanks may be full, partially full or empty. Where ballast tanks are partially full, the conditions in [2.2.1] are to be complied with. All cargo tanks/holds are to be empty including cargo tanks/holds suitable for the carriage of water ballast at sea. The propeller is to be fully immersed. The trim is to be by the stern and is not to exceed 0.015 L_{LL}.

c) Conditions covering ballast water exchange procedures with the calculations of intermediate conditions just before and just after ballasting and/or deballasting any ballast tank.

2.4 Harbour and sheltered water conditions

2.4.1

The following harbour and sheltered water conditions are to be included in the loading manual:

a) Conditions representing typical complete loading and unloading operations.

b) Docking condition afloat.

c) Propellers inspection afloat condition, in which the propeller shaft centreline is at least $D_p/4$ above the waterline in way of the propeller.

2.5 Loading conditions

2.5.1 Alternative design

For structural arrangement not covered by this section, the loading conditions, including loading pattern, corresponding draught, still water bending moment and shear forces are to be agreed by the Society.

3 OIL TANKERS

3.1 Specific design loading conditions

3.1.1 Seagoing conditions

The following seagoing loading conditions are to be included, as a minimum, in the loading manual:

a) Heavy ballast condition where the ballast tanks may be full, partially full or empty. Where ballast tanks are partially full, the conditions in [2.2.1] are to be complied with. The fore peak water ballast tank is to be full, if fitted. If upper and lower fore peak tanks are fitted, the lower is required to be full and the upper tank may be full, partially full or empty. All the cargo tanks are to be empty including cargo tanks suitable for the carriage of water ballast at sea. The draught at the forward perpendicular is not to be less than that for the normal ballast condition. The propeller is to be fully immersed. The trim is to be by the stern and is not to exceed 0.015 L.

b) Mid-voyage conditions relating to tank cleaning or other operations where these differ significantly from the ballast conditions.

c) Any specified non-uniform distribution of loading.

d) Conditions with high density cargo including the maximum design cargo density, when applicable.

e) Design ballast condition in which all segregated ballast tanks in the cargo tank region are full and all other tanks are empty including fuel oil and fresh water tanks. This design condition is for assessment of hull strength and is not intended for ship operation. This condition will also be covered by the IMO 73/78 SBT condition provided the corresponding condition in the loading manual only includes ballast in segregated ballast tanks in the cargo tank region.

3.1.2 Additional loading conditions

The following additional loading conditions are to be included in the loading manual if the ship is specifically approved and intended to be operated in such conditions:

a) Seagoing ballast conditions including water ballast carried in one or more cargo tanks which are intended for use in emergency situations as allowed by MARPOL Reg. 18.
b) Seagoing loading conditions where the net static upward load on the double bottom exceeds that given with the combination of an empty cargo tank and a mean ship's draught of 0.9 T_{SC}.
c) Seagoing loading conditions with cargo tanks less than 25% full with the combination of mean ship's draught greater than 0.9 T_{SC}.
d) Seagoing loading conditions where the net static downward load on the double bottom exceeds that given with the combination of a full cargo tank at a cargo density of 1.025 t/m^3 or greater and a mean ship's draught of 0.6 T_{SC}.
e) For ships arranged with cross ties in the centre cargo tank, seagoing loading conditions showing a non-symmetric loading pattern where the difference in filling level between corresponding port and starboard wing cargo tanks exceeds 25% of the filling height in the wing cargo tank.

3.2 Design load combinations for direct strength analysis

3.2.1

The design load combinations for FE analysis are given in Table 1 as follows:

Table 1 : Design load combination for oil tankers

	Midship cargo hold region	Outside midship cargo hold region	Foremost cargo tanks	Aftmost cargo tanks
Tankers with two oil-tight bulkheads	Table 2	Table 4	Table 6	Table 8
Tankers with one centreline oil-tight bulkhead	Table 3	Table 5	Table 7	Table 9
Note 1: **Outside midship cargo hold region means the forward or aft cargo hold region except the foremost and aftmost cargo holds**				

3.2.2

For tankers with two oil-tight longitudinal bulkheads, where the cargo tank length is less than 0.15 L, the draughts given in Table 2, Table 4, Table 6 and Table 8 are subject to special consideration by the Society.

3.2.3

For tankers with one centreline oil-tight longitudinal bulkhead, where the cargo tank length is less than 0.11 L, the draughts given in Table 3, Table 5, Table 7 and Table 9 are subject to special consideration by the Society.

3.2.4

For seagoing conditions, the dynamic load cases required to be investigated for each loading pattern are indicated in Table 2 to Table 9. Dynamic load cases are defined in Ch 4, Sec 2.

3.2.5 Ships with structure symmetrical about centreline

For ships with structure symmetrical about the centreline, the loading pattern mirrored about centreline of another pattern may be omitted provided the results (yield and buckling) are mirrored, e.g. Table 2 A7b, A12b.

3.2.6 Tankers with two oil-tight longitudinal bulkheads except with a cross tie arrangement in the wing cargo tanks

For tankers with two oil-tight longitudinal bulkheads except with a cross tie arrangement in the wing cargo tanks, loading patterns A7 and A12 in Table 2, Table 4, Table 6 and Table 8 are to be examined for the possibility that unequal filling levels in transversely paired wing cargo tanks would result in a more onerous stress response. Loading pattern A7 is required to be analysed only if such a non-symmetric seagoing loading condition is included in the ship loading manual. The actual loading pattern, draught, GM and k_r from the loading manual are to be used in the FE analysis. Where the GM and k_r are not given in the ship's loading manual, GM and k_r are to be determined in accordance with Ch 4, Sec 3.

If loading patterns A7 and A12 are not considered, an operational restriction describing that the difference in filling level between corresponding port and starboard wing cargo tanks is not to exceed 25% of the filling height in the wing cargo tank, is to be added in the loading manual.

Loading patterns A7 and A12 need not be examined for tankers with a cross tie arrangement in the wing cargo tanks.

3.2.7

For tankers with two oil-tight longitudinal bulkheads, seagoing loading pattern A3 and harbour loading pattern A13, with all cargo tanks abreast empty, in Table 2, Table 4, Table 6 and Table 8 are to be analysed with a ship draught of 0.65 T_{SC} and 0.7 T_{SC} respectively. If conditions in the ship loading manual specify greater draughts for loading pattern A3 or A13, then the maximum specified draught in the ship's loading manual for the loading pattern is to be used.

3.2.8

For tankers with two oil-tight longitudinal bulkheads, seagoing loading pattern A5 and harbour loading pattern A11, with all cargo tanks abreast fully loaded, in Table 2, Table 4, Table 6 and Table 8 are to be analysed with a ship draught of 0.65 T_{SC} and 0.6 T_{SC} respectively. If conditions in the ship loading manual specify lesser draughts for loading pattern A5 or A11, then the minimum specified draught in the ship's loading manual for the loading pattern is to be used.

3.2.9

For loading patterns A1, A2, B1, B2 and B3, with cargo tank(s) empty, in Table 2 to Table 9, a minimum ship draught of 0.9 T_{SC} is to be used in the analysis. If conditions in the ship loading manual specify greater draughts for loading patterns with empty cargo tank(s), then the maximum specified draught for the actual condition is to be used.

3.2.10 Ballast conditions

Where a ballast condition is specified in the ship loading manual with ballast water filled in one or more cargo tanks, loading patterns A8 or B7 in Table 2 or Table 3 are to be examined.

If the actual loading pattern as specified in the loading manual is different from load pattern A8 or B7 then:

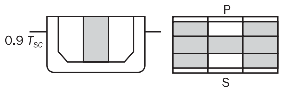
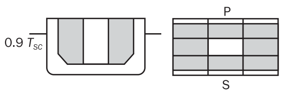
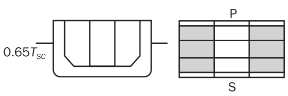
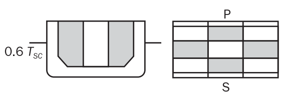
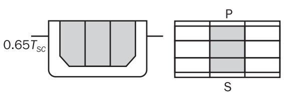
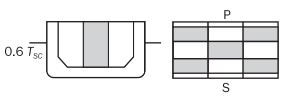
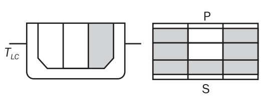
a) The actual loading patterns are to be substituted for the loading pattern A8 or B7 with the following calculation conditions:
   - Draught to be taken as T_{BAL-E},
   - C_{BM-LC} = 100% (sag.),
   - C_{SF-LC} = 100%,
   - 100% filling of the considered tanks carrying ballast water.

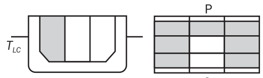
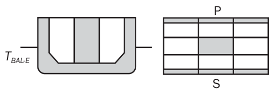
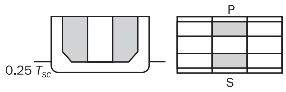
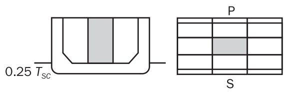
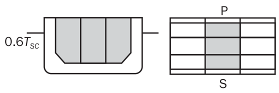
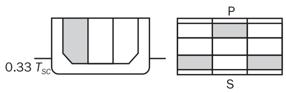
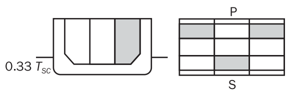
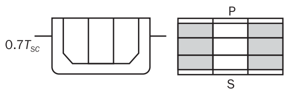
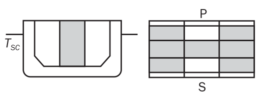
b) The strength assessment is to be carried out for all the dynamic load cases as defined in Ch 4, Sec 2.

c) An operational restriction corresponding to the analysed condition is to be added in the loading manual.

The actual loading pattern, draught, GM and k_r from the loading manual are to be used in the FE analysis. Where the GM and k_r are not given in the ship's loading manual, GM and k_r are to be determined in accordance with Ch 4, Sec 3.

Table 2 : Load combinations for FE analysis for two oil-tight bulkheads oil tankers applicable to midship cargo hold region

No.	Loading pattern	Still water loads			Dynamic load cases		
		Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Midship cargo region		
Seagoing conditions							
A1		$0.9T_{SC}$	100% (sagging)	100%	HSM-1	BSR-1P/S BSP-1P/S	OST-1P/S
			100% (hogging)	100%	HSM-2 FSM-2	BSP-1P/S	OST-2P/S OSA-1P/S
A2		$0.9T_{SC}$	100% (sagging)	100%	HSM-1 HSA-1	BSR-1P/S BSP-1P/S	OSA-1P/S
			100% (hogging)	100%	HSM-2 FSM-2	BSR-1P/S BSP-1P/S	N/A
A3		$0.65T_{SC}$	100% (hogging)	100% (4) Max SFLC	HSM-2	N/A	N/A
				100% (5) Max SFLC	HSM-2	N/A	N/A
				100%	N/A	BSR-1P/S BSP-1P/S	OSA-2P/S
			0%	100% (6) Max SFLC	HSM-1	N/A	N/A
A4		$0.6T_{SC}$	100% (sagging)	100%	HSM-1	BSR-1P/S BSP-1P/S	OST-2P/S OSA-2P/S
A5		$0.65T_{SC}$	100% (sagging)	100% (4) Max SFLC	HSM-1	N/A	N/A
				100% (5) Max SFLC	HSM-1	N/A	N/A
				100%	N/A	BSR-1P/S BSP-1P/S	OSA-2P/S
			0%	100% (6) Max SFLC	HSM-2	N/A	N/A
A6		$0.6T_{SC}$	100% (hogging)	100%	HSM-2 FSM-2	BSR-1P/S BSP-1P/S	OSA-2P/S
A7a		T_{LC}	100% (hogging)	100%	HSM-2 FSM-2	BSR-1P/S BSP-1P/S	OST-2P/S OSA-1P/S OSA-2P/S

No.	Loading pattern	Still water loads			Dynamic load cases		
		Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Midship cargo region		
A7b		T_{LC}	100% (hogging)	100%	HSM-2 FSM-2	BSR-1P/S BSP-1P/S	OST-2P/S OSA-1P/S OSA-2P/S
A8		T_{BAL-E}	100% (sagging)	100%	HSM-1	BSR-1P/S BSP-1P/S	OSA-2P/S
Harbour and testing conditions							
A9		$0.25T_{SC}$	100% (sagging)	100%	N/A		
A10		$0.25T_{SC}$	100% (sagging)	100%	N/A		
A11		$0.6T_{SC}$	100% (sagging)	100% **(2)** Max SFLC	N/A		
				100% **(3)** Max SFLC	N/A		
A12a **(1)**		$0.33T_{SC}$			N/A		
A12b **(1)**		$0.33T_{SC}$			N/A		
A13		$0.7T_{SC}$	100% (hogging)	100% **(2)** Max SFLC	N/A		
				100% **(3)** Max SFLC	N/A		
A14		T_{SC}	100% (hogging)	100%	N/A		

(1) The actual shear force and bending moment that results from the application of local loads to the FE model are to be used. Adjusting vertical loads and bending moments are not applied.

(2) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.

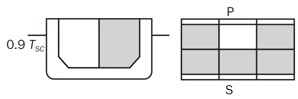
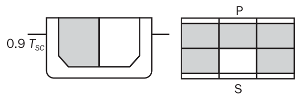
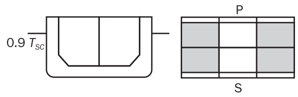
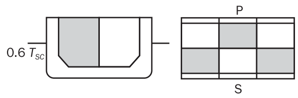
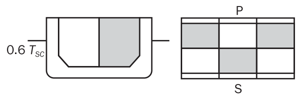
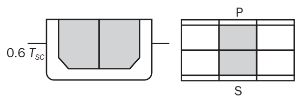
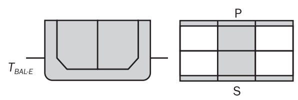
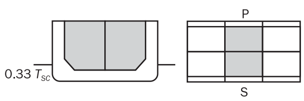
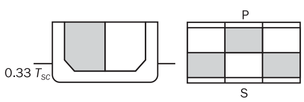
(3) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

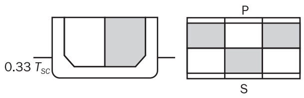
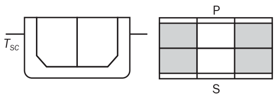
(4) For the mid-hold where $x_{b-aft} \leq 0.5L$ and $x_{b-fwd} \geq 0.5L$, the shear force is to be adjusted to target value at aft bulkhead of the mid-hold.

(5) For the mid-hold where $x_{b-aft} \leq 0.5L$ and $x_{b-fwd} \geq 0.5L$, the shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

(6) This load combination is to be considered only for the mid-hold where $x_{b-aft} > 0.5L$ or $x_{b-fwd} < 0.5L$.

Table 3 : Load combinations for FE analysis for one centreline oil-tight bulkheads oil tankers applicable to midship cargo region

No.	Loading pattern	Still water loads			Dynamic load cases		
		Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Midship cargo region		
Seagoing conditions							
B1		$0.9T_{SC}$	100% (sagging)	100%	HSM-1 HSA-1	BSP-1P/S	N/A
			100% (hogging)	100%	HSM-2 FSM-2	BSR-1P BSP-1P	OST-2P
B2		$0.9T_{SC}$	100% (sagging)	100%	HSM-1 HSA-1	BSP-1P/S	N/A
			100% (hogging)	100%	HSM-2 FSM-2	BSR-1S BSP-1S	OST-2S
B3		$0.9T_{SC}$	100% (hogging)	100% (3) Max SFLC	HSM-2 FSM-2	N/A	N/A
				100% (4) Max SFLC	HSM-2 FSM-2	N/A	N/A
				100%	N/A	BSP-1P/S	N/A
			0%	100% (5) Max SFLC	HSM-1 FSM-1	N/A	N/A
B4		$0.6T_{SC}$	100% (sagging)	75%	HSM-1	BSP-1P	OSA-2P/S
B5		$0.6T_{SC}$	100% (sagging)	75%	HSM-1	BSP-1S	OSA-2P/S
B6		$0.6T_{SC}$	100% (sagging)	100% (3) Max SFLC	HSM-1	N/A	N/A
				100% (4) Max SFLC	HSM-1	N/A	N/A
				100%	N/A	BSP-1P/S	N/A
			0%	100% (5) Max SFLC	HSM-2	N/A	N/A
B7		T_{BAL-E}	100% (sagging)	100%	HSM-1	BSP-1P/S	N/A
Harbour and testing conditions							
B8		$0.33T_{SC}$	100% (sagging)	100% (1) Max SFLC	N/A		
				100% (2) Max SFLC	N/A		
B9		$0.33T_{SC}$	100% (sagging)	75%	N/A		

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Midship cargo region
B10		$0.33T_{SC}$	100% (sagging)	75%	N/A
B11		T_{SC}	100% (hogging)	100% (1) Max SFLC	N/A
				100% (2) Max SFLC	N/A

(1) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.

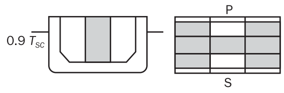
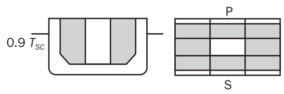
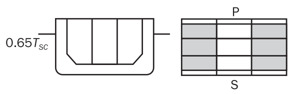
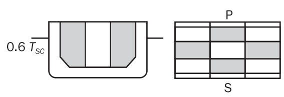
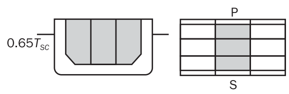
(2) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

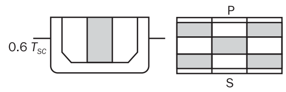
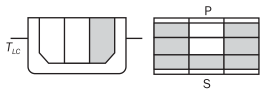
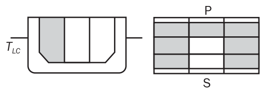
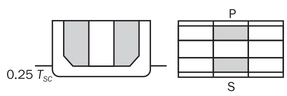
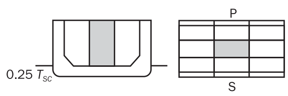
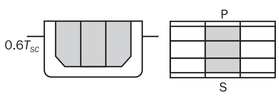
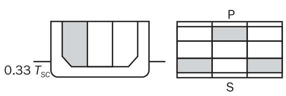
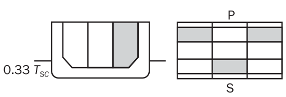
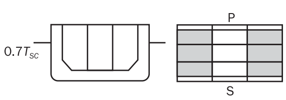
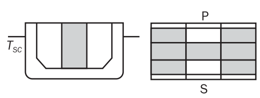
(3) For the mid-hold where $x_{b\text{-}aft} \le 0.5L$ and $x_{b\text{-}fwd} \ge 0.5L$, the shear force is to be adjusted to target value at aft bulkhead of the mid-hold.

(4) For the mid-hold where $x_{b\text{-}aft} \le 0.5L$ and $x_{b\text{-}fwd} \ge 0.5L$, the shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

(5) This load combination is to be considered only For the mid-hold where $x_{b\text{-}aft} > 0.5L$ or $x_{b\text{-}fwd} < 0.5L$.

Table 4 : Load combinations for FE analysis for two oil-tight bulkheads oil tankers applicable to outside midship cargo hold region

No.	Loading pattern	Still water loads			Dynamic load cases	
		Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Aft region	Forward region
Seagoing conditions						
A1		$0.9T_{SC}$	100% (sagging)	100%	HSM-1 BSP-1P/S, BSR-1P/S, OST-1P/S,	HSM-1, FSM-1 BSP-1P/S, BSR-1P/S, OST-1P/S,
			100% (hogging)	100%	HSM-2, FSM-2 BSP-1P/S, OST-2P/S, OSA-1P/S,	HSM-2, FSM-2 BSP-1P/S,
A2		$0.9T_{SC}$	100% (sagging)	100%	HSM-1 BSP-1P/S,	HSM-1, FSM-1 BSP-1P/S, BSR-1P/S, OSA-1P/S,
			100% (hogging)	100%	HSM-2, FSM-2 HSA-2 BSP-1P/S, BSR-1P/S, OST-2P/S, OSA-1P/S,	HSM-2, FSM-2 BSP-1P/S, BSR-1P/S, OST-2P/S,
A3		$0.65T_{SC}$	100% (hogging)	100% Max SFLC	HSM-2	HSM-2 FSM-2
				100%	BSP-1P/S,	BSP-1P/S, OSA-2P/S,
			0%	100% Max SFLC	HSM-1	HSM-1
				100%	BSP-1P/S,	BSP-1P/S, OSA-2P/S,
A4		$0.6T_{SC}$	100% (sagging)	100%	HSM-1 BSP-1P/S, BSR-1P/S,	HSM-1 BSP-1P/S, BSR-1P/S, OSA-2P/S,
A5		$0.65T_{SC}$	100% (sagging)	100% Max SFLC	HSM-1 FSM-1	HSM-1
				100%	BSP-1P/S,	BSP-1P/S,
			0%	100% Max SFLC	HSM-2	HSM-2

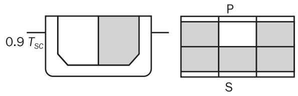
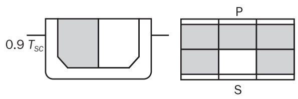
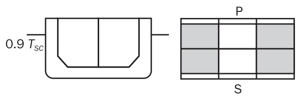
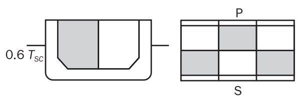
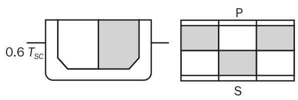
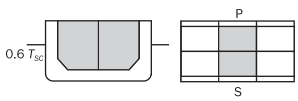
No.	Loading pattern	Still water loads			Dynamic load cases	
		Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Aft region	Forward region
A6		$0.6T_{SC}$	100% (hogging)	100%	HSM-2 BSP-1P/S, BSR-1P/S,	HSM-2, FSM-2 BSP-1P/S, BSR-1P/S, OSA-2P/S,
A7a		T_{LC}	100% (hogging)	100%	HSM-2, FSM-2 BSP-1P/S, BSR-1P, BSR-2S OSA-1P/S, OSA-2P/S, OST-1S, OST-2P	HSM-2, FSM-2 BSP-1P/S, BSR-1P, BSR-2S OSA-2P/S, OST-2P/S,
A7b		T_{LC}	100% (hogging)	100%	HSM-2, FSM-2 BSP-1P/S, BSR-2P, BSR-1S OSA-1P/S, OSA-2P/S, OST-1P, OST-2S	HSM-2, FSM-2 BSP-1P/S, BSR-2P, BSR-1S OSA-2P/S, OST-2P/S,
Harbour and testing conditions						
A9		$0.25T_{SC}$	100% (sagging)	100%	N/A	
A10		$0.25T_{SC}$	100% (sagging)	100%	N/A	
A11		$0.6T_{SC}$	100% (sagging)	100% **(2)** Max SFLC	N/A	
				100% **(3)** Max SFLC	N/A	
A12 a **(1)**		$0.33T_{SC}$			N/A	
A12 b **(1)**		$0.33T_{SC}$			N/A	
A13		$0.7T_{SC}$	100% (hogging)	100% **(2)** Max SFLC	N/A	
				100% **(3)** Max SFLC	N/A	
A14		T_{SC}	100% (hogging)	100%	N/A	

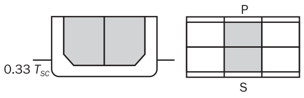
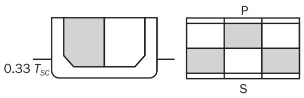
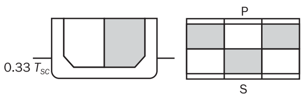
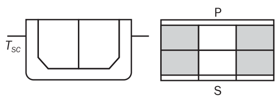
(1) The actual shear force and bending moment that results from the application of local loads to the FE model are to be used. Adjusting vertical loads and bending moments are not applied.

(2) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.

(3) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

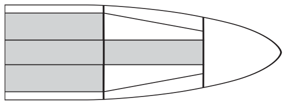
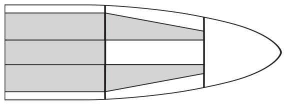
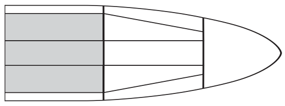
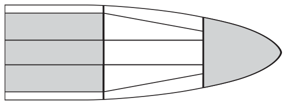
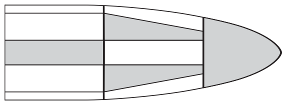
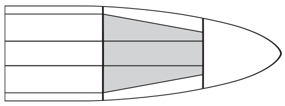
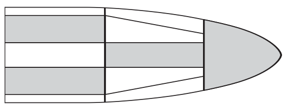
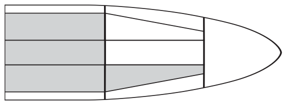
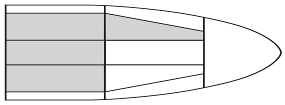
Table 5 : Load combinations for FE analysis for one centreline oil-tight bulkheads oil tankers applicable to outside midship cargo hold region

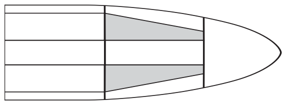
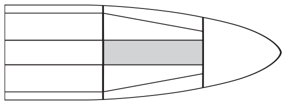
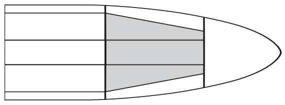
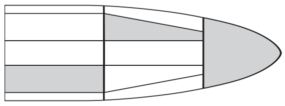
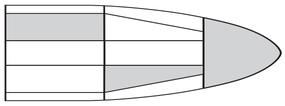
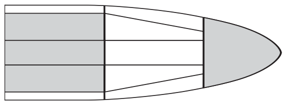
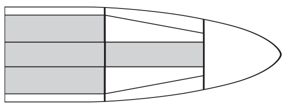
No.	Loading pattern	Still water loads			Dynamic load cases	
		Draught	C_{BM-LC}: % of perm. SWBM	C_{SF-LC}: % of perm. SWSF	Aft region	Forward region
Seagoing conditions						
B1		$0.9T_{SC}$	100% (sagging)	100%	HSM-1, FSM1 BSP-1P/S, OSA-1S	HSM-1 BSP-1P/S, OSA-2S
			100% (hogging)	100%	HSM-2, FSM-2 BSP-1P/S, OSA-1P OST-2P/S,	HSM-2, FSM-2 BSP-1P/S, OSA-2S
B2		$0.9T_{SC}$	100% (sagging)	100%	HSM-1, FSM-1 BSP-1P/S, OSA-1P	HSM-1 BSP-1P/S, OSA-2P
			100% (hogging)	100%	HSM-2, FSM-2 BSP-1P/S, OSA-1S OST-2P/S,	HSM-2, FSM-2 BSP-1P/S, OSA-2P
B3		$0.9T_{SC}$	100% (hogging)	100% Max SFLC	HSM-2 FSM-2	HSM-2 FSM-2
				100%	BSP-1P/S, BSR-1P/S,	BSR-1P/S,
			0%	100% Max SFLC	HSM-1 FSM-1	HSM-1 FSM-1
				100%	BSP-1P/S,	BSP-1P/S,
B4		$0.6T_{SC}$	100% (sagging)	75%	HSM-1 BSR-1P/S,	HSM-1 BSP-1P/S, OSA-2P/S,
B5		$0.6T_{SC}$	100% (sagging)	75%	HSM-1 BSR-1P/S,	HSM-1 BSP-1P/S, OSA-2P/S,
B6		$0.6T_{SC}$	100% (sagging)	100% Max SFLC	HSM-1 FSM-1	HSM-1 FSM-1
				100%	OST-1P/S,	OSA-2P/S,
			0%	100% Max SFLC	HSM-2 FSM-2	HSM-2 FSM-2
				100%	OSA-2P/S,	OSA-2P/S,

No.	Loading pattern	Still water loads			Dynamic load cases	
		Draught	C_{BM-LC}: % of perm. SWBM	C_{SF-LC}: % of perm. SWSF	Aft region	Forward region
Harbour and testing conditions						
B8		$0.33T_{SC}$	100% (sagging)	100% (1) Max SFLC	N/A	
				100% (2) Max SFLC	N/A	
B9		$0.33T_{SC}$	100% (sagging)	75%	N/A	
B10		$0.33T_{SC}$	100% (sagging)	75%	N/A	
B11		T_{SC}	100% (hogging)	100% (1) Max SFLC	N/A	
				100% (2) Max SFLC	N/A	

(1) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(2) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

Table 6 : Load combinations for FE analysis for two oil-tight bulkheads oil tankers applicable for foremost cargo hold

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Foremost cargo hold
Seagoing conditions					
A1		$0.9T_{SC}$	100% (sagging)	100%	HSM-1, FSM-1 BSP-1P/S, BSR-1P/S OSA-2P/S, OST-1P/S
A2		$0.9T_{SC}$	100% (sagging)	100%	HSM-1, OSA-2P/S
A3-1		$0.65T_{SC}$	100% (sagging)	100%	HSM-1, OSA-2P/S
A3-2 (1)		$0.65T_{SC}$	0%	100% Max SFLC	HSM-2
				100%	BSP-1P/S, OSA-2P/S
			100% (sagging)	100% Max SFLC	HSM-1
				100%	OSA-2P/S
A4 (1)		$0.6T_{SC}$	50% (hogging)	100%	FSM-1, BSP-1P/S, OSA-2P/S
A5		$0.65T_{SC}$	0%	100% Max SFLC	HSM-1
			100% (hogging)	100% Max SFLC	HSM-2
				100%	BSP-1P/S
A6 (1)		$0.6T_{SC}$	50% (hogging)	100%	OSA-2P/S
A7a		T_{LC}	100% (sagging)	100%	HSM-1, HSA-1, FSM-1, BSP-1P/S, BSR-1P/S OST-1P/S, OSA-2P/S
A7b		T_{LC}	100% (sagging)	100%	HSM-1, HSA-1, FSM-1, BSP-1P/S, BSR-1P/S OST-1P/S, OSA-2P/S
Harbour and testing conditions					

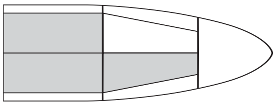
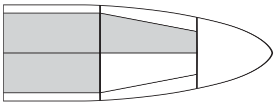
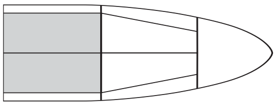
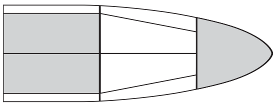
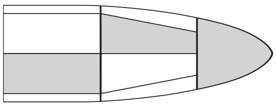
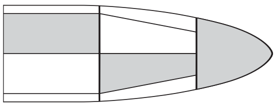
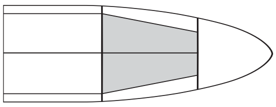
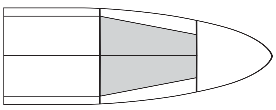
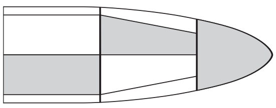
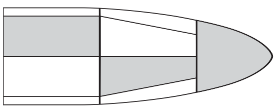
No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Foremost cargo hold
A9		$0.25T_{SC}$	100% (hogging)	100%	N/A
A10		$0.25T_{SC}$	100% (hogging)	100%	N/A
A11		$0.6T_{SC}$	100% (hogging)	100% (2) Max SFLC	N/A
				100% (3) Max SFLC	N/A
A12-a (1)		$0.33T_{SC}$	N/A	N/A	N/A
A12-b (1)		$0.33T_{SC}$	N/A	N/A	N/A
A13 (1)		$0.7T_{SC}$	100% (sagging)	100% (2) Max SFLC	N/A
				100% (3) Max SFLC	N/A
A14		T_{SC}	100% (sagging)	100%	N/A

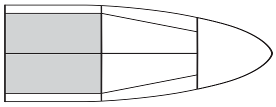
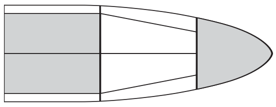
(1) 100% filling of all fore peak water ballast tanks.

(2) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.

(3) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

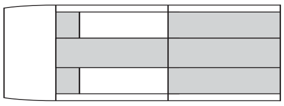
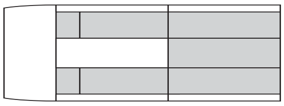
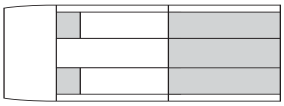
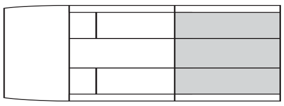
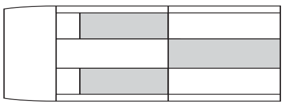
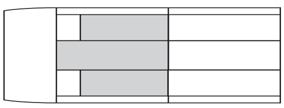
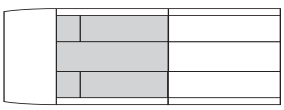
Table 7 : Load combination for FE analysis for one centreline oil-tight bulkheads oil tankers applicable for foremost cargo hold

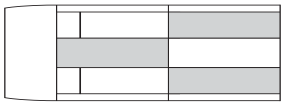
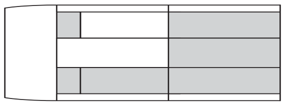
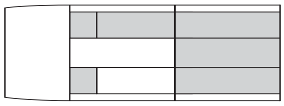
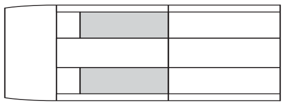
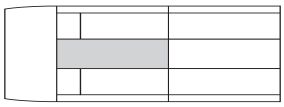
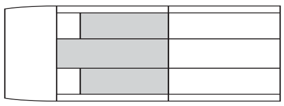
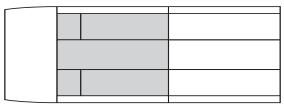
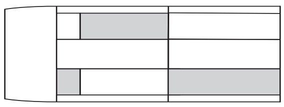
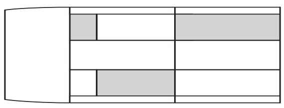
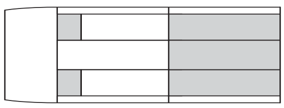
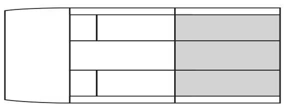
No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Foremost cargo hold
Seagoing conditions					
B1		$0.9T_{SC}$	100% (sagging)	100%	HSM-1 BSP-1P/S OSA-2P/S
B2		$0.9T_{SC}$	100% (sagging)	100%	HSM-1 BSP-1P/S OSA-2P/S
B3-1		$0.9T_{SC}$	100% (sagging)	100%	BSP-1S/P, OSA-2S/P, HSM-1
B3-2 (1)		$0.9T_{SC}$	0%	100% Max SFLC	HSM-2, BSP-1S/P, OSA-2S/P
			100% (sagging)	100% Max SFLC	HSM-1, FMS-1
				100%	BSP-1S/P, OST-1S/P, OSA-2P/S
B4 (1)		$0.6T_{SC}$	100% (hogging)	75%	BSP-1P/S, OSA-2P/S
B5 (1)		$0.6T_{SC}$	100% (hogging)	75%	BSP-1P/S, OSA-2P/S
B6		$0.6T_{SC}$	0%	100% Max SFLC	HSM-1
				100%	OSA-2P/S
			100% (hogging)	100% Max SFLC	HSM-2, FSM-2, OSA-2P/S
Harbour and testing conditions					
B8		$0.33T_{SC}$	100% (hogging)	100% (2) Max SFLC	N/A
				100% (3) Max SFLC	N/A
B9 (1)		$0.33T_{SC}$	100% (hogging)	75%	N/A
B10 (1)		$0.33T_{SC}$	100% (hogging)	75%	N/A

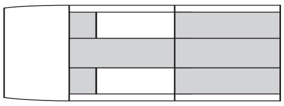
No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Foremost cargo hold
B11-1		T_{SC}	100% (sagging)	100%	N/A
B11-2 (1)		T_{SC}	100% (sagging)	100% (2) Max SFLC	N/A
				100% (3) Max SFLC	N/A

(1) 100% filling of all fore end water ballast tanks.
(2) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(3) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

Table 8 : Load combinations for FE analysis for two oil-tight bulkheads oil tankers applicable for aftmost cargo hold

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Aftmost cargo hold
Seagoing conditions					
A1		$0.9T_{SC}$	100% (sagging)	100%	FSM-1, HSM-1, BSP-1P/S
			100% (hogging)	100%	HSM-2, BSP-1P/S, BSR-1P/S OSA-1P/S
A2		$0.9T_{SC}$	100% (sagging)	100%	HSM-1, FSM-1 BSR-1P/S, OST-1P/S
			100% (hogging)	100%	HSM-2, FSM-1, FSM-2, OSA-1P/S
A3-1 (1) (2)		$0.65T_{SC}$	100% (hogging)	100% Max SFLC	HSM-2 FSM-2
			100% (sagging)	100% Max SFLC	HSM-1, FSM-1
				100%	BSP-1P/S
A3-2 (1) (3)		$0.65T_{SC}$	100% (hogging)	100% Max SFLC	HSM-2
				100%	BSP-1P/S, OSA-1P/S
			100% (sagging)	100% Max SFLC	HSM-1, FSM-1
				100%	BSP-1P/S, OST-1P/S
A4		$0.6T_{SC}$	100% (sagging)	100%	HSM-1, BSP-1P/S
			100% (hogging)	100%	HSM-2, FSM-1, BSP-1P/S, OSA-1P/S, OSA-2P/S
A5-1 (2)		$0.65T_{SC}$	0%	100% Max SFLC	HSM-1, HSM-2, FSM-1,
			100% (hogging)	100% Max SFLC	HSM-2, FSM-1
				100%	BSP-1P/S
A5-2 (3)		$0.65T_{SC}$	0%	100% Max SFLC	HSM-1, HSM-2
				100%	BSP-1P/S, BSR-1P/S
			100% (hogging)	100% Max SFLC	HSM-2, FSM-2

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Aftmost cargo hold
A6		$0.6T_{SC}$	100% (hogging)	100%	HSM-2, FSM-1, BSP-1P/S, BSR-1P/S, OSA-1P/S
A7a		T_{LC}	100% (hogging)	100%	HSM-2, FSM-1, BSP-1P/S, BSR-1P/S, OSA-1P/S
A7b		T_{LC}	100% (hogging)	100%	HSM-2, FSM-1, BSP-1P/S, BSR-1P/S, OSA-1P/S
Harbour and testing conditions					
A9		$0.25T_{SC}$	100% (hogging)	100%	N/A
A10		$0.25T_{SC}$	100% (hogging)	100%	N/A
A11-1 (2)		$0.6T_{SC}$	100% (hogging)	100% (5) Max SFLC	N/A
A11-2 (3)		$0.6T_{SC}$	100% (hogging)	100% (5) Max SFLC	N/A
				100% (6) Max SFLC	N/A
A12a (4)		$0.33T_{SC}$	N/A	N/A	N/A
A12b (4)		$0.33T_{SC}$	N/A	N/A	N/A
A13-1 (1) (2)		$0.7T_{SC}$	100% (hogging)	100% (5) Max SFLC	N/A
A13-2 (1) (3)		$0.7T_{SC}$	100% (hogging)	100% (5) Max SFLC	N/A
				100% (6) Max SFLC	N/A
			100% (sagging)	100% (5) Max SFLC	N/A
				100% (6) Max SFLC	N/A

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Aftmost cargo hold
A14		T_{SC}	100% (hogging)	100%	N/A
			100% (sagging)	100%	N/A

(1) 100% filling of fuel and water ballast tanks in engine room, with tank boundaries at the forward engine room bulkhead.

(2) The required adjustment in shear force at aft bulkhead of the considered hold is to be done at forward slop tank bulkhead.

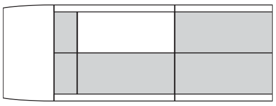
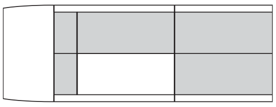
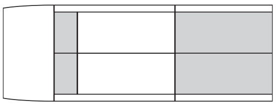
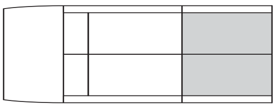
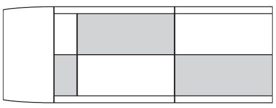
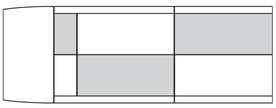
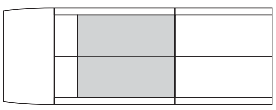
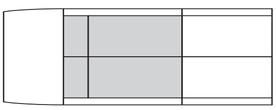
(3) The required adjustment in shear force at aft bulkhead of the considered hold is to be done at forward machinery space bulkhead.

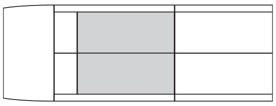
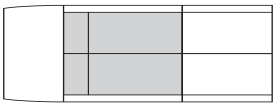
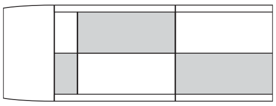
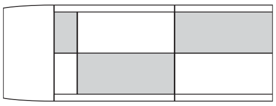
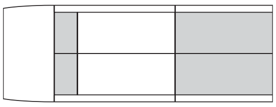
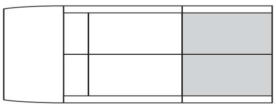
(4) The actual shear force and bending moment that results from the application of local loads to the FE model are to be used. Adjusting vertical loads and bending moments are not applied.

(5) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.

(6) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

Table 9 : Load combination for FE analysis for one centreline oil-tight bulkheads oil tankers applicable for the aftmost cargo hold

No.	Loading pattern	Still water loads: Draught	Still water loads: C_{BM-LC} : % of perm. SWBM	Still water loads: C_{SF-LC} : % of perm. SWSF	Dynamic load cases: Aftmost cargo hold
Seagoing conditions					
B1		$0.9T_{SC}$	100% (sagging)	100%	HSM-1, FSM-1 BSP-1P/S, BSR-1P/S
			100% (hogging)	100%	HSM-2 BSP-1P/S, OSA-1P/S
B2		$0.9T_{SC}$	100% (sagging)	100%	HSM-1, FSM-1 BSP-1P/S, BSR-1P/S
			100% (hogging)	100%	HSM-2 BSP-1P/S, OSA-1P/S
B3-1 (1) (2)		$0.9T_{SC}$	100% (hogging)	100% Max SFLC	HSM-2
				100%	BSP-1P/S
			100% (sagging)	100% Max SFLC	HSM-1 FSM-1
				100%	BSP-1P/S
B3-2 (1) (3)		$0.9T_{SC}$	100% (hogging)	100% Max SFLC	HSM-2, FSM-2
				100%	BSP-1P/S, OSA-1P/S
			100% (sagging)	100% Max SFLC	HSM-1 FSM-1
				100%	BSP-1P/S
B4		$0.6T_{SC}$	100% (hogging)	75%	HSM-2, BSP-1P/S, OSA-1P/S
B5		$0.6T_{SC}$	100% (hogging)	75%	HSM-2, BSP-1P/S, OSA-1P/S
B6-1 (2)		$0.6T_{SC}$	0%	100% Max SFLC	HSM-1
			100% (hogging)	100% Max SFLC	HSM-2
B6-2 (3)		$0.6T_{SC}$	0%	100% Max SFLC	HSM-1
			100% (hogging)	100% Max SFLC	HSM-2
				100%	HSA-2, BSR-1P/S,

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Aftmost cargo hold
Harbour and testing conditions					
B8-1 (2)		$0.33T_{SC}$	100% (hogging)	100% (4) Max SFLC	N/A
B8-2 (3)		$0.33T_{SC}$	100% (hogging)	100% (4) Max SFLC	N/A
				100% (5) Max SFLC	N/A
			100% (sagging)	100% (4) Max SFLC	N/A
				100% (5) Max SFLC	N/A
B9		$0.33T_{SC}$	100% (hogging)	75%	N/A
B10		$0.33T_{SC}$	100% (hogging)	75%	N/A
B11-1 (1) (2)		T_{SC}	100% (hogging)	100% (4) Max SFLC	N/A
			100% (sagging)	100% (4) Max SFLC	N/A
B11-2 (1) (3)		T_{SC}	100% (hogging)	100% (4) Max SFLC	N/A
				100% (5) Max SFLC	N/A
			100% (sagging)	100% (4) Max SFLC	N/A
				100% (5) Max SFLC	N/A

(1) 100% filling of fuel and water ballast tanks in engine room, with tank boundaries at the forward engine room bulkhead.

(2) The required adjustment in shear force at aft bulkhead of the considered hold is to be done at forward slop tank bulkhead.

(3) The required adjustment in shear force at aft bulkhead of the considered hold is to be done at forward machinery space bulkhead.

(4) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.

(5) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

4 BULK CARRIERS

4.1 Specific design loading condition

4.1.1 Seagoing conditions

The following seagoing loading conditions are to be included, as a minimum, in the loading manual:

a) Cargo loading conditions as defined in [4.1.2] to [4.1.4].

b) Heavy ballast condition where the ballast tanks may be full, partially full or empty. Where ballast tanks are partially full, the conditions in [2.2.1] are to be complied with. The propeller immersion ℓ/D_p is to be at least 60%. The trim is to be by the stern and is not to exceed 0.015 L. The moulded forward draught is not to be taken less than the smaller of 0.03 L or 8 m.

4.1.2 Cargo loading condition for BC-C

Homogeneous cargo loaded condition is to be included in the loading manual where the cargo density corresponds to all cargo holds, including hatchways, being 100% full at scantling draught with all ballast tanks empty.

4.1.3 Cargo loading condition for BC-B

As required for BC-C, plus:

Homogeneous cargo loaded condition is to be included in the loading manual where the cargo density is taken equal to 3.0 t/m^3, and all cargo holds are taken with the same filling ratio (cargo mass/hold cubic capacity) in all cargo holds at scantling draught with all ballast tanks empty.

In cases where the cargo density applied for this design loading condition is different from 3.0 t/m^3, the maximum density of the cargo that the ship is allowed to carry is to be indicated in the loading manual. If the maximum density is less than 3.0 t/m^3 then the additional service feature {maximum cargo density *x.y* t/m^3} is to be indicated as defined in Ch 1, Sec 1, [3.2.1].

4.1.4 Cargo loading condition for BC-A

As required for BC-B, plus:

At least one cargo loaded condition with specified holds empty, with cargo density 3.0 t/m^3, and the same filling ratio (cargo mass/hold cubic capacity) in all loaded cargo holds at scantling draught with all ballast tanks empty.

The combination of specified empty holds is to be indicated with the additional service feature {holds *a*, *b*, ... may be empty}.

In such cases where the design cargo density applied is different from 3.0 t/m^3, the maximum density of the cargo that the ship is allowed to carry is to be indicated in the loading manual. If the maximum density is less than 3.0 t/m^3 then the additional service feature {holds *a*, *b*, ... may be empty with maximum cargo density *x.y* t/m^3} is to be indicated as defined in Ch 1, Sec 1, [3.2.1].

4.1.5 Additional ballast conditions

The following ballast conditions are to be included in the loading manual for longitudinal strength assessment:

- Ballast conditions with all ballast tanks 100% full,
- Heavy ballast conditions with all ballast tanks 100% full and one cargo hold adapted and designated for the carriage of water ballast at sea, where provided, 100% full.
  Where more than one hold is adapted and designated for the carriage of water ballast at sea, it is not required that two or more holds be assumed 100% full simultaneously in the longitudinal strength assessment, unless such conditions are expected in the heavy ballast condition. Unless each hold is individually investigated, the designated heavy ballast hold and any/all restrictions for the use of other ballast hold(s) are to be indicated in the loading manual.

4.1.6 Steel coils or heavy cargoes

The following note is to be included in the loading manual:

"Where the ship engages in a service carrying such cargoes as steel coils or heavy cargoes that may have an adverse effect on the local strength of the double bottom and which is not described as cargo in the loading manual, the maximum permissible and the minimum required mass of cargo are to be considered specially."

4.2 Design load combinations for direct strength analysis

4.2.1 Applicable general loading patterns

The following loading patterns are to be applied:

a) Any cargo hold carrying M_{Full} with fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at scantling draught.

b) Any cargo hold carrying minimum 50% of M_H, with all double bottom tanks in way of the cargo hold being empty, at scantling draught.

c) Any cargo hold taken empty, with all double bottom tanks in way of the cargo hold being empty, at the deepest ballast draught.

4.2.2 Multiport conditions

The following multiport conditions are applicable to all types of bulk carriers except when the service feature {no MP} is assigned:

a) Any cargo hold carrying M_{Full} with fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of scantling draught.

b) Any cargo hold taken empty with all double bottom tanks in way of the cargo hold being empty, at 83% of scantling draught.

c) Any two adjacent cargo holds carrying M_{Full} with the next holds being empty, with fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of the scantling draught. This requirement to the mass of the cargo and fuel oil in double bottom tanks in way of the cargo hold applies also to the condition where the adjacent hold is filled with ballast.

d) Any two adjacent cargo holds being empty with the next holds being full, with all double bottom tanks in way of the cargo hold being empty, at 75% of scantling draught.

4.2.3 Alternate conditions

The following alternate conditions are applicable to BC-A only:

a) Cargo holds which are intended to be empty at scantling draught, being empty with all double bottom tanks in way of the cargo hold also being empty.

b) Cargo holds which are intended to be loaded with high density cargo, carrying M_{HD} plus 10% of M_H, in the partially filled condition with highest density according to Ch 4, Sec 6, Table 1. The fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom being empty in way of the cargo hold, at scantling draught.

c) Cargo holds which are intended to be loaded with high density cargo, carrying M_{HD} plus 10% of M_H in the full condition with lowest density according to Ch 4, Sec 6, Table 1. The fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom being empty in way of the cargo hold, at scantling draught.

d) If the ship is intended to operate in alternate block load condition, any two adjacent cargo holds are to be loaded with the next holds being empty, carrying 10% of M_H in each hold in addition to the maximum cargo load according to that design loading condition, with fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at

scantling draught. In operation the maximum allowable mass is to be limited to the maximum cargo load according to the design loading conditions.

4.2.4 Heavy ballast condition

The following condition applies to ballast holds only:

- Cargo holds which are designed as ballast water holds, being 100% full of ballast water including hatchways, with all double bottom tanks in way of the cargo hold being 100% full, at any heavy ballast draught. For ballast holds adjacent to topside wing, hopper and double bottom tanks, it shall be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty except if this loading condition is explicitly prohibited in the loading manual.

4.2.5 Additional harbour condition for all bulk carriers

The following additional harbour conditions apply to all bulk carriers:

a) At reduced draught during loading and unloading in harbour, the maximum allowable mass in a cargo hold may be increased by 15% of the maximum mass allowed at the scantling draught in seagoing condition, but is not to exceed the mass allowed at scantling draught in the seagoing condition. The minimum required mass may be reduced by the same amount.

b) Any single cargo hold holding the maximum allowable seagoing mass at 67% of scantling draught, in harbour condition.

c) Any two adjacent cargo holds carrying M_{Full} with the next holds being empty, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of scantling draught, in harbour condition.

4.2.6 Design load combinations for direct strength analysis

The loading patterns to be considered in the direct strength analysis of bulk carriers are summarised in Table 10. Load combinations providing the calculations details for each loading pattern are given in Table 12 to Table 21.

Table 10 : Applicable loading patterns according to additional service features

Loading pattern	Requirement	BC-			BC- {no MP}		
		A	B	C	A	B	C
Full load in homogeneous condition	[4.2.1] item a	×	×	×	×	×	×
Slack load	[4.2.1] item b	×	×	×	×	×	×
Deepest ballast	[4.2.1] item c	×	×	×	×	×	×
Multiport-1	[4.2.2] item a	×	×	×			
Multiport-2	[4.2.2] item b	×	×	×			
Multiport-3	[4.2.2] item c	×	×	×			
Multiport-4	[4.2.2] item d	×	×	×			
Alternate load partial	[4.2.3] items a & b	×			×		
Alternate load full	[4.2.3] items a & c	×			×		
Alternate block load	[4.2.3] item d	×			×		
Heavy ballast	[4.2.4]	×	×	×	×	×	×
Harbour condition	[4.2.5]	×	×	×	×	×	×

4.2.7

The design load combinations for FE analysis are given as follows:

Table 11 : Design load combinations for Bulk Carriers

	Midship cargo hold region	Outside midship cargo hold region	Aftmost cargo hold	Foremost cargo hold
BC-A – EA	Table 12	Table 15	N/A	N/A
BC-A – FA	Table 13	Table 16	Table 18	Table 20
BC- B & BC-C	Table 14	Table 17	Table 19	Table 21
Note 1: **Outside midship cargo hold region means the forward or aft cargo hold region except the foremost and aftmost cargo holds**				

4.3 Hold mass curves

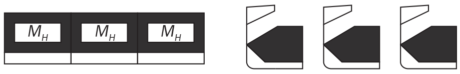
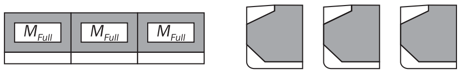
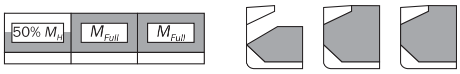
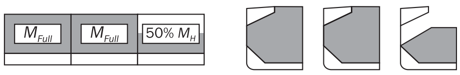
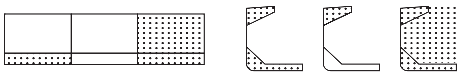
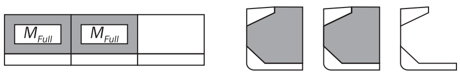
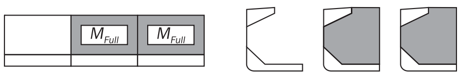
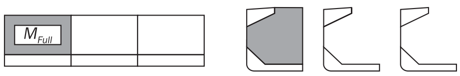
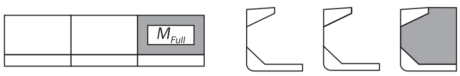
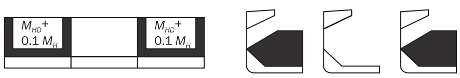
4.3.1

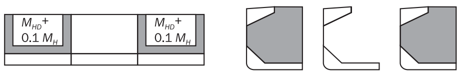
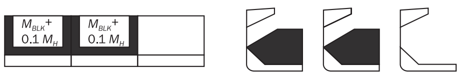
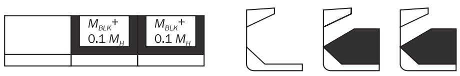
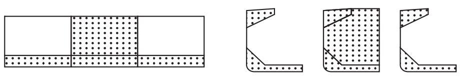
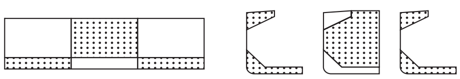
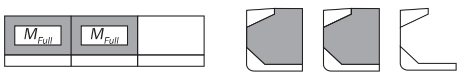
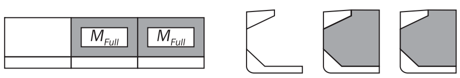
Based on the design loading criteria, as given in [4.2.1] to [4.2.5] except [4.2.4], hold mass curves for each single hold, as well as for any two adjacent holds are to be included in the loading manual and the loading instrument. The maximum allowable or minimum required cargo mass in a cargo hold, or in two adjacent loaded holds is related to the net load on the double bottom. The net load on the double bottom is a function of draught, cargo mass in the cargo hold, as well as the mass of fuel oil and ballast water contained in double bottom tanks.

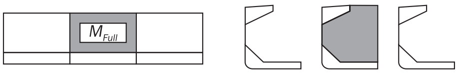
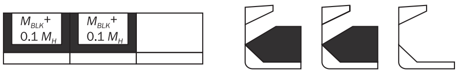
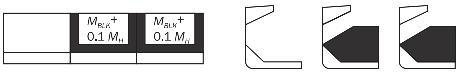
4.3.2

Hold mass curves are to be calculated according to Ch 4, App 1 showing maximum allowable and minimum required masses as a function of draught in seagoing condition as well as during loading and unloading in harbour.

Table 12 : FE Load combinations applicable to empty hold in alternate condition of BC-A (EA) - midship cargo hold region

No.	Description Req[t] ref	Loading pattern — Aft, Mid, Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case
Seagoing conditions						
1 [(2)]	Full load [4.1.3]		T_{SC}	50% (sag.)	100%	BSP-1P/S OST-1P/S
2 [(1)]	Full load [4.2.1] item a		T_{SC}	50% (sag.)	100%	BSP-1P/S
3	Slack load [4.2.1] item b		T_{SC}	0%	100%	BSP-1P/S
4	Slack load [4.2.1] item b		T_{SC}	0%	100%	BSP-1P/S
5 [(3)] [(4)]	Deepest ballast [4.2.1] item c		T_{Bal-H}	100% (hog.)	100%	FSM-2 BSR-1P/S OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S
6	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	HSM-1 OST-1P/S
7	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	HSM-1 OST-1P/S
8	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	HSM-2 OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S
9	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	HSM-2 OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S
10 [(2)]	Alternate load partial [4.2.3] items a and b		T_{SC}	100% (hog.)	100% [(9)] Max SFLC	FSM-2
					100% [(10)] Max SFLC	FSM-2
					100%	OST-2P/S
				0%	100%	BSP-1P/S OST-1P/S
					100% [(11)] Max SFLC	HSM-1

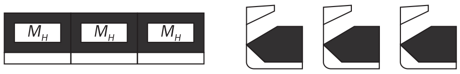
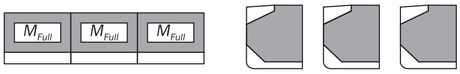
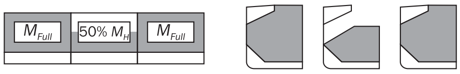
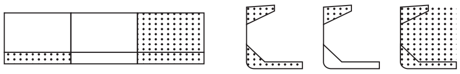
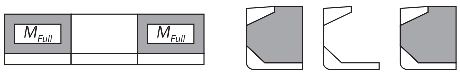
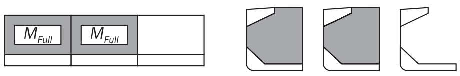
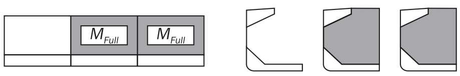
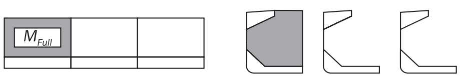
No.	Description Req^t ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case
11	Alternate load full [4.2.3] items a and c		T_{SC}	100% (hog.)	100% [9] Max SFLC	FSM-2 HSM-2
					100% [10] Max SFLC	FSM-2 HSM-2
					100%	OST-2P/S
				0%	100%	BSP-1P/S
					100% [11] Max SFLC	HSM-1
12 [2] [5] [6] [14]	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	FSM-2 OST-2P/S
				100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S
13 [2] [5] [6] [14]	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	FSM-2 OST-2P/S
				100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S
14 [7]	Heavy ballast [4.2.4]		T_{BAL-H}	0%	100% [11] Max SFLC	FSM-2 HSM-2
					100%	BSR-1P/S
				100% (sag.)	100% [9] Max SFLC	HSM-1
					100% [10] Max SFLC	HSM-1
					100%	BSR-1P/S
15 [7] [8]	Heavy ballast [4.2.4]		T_{BAL-H}	0%	100%	BSR-1P/S
				100% (sag.)	100%	BSR-1P/S
Harbour conditions						
16	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
17	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A

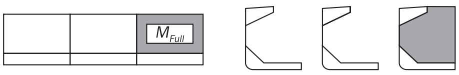
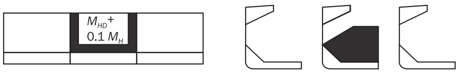
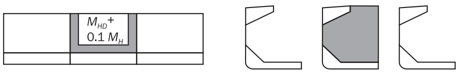
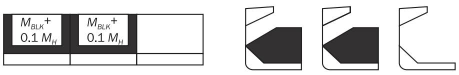
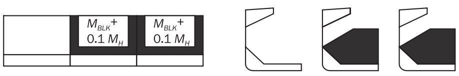
No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case
18	Harbour condition [4.2.5] items a and b		T_{H2}	100% (hog.)	100% (12) Max SFLC	N/A
					100% (13) Max SFLC	N/A
				100% (sag.)	100% (12) Max SFLC	N/A
					100% (13) Max SFLC	N/A
19 (14)	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
20 (14)	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A

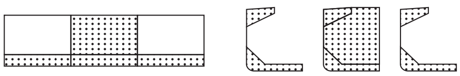
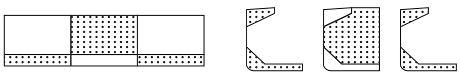
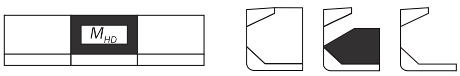
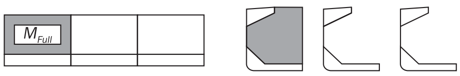
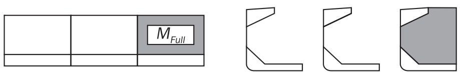
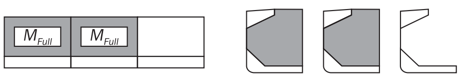
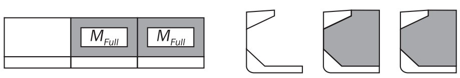
(1) Loading pattern No. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.4] can be analysed in lieu of this loading pattern.
(2) Maximum cargo density as defined in [4.1.4] is to be used for calculation of dry cargo pressure.
(3) In case of no ballast hold, normal ballast condition with assuming M_{SW} = 100% (hog.) is to be analysed.
(4) Position of ballast hold is to be adjusted as appropriate.
(5) This condition is only required when this loading condition is included in the loading manual.
(6) Actual still water vertical bending moment, as given in the loading manual, may be used instead of design value.
(7) This condition is to be considered for the empty hold which is assigned as ballast hold, if any.
(8) This condition is not required when this loading condition is explicitly prohibited in the loading manual.
(9) For the mid-hold where $x_{b\text{-}aft}$<0.5L and $x_{b\text{-}fwd}$>0.5L, the shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(10) For the mid-hold where $x_{b\text{-}aft}$<0.5L and $x_{b\text{-}fwd}$>0.5L, the shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(11) This load combination is to be considered only for the mid-hold where $x_{b\text{-}aft}$>0.5L or $x_{b\text{-}fwd}$<0.5L.
(12) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(13) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(14) This condition is only required when block loading condition is included in the loading manual.

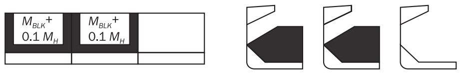
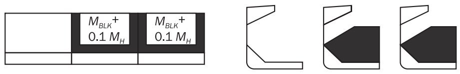
PART 1 CHAPTER 4 SECTION 8

Table 13 : FE Load combinations applicable to loaded hold in alternate condition of BC-A (FA) - midship cargo hold region

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case
Seagoing conditions						
1 [(2)]	Full load [4.1.3]		T_{SC}	50% (sag.)	100%	BSP-1P/S OST-1P/S
2 [(1)]	Full load [4.2.1] item a		T_{SC}	50% (sag.)	100%	BSP-1P/S
3	Slack load [4.2.1] item b		T_{SC}	0%	100%	BSP-1P/S
4 [(3)] [(4)]	Deepest ballast [4.2.1] item c		T_{BAL-H}	100% (hog.)	100%	FSM-2 BSR-1P/S OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S
5	Multiport 2 [4.2.2] item b		$0.83T_{SC}$	100% (hog.)	100% [(9)] Max SFLC	FSM-2 HSM-2
					100% [(10)] Max SFLC	FSM-2 HSM-2
					100%	OST-2P/S
				100% (sag.)	100% [(11)] Max SFLC	HSM-1
					100%	BSP-1P/S OST-1P/S
6	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	BSP-1P/S OST-1P/S
7	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	BSP-1P/S OST-1P/S
8	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	FSM-2, HSM-2 BSR-1P/S OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC}: % of perm. SWBM	C_{SF-LC}: % of perm. SWSF	Dynamic load case
9	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	FSM-2, HSM-2 BSR-1P/S OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S
10 (2)	Alternate load partial [4.2.3] items a and b		T_{SC}	100% (hog.)	100% (11) Max SFLC	FSM-2 HSM-2
					100%	OST-2P/S
				0%	100% (9) Max SFLC	FSM-1 HSM-1
					100% (10) Max SFLC	FSM-1 HSM-1
					100%	BSP-1P/S OST-1P/S
11	Alternate load full [4.2.3] items a and c		T_{SC}	100% (hog.)	100% (11) Max SFLC	FSM-2 HSM-2
					100%	OST-2P/S
				0%	100% (9) Max SFLC	HSM-1
					100% (10) Max SFLC	HSM-1
					100%	BSP-1P/S
12 (2) (5) (6) (14)	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	FSM-2 HSM-2 OST-2P/S
				100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S
13 (2) (5) (6) (14)	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	FSM-2 HSM-2 OST-2P/S
				100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S

No.	Description Req^t ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC}: % of perm. SWBM	C_{SF-LC}: % of perm. SWSF	Dynamic load case
14 (7)	Heavy ballast [4.2.4]		T_{BAL-H}	0%	100% (11) Max SFLC	FSM-2 HSM-2
					100%	BSR-1P/S
				100% (sag.)	100% (9) Max SFLC	HSM-1
					100% (10) Max SFLC	HSM-1
					100%	BSR-1P/S
15 (7) (8)	Heavy ballast [4.2.4]		T_{BAL-H}	0%	100%	BSR-1P/S
				100% (sag.)	100%	BSR-1P/S
Harbour conditions						
16 (2)	Harbour condition [4.2.5] items a and b		T_{H4}	100% (hog.)	100% (12) Max SFLC	N/A
					100% (13) Max SFLC	N/A
				100% (sag.)	100% (12) Max SFLC	N/A
					100% (13) Max SFLC	N/A
17	Harbour condition [4.2.5] item a		$0.67T_{SC}$	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
18	Harbour condition [4.2.5] item a		$0.67T_{SC}$	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
19	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
20	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case
21 **(14)**	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
22 **(14)**	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A

(1) Loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.4] can be analysed in lieu of this loading pattern.

(2) Maximum cargo density as defined in [4.1.4] is to be used for calculation of dry cargo pressure.

(3) In case of no ballast hold, normal ballast condition with assuming M_{SW} = 100% (hog.) is to be analysed.

(4) Position of ballast hold is to be adjusted as appropriate.

(5) This condition is only required when block loading condition is included in the loading manual.

(6) Actual still water vertical bending moment, as given in the loading manual, may be used instead of design value.

(7) This condition is to be considered for the heavy cargo hold which is assigned as ballast hold, if any.

(8) This condition is not required when this loading condition is explicitly prohibited in the loading manual.

(9) For the mid-hold where x_{b-aft}<0.5L and x_{b-fwd}>0.5L, the shear force is to be adjusted to target value at aft bulkhead of the mid-hold.

(10) For the mid-hold, where x_{b-aft}<0.5L and x_{b-fwd}>0.5L, the shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

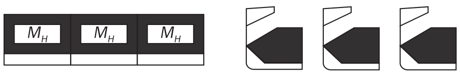
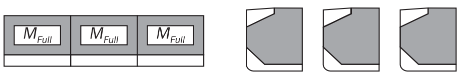
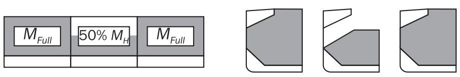
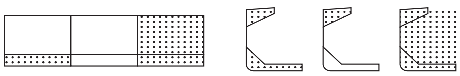
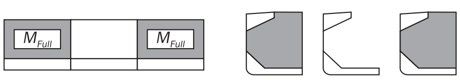
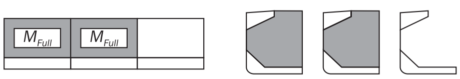
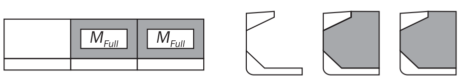
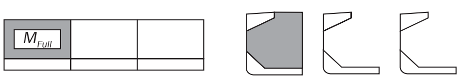
(11) This load combination is to be considered only for the mid-hold, where x_{b-aft}>0.5L or x_{b-fwd}<0.5L.

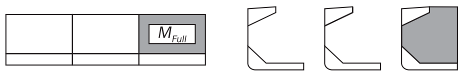
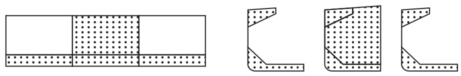
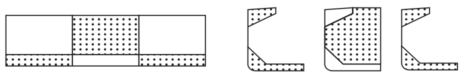
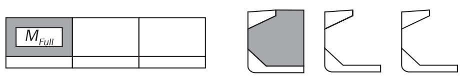
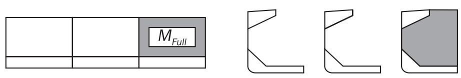
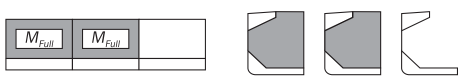
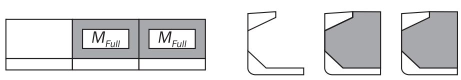
(12) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.

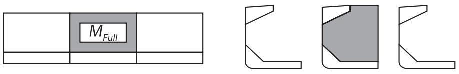
(13) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

(14) This condition is only required when block loading condition is included in the loading manual.

Table 14 : FE Load combinations applicable for BC-B & BC-C - midship cargo hold region

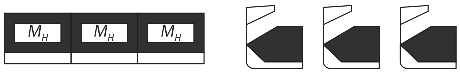
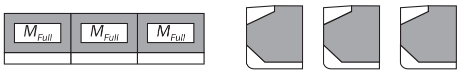
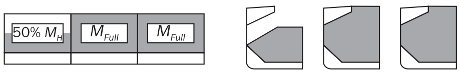
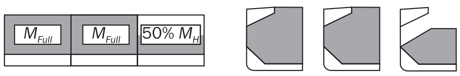
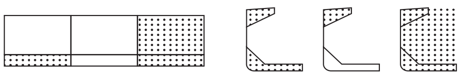
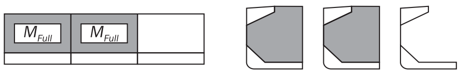
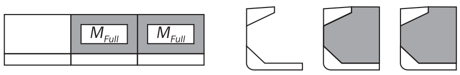
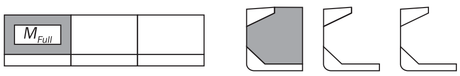
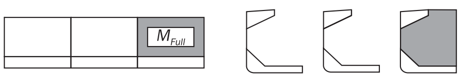
No.	Description Req^t ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case
Seagoing conditions						
1 (1) (3)	Full load [4.1.3]		T_{SC}	50% (sag.)	100%	BSP-1P/S OST-1P/S
2 (2)	Full load [4.2.1] item a		T_{SC}	50% (sag.)	100%	BSP-1P/S OST-1P/S
3	Slack load [4.2.1] item b		T_{SC}	0%	100%	BSP-1P/S
4 (4) (5)	Deepest ballast [4.2.1] item c		T_{BAL-H}	100% (hog.)	100%	FSM-2, BSR-1P/S OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S
5	Multiport 2 [4.2.2] item b		$0.83T_{SC}$	100% (hog.)	100% (8) Max SFLC	FSM-2 HSM-2
					100% (9) Max SFLC	FSM-2 HSM-2
					100%	OST-2P/S
				100% (sag.)	100% (10) Max SFLC	HSM-1
					100%	BSP-1P/S OST-1P/S
6	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	BSP-1P/S OST-1P/S
7	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	BSP-1P/S OST-1P/S
8	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	FSM-2 HSM-2 BSR-1P/S OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S

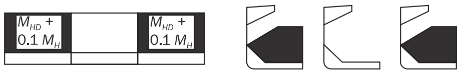
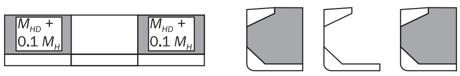
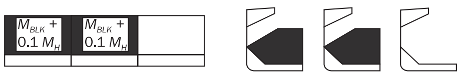
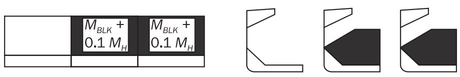
No.	Description Req^t ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC}: % of perm. SWBM	C_{SF-LC}: % of perm. SWSF	Dynamic load case
9	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	FSM-2 HSM-2 BSR-1P/S OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S
10 (6)	Heavy ballast [4.2.4]		T_{BAL-H}	0%	100% (10) Max SFLC	FSM-2 HSM-2
					100%	BSR-1P/S
				100% (sag.)	100% (8) Max SFLC	HSM-1
					100% (9) Max SFLC	HSM-1
					100%	BSR-1P/S
11 (6) (7)	Heavy ballast [4.2.4]		T_{BAL-H}	0%	100%	BSR-1P/S
				100% (sag.)	100%	BSR-1P/S
Harbour conditions						
12	Harbour condition [4.2.5] item a		$0.67T_{SC}$	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
13	Harbour condition [4.2.5] item a		$0.67T_{SC}$	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
14	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
15	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A

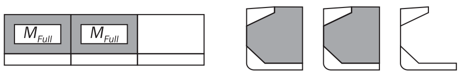
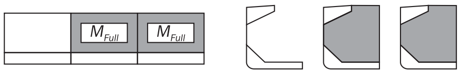
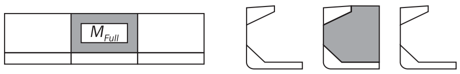
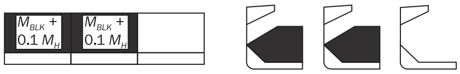
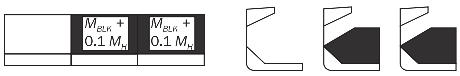
No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case
16	Harbour condition [4.2.5] items a and b		T_{H2}	100% (hog.)	100% **(11)** Max SFLC	N/A
					100% **(12)** Max SFLC	N/A
				100% (sag.)	100% **(11)** Max SFLC	N/A
					100% **(12)** Max SFLC	N/A

(1) Applicable to BC-B only.
(2) For BC-B ships, the loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.3] can be analysed in lieu of this loading pattern.
(3) Maximum cargo density as defined in [4.1.3] is to be used for calculation of dry cargo pressure.
(4) In case of no ballast hold, normal ballast condition with assuming M_{SW} = 100% (hog.) is to be analysed.
(5) Position of ballast hold is to be adjusted as appropriate.
(6) This condition is to be considered for the cargo hold which is assigned as ballast hold, if any.
(7) This condition is not required when this loading condition is explicitly prohibited in the loading manual.
(8) For the mid-hold where $x_{b\text{-}aft}$<0.5L and $x_{b\text{-}fwd}$>0.5L, the shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(9) For the mid-hold where $x_{b\text{-}aft}$<0.5L and $x_{b\text{-}fwd}$>0.5L, the shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(10) This load combination is to be considered only for the mid-hold where $x_{b\text{-}aft}$>0.5L or $x_{b\text{-}fwd}$<0.5L.
(11) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(12) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

Table 15 : FE Load combinations applicable to empty hold in alternate condition of BC-A (EA) - outside midship cargo hold region

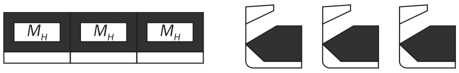
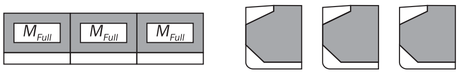
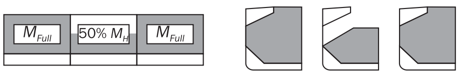
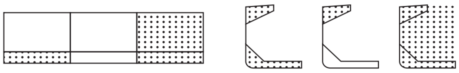
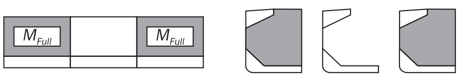
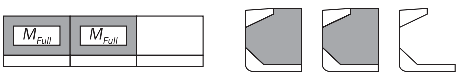
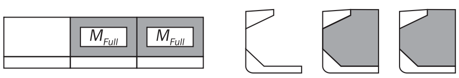
No.	Description Req[t] ref	Loading pattern (Aft, Mid, Fore)	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case: aft region	Dynamic load case: forward region
Seagoing conditions							
1 (2)	Full load [4.1.3]		T_{SC}	50% (sag.)	100%	BSP-1P/S OST-1P/S OSA-1P/S	HSM-1 BSP-1P/S OST-1P/S OSA-2P/S
2 (1)	Full load [4.2.1] item a		T_{SC}	50% (sag.)	100%	BSP-1P/S	BSP-1P/S
3	Slack load [4.2.1] item b		T_{SC}	0%	100%	BSP-1P/S	BSP-1P/S
4	Slack load [4.2.1] item b		T_{SC}	0%	100%	BSP-1P/S	BSP-1P/S
5 (3) (4)	Deepest ballast [4.2.1] item c		T_{BAL-H}	100% (hog.)	100%	HSM-2 HSA-2 BSR-1P/S OST-2P/S	FSM-2 BSP-1P/S BSR-1P/S OSA-2P/S
				100% (sag.) (10)	100%	HSM-1 BSP-1P/S	HSM-1 BSP-1P/S BSR-1P/S OSA-2P/S
6 (5)	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	HSM-1 OST-1P/S	HSM-1 OST-1P/S
7 (5)	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	HSM-1 OST-1P/S	BSP-1P/S OSA-2P/S
8 (5)	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	HSM-2 OST-2P/S	HSM-2 BSR-1P/S OST-2P/S
				100% (sag.)	100%	HSM-1 FSM-1 BSP-1P/S OST-1P/S	HSM-1 BSP-1P/S OST-1P/S
9 (5)	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	HSM-2 OST-2P/S	HSM-2 OST-2P/S
				100% (sag.)	100%	HSM-1 FSM-1 BSP-1P/S OST-1P/S	HSM-1 BSP-1P/S BSR-1P/S OST-1P/S

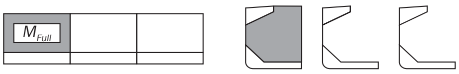
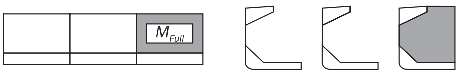
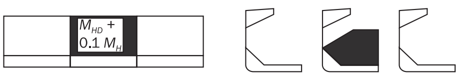
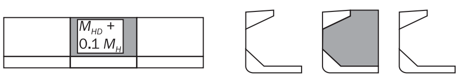
No.	Description Req^t ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case	
						aft region	forward region
10 (2)	Alternate load partial [4.2.3] items a and b		T_{SC}	100% (hog.)	100% Max SFLC	FSM-2 HSM-2	FSM-2 HSM-2
					100%	BSP-1P/S OST-2P/S OSA-1P/S	BSP-1P/S BSR-1P/S OST-2P/S OSA-2P/S
				0%	100%	BSP-1P/S OST-2P/S OSA-1P/S	BSP-1P/S OST-2P/S
					100% Max SFLC	HSM-1 FSM-1	HSM-1 FSM-1
11	Alternate load full [4.2.3] items a and c		T_{SC}	100% (hog.)	100% Max SFLC	HSM-2 FSM-2	HSM-2 FSM-2
					100%	BSP-1P/S OST-2P/S	BSP-1P/S BSR-1P/S OST-2P/S OSA-2P/S
				0%	100%	BSP-1P/S	HSA-1 BSP-1P/S
					100% Max SFLC	HSM-1 FSM-1	HSM-1 FSM-1
12 (2) (6) (7) (11)	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	FSM-2 BSP-1P/S OST-2P/S	FSM-2 BSP-1P/S OSA-2P/S
				100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S	HSM-1 BSP-1P/S OSA-2P/S
13 (2) (6) (7) (11)	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	FSM-2 BSP-1P/S OST-2P/S	FSM-2 BSP-1P/S OSA-2P/S OST-1P/S
				100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S	HSM-1 BSP-1P/S OSA-2P/S

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC}: % of perm. SWBM	C_{SF-LC}: % of perm. SWSF	Dynamic load case aft region	Dynamic load case forward region
			Harbour conditions				
14	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
15	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
16	Harbour condition [4.2.5] items a and b		T_{H2}	100% (hog.)	100% (8) Max SFLC	N/A	N/A
					100% (9) Max SFLC	N/A	N/A
				100% (sag.)	100% (8) Max SFLC	N/A	N/A
					100% (9) Max SFLC	N/A	N/A
17 (11)	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
18 (11)	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A

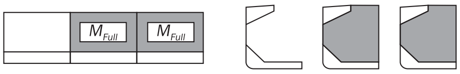
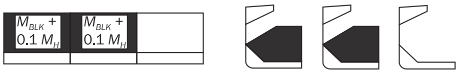
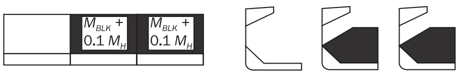
(1) Loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.4] can be analysed in lieu of this loading pattern.
(2) Maximum cargo density as defined in [4.1.4] is to be used for calculation of dry cargo pressure.
(3) In case of no ballast hold, normal ballast condition with assuming M_{SW} = 100% (hog.) is to be analysed.
(4) Position of ballast hold is to be adjusted as appropriate.
(5) This condition is not required when {no MP} notation is assigned.
(6) This condition is only required when this loading condition is included in the loading manual.
(7) Actual still water vertical bending moment, as given in the loading manual, may be used instead of design value.
(8) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(9) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(10) This loading condition is required only when the ballast hold is located inside the cargo hold model.
(11) This condition is only required when block loading condition is included in the loading manual.

Table 16 : FE Load combinations applicable to loaded hold in alternate condition of BC-A (FA) - outside midship cargo hold region

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case Aft Region	Dynamic load case Forward region
Seagoing conditions							
1 (2)	Full load [4.1.3]		T_{SC}	50% (sag.)	100%	HSM-1 BSP-1P/S OSA-1P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S
2 (1)	Full load [4.2.1] item a		T_{SC}	50% (sag.)	100%	N/A	BSP-1P/S OSA-2P/S
3	Slack load [4.2.1] item b		T_{SC}	0%	100%	HSM-2 HSA-1 BSP-1P/S OSA-1P/S	HSM-1 HSA-1 FSM-2 BSP-1P/S
4 (3) (4)	Deepest ballast [4.2.1] item c		T_{BAL-H}	100% (hog.)	100%	HSM-2 FSM-2 OST-2P/S	HSM-2
				100% (sag.)	100%	HSM-1 FSM-1 OST-1P/S OSA-2P/S	HSM-1 HSA-1 FSM-1 BSP-1P/S OSA-2P/S
5	Multiport 2 [4.2.2] item b		$0.83T_{SC}$	100% (hog.)	100% Max SFLC	HSM-2	N/A
					100%	BSP-1P/S	BSP-1P/S
				100% (sag.)	100%	BSP-1P/S	HSA-1 BSR-1P/S
					100% Max SFLC	HSM-1	N/A
6	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	BSP-1P/S BSR-1P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S
7	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S	HSM-1

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case Aft Region	Dynamic load case Forward region
8	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	HSM-2 FSM-2 BSR-1P/S BSP-1P/S OSA-1P/S OST-2P/S	FSM-2 OSA-2P/S
				100% (sag.)	100%	BSR-1P/S BSP-1P/S OST-1P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S
9	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	HSM-2 BSR-1P/S OST-2P/S	FSM-2 BSR-1P/S
				100% (sag.)	100%	HSM-1 FSM-1 BSP-1P/S BSR-1P/S OST-1P/S	HSM-1 HSA-1 BSP-1P/S OST-1P/S
10 (2)	Alternate load partial [4.2.3] items a and b		T_{SC}	100% (hog.)	100%	HSA-2 BSP-1P/S OSA-1P/S OST-2P/S	BSP-1P/S OSA-2P/S OST-2P/S
					100% Max SFLC	HSM-2 FSM-2	FSM-2
				0%	100% Max SFLC	HSM-1 FSM-1	HSM-1
					100%	BSP-1P/S OSA-1P/S	BSP-1P/S OSA-1P/S OSA-2P/S
11	Alternate load full [4.2.3] items a and c		T_{SC}	100% (hog.)	100%	HSA-2 BSP-1P/S OSA-1P/S	OSA-1P/S OSA-2P/S
					100% Max SFLC	HSM-2	FSM-2 HSM-2
				0%	100% Max SFLC	HSM-1	HSM-1
					100%	BSP-1P/S OSA-1P/S	OSA-1P/S OST-2P/S

No.	Description Req^{t} ref	Loading pattern	Aft	Mid	Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case	
									Aft Region	Forward region
12 (2) (5) (6) (9)	Alt-block load [4.2.3] item d	M_{BLK} + 0.1 M_H / M_{BLK} + 0.1 M_H / –				T_{SC}	100% (hog.)	100%	HSA-2 FSM-2 BSP-1P/S OSA-1P/S OST-2P/S	HSM-2 FSM-2 BSP-1P/S OSA-2P/S
							100% (sag.)	100%	HSM-1 BSP-1P/S OSA-1P/S OST-1P/S	HSM-1 BSP-1P/S OSA-2P/S
13 (2) (5) (6) (9)	Alt-block load [4.2.3] item d	– / M_{BLK} + 0.1 M_H / M_{BLK} + 0.1 M_H				T_{SC}	100% (hog.)	100%	FSM-2 BSP-1P/S	HSM-2 FSM-2 BSP-1P/S OSA-2P/S OST-2P/S
							100% (sag.)	100%	HSM-1 HSA-1 FSM-1 BSP-1P/S OST-1P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S
Harbour conditions										
14 (2)	Harbour condition [4.2.5] items a and b	– / M_{HD} / –				T_{H4}	100% (hog.)	100% (7) Max SFLC	N/A	N/A
								100% (8) Max SFLC	N/A	N/A
							100% (sag.)	100% (7) Max SFLC	N/A	N/A
								100% (8) Max SFLC	N/A	N/A
15	Harbour condition [4.2.5] item a	M_{Full} / – / –				$0.67T_{SC}$	100% (hog.)	100%	N/A	N/A
							100% (sag.)	100%	N/A	N/A
16	Harbour condition [4.2.5] item a	– / – / M_{Full}				$0.67T_{SC}$	100% (hog.)	100%	N/A	N/A
							100% (sag.)	100%	N/A	N/A
17	Harbour condition[4.2.5] items a and c	M_{Full} / M_{Full} / –				T_{H1}	100% (hog.)	100%	N/A	N/A
							100% (sag.)	100%	N/A	N/A

No.	Description Req[t] ref	Loading pattern (Aft, Mid, Fore)	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case: Aft Region	Dynamic load case: Forward region
18	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
19 (9)	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
20 (9)	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A

(1) Loading pattern No. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.4] can be analysed in lieu of this loading pattern.

(2) Maximum cargo density as defined in [4.1.4] is to be used for calculation of dry cargo pressure.

(3) In case of no ballast hold, normal ballast condition with assuming M_{SW} = 100% (hog.) is to be analysed.

(4) Position of ballast hold is to be adjusted as appropriate.

(5) This condition is only required when this loading condition is included in the loading manual.

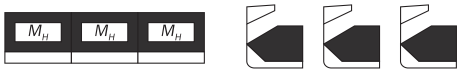
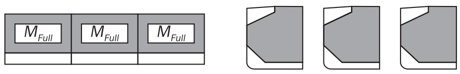
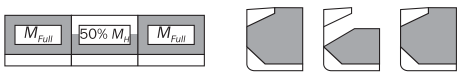
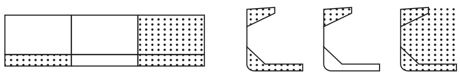
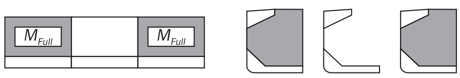
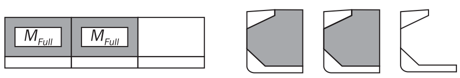
(6) Actual still water vertical bending moment, as given in the loading manual, may be used instead of design value.

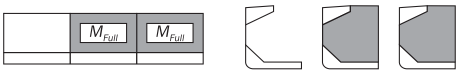
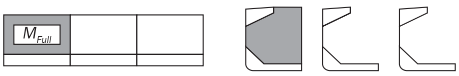
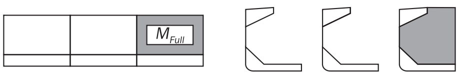
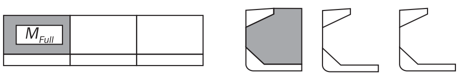
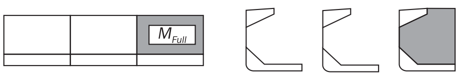
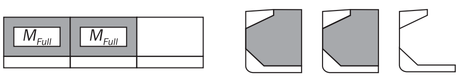
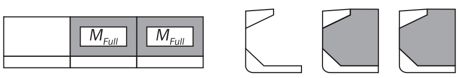
(7) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.

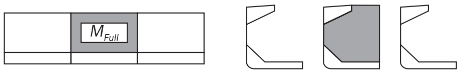
(8) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

(9) This condition is only required when block loading condition is included in the loading manual.

Table 17 : FE Load combinations applicable for BC-B & BC-C - outside midship cargo hold region

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC}: % of perm. SWBM	C_{SF-LC}: % of perm. SWSF	Dynamic load case aft region	Dynamic load case forward region
			Seagoing conditions				
1 (1) (3)	Full load [4.1.3]		T_{SC}	50% (sag.)	100%	HSM-1 FSM-1 BSP-1P/S OSA-1P/S OST-1P/S OST-2P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S
2 (2)	Full load [4.2.1] item a		T_{SC}	50% (sag.)	100%	HSM-1 FSM-1 BSP-1P/S OSA-1P/S OST-1P/S OST-2P/S	HSM-1 HSA-1 BSP-1P/S OSA-1P/S
3	Slack load [4.2.1] item b		T_{SC}	0%	100%	HSM-1 HSM-2 HSA-1 FSM-2 BSP-1P/S OSA-1P/S OST-2P/S	HSM-1 HSA-1 FSM-2 BSP-1P/S OST-2P/S
4 (4) (5)	Deepest ballast [4.2.1] item c		T_{BAL-H}	100% (hog.)	100%	HSM-2 FSM-2 OST-2P/S	HSM-2
				100% (sag.)	100%	HSM-1 FSM-1 OSA-2P/S OST-1P/S	HSM-1 HSA-1 FSM-1 BSP-1P/S OSA-2P/S
5	Multiport 2 [4.2.2] item b		$0.83T_{SC}$	100% (hog.)	100% Max SFLC	HSM-2	N/A
					100%	BSP-1P/S	BSP-1P/S
				100% (sag.)	100%	BSP-1P/S	HSA-1 BSR-1P/S
					100% Max SFLC	HSM-1	N/A
6	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	BSP-1P/S BSR-1P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S

No.	Description Req[t] ref	Loading pattern (Aft, Mid, Fore)	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case: aft region	Dynamic load case: forward region
7	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	HSM-1 FSM-1 BSP-1P/S OST-1P/S	HSM-1 BSP-1P/S
8	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	HSM-2 FSM-2 BSP-1P/S BSR-1P/S OSA-1P/S OST-2P/S	HSM-2 FSM-2 OSA-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S
9	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	HSM-2 BSR-1P/S OST-2P/S	FSM-2 BSR-1P/S
				100% (sag.)	100%	HSM-1 FSM-1 BSP-1P/S BSR-1P/S OST-1P/S	HSM-1 HSA-1 BSP-1P/S OST-1P/S
Harbour conditions							
10	Harbour condition [4.2.5] item a		$0.67T_{SC}$	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
11	Harbour condition [4.2.5] item a		$0.67T_{SC}$	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
12	Harbour condition[4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
13	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC}: % of perm. SWBM	C_{SF-LC}: % of perm. SWSF	Dynamic load case	
						aft region	forward region
14	Harbour condition [4.2.5] items a and b		T_{H2}	100% (hog.)	100% (6) Max SFLC	N/A	N/A
					100% (7) Max SFLC	N/A	N/A
				100% (sag.)	100% (6) Max SFLC	N/A	N/A
					100% (7) Max SFLC	N/A	N/A

(1) Applicable to BC-B only.

(2) For BC-B ships, the loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.3]can be analysed in lieu of this loading pattern.

(3) Maximum cargo density as defined in [4.1.3] is to be used for calculation of dry cargo pressure.

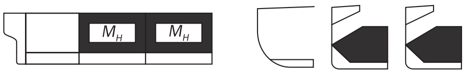
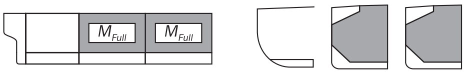
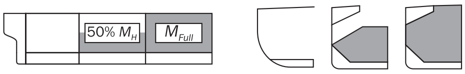
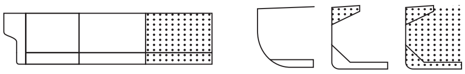
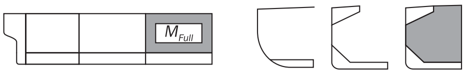
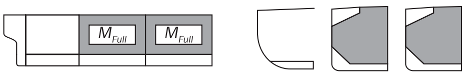
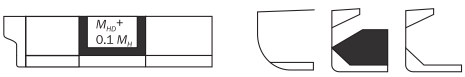
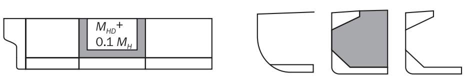
(4) In case of no ballast hold, normal ballast condition with assuming M_{SW} = 100% (hog.) is to be analysed.

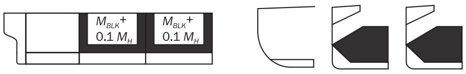
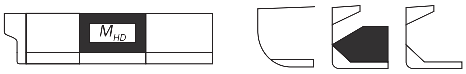
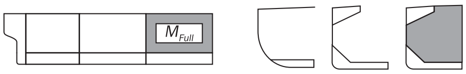
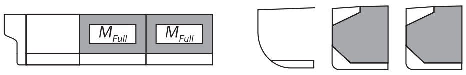
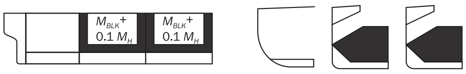
(5) Position of ballast hold is to be adjusted as appropriate.

(6) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.

(7) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

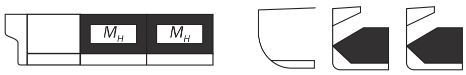
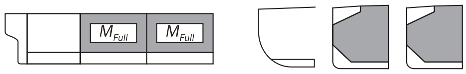
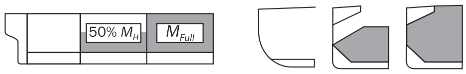
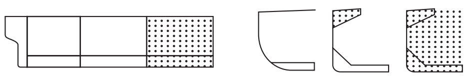
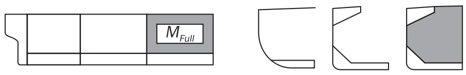
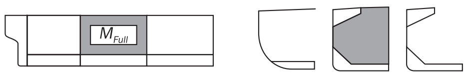
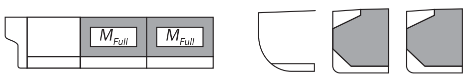
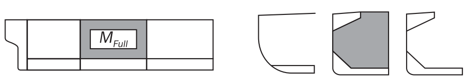
Table 18 : FE Load combinations applicable to loaded hold in alternate condition of BC-A (FA) - aftmost cargo hold

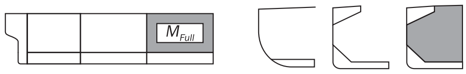
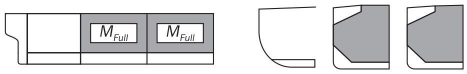
No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case
Seagoing conditions						
1 (2)	Full load [4.1.3]		T_{SC}	80% (sag.)	100%	FSM-1 BSP-1P/S OST-1P/S
2 (1)	Full load [4.2.1] item a		T_{SC}	80% (sag.)	100%	FSM-1
3	Slack load [4.2.1] item b		T_{SC}	100% (sag.)	100%	FSM-1 BSP-1P/S OST-1P/S
4 (3) (4)	Deepest ballast [4.2.1] item c		$T_{BAL\text{-}H}$	100% (hog.)	100%	HSM-2, FSM-1 BSP-1P/S BSR-1P/S OST-1P/S OST-2P/S OSA-1P/S
5	Multiport 2 [4.2.2] item b		$0.83T_{SC}$	30% (hog.)	100%	FSM-1, OSA-1P/S
				30% (sag.)	100%	FSM-1 BSP-1P/S
6	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	50% (sag.)	100%	BSP-1P/S OST-1P/S
7 (2)	Alternate load partial [4.2.3] items a and b		T_{SC}	50% (hog.)	100% Max SFLC	HSM-2,
					100%	BSP-1P/S OSA-1P/S
				0%	100% Max SFLC	FSM-1
					100%	BSP-1P/S OST-1P/S OSA-1P/S
8	Alternate load full [4.2.3] items a and c		T_{SC}	50% (hog.)	100% Max SFLC	HSM-2, FSM-2
					100%	BSP-1P/S, OSA-1P/S
				0%	100% Max SFLC	HSM-1
					100%	BSP-1P/S OST-1P/S OSA-1P/S

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case
9 (2) (5) (6)	Alt-block load [4.2.3] item d		T_{SC}	50% (sag.)	100%	BSP-1P/S OST-1P/S
Harbour conditions						
10 (2)	Harbour condition [4.2.5] items a and b		T_{H4}	100% (hog.)	100%	N/A
				50% (hog.)	100% (7) Max SFLC	N/A
					100% (8) Max SFLC	N/A
11	Harbour condition [4.2.5] item a		$0.67T_{SC}$	50% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
12	Harbour condition [4.2.5] items a and c		T_{H1}	50% (hog.)	100%	N/A
				50% (sag.)	100%	N/A
13 (9)	Alt-block harbour condition [4.2.3] item d		T_{H3}	50% (hog.)	100%	N/A
				50% (sag.)	100%	N/A

(1) Loading pattern no. 1 with the cargo mass M_H and the maximum cargo density as defined in [4.1.4] can be analysed in lieu of this loading pattern.
(2) Maximum cargo density as defined in [4.1.4] is to be used for calculation of dry cargo pressure.
(3) In case of no ballast hold, normal ballast condition with assuming M_{SW} = 100% (hog.) is to be analysed.
(4) Position of ballast hold is to be adjusted as appropriate.
(5) This condition is only required when this loading condition is included in the loading manual.
(6) Actual still water vertical bending moment, as given in the loading manual, may be used instead of design value.
(7) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(8) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(9) This condition is only required when block loading condition is included in the loading manual.

Table 19 : FE Load combinations applicable for BC-B & BC-C - aftmost cargo hold

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case
Seagoing conditions						
1 (1) (3)	Full load [4.1.3]		T_{SC}	80% (sag.)	100%	FSM-1 BSP-1P/S OST-1P/S OSA-1P/S
2 (2)	Full load [4.2.1] item a		T_{SC}	80% (sag.)	100%	FSM-1 BSP-1P/S OST-1P/S
3	Slack load [4.2.1] item b		T_{SC}	100% (sag.)	100%	FSM-1 BSP-1P/S OST-1P/S
4 (4) (5)	Deepest ballast [4.2.1] item c		T_{BAL-H}	100% (hog.)	100%	HSM-2, FSM-1 BSP-1P/S BSR-1P/S OST-1P/S OST-2P/S OSA-1P/S
5	Multiport 2 [4.2.2] item b		$0.83T_{SC}$	30% (hog.)	100%	FSM-1 BSR-1P/S OSA-1P/S
				30% (sag.)	100%	FSM-1, OST-1P/S
6	Multiport 3 [4.2.2] item a		$0.67T_{SC}$	60% (hog.)	100%	BSP-1P/S
					100% Max SFLC	HSM-2
				0%	100% Max SFLC	HSM-1
7	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	50% (sag.)	100%	BSP-1P/S OST-1P/S
Harbour conditions						
8	Harbour condition [4.2.5] items a and b		T_{H2}	100% (hog.)	100%	N/A
				50% (hog.)	100% (6) Max SFLC	N/A
					100% (7) Max SFLC	N/A

No.	Description Req^t ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case
9	Harbour condition [4.2.5] item a		$0.67T_{SC}$	50% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
10	Harbour condition [4.2.5] items a and c		T_{H1}	50% (hog.)	100%	N/A
				50% (sag.)	100%	N/A

(1) Applicable to BC-B only.

(2) For BC-B ships, the loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.3] can be analysed in lieu of this loading pattern.

(3) Maximum cargo density as defined in [4.1.3] is to be used for calculation of dry cargo pressure.

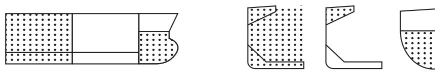
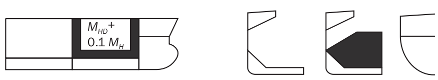
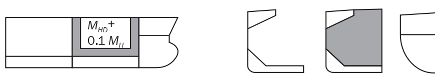
(4) In case of no ballast hold, normal ballast condition with assuming M_{SW} = 100% (hog.) is to be analysed.

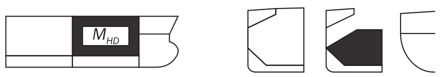
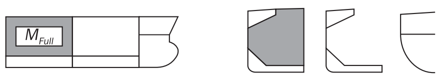
(5) Position of ballast hold is to be adjusted as appropriate.

(6) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.

(7) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold

Table 20 : FE Load combinations applicable to loaded hold in alternate condition of BC-A (FA) - foremost cargo hold

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case
Seagoing conditions						
1 (2)	Full load [4.1.3]		T_{SC}	60% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S OSA-2P/S
2 (1)	Full load [4.2.1] item a		T_{SC}	60% (sag.)	100%	HSM-1 BSP-1P/S OSA-2P/S
3	Slack load [4.2.1] item b		T_{SC}	100% (sag.)	100%	HSM-1 BSP-1P/S OSA-2P/S
4 (3) (4)	Deepest ballast [4.2.1] item c		T_{BAL-H}	100% (hog.)	100%	HSM-1, HSM-2 BSP-1P/S BSR-1P/S OSA-2P/S
5	Multiport 2 [4.2.2] item b		$0.83T_{SC}$	60% (sag.)	100%	HSM-1, FSM-1 BSP-1P/S OSA-2P/S
6	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	50% (sag.)	100%	HSM-1 BSP-1P/S OSA-2P/S
7	Multiport 3 [4.2.2] item a		$0.67T_{SC}$	60% (hog.)	100%	FSM-2
8 (2)	Alternate load partial [4.2.3] items a and b		T_{SC}	60% (hog.)	100%	BSP-1P/S OST-2P/S OSA-2P/S
					100% Max SFLC	HSM-2
				0%	100% Max SFLC	HSM-1
					100%	BSP-1P/S OSA-2P/S
9	Alternate load full [4.2.3] items a and c		T_{SC}	60% (hog.)	100%	BSP-1P/S OST-2P/S OSA-2P/S
					100% Max SFLC	HSM-2
				0%	100% Max SFLC	HSM-1
					100%	BSP-1P/S OSA-2P/S

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case
10 (2) (5) (6) (9)	Alt-block load [4.2.3] item d		T_{SC}	50% (sag.)	100%	HSM-1 BSP-1P/S OSA-2P/S
Harbour conditions						
11 (2)	Harbour condition [4.2.5] items a and b		T_{H4}	100% (hog.)	100%	N/A
				50% (hog.)	100% (7) Max SFLC	N/A
					100% (8) Max SFLC	N/A
12	Harbour condition [4.2.5] item a		$0.67T_{SC}$	100% (sag.)	100%	N/A
13	Harbour condition [4.2.5] items a and c		T_{H1}	50% (hog.)	100%	N/A
14 (9)	Alt-block harbour condition [4.2.3] item d		T_{H3}	50% (hog.)	100%	N/A

(1) Loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.4] can be analysed in lieu of this loading pattern.

(2) Maximum cargo density as defined in [4.1.4] is to be used for calculation of dry cargo pressure.

(3) In case of no ballast hold, normal ballast condition with assuming M_{SW} = 100% (hog.) is to be analysed.

(4) Position of ballast hold is to be adjusted as appropriate.

(5) This condition is only required when this loading condition is included in the loading manual.

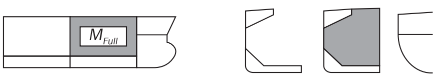
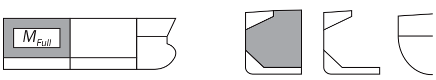
(6) Actual still water vertical bending moment, as given in the loading manual, may be used instead of design value.

(7) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.

(8) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

(9) This condition is only required when block loading condition is included in the loading manual.

Table 21 : FE Load combinations applicable for BC-B & BC-C - foremost cargo hold

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case
Seagoing conditions						
1 (1) (3)	Full load [4.1.3]		T_{SC}	60% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S OSA-2P/S
2 (2)	Full load [4.2.1] item a		T_{SC}	60% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S OSA-2P/S
3	Slack load [4.2.1] item b		T_{SC}	100% (sag.)	100%	HSM-1 BSP-1P/S OSA-2P/S
4 (4) (5)	Deepest ballast [4.2.1] item c		T_{BAL-H}	100% (hog.)	100%	HSM-1, HSM-2 BSP-1P/S BSR-1P/S OSA-2P/S
5	Multiport 2 [4.2.2] item b		$0.83T_{SC}$	60% (sag.)	100%	HSM-1, FSM-1 BSP-1P/S OSA-2P/S
6	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	50% (sag.)	100%	HSM-1 BSP-1P/S OSA-2P/S
7	Multiport 3 [4.2.2] item a		$0.67T_{SC}$	60% (hog.)	100%	BSP-1P/S OST-2P/S OSA-2P/S
					100% Max SFLC	HSM-2
				0%	100% Max SFLC	HSM-1
Harbour conditions						
8	Harbour condition [4.2.5] items a and b		T_{H2}	100% (hog.)	100%	N/A
				50% (hog.)	100% (6) Max SFLC	N/A
					100% (7) Max SFLC	N/A
9	Harbour condition [4.2.5] item a		$0.67T_{SC}$	100% (sag.)	100%	N/A

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case
10	Harbour condition [4.2.5] items a and c		T_{H1}	50% (hog.)	100%	N/A

(1) Applicable to BC-B only.
(2) For BC-B ships, the loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.3] can be analysed in lieu of this loading pattern.
(3) Maximum cargo density as defined in [4.1.3] is to be used for calculation of dry cargo pressure.
(4) In case of no ballast hold, normal ballast condition with assuming M_{Sw} = 100% (hog.) is to be analysed.
(5) Position of ballast hold is to be adjusted as appropriate.
(6) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(7) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

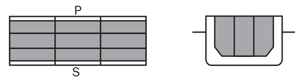
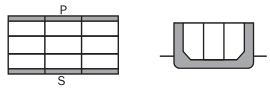
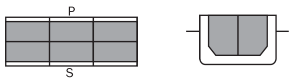
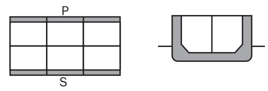
5 STANDARD LOADING CONDITIONS FOR FATIGUE ASSESSMENT

5.1 Oil tanker

5.1.1

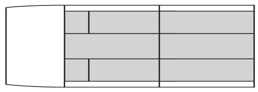
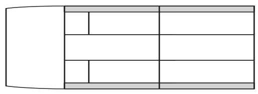
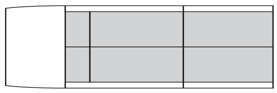
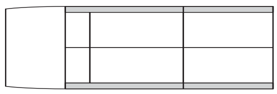
The standard loading conditions to be applied to oil tankers for fatigue assessment as required in Ch 9, Sec 1, [6.2], are defined in Table 22 to Table 24.

Table 22 : Standard design FE loading conditions for fatigue assessment of oil tankers except for foremost and aftmost cargo holds

No.	Description	Loading pattern	Still water loads			Dynamic load cases
			Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF (1)	
Oil tankers with two oil-tight bulkheads						
A1-F	Full load		T_{SC}	60% (sag.)		All
A2-F	Normal ballast		T_{BAL}	80% (hog.)		All
Oil tankers with centreline oil-tight bulkhead						
B1-F	Full load		T_{SC}	60% (sag.)		All
B2-F	Normal ballast		T_{BAL}	80% (hog.)		All

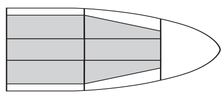
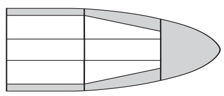
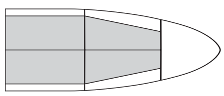
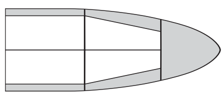
(1) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.

Table 23 : Standard design FE loading conditions for fatigue assessment of oil tankers for aftmost cargo hold

No.	Description	Loading pattern	Still water loads: Draught	Still water loads: C_{BM-LC} : % of perm. SWBM	Still water loads: C_{SF-LC} : % of perm. SWSF (1)	Dynamic load cases
Oil tankers with two oil-tight bulkheads						
A1-F	Full load		T_{SC}	60% (sag.)		All
A2-F	Normal ballast		T_{BAL}	80% (hog.)		All
Oil tankers with centreline oil-tight bulkhead						
B1-F	Full load		T_{SC}	60% (sag.)		All
B2-F	Normal ballast		T_{BAL}	80% (hog.)		All

(1) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.

Table 24 : Standard design FE loading conditions for fatigue assessment of oil tankers for foremost cargo hold

No.	Description	Loading pattern	Still water loads: Draught	Still water loads: C_{BM-LC} : % of perm. SWBM	Still water loads: C_{SF-LC} : % of perm. SWSF (1)	Dynamic load cases
Oil tankers with two oil-tight bulkheads						
A1-F	Full load		T_{SC}	60% (sag.)		All
A2-F	Normal ballast		T_{BAL}	80% (hog.)		All
Oil tankers with centreline oil-tight bulkhead						
B1-F	Full load		T_{SC}	60% (sag.)		All
B2-F	Normal ballast		T_{BAL}	80% (hog.)		All

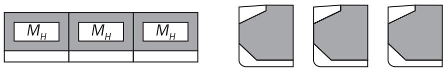
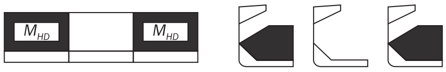
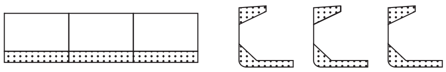
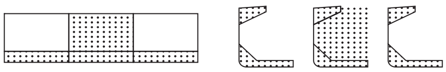
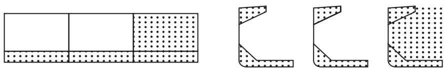
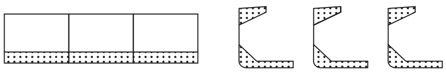
(1) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.

5.2 Bulk carriers

5.2.1

The standard loading conditions to be applied to bulk carriers for fatigue assessment as required in Ch 9, Sec 1, [6.3] are defined in Table 25, to Table 31 according to their additional service feature notations and the location of the assessed details.

Table 25 : Standard design FE Load combinations for fatigue assessment applicable to empty hold of BC-A in alternate condition (EA) - cargo hold region except aftmost and foremost cargo holds

No.	Description	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case
1-F (1)	Full load homogeneous		T_{SC}	40% (sag.)		All
2-F (2)	Full load alternate		T_{SC}	75% (hog.)	100%	All
3-F (1)	Normal ballast		T_{BAL}	80% (hog.)		All
4-F (2) (3)	Heavy ballast		T_{BAL-H}	75% (sag.)	100%	All
5-F (2) (4)			T_{BAL-H}	45% (hog.)	100%	All
6-F (1) (5)			T_{BAL-H}	45% (hog.)		All

(1) The actual shear force curve that results from the application of static and dynamic local loads to the FE model are to be used.

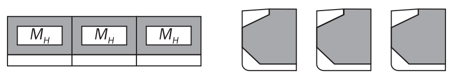
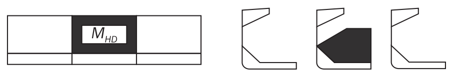
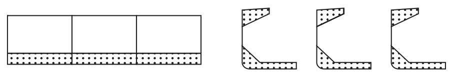
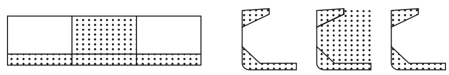
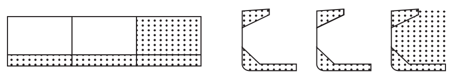
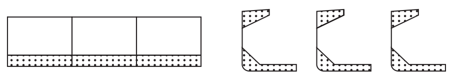
(2) The actual shear force curve that results from the application of static and dynamic local loads to the FE model are to be used. Where this shear force exceeds the target value, the correction of vertical loads is to be applied to adjust the shear force down to the target value.

(3) This condition is to be considered for empty cargo hold which is assigned as ballast hold, if any

(4) This condition is applicable when the WB hold corresponds to the forward or aft hold of the 3 hold model.

(5) This condition is applicable when the WB hold is located outside the 3 cargo hold model

Table 26 : Standard design FE Load combinations for fatigue assessment applicable to loaded hold of BC-A in alternate condition (FA) - cargo hold region except aftmost and foremost cargo holds

No.	Description	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case
1-F (1)	Full load homogeneous		T_{SC}	40% (sag.)		All
2-F (2)	Full load alternate		T_{SC}	75% (hog.)	100%	All
3-F (1)	Normal ballast		T_{BAL}	80% (hog.)		All
4-F (2) (3)	Heavy ballast		T_{BAL-H}	75% (sag.)	100%	All
5-F (2) (4)			T_{BAL-H}	45% (hog.)	100%	All
6-F (1) (5)			T_{BAL-H}	45% (hog.)		All

(1) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.

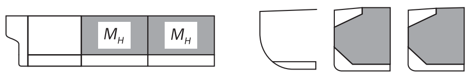
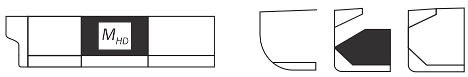
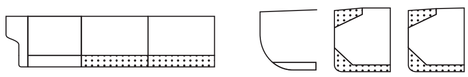
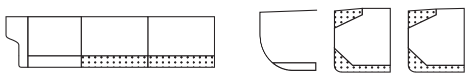
(2) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used. Where this shear force exceeds the target value, the correction of vertical loads is to be applied to adjust the shear force down to the target value.

(3) This condition is to be considered for loaded cargo hold which is assigned as ballast hold, if any

(4) This condition is applicable when the WB hold corresponds to the forward or aft hold of the 3 hold model.

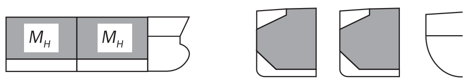
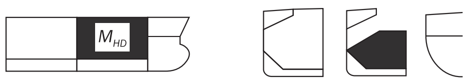
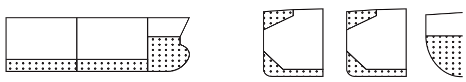
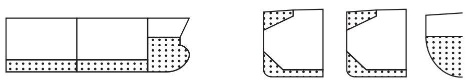
(5) This condition is applicable when the WB hold is located outside the 3 cargo hold model.

Table 27 : Standard design FE Load combinations for fatigue assessment applicable to loaded hold of BC-A in alternate condition (FA) - Aftmost cargo hold

No.	Description	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case
1-F (1)	Full load homogeneous		T_{SC}	40% (sag.)		All
2-F (2)	Full load alternate		T_{SC}	75% (hog.)	100%	All
3-F (1)	Normal ballast		T_{BAL}	80% (hog.)		All
4-F (1) (3)	Heavy ballast		T_{BAL-H}	45% (hog.)		All

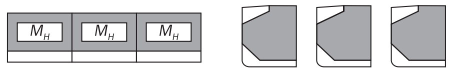
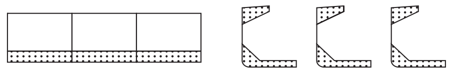
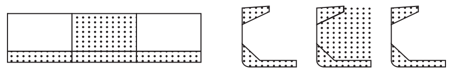
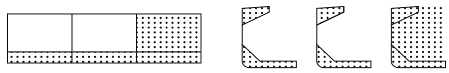
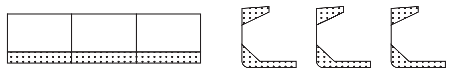
(1) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.
(2) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used. Where this shear force exceeds the target value, the correction of vertical loads is to be applied to adjust the shear force down to the target value.
(3) This condition is applicable when the WB hold is located outside the 3 cargo hold model.

Table 28 : Standard design FE Load combinations for fatigue assessment applicable to loaded hold of BC-A in alternate condition (FA) - Foremost cargo hold

No.	Description	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case
1-F (1)	Full load homogeneous		T_{SC}	40% (sag.)		All
2-F (2)	Full load alternate		T_{SC}	75% (hog.)	100%	All
3-F (1)	Normal ballast		T_{BAL}	80% (hog.)		All
4-F (1) (3)	Heavy ballast		T_{BAL-H}	45% (hog.)		All

(1) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.
(2) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used. Where this shear force exceeds the target value, the correction of vertical loads is to be applied to adjust the shear force down to the target value.
(3) This condition is applicable when the WB hold is located outside the 3 cargo hold model.

Table 29 : Standard design FE load combinations for fatigue assessment of BC-B, BC-C bulk carriers - cargo hold region except aftmost and foremost cargo holds

No.	Description	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case
1-F (1)	Full load homogeneous		T_{SC}	40% (sag.)		All
2-F (1)	Normal ballast		T_{BAL}	80% (hog.)		All
3-F (2) (3)	Heavy ballast		T_{BAL-H}	75% (sag.)	100%	All
4-F (2) (4)			T_{BAL-H}	45% (hog.)	100%	All
5-F (1) (5)			T_{BAL-H}	45% (hog.)		All

(1) The actual shear force curve that results from the application of static and dynamic local loads to the FE model are to be used.

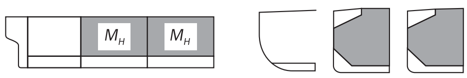
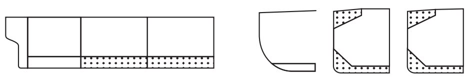
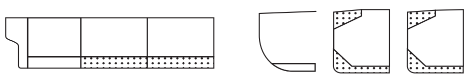
(2) The actual shear force curve that results from the application of static and dynamic local loads to the FE model are to be used. Where this shear force exceeds the target value, the correction of vertical loads is to be applied to adjust the shear force down to the target value.

(3) This condition is to be considered for cargo hold which is assigned as ballast hold, if any.

(4) This condition is applicable when the WB hold corresponds to the forward or aft hold of the 3 hold model.

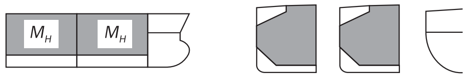
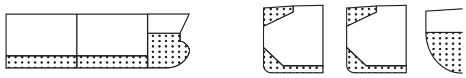
(5) This condition is applicable when the WB hold is located outside the 3 cargo hold model.

Table 30 : Standard design FE load combinations for fatigue assessment of BC-B, BC-C bulk carriers - Aftmost cargo hold

No.	Description	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case
1-F (1)	Full load homogeneous		T_{SC}	40% (sag.)		All
2-F (1)	Normal ballast		T_{BAL}	80% (hog.)		All
3-F (1)	Heavy ballast		T_{BAL-H}	45% (hog.)		All

(1) The actual shear force curve that results from the application of static and dynamic local loads to the FE model are to be used.

Table 31 : Standard design FE load combinations for fatigue assessment of BC-B, BC-C bulk carriers - Foremost cargo hold

No.	Description	Loading pattern Aft Mid Fore	Draught	C_{BM-LC} : % of perm. SWBM	C_{SF-LC} : % of perm. SWSF	Dynamic load case
1-F (1)	Full load homogeneous		T_{SC}	40% (sag.)		All
2-F (1)	Normal ballast		T_{BAL}	80% (hog.)		All
3-F (1)	Heavy ballast		T_{BAL-H}	45% (hog.)		All
(1)	The actual shear force curve that results from the application of static and dynamic local loads to the FE model are to be used.					

APPENDIX 1
HOLD MASS CURVES

SYMBOLS

Symbols

h : Vertical distance from the top of inner bottom plating to the lowest point of the upper deck plating at the ship's centreline, in m.

h_a : Vertical distance from the top of inner bottom plating to the lowest point of the upper deck plating at the ship's centreline of the aft cargo hold of two adjacent cargo holds, in m.

h_f : Vertical distance from the top of inner bottom plating to the lowest point of the upper deck plating at the ship's centreline of the fore cargo hold of two adjacent cargo holds, in m.

M_H : Cargo mass, in t, as defined in Ch 4, Sec 6.

M_{Full} : Cargo mass, in t, as defined in Ch 4, Sec 6.

M_{HD} : Cargo mass, in t, as defined in Ch 4, Sec 6.

M_{BLK} : The maximum cargo mass in a cargo hold of two adjacent cargo holds according to the block loading condition in the loading manual, in t.

T_i : In loading condition No. *i*, draught, in m, at mid-hold position of single cargo hold length or at mid-length of the two adjacent cargo holds considered.

T_{min} : 0.75 T_{SC} or draught in ballast conditions with the two adjacent cargo holds empty, whichever is greater, in m.

T_{H1} : Minimum permissible draught, in m, in harbour condition with M_{Full} in each of the two adjacent holds to be taken as:

- For ships having {No MP} notation assigned:

$$T_{H1} = min\begin{cases} 0.67T_{SC} \\ T_{SC} - \dfrac{0.15\sum M_{Full}}{1.025\left(\dfrac{V_f}{h_f} + \dfrac{V_a}{h_a}\right)} \end{cases}$$

- For ships not having {No MP} notation assigned:

$$T_{H1} = 0.67T_{SC} - \frac{0.15\sum M_{Full}}{1.025\left(\dfrac{V_f}{h_f} + \dfrac{V_a}{h_a}\right)}$$

T_{H2} : Minimum permissible draught, in m, in harbour condition with M_{Full} in EA holds of BC-A ships or with M_{Full} in any holds of BC-B and BC-C ships to be taken as:

- For ships having {No MP} notation assigned:

$$T_{H2} = min\begin{cases} 0.67T_{SC} \\ T_{SC} - \dfrac{0.15M_{Full}}{1.025\dfrac{V_H}{h}} \end{cases}$$

- For ships not having {No MP} notation assigned:

$$T_{H2} = 0.67T_{SC} - \frac{0.15M_{Full}}{1.025\frac{V_H}{h}}$$

T_{H3} : Minimum permissible draught, in m, in harbour condition in case of block loading with M_{BLK} in each of the two adjacent holds of BC-A ships to be taken as:

$$T_{H3} = T_{SC} - \frac{\sum(0.15M_{BLK} + 0.1M_H)}{1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)}$$

T_{H4} : Minimum permissible draught, in m, in harbour condition with M_{HD} in FA holds of BC-A ships to be taken as:

$$T_{H4} = min\begin{cases} 0.67T_{SC} \\ T_{SC} - \frac{0.15M_{HD} + 0.1M_H}{1.025\frac{V_H}{h}} \end{cases}$$

V_H : Volume in m^3, as defined in Ch 4, Sec 6.

V_a : Volume of the after cargo hold of two adjacent cargo holds excluding volume of the hatchway part, in m^3.

V_f : Volume of the forward cargo hold of two adjacent cargo holds excluding volume of the hatchway part, in m^3

Σ : The sum of masses of two adjacent cargo holds.

EA : Empty hold in alternate loading condition.

FA : Full hold in alternate loading condition.

1 GENERAL

1.1 Application

1.1.1

The requirements of this appendix apply to bulk carriers of 150 m in length *L* and above.

1.1.2

This appendix describes the procedure to be used for determination of:

- The maximum and minimum mass of cargo in each cargo hold as a function of the draught at mid-hold position of cargo hold.
- The maximum and minimum mass of cargo in any two adjacent holds as a function of the draught at mid-length of these two adjacent cargo holds.

1.1.3 General

The cargo mass curves of single cargo hold or of two adjacent cargo holds in seagoing and harbour conditions as defined in [2] and [3] are based on the loading conditions considered in Ch 4, Sec 8, [4.2]. However if the ship structure is checked for more severe loading conditions than the ones considered in Ch 4, Sec 8, [4.2.7], the minimum required cargo mass and the maximum allowable cargo mass can be based on those corresponding loading conditions.

1.1.4 Loading/unloading conditions in harbour

For any bulk carrier, the maximum permissible cargo mass and the minimum required cargo mass of single cargo hold or of two adjacent cargo holds, corresponding to draught for loading/unloading conditions in harbour may be increased or decreased by 15% of the maximum permissible mass at the maximum draught for the cargo hold in seagoing condition. However, maximum permissible mass is in no case to be greater than the maximum permissible cargo mass at designed maximum load draught for each cargo hold.

1.1.5 Maximum and minimum permissible mass expression

The maximum and minimum permissible mass in seagoing conditions, ($W_{maxS}(T_i)$, $W_{minS}(T_i)$) and in harbour condition (($W_{maxH}(T_i)$, $W_{minH}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae given in tables of [2] and [3] for the followings.:

- BC-A ship not having {No MP} notation assigned,
- BC-A ship having {No MP} notation assigned,
- BC-B and BC-C ships not having {No MP} notation assigned,
- BC-B and BC-C ships having {No MP} notation assigned,

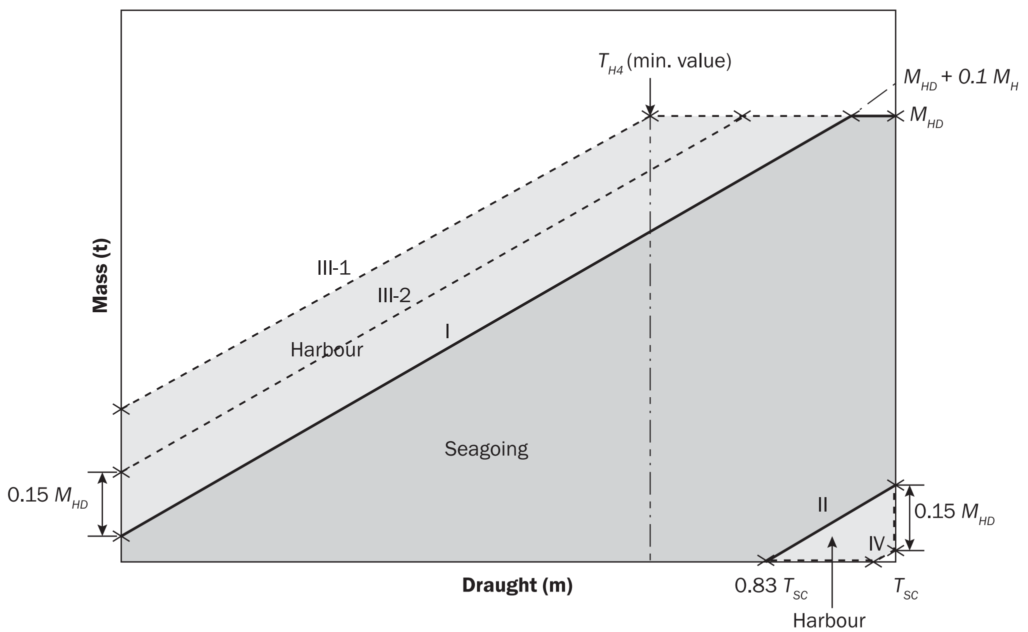
Examples for mass curve of loaded cargo holds and cargo hold which can be empty at the maximum draught for BC-A ships not having {No MP} assigned are shown in figures of the above mentioned tables.

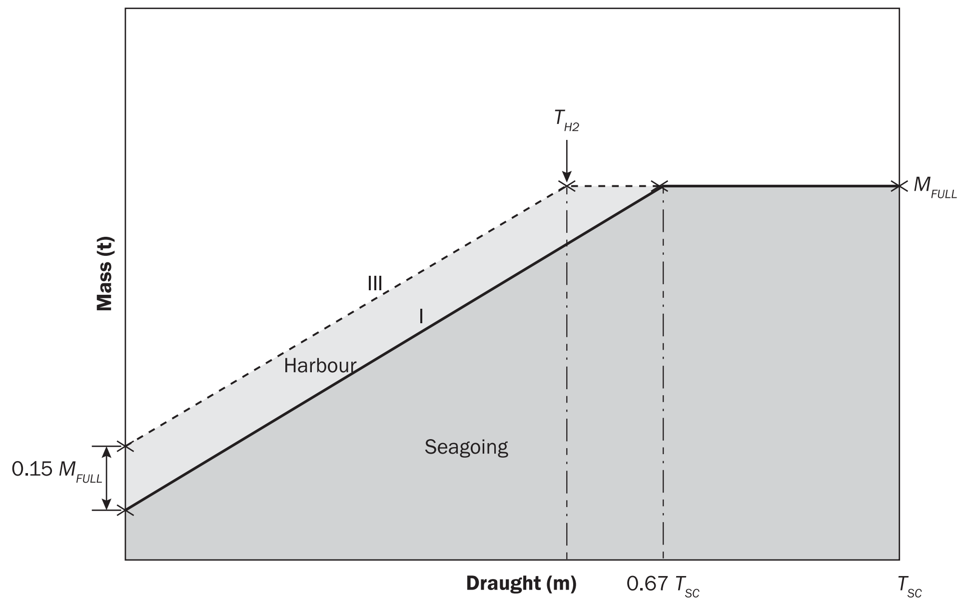
2 MAXIMUM AND MINIMUM MASSES OF CARGO IN EACH HOLD

2.1 Maximum permissible mass and minimum required mass of single cargo hold

2.1.1 BC-A ship not having {No MP} notation assigned

Table 1 : BC-A ship not having {No MP} notation assigned

Hold	Loading conditions	Max / Min curves	Curve Ref	Ref
FA	Seagoing	Maximum: $W_{maxS}\ (T_i) = M_{HD} + 0.1\ M_H - 1.025\ V_H \dfrac{(T_{SC} - T_i)}{h} \le M_{HD}$	I	Ch 4, Sec 8, [4.2.3] b & c
		Minimum: $W_{minS}\ (T_i) = 1.025\ V_H \dfrac{(T_i - 0.83 T_{SC})}{h} \ge 0$	II	Ch 4, Sec 8, [4.2.2] b
	Harbour	Maximum: $W_{maxH}(T_i) = max \begin{cases} M_{HD} - 1.025\ V_H \dfrac{(0.67 T_{SC} - T_i)}{h} \le M_{HD} \\ W_{maxS}\ (T_i) + 0.15 M_{HD} \le M_{HD} \end{cases}$	III-1 III-2	Ch 4, Sec 8, [4.2.6] a Ch 4, Sec 8, [4.2.5]
		Minimum: $W_{minH}(T_i) = W_{minS}(T_i) - 0.15 M_{HD} \ge 0$	IV	Ch 4, Sec 8, [4.2.5]
	Example BC-A ships not having {No MP} for FA holds 			

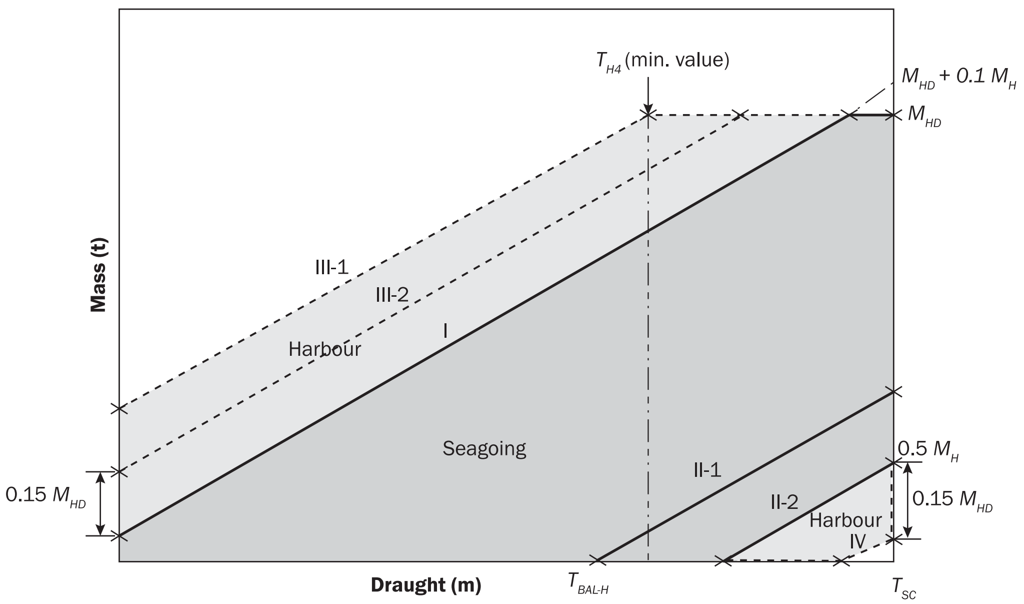
Hold	Loading conditions	Max / Min curves	Curve Ref	Ref
EA	Seagoing	Maximum $W_{maxS}\ (T_i)\ =\ M_{Full} - 1.025\ V_H\ \dfrac{(0.67T_{SC} - T_i)}{h} \le M_{Full}$	I	Ch 4, Sec 8, [4.2.2] a
		Minimum: $W_{minS}\ (T_i)\ =\ 1.025\ V_H\ \dfrac{(T_i - T_{SC})}{h} \ge 0$	II	Ch 4, Sec 8, [4.2.3] a
	Harbour	Maximum $W_{maxH}(T_i)\ =\ W_{maxS}(T_i) + 0.15M_{Full} \le M_{Full}$	III	Ch 4, Sec 8, [4.2.5]
		Minimum: $W_{minH}(T_i)\ =\ W_{minS}(T_i) - 0.15M_{Full} \ge 0$	IV	Ch 4, Sec 8, [4.2.5]
	Example BC-A ships not having {No MP} for EA hold 			

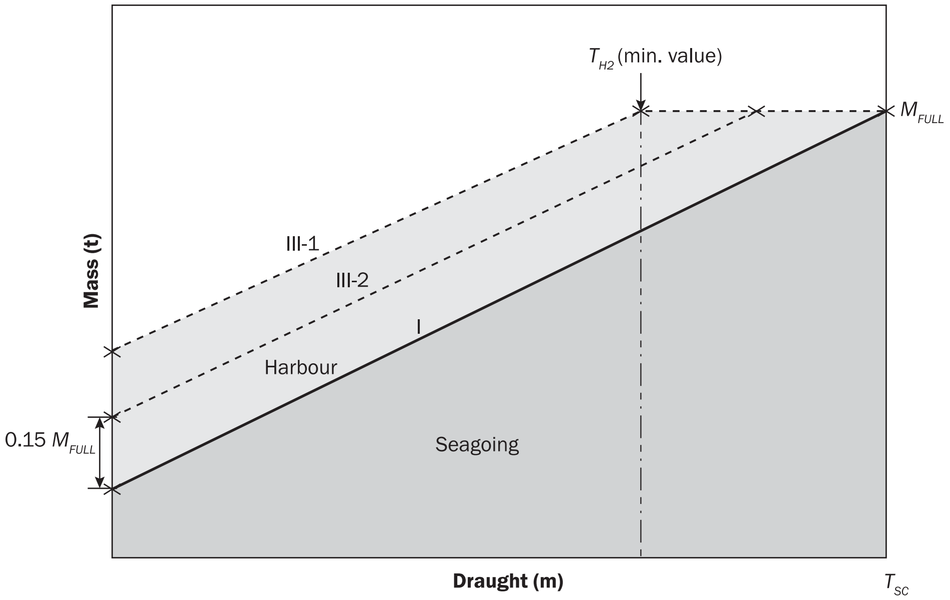
2.1.2 BC-A ship having {No MP} notation assigned

Table 2 : BC-A ship having {No MP} notation assigned

Hold	Loading conditions	Max / Min curves	Curve Ref	Ref
FA	Seagoing	Maximum: $W_{maxS}\ (T_i) = M_{HD} + 0.1\ M_H - 1.025\ V_H \dfrac{(T_{SC} - T_i)}{h} \le M_{HD}$	I	Ch 4, Sec 8, [4.2.3] b & c
		Minimum: $W_{minS}\ (T_i) = min \left\{ \begin{array}{l} 1.025 V_H \dfrac{(T_i - T_{BAL-H})}{h} \ge 0 \\ 0.5 M_H - 1.025\ V_H \dfrac{(T_{SC} - T_i)}{h} \ge 0 \end{array} \right.$	II-1 II-2	Ch 4, Sec 8, [4.2.1] c Ch 4, Sec 8, [4.2.1] b
	Harbour	Maximum: $W_{maxH}(T_i) = max \left\{ \begin{array}{l} M_{HD} - 1.025\ V_H \dfrac{(0.67 T_{SC} - T_i)}{h} \le M_{HD} \\ W_{maxS}\ (T_i) + 0.15 M_{HD} \le M_{HD} \end{array} \right.$	III-1 III-2	Ch 4, Sec 8, [4.2.6] a Ch 4, Sec 8, [4.2.5]
		Minimum: $W_{minH}(T_i) = W_{minS}(T_i) - 0.15 M_{HD} \ge 0$	IV	Ch 4, Sec 8, [4.2.5]

Example BC-A ships having {No MP} for FA hold



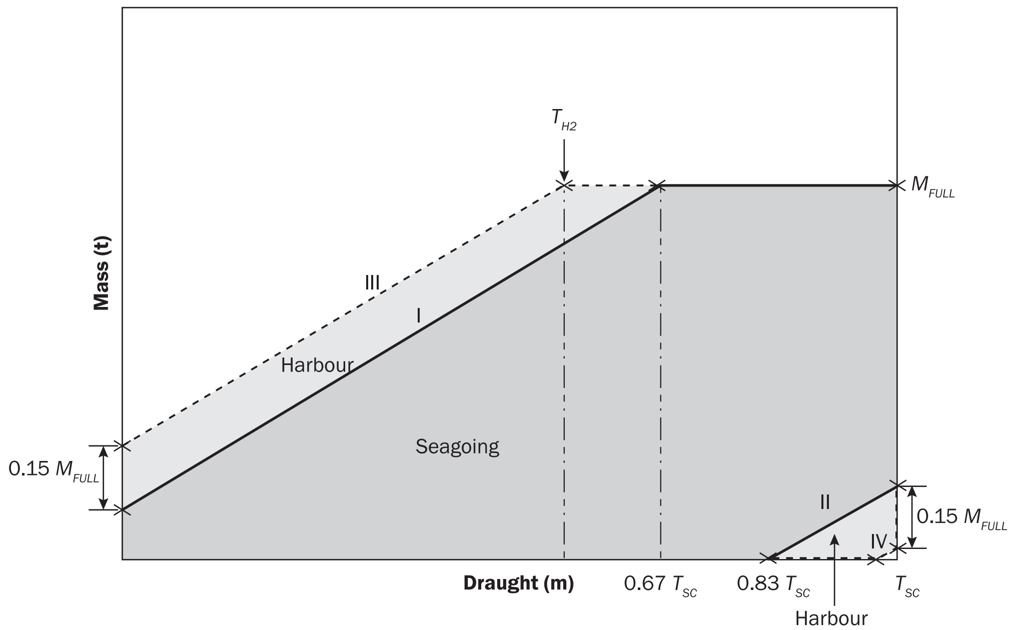
Hold	Loading conditions	Max / Min curves	Curve Ref	Ref
EA	Seagoing	Maximum $W_{maxS}\ (T_i)\ =\ M_{Full} - 1.025\ V_H \dfrac{(T_{SC} - T_i)}{h} \le M_{Full}$	I	Ch 4, Sec 8, [4.2.1] a
		Minimum: $W_{minS}\ (T_i) = 1.025\ V_H \dfrac{(T_i - T_{SC})}{h} \ge 0$	II	Ch 4, Sec 8, [4.2.3] a
	Harbour	Maximum $W_{maxH}(T_i)\ =\ max\begin{cases} M_{Full} - 1.025\ V_H \dfrac{(0.67T_{SC} - T_i)}{h} \le M_{Full} \\ W_{maxS}(T_i) + 0.15M_{Full} \le M_{Full} \end{cases}$	III-1 III-2	Ch 4, Sec 8, [4.2.6] a Ch 4, Sec 8, [4.2.5]
		Minimum: $W_{minH}(T_i) = W_{minS}(T_i) - 0.15M_{Full} \ge 0$	IV	Ch 4, Sec 8, [4.2.5]
	Example BC-A ships having {No MP} for EA hold 			

2.1.3 BC-B and BC-C ships not having {No MP} notation assigned

Table 3 : BC-B and BC-C ships not having {No MP} notation assigned

Loading conditions	Max / Min curves	Curve Ref	Ref
Seagoing	Maximum $W_{maxS}\ (T_i)\ =\ M_{Full} - 1.025\ V_H \dfrac{(0.67T_{SC} - T_i)}{h} \le M_{Full}$	I	Ch 4, Sec 8, [4.2.2] a
	Minimum: $W_{minS}\ (T_i)\ =\ 1.025\ V_H \dfrac{(T_i - 0.83T_{SC})}{h} \ge 0$	II	Ch 4, Sec 8, [4.2.2] b
Harbour	Maximum $W_{maxH}(T_i)\ =\ W_{maxS}(T_i) + 0.15M_{Full} \le M_{Full}$	III	Ch 4, Sec 8, [4.2.5]
	Minimum: $W_{minH}(T_i)\ =\ W_{minS}(T_i) - 0.15M_{Full} \ge 0$	IV	Ch 4, Sec 8, [4.2.5]

Example BC-B and BC-C ships not having {No MP}

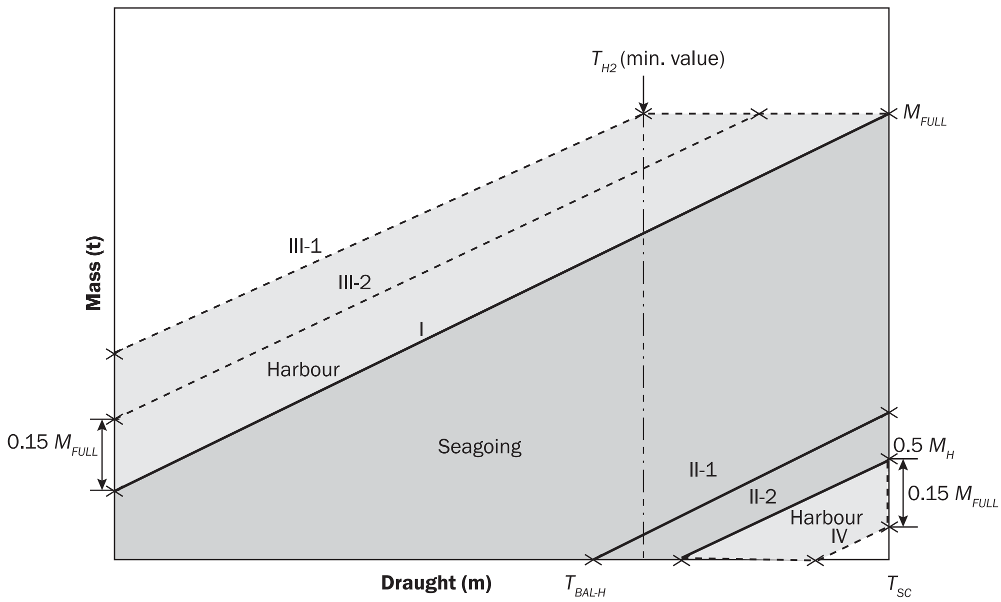


2.1.4 BC-B and BC-C ships having {No MP} notation assigned

Table 4 : BC-B and BC-C ships having {No MP} notation assigned

Loading conditions	Max / Min curves	Curve Ref	Ref
Seagoing	Maximum: $W_{maxS}\ (T_i)\ =\ M_{Full} - 1.025\ V_H\ \dfrac{(T_{SC} - T_i)}{h} \le M_{Full}$	I	Ch 4, Sec 8, [4.2.1] a
	Minimum: $W_{minS}\ (T_i)\ =\ min\begin{cases} 1.025 V_H\ \dfrac{(T_i - T_{BAL-H})}{h} \ge 0 \\ 0.5 M_H - 1.025\ V_H\ \dfrac{(T_{SC} - T_i)}{h} \ge 0 \end{cases}$	II-1 II-2	Ch 4, Sec 8, [4.2.1] c Ch 4, Sec 8, [4.2.1] b
Harbour	Maximum: $W_{maxH}(T_i)\ =\ max\begin{cases} M_{Full} - 1.025\ V_H\ \dfrac{(0.67 T_{SC} - T_i)}{h} \le M_{Full} \\ W_{maxS}\ (T_i) + 0.15 M_{Full} \le M_{Full} \end{cases}$	III-1 III-2	Ch 4, Sec 8, [4.2.6] a Ch 4, Sec 8, [4.2.5]
	Minimum: $W_{minH}(T_i) = W_{minS}(T_i) - 0.15 M_{Full} \ge 0$	IV	Ch 4, Sec 8, [4.2.5]

Example BC-B and BC-C ships having {No MP}



3 MAXIMUM AND MINIMUM MASSES OF CARGO OF TWO ADJACENT HOLDS

3.1 Maximum permissible mass and minimum required mass of two adjacent holds

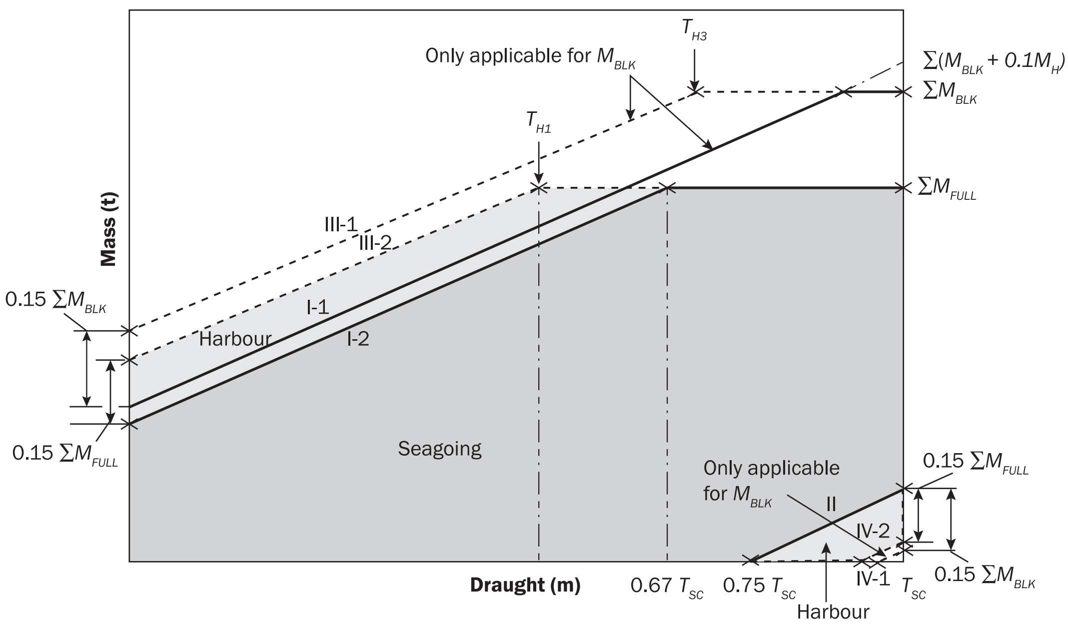
3.1.1 BC-A ships not having {No MP} notation assigned

Table 5 : BC-A ship not having {No MP} notation assigned

Loading conditions	Max / Min curves	Curve Ref	Ref
Seagoing	Maximum: $$W_{maxS}\ (T_i) = max \begin{cases} \sum(M_{BLK} + 0.1\ M_H) - 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right) (T_{SC} - T_i) \le \sum M_{BLK} \\ \sum M_{Full} - 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right) (0.67\,T_{SC} - T_i) \le \sum M_{Full} \end{cases}$$	I-1 **(1)** I-2	Ch 4, Sec 8, [4.2.3] d Ch 4, Sec 8, [4.2.2] c
	Minimum: $$W_{minS}\ (T_i) = 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right) (T_i - 0.75\,T_{SC}) \ge 0$$	II	Ch 4, Sec 8, [4.2.2] d
Harbour	Maximum: $$W_{maxH}(T_i) = max \begin{cases} W_{maxS}\ (T_i) + 0.15 \sum M_{BLK} \le \sum M_{BLK} \\ W_{maxS}\ (T_i) + 0.15 \sum M_{Full} \le \sum M_{Full} \end{cases}$$	III-1 **(1)** III-2	Ch 4, Sec 8, [4.2.5] Ch 4, Sec 8, [4.2.5]
	Minimum: $$W_{minH}(T_i) = min \begin{cases} W_{minS}\ (T_i) - 0.15 \sum M_{BLK} \ge 0 \\ W_{minS}\ (T_i) - 0.15 \sum M_{Full} \ge 0 \end{cases}$$	IV-1 **(1)** IV-2	Ch 4, Sec 8, [4.2.5] Ch 4, Sec 8, [4.2.5]

(1) This limit curve is only applicable when block loading condition is included in the loading manual.

Example BC-A ships not having {No MP} for two adjacent holds



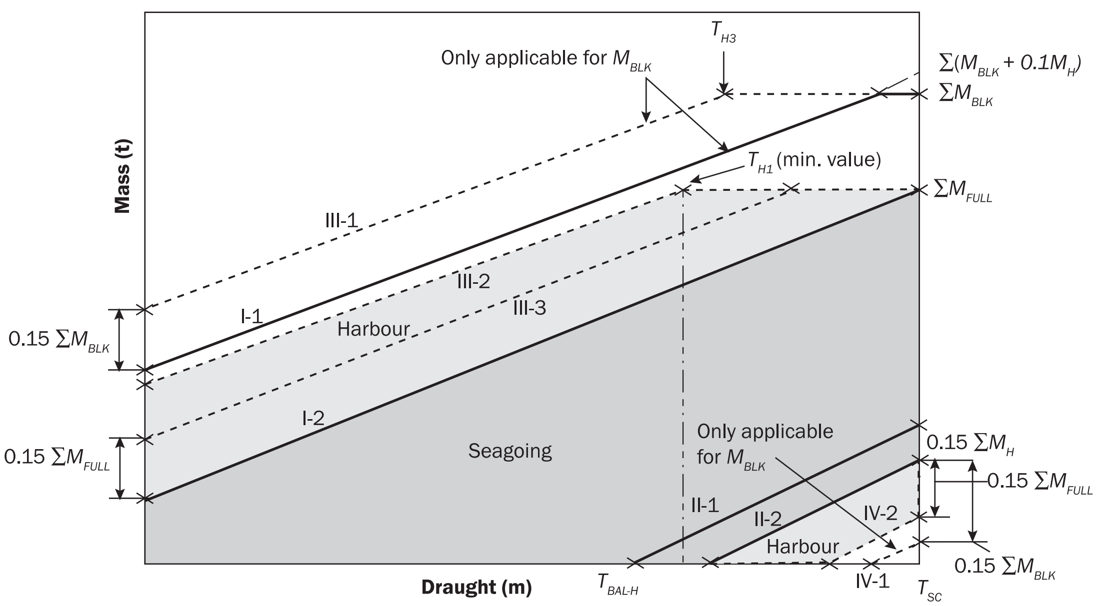
3.1.2 BC-A ships having {No MP} notation assigned

Table 6 : BC-A ship having {No MP} notation assigned

Loading conditions	Max / Min curves	Curve Ref	Ref
Seagoing	Maximum: $W_{maxS}\ (T_i) = max \begin{cases} \sum (M_{BLK} + 0.1\ M_H) - 1.025 \left(\dfrac{V_f}{h_f} + \dfrac{V_a}{h_a}\right) (T_{SC} - T_i) \leq \sum M_{BLK} \\ \sum M_{Full} - 1.025 \left(\dfrac{V_f}{h_f} + \dfrac{V_a}{h_a}\right) (T_{SC} - T_i) \leq \sum M_{Full} \end{cases}$	I-1 (1) I-2	Ch 4, Sec 8, [4.2.3] d Ch 4, Sec 8, [4.2.2] a
	Minimum: $W_{minS}\ (T_i) = min \begin{cases} 1.025 \left(\dfrac{V_f}{h_f} + \dfrac{V_a}{h_a}\right) (T_i - T_{BAL-H}) \geq 0 \\ 0.5 \sum M_H - 1.025 \left(\dfrac{V_f}{h_f} + \dfrac{V_a}{h_a}\right) (T_{SC} - T_i) \geq 0 \end{cases}$	II-1 II-2	Ch 4, Sec 8, [4.2.2] c Ch 4, Sec 8, [4.2.2] b
Harbour	Maximum: $W_{maxH}(T_i) = max \begin{cases} W_{maxS}\ (T_i) + 0.15 \sum M_{BLK} \leq \sum M_{BLK} \\ \sum M_{Full} - 1.025 \left(\dfrac{V_f}{h_f} + \dfrac{V_a}{h_a}\right) (0.67 T_{SC} - T_i) \leq \sum M_{Full} \\ W_{maxS}\ (T_i) + 0.15 \sum M_{Full} \leq \sum M_{Full} \end{cases}$	III-1 (1) III-2 III-3	Ch 4, Sec 8, [4.2.5] Ch 4, Sec 8, [4.2.6] b Ch 4, Sec 8, [4.2.5]
	Minimum: $W_{minH}(T_i) = min \begin{cases} W_{minS}\ (T_i) - 0.15 \sum M_{BLK} \geq 0 \\ W_{minS}\ (T_i) - 0.15 \sum M_{Full} \geq 0 \end{cases}$	IV-1 (1) IV-2	Ch 4, Sec 8, [4.2.5] Ch 4, Sec 8, [4.2.5]

(1) This limit curve is only applicable when block loading condition is included in the loading manual.

Example BC-A ships having {No MP} for two adjacent holds

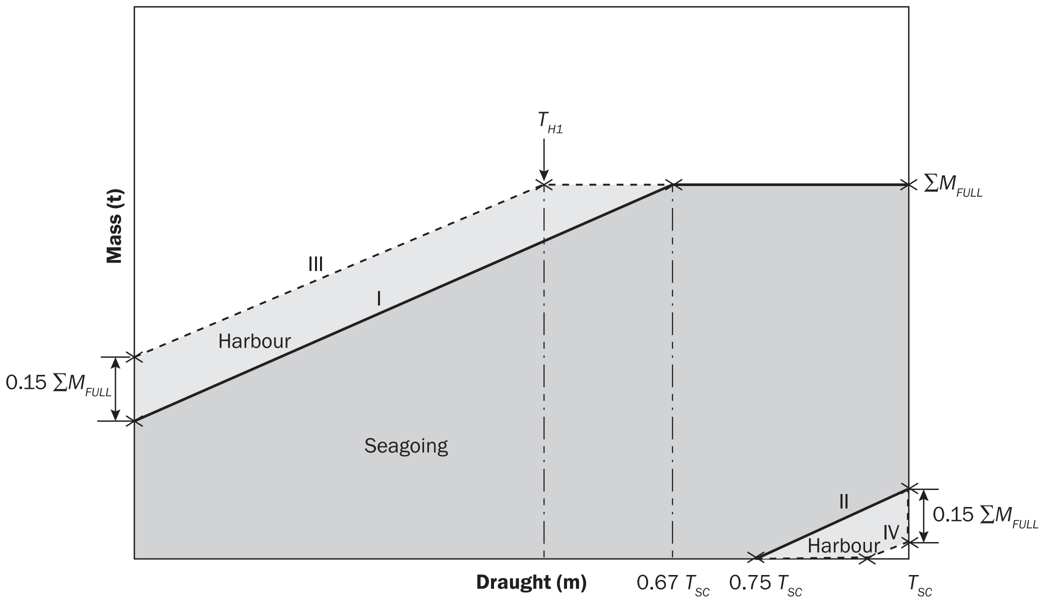


3.1.3 BC-B, BC-C ships, not having {No MP} notation assigned

Table 7 : BC-B and BC-C ships not having {No MP} notation assigned

Loading conditions	Max / Min curves	Curve Ref	Ref
Seagoing	Maximum: $W_{maxS}\ (T_i) = \sum M_{Full} - 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right) (0.67 T_{SC} - T_i) \leq \sum M_{Full}$	I	Ch 4, Sec 8, [4.2.2] c
	Minimum: $W_{minS}\ (T_i) = 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right) (T_i - 0.75 T_{SC}) \geq 0$	II	Ch 4, Sec 8, [4.2.2] d
Harbour	Maximum: $W_{maxH}(T_i) = W_{maxS}\ (T_i) + 0.15 \sum M_{Full} \leq \sum M_{Full}$	III	Ch 4, Sec 8, [4.2.5]
	Minimum: $W_{minH}(T_i) = W_{minS}\ (T_i) - 0.15 \sum M_{Full} \geq 0$	IV	Ch 4, Sec 8, [4.2.5]

Example BC-B and BC-C ships not having {No MP} for two adjacent holds

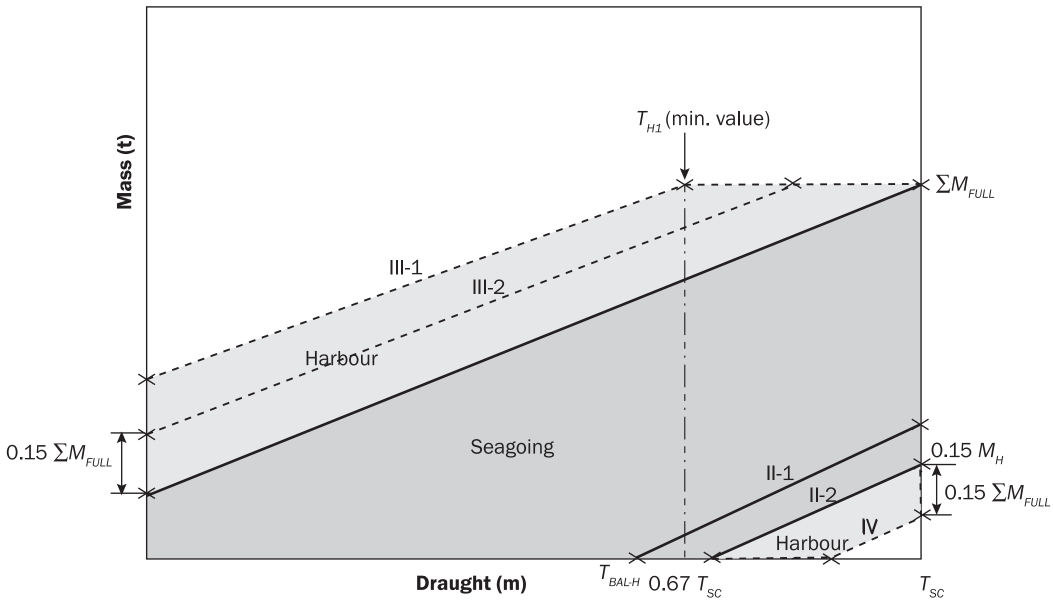


3.1.4 BC-B, BC-C ships, having {No MP} notation assigned

Table 8 : BC-B and BC-C ships having {No MP} notation assigned

Loading conditions	Max / Min curves	Curve Ref	Ref
Seagoing	Maximum: $W_{maxS}\ (T_i)\ =\ \sum M_{Full} - 1.025\left(\frac{V_f}{h_f}+\frac{V_a}{h_a}\right)(T_{SC}-T_i) \le \sum M_{Full}$	I	Ch 4, Sec 8, [4.2.1] a
	Minimum: $W_{minS}\ (T_i)\ =\ min\begin{cases} 1.025\left(\frac{V_f}{h_f}+\frac{V_a}{h_a}\right)(T_i-T_{BAL-H}) \ge 0 \\ 0.5\sum M_H - 1.025\left(\frac{V_f}{h_f}+\frac{V_a}{h_a}\right)(T_{SC}-T_i) \ge 0 \end{cases}$	II-1 II-2	Ch 4, Sec 8, [4.2.1] c Ch 4, Sec 8, [4.2.1] b
Harbour	Maximum: $W_{maxH}(T_i)\ =\ max\begin{cases} \sum M_{Full} - 1.025\left(\frac{V_f}{h_f}+\frac{V_a}{h_a}\right)(0.67\,T_{SC}-T_i) \le \sum M_{Full} \\ W_{maxS}\ (T_i) + 0.15\sum M_{Full} \le \sum M_{Full} \end{cases}$	III-1 III-2	Ch 4, Sec 8, [4.2.6] a Ch 4, Sec 8, [4.2.5]
	Minimum: $W_{minH}(T_i)\ =\ W_{minS}\ (T_i) - 0.15\sum M_{Full} \ge 0$	IV	Ch 4, Sec 8, [4.2.5]

Example BC-B and BC-C ships having {No MP} for two adjacent holds



PART 1 CHAPTER 5

HULL GIRDER STRENGTH

Table of Contents

SECTION 1
HULL GIRDER YIELDING STRENGTH

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

M_{sw} : Permissible hogging and sagging vertical still water bending moment in intact seagoing condition, in kNm, at the hull transverse section considered, defined in Ch 4, Sec 4, [2.2.2].

M_{sw-p} : Permissible hogging and sagging vertical still water bending moment for harbour/sheltered water operation, in kNm, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.2.3].

M_{sw-f} : Permissible hogging and sagging vertical still water bending moment in flooded condition at sea, in kNm, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.2.4].

M_{wv} : Vertical wave bending moment in seagoing condition, in kNm, in intact or flooded conditions at the hull transverse section considered, defined in Ch 4, Sec 4, [3.1.1].

M_{wh} : Horizontal wave bending moment, in kNm, at the hull transverse section considered, defined in Ch 4, Sec 4, [3.3.1].

Q_{sw} : Permissible positive or negative still water shear force for seagoing operation, in kN, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.3.3].

Q_{sw-p} : Permissible positive or negative still water shear force for harbour/sheltered operation, in kN, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.3.4].

Q_{sw-f} : Permissible positive or negative still water shear force for in flooded condition at sea, in kN, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.3.5].

Q_{wv} : Vertical wave shear force in seagoing condition, in kN, in intact or flooded conditions at the hull transverse section considered, defined in Ch 4, Sec 4, [3.2.1].

Q_{sw-Lcd} : Vertical still water shear force for the considered loading condition in seagoing operation, in kN, at the hull transverse section considered.

$Q_{sw-Lcd-p}$: Vertical still water shear force for the considered loading condition in harbour/sheltered operation, in kN, at the hull transverse section considered.

$Q_{sw-Lcd-f}$: Vertical still water shear force for the considered flooded condition in seagoing operation, in kN, at the hull transverse section considered.

x : X coordinate, in m, of the calculation point with respect to the reference coordinate system defined in Ch 1, Sec 4, [3.6].

V_D : Vertical distance to the equivalent deck line, in m, as defined in [1.4.3].

z : Z coordinate, in m, of the calculation point with respect to the reference coordinate system defined in Ch 1, Sec 4, [3.6].

z_n : Z coordinate, in m, of horizontal neutral axis of the hull transverse section with net scantling defined in [1.2], with respect to the reference coordinate system defined in Ch 1, Sec 4, [3.6].

I_{y-n50} : Net moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis, to be calculated according to [1.5].

I_{z-n50} : Net moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis, to be calculated according to [1.5].

Z_{A-n50} : Net section modulus, in m^3, at any point of the hull transverse section, to be calculated according [1.4.1].

Z_{B-n50}, Z_{D-n50}: Net section moduli, in m^3, at bottom and deck, respectively, to be calculated according to [1.4.2] and [1.4.3].

z_{VD} : Z coordinate, in m, taken equal to $V_D + z_n$.

C_w : Wave parameter defined in Ch 4, Sec 4.

ρ : Seawater density, taken equal to 1.025 t/m^3.

1 STRENGTH CHARACTERISTICS OF HULL GIRDER TRANSVERSE SECTIONS

1.1 General

1.1.1

This section specifies the criteria for calculating the hull girder strength characteristics to be used for the checks in [2] to [3], in association with the hull girder loads specified in Ch 4, Sec 4.

1.2 Hull girder transverse sections

1.2.1 General

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder longitudinal strength, i.e. all continuous longitudinal members below and including the strength deck defined in [1.3], taking into account the requirements in [1.2.2] to [1.2.13].

1.2.2 Net scantling

The members contributing to the hull girder longitudinal strength are to be considered using the net offered scantlings based on gross offered thickness reduced by 0.5 t_c, as defined in Ch 3, Sec 3, when the hull girder strength characteristics are used for the hull girder yielding check according to [2] to [3].

1.2.3 Structural members not contributing to hull girder sectional area

The following members are not to be considered in the calculation as they are considered not contributing to the hull girder sectional area:

- Superstructures which do not form a strength deck.
- Deckhouses.
- Vertically corrugated bulkheads, according to [1.2.7].
- Bulwarks and gutter plates.
- Bilge keels.
- Sniped or non-continuous longitudinal stiffeners.
- Non-continuous hatch coaming.

1.2.4 Continuous trunks and longitudinal continuous hatch coamings

Continuous trunks and longitudinal continuous hatch coamings may be included in the hull girder transverse sections, provided that they are effectively supported by longitudinal bulkheads or primary supporting members.

1.2.5 Longitudinal stiffeners or girders welded above the strength deck

Longitudinal stiffeners or girders welded above the strength deck, including the deck of any trunk fitted as specified in [1.2.4], are to be included in the hull girder transverse sections.

1.2.6 Longitudinal girders between hatchways, supported by longitudinal bulkheads

Where longitudinal girders, effectively supported by longitudinal bulkheads, are fitted between hatchways, the sectional area of these longitudinal girders are to be included in the hull girder transverse section.

1.2.7 Longitudinal bulkheads with vertical corrugations

For longitudinal bulkheads with vertical corrugations, the vertical corrugations are not to be included in the hull girder transverse section. Longitudinal bulkheads with vertical corrugations are not effective for hull girder bending, but they are effective for hull girder shear force.

1.2.8 Members in materials other than steel

Where a member contributing to the longitudinal strength is made in material other than steel with a Young's modulus, E equal to 2.06×10^5 N/mm^2, the steel equivalent sectional area that may be included in hull girder transverse section is obtained, in m^2, from the following formula:

$$A_{SE-n50} = \frac{E}{2.06 \times 10^5} A_{M-n50}$$

where:

$A_{M\text{-}n50}$: Sectional area, in m^2, of the member under consideration.

1.2.9 Definitions of openings

The following definitions of opening are to be applied:

a) Large openings are:
   - Elliptical openings exceeding 2.5 m in length or 1.2 m in breadth.
   - Circular openings exceeding 0.9 m in diameter.

b) Small openings (i.e. manholes, lightening holes, etc) are openings that are not large ones.

c) Isolated openings are openings spaced not less than 1 m apart in the ship's transverse/vertical direction.

1.2.10 Large openings and nearby small openings

Large openings are to be deducted from the sectional area used in hull girder moment of inertia and section modulus. When small openings are spaced less than 1 m apart in the ship's transverse/vertical direction to large openings, the total breadth of them is to be deducted from the sectional area.

Additionally, isolated small openings which do not comply with the arrangement requirements given in Ch 3, Sec 6, [6.3.2] are to be deducted from the sectional areas included in the hull girder transverse sections.

1.2.11 Isolated small openings

Isolated small openings in one transverse section in the strength deck or bottom area need not be deducted from the sectional areas included in the hull girder transverse sections, provided that:

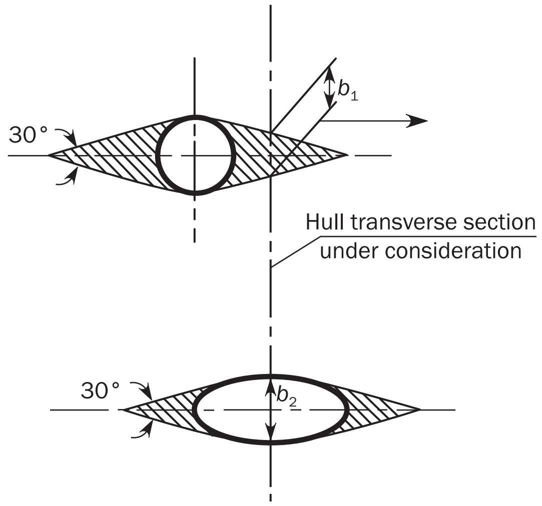
$$\Sigma b_S \le 0.06(B - \Sigma b)$$

Σb_S : Total breadth of isolated small openings, in m, in the strength deck or bottom area at the transverse section considered, determined as indicated in Figure 1, not deducted from the section area as per [1.2.10].

Σb : Total breadth of large openings, in m, at the transverse section considered, determined as indicated in Figure 1, deducted from the section area as defined in [1.2.10].

Where the total breadth of isolated small openings Σb_s does not fulfil the above criteria, only the excess of breadth is to be deducted from the sectional areas included in the hull girder transverse sections.

Figure 1 : Calculation of Σb and Σb_s



b_1 and b_2 included in Σb and Σb_s

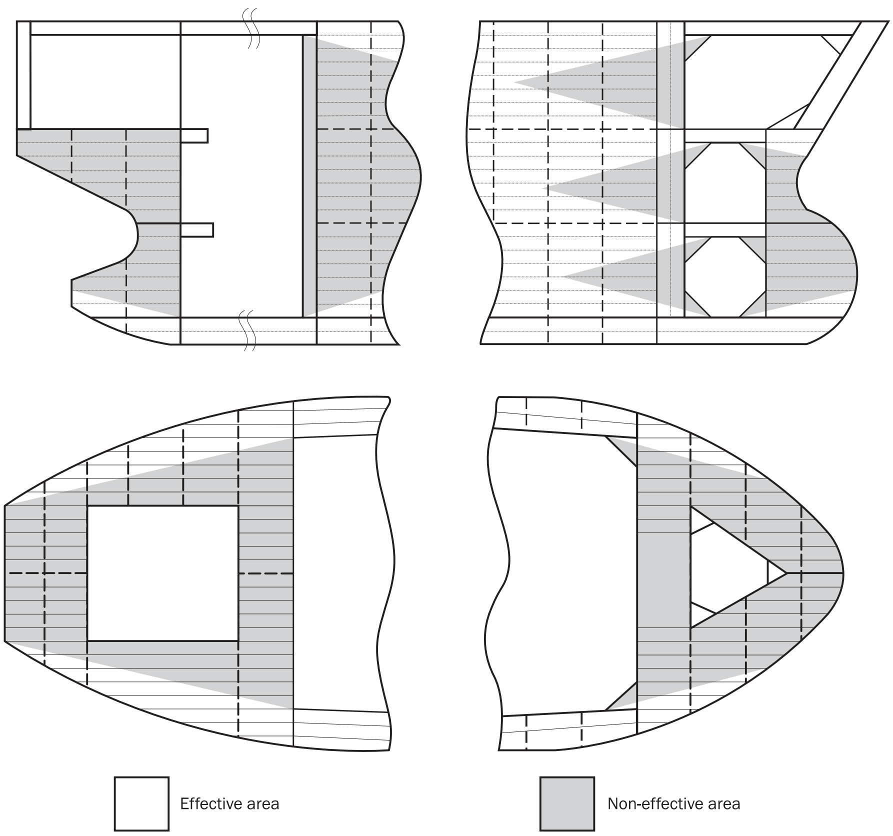
1.2.12 Lightening holes, draining holes and single scallops

Lightening holes, draining holes and single scallops in longitudinals need not be deducted if their height is less than 0.25 h_w, where h_w is the web height of the longitudinals, in mm. Otherwise, the excess is to be deducted from the sectional area or compensated.

1.2.13 Non-continuous decks and longitudinal bulkheads

When calculating the effective area in way of non-continuous decks and longitudinal bulkheads, the effective area is to be taken as shown in Figure 2. The shadow area, which indicates the ineffective area, is obtained by drawing two tangent lines with an angle of 15 deg to the longitudinal axis of the ship.

Figure 2 : Effective area in way of non-continuous decks and bulkheads



1.3 Strength deck

1.3.1

The strength deck is, in general, the uppermost continuous deck. In the case of a superstructure or deckhouses contributing to the longitudinal strength, the strength deck is the deck of the superstructure or the deck of the uppermost deckhouse.

1.4 Section modulus

1.4.1 Section modulus at any point

The section modulus at any point of a hull transverse section is obtained, in m^3, from the following formula:

$$Z_{A-n50} = \frac{I_{y-n50}}{|z - z_n|}$$

1.4.2 Section modulus at bottom

The section modulus at bottom is obtained, in m^3, from the following formula:

$$Z_{B-n50} = \frac{I_{y-n50}}{z_n}$$

1.4.3 Section modulus at deck

The section modulus at equivalent deck line is obtained, in m^3, from the following formula:

$$Z_{D-n50} = \frac{I_{y-n50}}{V_D}$$

where:

V_D : Vertical distance of the equivalent deck line, in m, taken equal to:

When no effective longitudinal members specified in [1.2.4] and [1.2.5] are positioned above a line extending from strength deck at side to a position $(z_D - z_n)/0.9$ from the neutral axis at the centreline

$$V_D = z_D - z_n$$

When effective longitudinal members as specified in [1.2.4] and [1.2.5] are positioned above a line extending from strength deck at side to a position $(z_D - z_n)/0.9$ from the neutral axis at the centreline

$$V_D = (z_T - z_n)\left(0.9 + 0.2\frac{y_T}{B}\right) \geq z_D - z_n$$

z_D : Z coordinate, in m, of strength deck at side, defined in [1.3].

y_T, z_T : Y and Z coordinates, in m, of the top of continuous trunk, hatch coaming, longitudinal stiffeners or girders, to be measured for the point which maximises the value of V_D.

1.5 Moments of inertia

1.5.1

The net moment of inertia, I_{y-n50} and I_{z-n50}, in m^4, are those, calculated about the horizontal and vertical neutral axes, respectively, of the hull transverse sections defined in [1.2].

2 HULL GIRDER BENDING ASSESSMENT

2.1 General

2.1.1

Scantlings of all continuous longitudinal members of the hull girder based on moment of inertia and section modulus requirement in [2.3] are to be maintained within 0.4 *L* amidships.

2.1.2

The *k* material factors are to be defined with respect to the materials used for the bottom and deck members contributing to the longitudinal strength according to [1]. When material factors for higher strength steels are used, the requirements in [2.4] apply.

2.2 Normal stresses

2.2.1

The normal stress, σ_L induced by vertical bending moments, is to be assessed for both hogging and sagging conditions, along the full length of the hull girder, from AE to FE.

The normal stress, σ_L at any point of the hull transverse section located below z_{VD} is to comply with the following formula:

$\sigma_L \le \sigma_{perm}$

where:

σ_L : Normal stress, in N/mm^2, as defined in [2.2.2].

σ_{perm} : Permissible hull girder bending stress, in N/mm^2, as given in Table 1.

2.2.2

The normal stresses, σ_L in N/mm^2, induced by vertical bending moments are given in Table 2:

2.2.3

The normal stresses in a member made in material other than steel with a Young's modulus, *E* equal to 2.06×10^5 N/mm^2, included in the hull girder transverse sections as specified in [1.2.8], are obtained from the following formula:

$$\sigma_L = \frac{E}{2.06 \times 10^5} \sigma_{Ls}$$

where:

σ_{LS} : Normal stress, in N/mm^2, in the member under consideration, calculated according to [2.2.2] considering this member as having the steel equivalent sectional area A_{SE} defined in [1.2.8].

2.3 Minimum net moment of inertia and net section modulus at midship section

2.3.1

At the transverse section in the midship part, the net moment of inertia about the horizontal axis, $I_{y\text{-}n50}$ is to be not less than the value obtained, in m^4, from the following formula:

$$I_{yR} = 2.7\ C_w\ L^3\ B\,(C_B + 0.7)\ 10^{-8}$$

Table 1 : Permissible hull girder bending stress

Operation	Design load	Permissible hull girder bending stress, σ_{perm}				
		$\frac{x}{L} \le 0.1$	$0.1 < \frac{x}{L} < 0.3$	$0.3 \le \frac{x}{L} \le 0.7$	$0.7 < \frac{x}{L} < 0.9$	$\frac{x}{L} \ge 0.9$
Seagoing	(S+D)	$140/k$	Linear interpolation	$190/k$	Linear interpolation	$140/k$
Harbour/sheltered water	(S)	$105/k$	Linear interpolation	$143/k$	Linear interpolation	$105/k$
Flooded condition at sea for bulk carriers having a length L of 150 m or above	(A:S+D)	$140/k$	Linear interpolation	$190/k$	Linear interpolation	$140/k$

Table 2 : Normal stress, σ_L

Operation	Normal stress, σ_L		
	At any point located below Z_{VD}	At bottom (1)	At deck (1)
Seagoing	$\sigma_L = \frac{M_{sw} + M_{wv}}{Z_{A-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw} + M_{wv}}{Z_{B-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw} + M_{wv}}{Z_{D-n50}} 10^{-3}$
Harbour/sheltered water	$\sigma_L = \frac{M_{sw-p}}{Z_{A-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw-p}}{Z_{B-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw-p}}{Z_{D-n50}} 10^{-3}$
Flooded condition at sea for bulk carriers having a length L of 150 m or above	$\sigma_L = \frac{M_{sw-f} + M_{wv}}{Z_{A-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw-f} + M_{wv}}{Z_{B-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw-f} + M_{wv}}{Z_{D-n50}} 10^{-3}$
(1) The σ_L values at bottom and deck, correspond to the application of formula given for any point, calculated at equivalent deck line and at baseline.			

2.3.2

At the transverse section in the midship part, the vertical hull girder net section modulus at the deck and the bottom, $Z_{D\text{-}n50}$ and $Z_{B\text{-}n50}$, are not to be less than the value obtained, in m^3, from the following formula:

$$Z_R = 0.9k\ C_w\ L^2\ B\,(C_B + 0.7)\,10^{-6}$$

2.4 Extent of high tensile steel

2.4.1 Vertical extent

The vertical extent of higher strength steel, $z_{hts,i}$, in m, used in the deck zone or bottom zone and measured respectively from the moulded deck line at side or baseline is not to be taken less the value obtained from the following formula, see Figure 3:

$$z_{hts,\,i} = z_1\left(1 - \frac{\sigma_{perm,\,i}}{\sigma_L}\right)$$

where:

z_1 : Distance from horizontal neutral axis to moulded deck line or baseline respectively, in m.

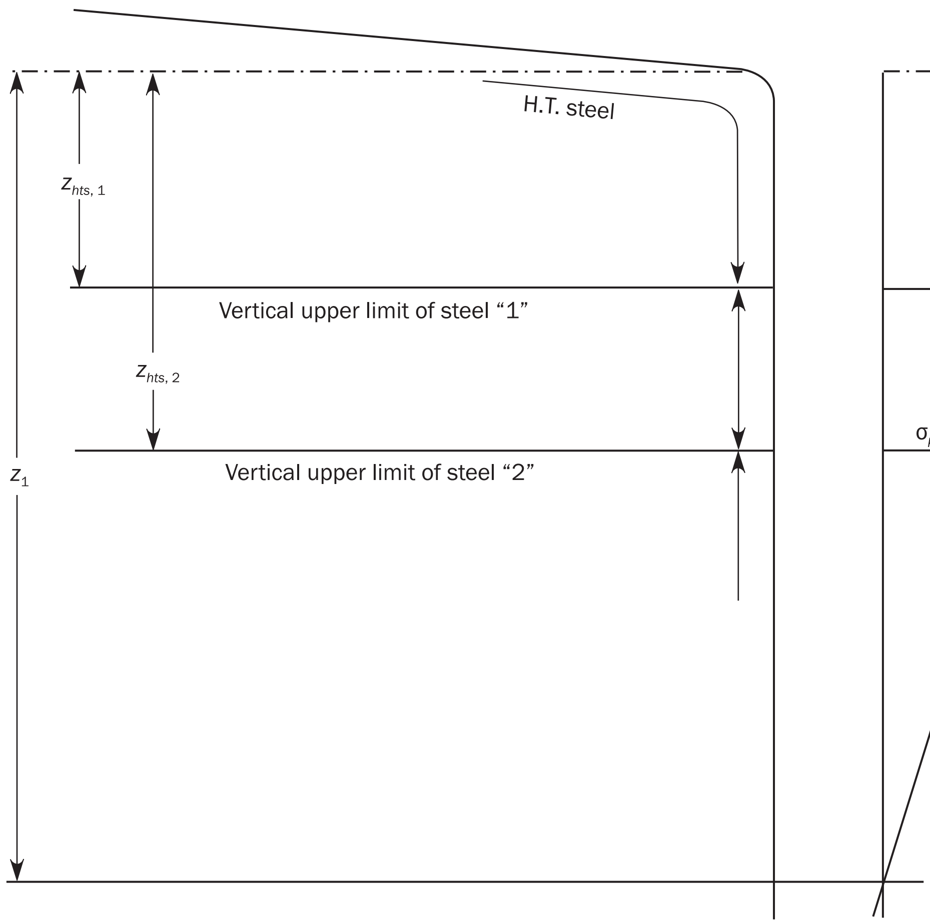
$\sigma_{perm,i}$: Permissible hull girder bending stress of the considered steel, in N/mm², as given in Table 1 and Figure 3.

σ_L : Hull girder bending stress, σ_{dk} at moulded deck line or σ_{bl} at baseline respectively, in N/mm² given in Table 3.

Table 3 : Hull girder stresses at baseline and moulded deck line

Operation	At baseline	At moulded deck line
Seagoing	$\sigma_{bl} = \dfrac{\lvert M_{sw} + M_{wv}\rvert}{I_{y-n50}} z_n 10^{-3}$	$\sigma_{dk} = \dfrac{\lvert M_{sw} + M_{wv}\rvert}{I_{y-n50}} (z_{dk-s} - z_n) 10^{-3}$
Harbour/sheltered water	$\sigma_{bl} = \dfrac{\lvert M_{sw-p}\rvert}{I_{y-n50}} z_n 10^{-3}$	$\sigma_{dk} = \dfrac{\lvert M_{sw-p}\rvert}{I_{y-n50}} (z_{dk-s} - z_n) 10^{-3}$
Flooded condition at sea for bulk carriers having a length L of 150 m or above	$\sigma_{bl} = \dfrac{\lvert M_{sw-f} + M_{wv}\rvert}{I_{y-n50}} z_n 10^{-3}$	$\sigma_{dk} = \dfrac{\lvert M_{sw-f} + M_{wv}\rvert}{I_{y-n50}} (z_{dk-s} - z_n) 10^{-3}$
$z_{dk\text{-}s}$: Distance from baseline to moulded deck line at side, in m.		

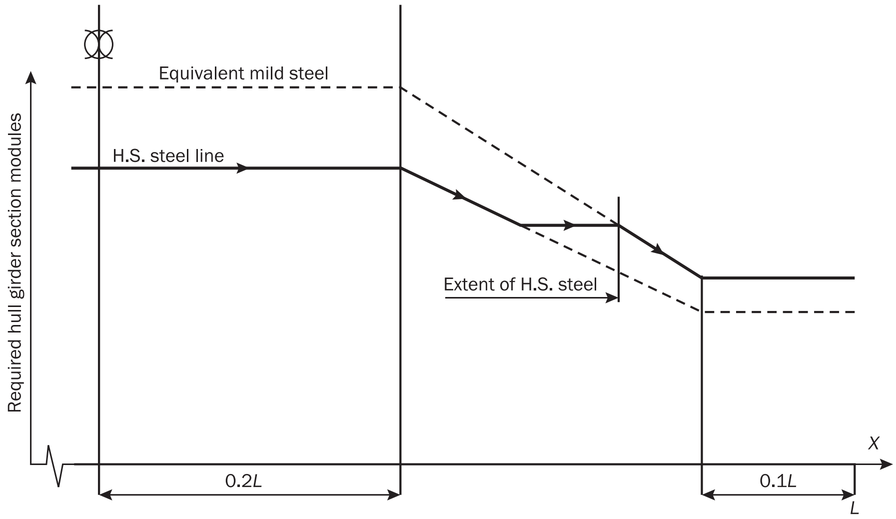
Figure 3 : Vertical extent of higher strength steel



2.4.2 Longitudinal extent

Where used, the application of higher strength steel is to be continuous over the length of the ship to the location where the longitudinal stress levels are within the allowable range for mild steel structure, as shown in Figure 4.

Figure 4 : Longitudinal extent of higher strength steel



3 HULL GIRDER SHEAR STRENGTH ASSESSMENT

3.1 General

3.1.1

The hull girder shear strength requirements apply along the full length of the hull girder, from AE to FE.

3.2 Hull girder shear capacity

3.2.1

The total vertical hull girder shear capacity, Q_R in kN, is the minimum of the calculated values for all plates *i* contributing to the hull girder shear of the considered transverse section and is to be taken as:

$$Q_R = \min_i\left(\frac{\tau_{i-perm} \cdot t_{i-n50}}{q_{vi}} \cdot 10^{-3}\right)$$

where:

$t_{i\text{-}n50}$: Net thickness of plate *i*, in mm. For longitudinal bulkheads between cargo tanks of oil tankers, $t_{i\text{-}n50}$ is to be taken as $t_{sfi\text{-}n50}$ (see [3.4.1]) and $t_{sti\text{-}k\text{-}n50}$ (see [3.5.1]) as appropriate.

q_{vi} : Contribution ratio for hull girder shear force per mm, in mm^{-1}, for the plate *i* based on net scantlings with deduction of 0.5 t_c, which is equal to the unit shear flow per mm, in N/mm, obtained from a numerical calculation based on thin-walled beam theory according to Ch 5, App 1.

$\tau_{i\text{-}perm}$: Permissible shear stress, in N/mm^2, as given in Table 4, for plate *i*.

Table 4 : Permissible hull girder shear stress

Operation	Design load	Permissible hull girder shear, $\tau_{i\text{-}perm}$
Seagoing	(S+D)	120/*k*
Harbour/sheltered water	(S)	105/*k*
Flooded condition at sea of bulk carriers having a length *L* of 150 m or above	(A:S+D)	120/*k*

3.3 Acceptance criteria

3.3.1 Permissible vertical shear force

The positive and negative permissible vertical shear forces are to comply with the following criteria:

- For seagoing operation:

  $|Q_{sw}| \le Q_R - |Q_{wv}|$

- For harbour/sheltered water operation:

  $|Q_{sw-p}| \le Q_R$

- For flooded condition at sea of bulk carriers having a length L of 150 m or above:

  $|Q_{sw-f}| \le Q_R - |Q_{wv}|$

where:

Q_R : Total vertical hull girder shear capacity, in kN, as defined in [3.2.1].

The shear force Q_{wv}, used in 2 above criteria is to be taken with the same sign as the considered shear forces Q_{sw}, and Q_{sw-f} respectively.

3.3.2 Vertical still water shear force

The vertical still water shear forces, in kN, for all loading conditions are to comply with the following criteria:

- For seagoing operation:

  $|Q_{sw-Lcd} - \Delta Q_{mdf}| \le |Q_{sw}|$

- For harbour/sheltered water operation:

  $|Q_{sw-Lcd-p} - \Delta Q_{mdf}| \le |Q_{sw-p}|$

- For flooded condition at sea of bulk carriers having a length L of 150 m or above:

  $|Q_{sw-Lcd-f} - \Delta Q_{mdf}| \le |Q_{sw-f}|$

where:

ΔQ_{mdf} : Shear force correction at the transverse section considered, in kN, taken as:

- For bulk carriers, the value defined in [3.6.1].
- For oil tankers, $\Delta Q_{mdf} = 0$.

The permissible shear forces Q_{sw}, Q_{sw-p} and Q_{sw-f} are to be taken with the same sign as the considered shear forces Q_{sw-Lcd}, $Q_{sw-Lcd-p}$ and $Q_{sw-Lcd-f}$ respectively.

3.4 Effective net thickness for longitudinal bulkheads between cargo tanks of oil tankers

3.4.1

For longitudinal bulkheads between cargo tanks, the net thickness of the plating above the inner bottom, $t_{sfi-n50}$ for plate i, in mm, is given by:

$$t_{sfi-n50} = t_{i-n50} - t_{\Delta i}$$

where:

$t_{\Delta i}$: Thickness deduction for plate i, in mm, as defined in [3.4.2].

3.4.2

The vertical distribution of thickness reduction for shear force correction is to be triangular as indicated in Figure 5. The thickness deduction, $t_{\Delta i}$ in mm, to account for shear force correction on the plate i, is to be taken as:

$$t_{\Delta i} = \frac{\delta Q_3}{h_{blk}\ \tau_{i-perm}}\left(1 - \frac{x_{blk}}{0.5\ell_{tk}}\right)\left(2 - \frac{2(z_p - h_{db})}{h_{blk}}\right)$$

where:

δQ_3 : Shear force correction for longitudinal bulkhead as defined in [3.4.3] and [3.4.4] for ships with one or two longitudinal bulkheads respectively, in kN.

ℓ_{tk} : Length of cargo tank, in m.

h_{blk} : Height of longitudinal bulkhead, in m, defined as the distance from inner bottom to the deck at the top of the bulkhead, as shown in Figure 5.

x_{blk} : Minimum longitudinal distance from section considered to the nearest cargo tank transverse bulkhead, in m. To be taken positive and not greater than 0.5 ℓ_{tk}.

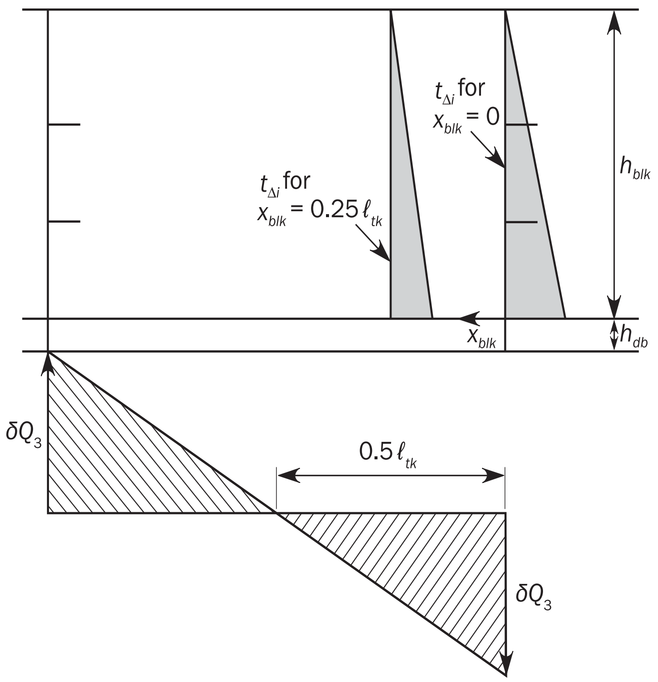
z_p : Vertical distance from the lower edge of plate i to the base line, in m, but not taken less than h_{db}.

h_{db} : Height of double bottom, in m, as shown in Figure 5.

$\tau_{i\text{-}perm}$: Permissible hull girder shear stress, in N/mm^2, for plate i:

$\tau_{i\text{-}perm}$ = 120/k.

Figure 5 : Shear force correction for longitudinal bulkheads



3.4.3 Shear force correction for a ship with a centreline longitudinal bulkhead

For ships with a centreline longitudinal bulkhead, the shear force correction in way of transverse bulkhead, δQ_3, in kN, is to be obtained from the following formula:

$$\delta Q_3 = 0.5\ K_3\ F_{db}$$

where:

F_{db} : Maximum resulting force on the double bottom in a tank, in kN, as defined in [3.4.5].

K_3 : Correction factor, to be taken equal to:

$$K_3 = 0.4 \cdot \left(1 - \frac{1}{1+n}\right) - f_3$$

n : Number of floors between transverse bulkheads.

f_3 : Shear force distribution factor, as defined in Table 5.

3.4.4 Shear force correction for a ship with two longitudinal bulkheads between the cargo tanks

For ships with two longitudinal bulkheads between the cargo tanks, the shear force correction, δQ_3 in kN, is to be obtained from the following formula:

$$\delta Q_3 = 0.5\ K_3\ F_{db}$$

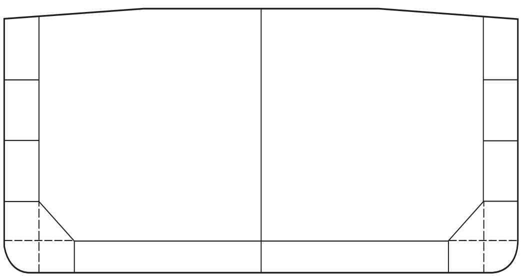
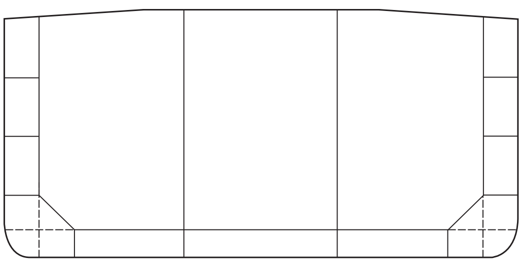
where:

F_{db} : Maximum resulting force on the double bottom in a tank, in kN, as defined in [3.4.5].

K_3 : Correction factor, to be taken equal to:

$$K_3 = 0.5 \cdot \left(1 - \frac{1}{1+n}\right)\left(\frac{1}{r+1}\right) - f_3$$

Table 5 : Shear force distribution factor for oil tanker

Hull configuration	f_3 factor
One centreline bulkhead 	$f_3 = 0.504 - 0.076\dfrac{A_{1-n50}}{A_{2-n50}} - 0.156\dfrac{A_{2-n50}}{A_{3-n50}}$
Two longitudinal bulkheads 	$f_3 = 0.353 - 0.049\dfrac{A_{1-n50}}{A_{2-n50}} - 0.095\dfrac{A_{2-n50}}{A_{3-n50}}$

where:

$A_{1\text{-}n50}$, $A_{2\text{-}n50}$, $A_{3\text{-}n50}$: Net projected area onto the vertical plane based on net thickness, t_{n50}, of the side shell, inner hull or the longitudinal bulkhead respectively, at one side of the section under consideration.

The area $A_{1\text{-}n50}$ includes the net plating area of the side shell, including the bilge.

The area $A_{2\text{-}n50}$ includes the net plating area of the inner hull, including the hopper side and the outboard girder under.

The Area $A_{3\text{-}n50}$ includes the net plating area of the longitudinal bulkheads, including the double bottom girders in line. The area $A_{3\text{-}n50}$ for the centreline bulkhead is not to be reduced for symmetry around the centreline. When the longitudinal bulkhead is made with corrugation, $A_{3\text{-}n50}$ is to consider the equivalent net thickness of the corrugation as defined in [3.4.6].

where:

n : Number of floors between transverse bulkheads.

r : Ratio of the part load carried by the wash bulkheads and floors from longitudinal bulkhead to the double side taken as:

$$r = \frac{1}{\left[\dfrac{A_{3-n50}}{A_{1-n50} + A_{2-n50}} + \dfrac{2 \times 10^4 \, b_{80} (n_s + 1) A_{3-n50}}{\ell_{tk} (n_s \, A_{T-n50} + R)}\right]}$$

ℓ_{tk} : Length of cargo tank, between transverse bulkheads in the side cargo tank, in m.

b_{80} : 80% of the distance from longitudinal bulkhead to the inner hull longitudinal bulkhead, in m, at tank mid length.

$A_{T\text{-}n50}$: Net shear area of the transverse wash bulkhead, including the double bottom floor directly below, in the side cargo tank, in cm^2, taken as the smallest area in a vertical section.

$A_{1\text{-}n50}$, $A_{2\text{-}n50}$, $A_{3\text{-}n50}$:Net areas, as defined in Table 5, in m^2.

f_3 : Shear force distribution factor, as defined in Table 5.

n_S : Number of wash bulkheads in the side cargo tank.

R : Total efficiency of the transverse primary supporting members in the side tank in cm^2.

$$R = \left(\frac{n - n_s}{2} - 1\right) \frac{A_{Q-n50}}{\gamma}$$

$$\gamma = 1 + \frac{300 \;\, {b_{80}}^2 \; A_{Q-n50}}{I_{psm-n50}}$$

$A_{Q\text{-}n50}$: Net shear area, in cm^2, of a transverse primary supporting member in the wing cargo tank, taken as the sum of the net shear areas of floor, cross ties and deck transverse webs. The net shear area is to be calculated at the mid span of the members.

$I_{psm\text{-}n50}$: Net moment of inertia for transverse primary supporting members, in cm^4, in the wing cargo tank, taken as the sum of the moments of inertia of transverses and cross ties. The net moment of inertia is to be calculated at the mid span of the member including an attached plate width equal to the primary supporting member spacing.

3.4.5 Vertical force on double bottom

The maximum vertical resulting force on the double bottom in a tank, F_{db} is in no case to be less than that given by the minimum conditions given in Table 6.

The maximum resulting force on the double bottom in a tank, F_{db} in kN, is to be taken as:

$$F_{db} = g \left| W_{CT} + W_{CWBT} - \rho \;\, b_2 \;\, \ell_{tk} \; T_{mean} \right|$$

where:

W_{CT} : Weight of cargo, in tonnes, as defined in Table 7.

W_{CWBT} : Weight of ballast, in tonnes, as defined in Table 7.

b_2 : Breadth, in m, as defined in Table 7.

ℓ_{tk} : Length of cargo tank, between watertight transverse bulkheads in the wing cargo tank, in m.

T_{mean} : Draught at the mid length of the tank for the loading condition considered, in m.

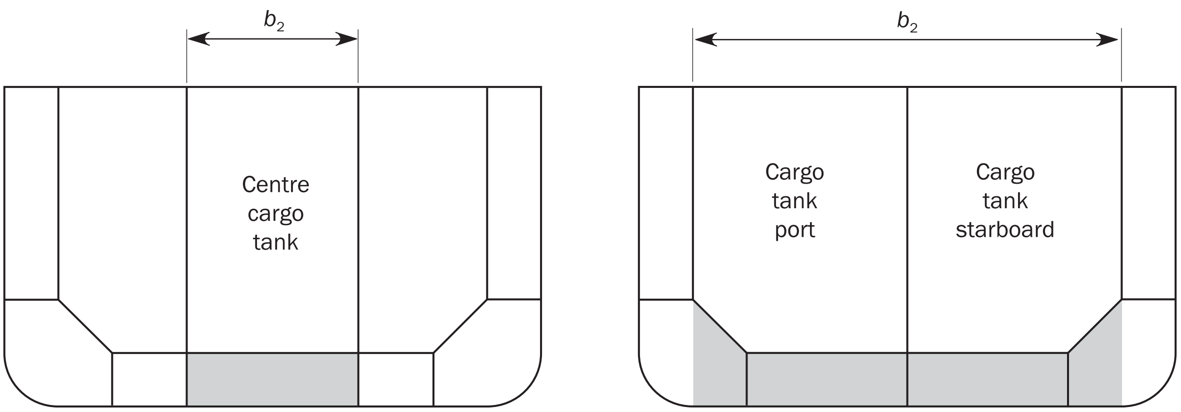
Table 6 : Minimum conditions for double bottom

Structural configuration	Positive/negative force, F_{db}	Minimum condition
Ships with centreline bulkhead	Max positive net vertical force, F_{db+}	0.9 T_{sc} and empty cargo tanks and ballast tanks
	Max negative net vertical force, F_{db-}	0.6 T_{sc} and full cargo tanks and empty ballast tanks
Ships with two longitudinal bulkheads	Max positive net vertical force, F_{db+}	0.9 T_{sc} and empty cargo tanks and ballast tanks
	Max negative net vertical force, F_{db-}	0.6 T_{sc} and full centre cargo tank and empty ballast tanks

Table 7 : Design conditions for double bottom

Structural configuration	W_{CT}	W_{CWBT}	b_2
Ships with centreline bulkhead	Weight of cargo in cargo tanks, in tonnes, using a minimum density of 1.025 t/m^3.	Weight of ballast between port and starboard inner sides, in t.	Maximum breadth between port and starboard inner sides at mid length of tank, in m, as shown in Figure 6.
Ships with two longitudinal bulkheads	Weight of cargo in the centre tank, in tonnes, using a minimum density of 1.025 t/m^3.	Weight of ballast below the centre cargo tank, in t.	Maximum breadth of the centre cargo tank at mid length of tank, in m, as shown in Figure 6.

Figure 6 : Tank breadth b_2



3.4.6 Equivalent net thickness of corrugation

The equivalent net thickness, in mm, of the corrugation of vertical and horizontal corrugated bulkheads, $t_{cor\text{-}n50}$, to be used for the calculation of the effective net shear area and for the unit shear flow, is given as follows:

$$t_{cor-n50} = \frac{t_{w-gr} + t_{f-gr}}{2} \cdot \frac{s_c}{c+a} - 0.5t_c$$

where:

$t_{w\text{-}gr}$: Gross corrugation web thickness, in mm.

$t_{f\text{-}gr}$: Gross corrugation flange thickness, in mm.

s_c : Projected length of one corrugation, in mm, as defined in Ch 3, Sec 6, Figure 21.

c : Breadth of corrugation web, in mm, as defined in Ch 3, Sec 6, Figure 21.

a : Breadth of corrugation flange, in mm, as defined in Ch 3, Sec 6, Figure 21.

3.5 Effective net thickness for longitudinal bulkheads between cargo tanks of oil tankers - Correction due to loads from transverse bulkhead stringers

3.5.1

In way of transverse bulkhead stringer connections, within areas as specified in Figure 7, the equivalent net thickness of plate, $t_{sti\text{-}k\text{-}n50}$ in mm, where the index k refers to the identification number of the stringer, is not to be taken greater than:

$$t_{sti-k-n50} = t_{sfi-n50}\left(1 - \frac{\tau_{sti-k}}{\tau_{i-perm}}\right)$$

where:

$\tau_{sti\text{-}k}$: Shear stress in plate i, in N/mm^2, in the longitudinal bulkhead due to the stringer force in way of stringer k, taken as:

$$\tau_{sti-k} = \frac{Q_{st-k}}{\ell_{st-k}\ t_{sfi-n50}}$$

$t_{sfi\text{-}n50}$: Effective net plating thickness, in mm, calculated at the transverse bulkhead for the height corresponding to the level of the stringer.

$\tau_{i\text{-}perm}$: permissible hull girder shear stress, in N/mm^2, as defined in Table 4 for the plate i.

$\ell_{st\text{-}k}$: Connection length of stringer k, in m, as defined in Figure 7.

$Q_{st\text{-}k}$: Shear force on the longitudinal bulkhead from the stringer in loaded condition with tanks abreast full in kN, taken as:

$$Q_{st-k} = 0.8\ F_{st-k}\left(1 - \frac{z_{st-k} - h_{db}}{h_{blk}}\right)$$

$F_{st\text{-}k}$: Total stringer supporting force in way of a longitudinal bulkhead, in kN, taken as:

$$F_{st-k} = \frac{P_{st-k}\ b_{st-k}(h_k + h_{k-1})}{2}$$

h_{db} : Double bottom height, in m.

h_{blk} : Height of bulkhead, in m, defined as the distance from inner bottom to the deck at the top of the bulkhead.

$z_{st\text{-}k}$: Z coordinate of the stringer k, in m.

$P_{st\text{-}k}$: Pressure on stringer k, in kN/m^2, taken as:.

$$P_{st-k} = g\ \rho_L\ h_{tt-k}$$

ρ_L : Density of the liquid in cargo tank, in t/m^3, ad defined in Ch 4, Sec 6.

$h_{tt\text{-}k}$: Height from the top of the tank to the midpoint of the load area between $h_k/2$ below and $h_{k-1}/2$ above the stringer k, in m.

h_k : Vertical distance from the considered stringer k to the stringer k+1 below. For the lowermost stringer, it is to be taken as 80% of the average vertical distance to the inner bottom, in m.

$h_{k\text{-}1}$: Vertical distance from the considered stringer k to the stringer k-1 above. For the uppermost stringer, it is to be taken as 80% of the average vertical distance to the upper deck, in m.

$b_{st\text{-}k}$: Load breadth acting on stringer k, in m, as defined in Figure 9 and Figure 10.

Figure 7 : Effective connection length of stringer

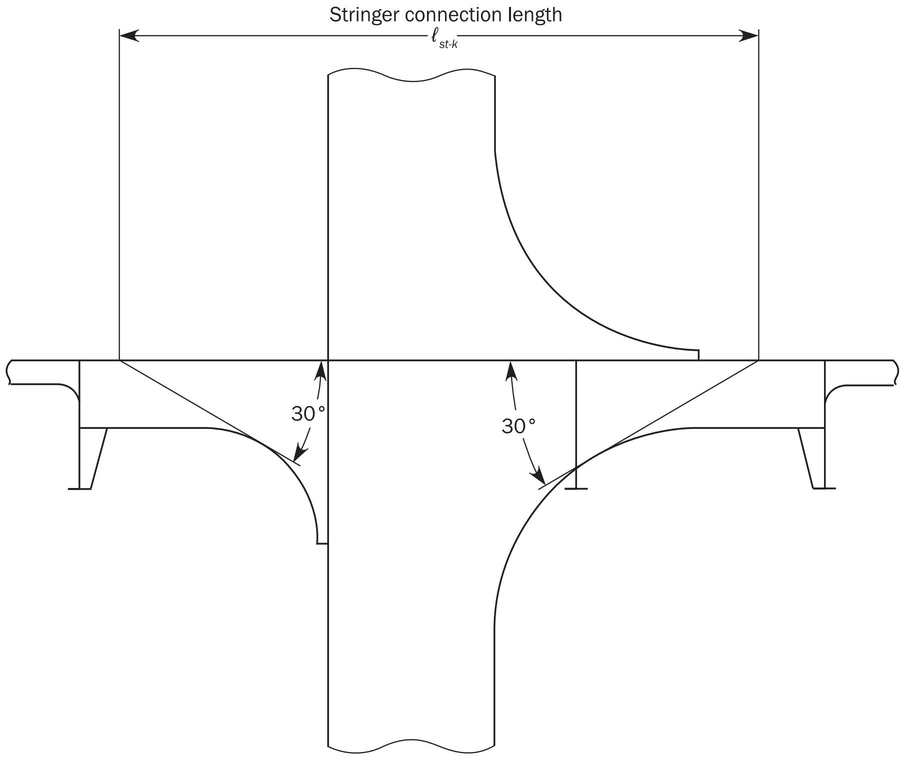


Figure 8 : Region for stringer correction, t_i, for ships with 3 stringers

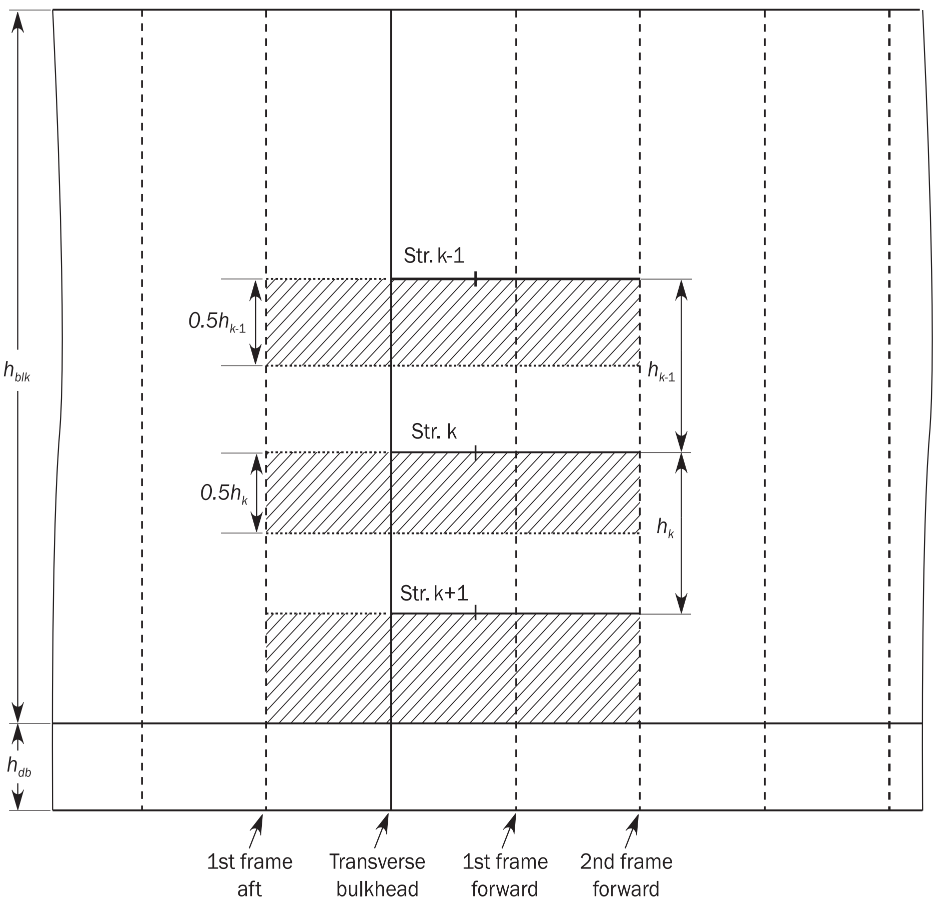


Figure 9 : Load breadth of stringers for ships with a centreline bulkhead

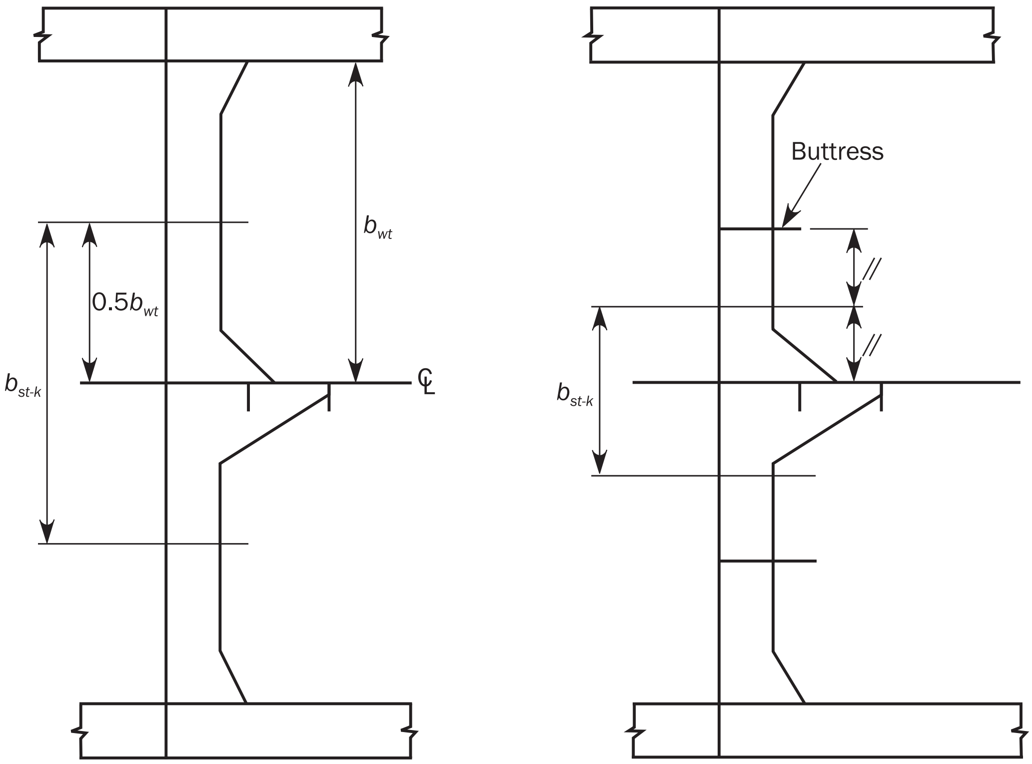
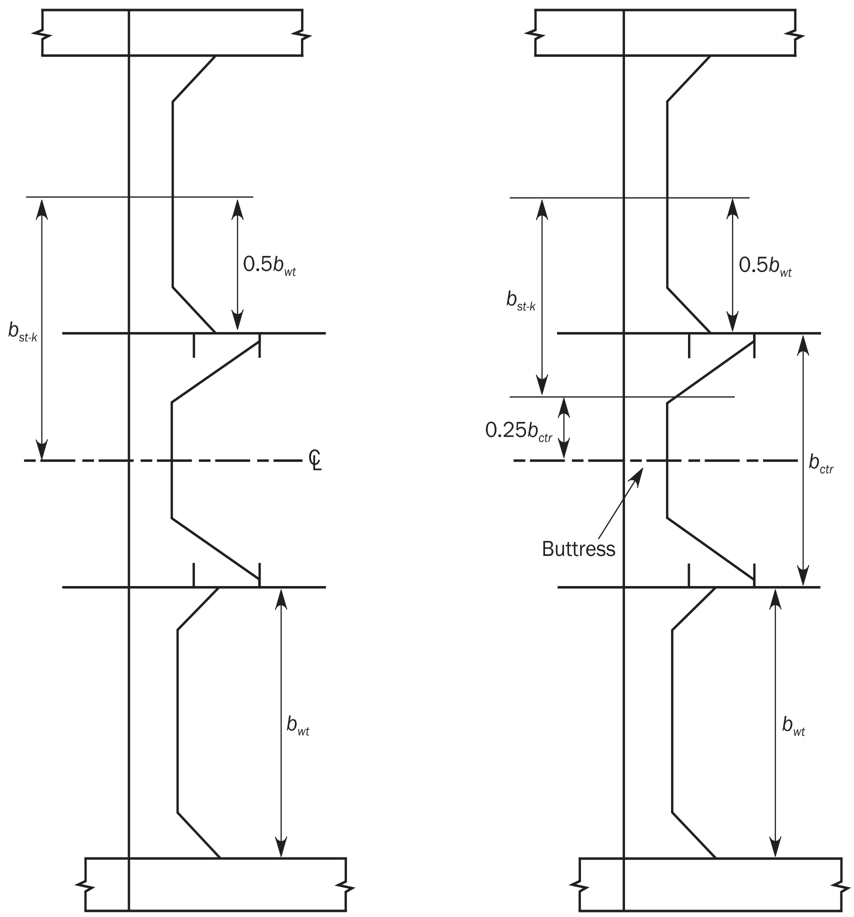


Figure 10 : Load breadth of stringers for ships with 2 inner longitudinal bulkheads



In this figure:

b_{wt} is the breadth of wing cargo tank, in m.

b_{ctr} is the breadth of centre cargo tank, in m.

3.5.2

Where reinforcement is provided to meet the above requirement, the reinforced area based on the maximum value of $t_{sti-k-n50}$ is to extend longitudinally for the full length of the stringer connection and a minimum of one frame spacing forward and aft of the bulkhead. The reinforced area is to extend vertically from above the stringer level and down to 0.5 h_k below the stringer, where h_k, the vertical distance from the considered stringer to the stringer below is as defined in [3.5.1]. For the lowermost stringer the maximum plate thickness requirement, $t_{sti-k-n50}$ is to extend down to the inner bottom, see Figure 8.

3.6 Shear force correction for bulk carriers

3.6.1

When hull girder shear strength assessment is performed in accordance with [3], shear force correction, which takes into account the portion of loads transmitted by the double bottom longitudinal girders to the transverse bulkheads, is to be considered.

For the considered cargo hold, the shear force correction at the considered transverse section is to be obtained, in kN, from the following formula:

$$\Delta Q_{mdf} = C_d \alpha \left(\frac{M}{B_H \ \ell_H} - \rho T_{LC,mh} \right)$$

where:

C_d : Distribution coefficient taken as:

- C_d = -1 at the aft end of the considered cargo hold except for aftmost cargo hold.
- C_d = 1 at the fore end of the considered cargo hold except for foremost cargo hold.
- C_d = 0 at mid-length of the cargo hold.
- C_d = 0 at the aft bulkhead of the aftmost cargo hold.
- C_d = 0 at the fore bulkhead of the foremost cargo hold.
- C_d : Linearly distributed at other locations.

α : Coefficient taken as:

$$\alpha = g \frac{\ell_0 \ b_0}{2 + \varphi \frac{\ell_0}{b_0}}$$

M : Mass, in t, in the hold in way of the considered transverse section for the considered loading condition. M is to include the mass of ballast water and fuel oil located directly below the flat portion of the inner bottom, if any, excluding the portion under the bulkhead stool.

B_H : Breadth of the cargo hold, in m, as defined in Ch 4, Sec 6.

ℓ_H : Length of the cargo hold, in m, as defined in Ch 4, Sec 6.

ℓ_0, b_0 : Length and breadth, respectively, in m, of the flat portion of the double bottom in way of the hold considered; b_0 is to be measured on the hull transverse section at the middle of the hold.

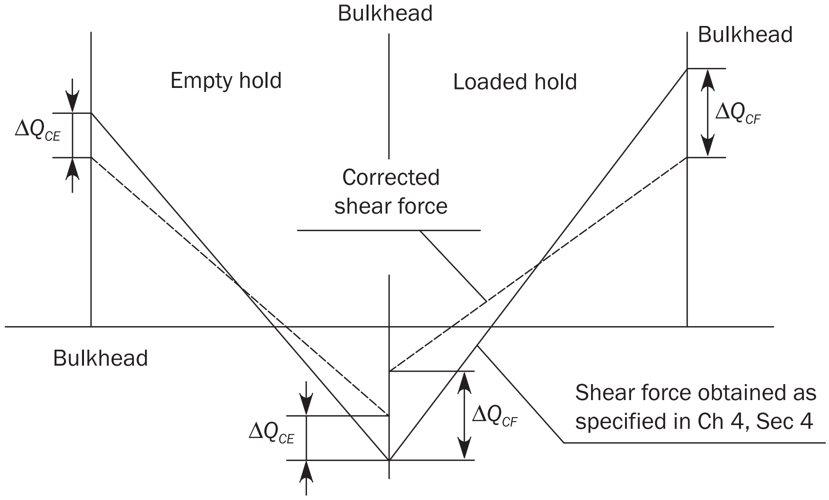
$$\varphi = 1.38 + 1.55 \frac{\ell_0}{b_0}$$, but not greater than 3.7.

$T_{LC,mh}$: Draught, in m, measured vertically on the hull transverse section at the middle of the hold considered, from the moulded baseline to the waterline in the loading condition considered.

ΔQ_{CF} : Shear force correction for the full hold.

ΔQ_{CE} : Shear force correction for the empty hold.

Figure 11 : Shear force correction, ΔQ_C



SECTION 2
HULL GIRDER ULTIMATE STRENGTH

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4

$M_{sw\text{-}h}$,$M_{sw\text{-}s}$: Permissible hogging and sagging vertical still water bending moment in intact seagoing condition, in kNm, at the hull transverse section considered, defined in Ch 4, Sec 4, [2.2.2].

$M_{sw\text{-}p\text{-}h}$, $M_{sw\text{-}p\text{-}s}$: Permissible hogging and sagging vertical still water bending moment for harbour/sheltered water operation, in kNm, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.2.3].

$M_{sw\text{-}f}$: Permissible hogging and sagging vertical still water bending moment in flooded condition at sea, in kNm, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.2.4].

1 APPLICATION

1.1 General

1.1.1

The requirements of this section apply to ships equal to or greater than 150 m in length *L*.

1.1.2

The hull girder ultimate strength is to be assessed through the cargo hold region and machinery space.

1.1.3

The hull girder ultimate bending capacity is to be checked to ensure that it satisfies the checking criteria given in [2]. Such checking criteria are applicable to intact ship structures in the following conditions:

- For bulk carriers: seagoing, harbour/sheltered water and flooded conditions.
- For oil tankers: seagoing and harbour/sheltered water conditions.

2 CHECKING CRITERIA

2.1 General

2.1.1

The vertical hull girder ultimate bending capacity is to be checked for hogging and sagging conditions, for the following design load scenarios, as defined in Table 1:

- For bulk carriers: design load scenario A, for seagoing, harbour/sheltered water and flooded conditions.
- For oil tankers: design load scenario A, for seagoing and harbour/sheltered water conditions; and design load scenario B, for the operational seagoing homogeneous full load condition.

Table 1 : Design load scenarios

Design load scenarios		Permissible still water bending moment, M_{sw-U}
A	S+D	M_{sw-h} or M_{sw-s}
	S	M_{sw-p-h} or M_{sw-p-s}
	A: S+D	M_{sw-f}
B	S+D	Maximum sagging still water bending moment for operational seagoing homogeneous full load condition (1)
(1) The maximum still water bending moment is to be taken from the departure condition with the ship homogeneously loaded at maximum draught and corresponding arrival and any mid-voyage conditions.		

2.1.2

The vertical hull girder ultimate bending capacity at any hull transverse section is to satisfy the following criteria:

$$M \le \frac{M_U}{\gamma_R}$$

where:

M : Vertical bending moment, in kNm, to be obtained as specified in [2.2.1].

M_U : Vertical hull girder ultimate bending capacity, in kNm, to be obtained as specified in [2.3].

γ_R : Partial safety factor for the vertical hull girder ultimate bending capacity to be taken equal to:

$\gamma_R = \gamma_M \gamma_{DB}$

γ_M : Partial safety factor for the vertical hull girder ultimate bending capacity, covering material, geometric and strength prediction uncertainties; in general, to be taken equal to:

$\gamma_M = 1.1$

γ_{DB} : Partial safety factor for the vertical hull girder ultimate bending capacity, covering the effect of double bottom bending, to be taken equal to:

- For hogging condition:
  - $\gamma_{DB} = 1.25$ for empty cargo holds in alternate condition of BC-A bulk carriers,
  - $\gamma_{DB} = 1.10$ for oil tankers, for BC-B and BC-C bulk carriers and loaded cargo holds in alternate condition of BC-A bulk carriers,
- For sagging condition: $\gamma_{DB} = 1.0$

2.2 Hull girder ultimate bending loads

2.2.1

The vertical hull girder bending moment, M in hogging and sagging conditions, to be considered in the ultimate strength check is to be taken as:

$$M = \gamma_S M_{sw-U} + \gamma_W M_{wv}$$

where:

M_{sw-U} : Permissible still water bending moment, in kNm, in hogging and sagging conditions at the hull transverse section considered as defined in Table 1.

M_{wv} : Vertical wave bending moment, in kNm, in hogging and sagging conditions at the hull transverse section considered as defined in Ch 4, Sec 4, [3.1].

γ_S : Partial safety factor for the still water bending moment, as defined in Table 2.

γ_W : Partial safety factor for the vertical wave bending moment, as defined in Table 2.

Table 2 : Partial safety factors

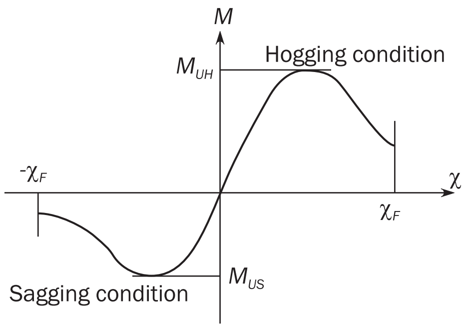
Design load scenarios	γ_S	γ_W
A	1.0	1.2
B	1.0	1.3

2.3 Hull girder ultimate bending capacity

2.3.1

The ultimate bending moment capacities of a hull girder transverse section, in hogging and sagging conditions, are defined as the maximum values of the curve of bending moment capacity versus the curvature χ of the transverse section considered (see Figure 1). The curvature χ is positive for hogging condition and negative for sagging condition.

Figure 1 : Bending moment capacity versus curvature χ



The hull girder ultimate bending capacity, M_U, is to be calculated according to Ch 5, App 2.

2.3.2

The effective area for the hull girder ultimate strength capacity assessment is specified in Ch 5, App 2.

SECTION 3
HULL GIRDER RESIDUAL STRENGTH

1 APPLICATION

1.1 General

1.1.1

The requirements of this section apply to ships equal to or greater than 150 m in length *L*.

1.1.2

The hull girder ultimate bending capacity in the damaged condition is to be checked for the seagoing condition to ensure that it satisfies the residual strength checking criteria given in [2].

1.1.3

The hull girder residual strength is to be assessed through the cargo hold region and the machinery space.

2 CHECKING CRITERIA

2.1 General

2.1.1

The vertical hull girder ultimate bending capacity in the damaged condition is to be checked for the damage conditions specified in [2.2] in hogging and sagging conditions. For the damage conditions specified in [2.2], for the design load scenario A, as defined in Table 1:

Table 1 : Design load scenarios

	Design load scenario	Permissible still water bending moment in damage, $M_{sw\text{-}D}$
Collision	A: S+D	$M_{sw\text{-}h}$ or $M_{sw\text{-}s}$
Grounding	A: S+D	$M_{sw\text{-}h}$ or $M_{sw\text{-}s}$

2.1.2

The vertical hull girder ultimate bending capacity in the damaged condition at any hull transverse section is to satisfy the following criteria:

$$M_D \le \frac{M_{UD}}{\gamma_{RD} \cdot C_{NA}}$$

where:

M_D : Vertical bending moment in the damaged condition, in kNm, to be obtained as specified in [2.3].

M_{UD} : Vertical hull girder ultimate bending capacity in the damaged condition, in kNm, to be obtained as specified in [2.4].

γ_{RD} : Partial safety factor for the vertical hull girder ultimate bending capacity in the damaged condition, to be taken equal to:
$\gamma_{RD} = 1.0$

C_{NA} : Neutral axis coefficient taken as:

- C_{NA} = 1.0 for grounding,
- C_{NA} = 1.1 for collision.

2.2 Damage conditions

2.2.1 General

The damage conditions specified for collision in [2.2.2] and for grounding in [2.2.3] are to be considered. The damage extents specified in [2.2.2] and [2.2.3] are to be measured from the moulded lines of the ship.

Plates of inner bottom and inner hull longitudinal bulkhead are to be considered intact unless the damage extent exceeds the distance from inner bottom and inner hull longitudinal bulkhead plate respectively, to the hull envelope plate.

Stiffener element is to be considered intact unless the connection of stiffener with attached plate is included in the damaged extent.

Plates and stiffeners of inner bottom and inner hull longitudinal bulkhead are to be considered intact unless the damage extent exceeds the moulded distance from inner bottom and inner hull longitudinal bulkhead plate respectively, to the hull envelope plate.

2.2.2 Collision

For the collision assessment of the considered transverse damage cross section, the damage is to be considered on one side and inclusive of the freeboard deck.

The damage for collision extends from the point of intersection of the moulded lines of deck and side:

- vertically downward for a distance h and upward without limit,
- transversally inboard for a distance d and outward without limit,

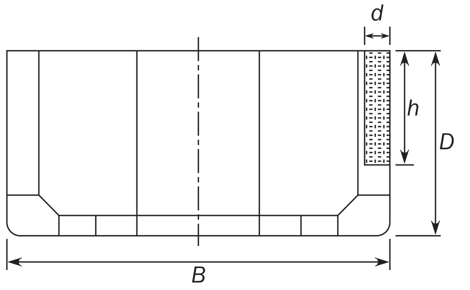
where h and d are given in Table 2 according to the side shell arrangement in the considered damage transverse section.

On ships with a rounded gunwale, the point of intersection is to be taken from the continuation of the moulded lines of deck and side.

Table 2 : Damage extent for collision

Damage penetration, in m	Side shell arrangement	
	Single side	Double side
Height, h	0.75 D	0.60 D
Depth, d	B /16	B /16

Figure 1 : Damage extent for collision



The capacity of the damaged transverse cross section is calculated with the damage extent on one side, the ship kept in upright position.

2.2.3 Grounding

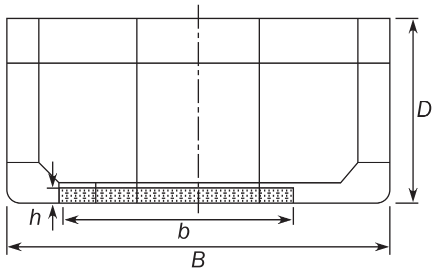
For the grounding assessment of the considered transverse damage cross section, the damage is to be considered on the bottom in the most unfavourable transversal position as regard to the structure considered by the damage.

The damage extent for grounding is given in Table 3.

Table 3 : Damage extent for grounding

Damage penetration, in m	Bulk carriers	Oil tankers
Height, h	Min (B /20, 2)	Min (B /15, 2)
Breadth, b	0.60 B	0.60 B

Figure 2 : Damage extent for grounding



2.3 Hull girder ultimate bending loads in the damaged condition

2.3.1

The vertical bending moment, M_D in hogging and sagging conditions, to be considered in the ultimate strength check of the hull girder in the damaged condition, is to be obtained from the following formula:

$$M_D = \gamma_{SD} M_{sw-D} + \gamma_{WD} M_{wv}$$

where:

M_{sw-D} : Permissible still water bending moment, in kNm, in hogging and sagging conditions at the hull transverse section considered, as defined in Table 1.

M_{wv} : Vertical wave bending moment, in kNm, in hogging and sagging conditions at the hull transverse section considered, as defined in Ch 4, Sec 4, [3.1].

γ_{SD} : Partial safety factor for the still water bending moment in the damaged condition, to be taken equal to:
$\gamma_{SD} = 1.1$

γ_{WD} : Partial safety factor for the vertical wave bending moment in the damaged condition, to be taken equal to:
$\gamma_{WD} = 0.67$

2.4 Hull girder ultimate bending capacity in the damaged condition

2.4.1

The hull girder ultimate bending capacity in the damaged condition is to be calculated according to Ch 5, App 2, with the damaged parts assumed not to contribute to the hull girder strength. When assessing the ultimate bending capacity, M_{UD} of the damaged hull sections, damaged area as defined in [2.2] carries no loads and is to be removed in the capacity model.

2.4.2

The effective area of the intact parts for the hull girder ultimate strength capacity assessment is specified in Ch 5, App 2.

APPENDIX 1
DIRECT CALCULATION OF SHEAR FLOW

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

1 CALCULATION FORMULA

1.1 General

1.1.1

This appendix describes the procedures of direct calculation of shear flow which is working along a ship cross section due to hull girder vertical shear force. Shear flow q_v, at each location in the cross section, is calculated where considering the cross section is subjected to a unit vertical shear force, 1 N, in the direction of z coordinate.

The unit shear flow per mm, q_v in N/mm, can be considered equal to:

$$q_v = q_D + q_I$$

where:

q_D : Determinate shear flow, as defined in [1.2].

q_I : Indeterminate shear flow which circulates around the closed cells, as defined in [1.3].

In the calculation of the unit shear flow, q_v, the longitudinal stiffeners are to be taken into account.

1.2 Determinate shear flow

1.2.1

The determinate shear flow, q_D in N/mm, at each location in the cross section can be obtained from the following line integration:

$$q_D\,(S) = -\frac{1}{10^6\ I_{y-n50}}\int_0^s (z - z_n)\ t_{n50}ds$$

where:

s : Coordinate value of running coordinate along the cross section, in m.

I_{y-n50} : Moment inertia of the cross section, in m^4.

t_{n50} : Net thickness of plating, in mm, or equivalent net thickness of corrugated plate as defined in Ch 5, Sec 1, [3.4.6].

1.2.2

Assuming the cross section is composed of line segments as shown in Figure 1, the determinate shear flow can be calculated by the following equation.

$$q_{Dk} = q_D(\ell) = -\frac{t_{n50}\ell}{2\times10^6\ I_{y-n50}}(z_k + z_i - 2z_n) + q_{Di}$$

where:

q_{Dk}, q_{Di} : Determinate shear flow at node k and node i respectively, in N/mm.

ℓ : Length of line segments, in m.

z_k, z_i : Z coordinate of the end point of line segment, in m, as defined in Figure 1.

1.2.3

Where the cross section includes closed cells, the closed cell are to be cut with virtual slits, as shown in Figure 2 in order to obtain the determinate shear flow.

However, the virtual slits must not be located at the walls by which the other closed cell is also bounded.

1.2.4

Calculations of the determinate shear flow at bifurcation points can be calculated such as water flow calculations as shown in Figure 3.

Figure 1 : Definition of line segment

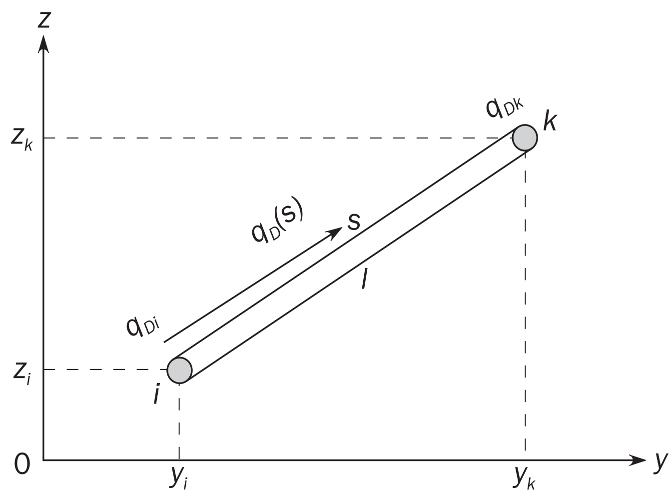
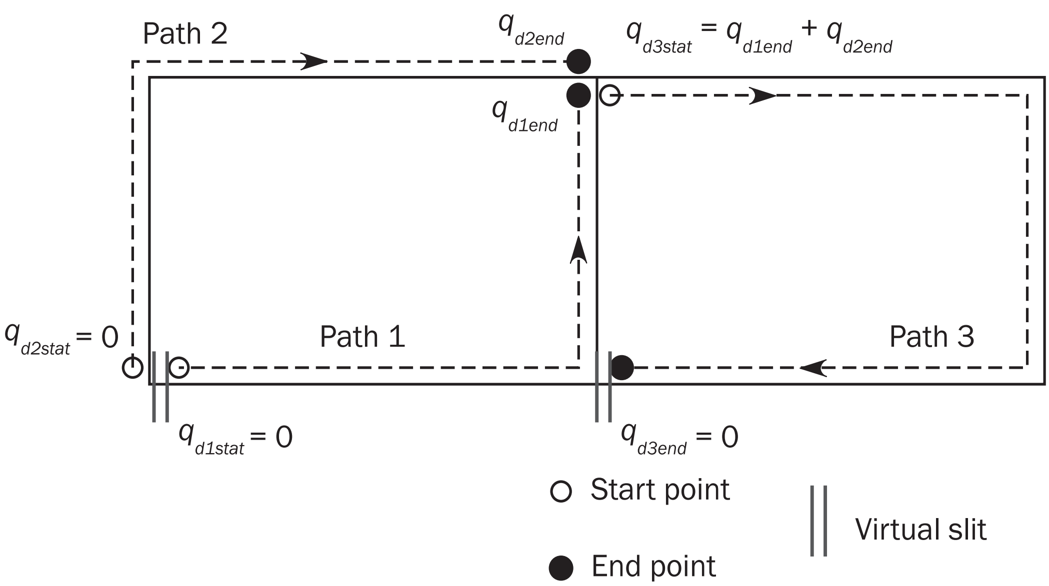


Figure 2 : Calculation of determinate shear flow at bifurcation



1.3 Indeterminate shear flow

1.3.1

The indeterminate shear flow is working around the closed cells and can be considered as a constant value within the same closed cell. The following system of equation for determination of indeterminate shear flows can be developed. In the equations, contour integrations of several parameters around all closed cells are performed.

$$q_{Ik} \oint_k \frac{1}{t_{n50}}\, ds - \sum_i q_{Ii} \oint_{k,i} \frac{1}{t_{n50}}\, ds = -\oint_k \frac{q_D}{t_{n50}}\, ds$$

where:

q_{Ik}, q_{Ii} : Indeterminate shear flow around the closed cell *k* and *i* respectively, in N/mm.

1.3.2

With assuming assembly of line segments shown in Figure 1, the equations in [1.3.1] can be expressed as follows:

$$q_{Ik} \sum_{cell\,k} \frac{\ell}{t_{n50}} - \sum_i q_{Ii} \left(\frac{\ell}{t_{n50}}\right)\Bigg|_{common\ wall\ with\ cell\,k} = -\sum_{cell\,k} \phi$$

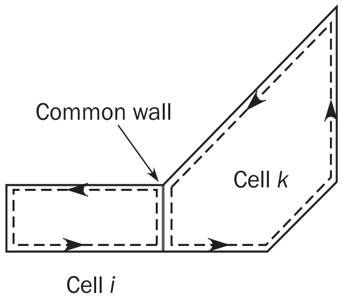
$$\phi = \int_0^{\ell} \frac{q_D(s)}{t_{n50}}\, ds = -\frac{\ell^2}{6 \times 10^3\, I_{y-n50}}\,(z_k + 2z_i - 3z_n) + \frac{\ell}{t_{n50}}\, q_{Di}$$

where:

q_{Di} : Determinate shear flow, in N/mm, calculated according to [1.2.2].

The difference in the directions of running coordinates specified in [1.2] and this sub-article is to be considered.

Figure 3 : Closed cells and common wall



1.4 Computation of several properties of the cross section

1.4.1

Properties of the cross section can be obtained by the following formulae where the cross section is assumed as the assembly of line segments:

$$\ell = \sqrt{(y_k - y_i)^2 + (z_k - z_i)^2}$$

$$a_{n50} = 10^{-3}\, \ell t_{n50} \qquad A_{n50} = \sum a_{n50}$$

$$s_{y-n50} = \frac{a_{n50}}{2}\,(z_k + z_i) \qquad S_{y-n50} = \sum s_{y-n50}$$

$$i_{y0-n50} = \frac{a_{n50}}{3}\,(z_k^2 + z_k z_i + z_i^2) \qquad I_{y0-n50} = \sum i_{y0-n50}$$

where:

a_{n50}, A_{n50}: Area of the line segment and the cross section respectively, in m^2.

$s_{y\text{-}n50}$, $S_{y\text{-}n50}$: First moment of the line segment and the cross section about the baseline, in m^3.

$i_{y0\text{-}n50}$, $I_{y0\text{-}n50}$: Moment inertia of the line segment and the cross section about the baseline, in m^4.

1.4.2

The height of horizontal neutral axis, z_G in m, can be obtained as follows:

$$z_G = \frac{S_{y-n50}}{A_{n50}}$$

1.4.3

Inertia moment about the horizontal neutral axis, in m^4, can be calculated as follows:

$$I_{y-n50} = I_{y0-n50} - z_n^2 A_{n50}$$

2 EXAMPLE OF CALCULATIONS FOR A SINGLE SIDE HULL CROSS SECTION

2.1 Cross section data

2.1.1

The cross section is shown in Figure 4. The coordinates of the node points marked by filled black circles in Figure 4 are given in Table 1, where the plate thickness and the line segments (marked by circles in Figure 4) of the cross section are given in Table 2.

The sample calculations are performed taking advantage of symmetry of the cross section.

Table 1 : Node coordinates of cross section

Node number	*Y* coordinate (m)	*Z* coordinate (m)
0	0.00	0.00
1	5.80	0.00
2	11.70	0.00
3	14.42	0.00
4	16.13	1.72
5	16.13	6.11
6	11.70	1.68
7	5.80	1.68
8	0.00	1.68
9	16.13	14.15
10	16.13	19.60
11	7.50	20.25
12	7.50	19.63

Table 2 : Calculation of cross sectional properties

Line no.	Node i	Node k	Thickness (mm)	Length (m)	a_{n50} (m^2)	$s_{y\text{-}n50}$ (m^3)	$i_{y0\text{-}n50}$ (m^4)
1	0	1	17.0	5.80	0.099	0.000	0.00
2	1	2	17.0	5.90	0.100	0.000	0.00
3	2	3	17.0	2.72	0.046	0.000	0.00
4	3	4	17.0	2.43	0.041	0.035	0.04
5	4	5	18.0	4.39	0.079	0.309	1.34
6	5	6	19.0	6.26	0.119	0.464	2.00
7	6	7	21.0	5.90	0.124	0.208	0.35
8	7	8	21.0	5.80	0.122	0.205	0.34
9	5	9	18.0	8.04	0.145	1.466	15.63
10	9	10	21.0	5.45	0.114	1.931	32.87
11	10	11	24.0	8.65	0.208	4.139	82.47
12	11	12	24.0	0.62	0.015	0.297	5.92
13	12	9	15.0	10.22	0.153	2.590	44.13
14	2	6	15.0	1.68	0.025	0.021	0.02
15	1	7	15.0	1.68	0.025	0.021	0.02
				Total	1.416	11.686	185.138

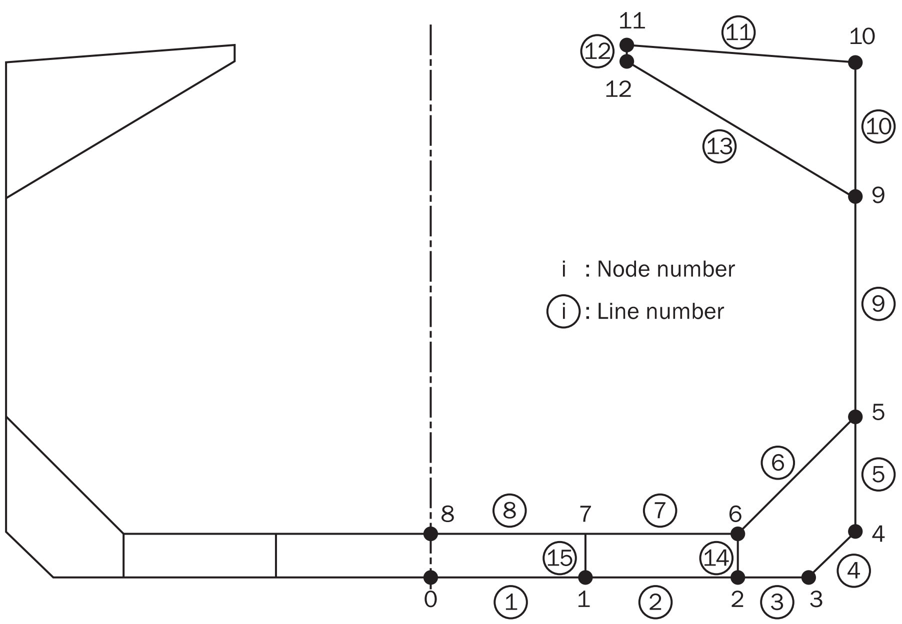
2.1.2

The Z coordinate of horizontal neutral axis and the inertia moment about the neutral axis are calculated as follow:

$$z_G = \frac{\sum s_{y-n50}}{\sum a_{n50}} = \frac{11.686}{1.416} = 8.255$$

$$I_{y-n50} = 2\left(\sum i_{y0-n50} - z_n^2 \sum a_{n50}\right) = 2(185.138 - 8.255^2 \times 1.416) = 177.34$$

Figure 4 : Numbering of nodes and lines



2.2 Calculations of the determinate shear flow

2.2.1

The virtual slits are added to cut the walls of the closed cells as shown in Figure 5. And then, the line integrations specified in [1.2.2] are performed to obtain determinate shear flow, q_D. The calculation results are shown in Table 3. The locations of the virtual slits and the paths of line integrations shown in Figure 5 are one such example. These definitions can be arbitrarily determined so as to calculate them easily.

Figure 5 : Ranges and directions of paths for line integrations

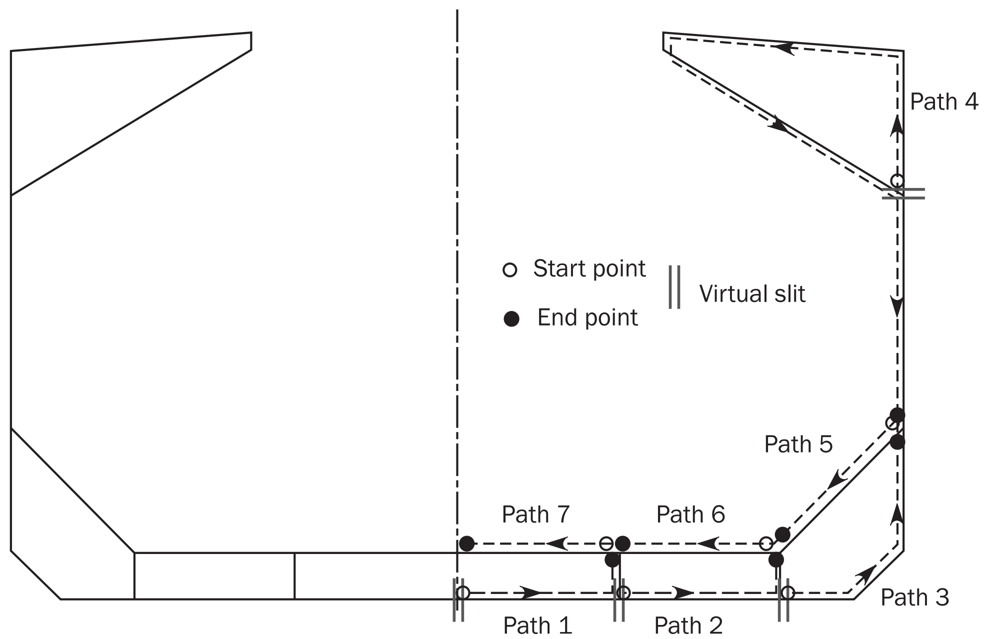


Table 3 : Calculation of determinate shear flow

Path no.	Line no.	Node i	Node k	q_{Di}×10^{-6} (N/mm)	q_{Dk}×10^{-6} (N/mm)	Note
1	1	0	1	0.0	4.6	Start from the virtual slit
	15	1	7	4.6	5.6	-
2	2	1	2	0.0	4.7	Start from the virtual slit
	14	2	6	4.7	5.7	-
3	3	2	3	0.0	2.2	Start from the virtual slit
	4	3	4	2.2	3.9	-
	5	4	5	3.9	5.8	-
4	10	9	10	0.0	-5.6	Start from the virtual slit
	11	10	11	-5.6	-19.2	-
	12	11	12	-19.2	-20.2	-
	13	12	9	-20.2	-27.7	-
	9	9	5	-27.7	-29.2	-
5	6	5	6	-23.4	-20.5	Start with the sum of q_{DK} at the ends of path 3 & 4
6	7	6	7	-14.8	-10.2	Start with the sum of q_{DK} at the ends of path 2 & 5
7	8	7	8	-4.5	0.0	Start with the sum of q_{DK} at the ends of path 1 & 6

2.3 Calculations of the indeterminate shear flow

2.3.1

To obtain the system of equations for indeterminate shear flows, the contour integrations around 3 closed cells as defined in Figure 6 are performed. The closed cell at the centre of double bottom is considered as an open shape since the symmetrical condition of the cross section is considered. The calculation results of contour integrations around the closed cells are shown in Table 4 to Table 6.

Table 4 : Contour integration of ℓ/t_{n50} and ϕ around cell 1

Line no.	Node *i*	Node *k*	q_{Di}×10^{-6} (N/mm)	ℓ/t_{n50}	ϕ×10^{-3} (N/mm)	Note
2	1	2	0.0	347.1	0.81	-
14	2	6	4.7	112.0	0.58	Common wall with cell 2
7	6	7	-14.8	281.0	-3.50	-
15	7	1	-5.6	112.0	-0.58	-
			Total	852.0	-2.68	-

Table 5 : Contour integration of ℓ/t_{n50} and ϕ around cell 2

Line no.	Node *i*	Node *k*	q_{Di}×10^{-6} (N/mm)	ℓ/t_{n50}	ϕ×10^{-3} (N/mm)	Note
3	2	3	0.0	160.0	0.17	-
4	3	4	2.2	142.7	0.43	-
5	4	5	3.9	243.9	1.22	-
6	5	6	-23.4	329.7	-7.32	-
14	6	2	-5.7	112.0	-0.58	Common wall with cell 1
			Total	988.3	-6.07	-

Table 6 : Contour integration of ℓ/t_{n50} and ϕ around cell 3

Line no.	Node *i*	Node *k*	q_{Di}×10^{-6} (N/mm)	ℓ/t_{n50}	ϕ×10^{-3} (N/mm)	Note
10	9	10	0.0	259.5	-0.65	-
11	10	11	-5.6	360.6	-4.45	-
12	11	12	-19.2	25.8	-0.51	-
13	12	9	-20.2	681.5	-16.59	-
			Total	1327.5	-22.19	-

2.3.2

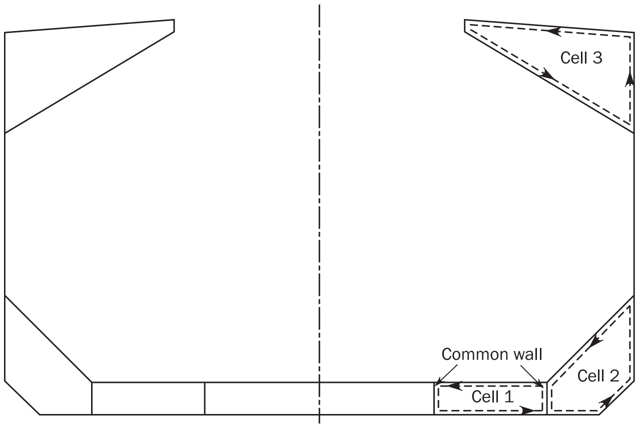
The following system of equations can be developed by using the results of the contour integration around each closed cell:

- Cell 1: $852.0\, q_{I1} - 112.0\, q_{I2} = 2.68 \times 10^{-3}$
- Cell 2: $-112.0\, q_{I1} + 988.3\, q_{I2} = 6.07 \times 10^{-3}$
- Cell 3: $1327.5\, q_{I3} = 2.219 \times 10^{-2}$

The solution of this system gives indeterminate shear flows of the closed cell 1 to 3:

$q_{I1} = 4.01 \times 10^{-6}$, $q_{I2} = 6.60 \times 10^{-6}$, $q_{I3} = 1.67 \times 10^{-5}$

Figure 6 : Numbering of closed cells

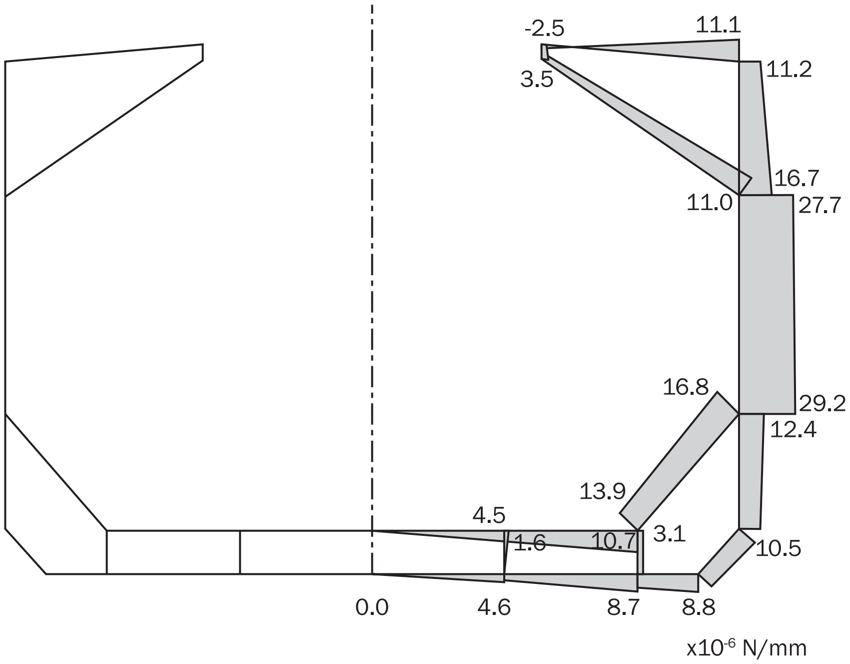


2.4 Summation

2.4.1

The shear flow q_v, at all locations of the cross section can be obtained by the summation of determinate shear flow, q_D and indeterminate shear flow, q_I as shown in Figure 7.

Figure 7 : Calculation results of shear flow q_v, in 10^{-6} N/mm for vertical shear force with 1 N



APPENDIX 2
HULL GIRDER ULTIMATE CAPACITY

SYMBOLS

For symbols not defined in this article, refer to Ch 1, Sec 4.

I_{y-n50} : Moment of inertia, in m^4, of the hull transverse section around its horizontal neutral axis, to be calculated according to Ch 5, Sec 1.

Z_{B-n50}, Z_{D-n50} : Section moduli, in m^3, at bottom and deck, respectively, defined in Ch 5, Sec 1.

R_{eHs} : Minimum yield stress, in N/mm^2, of the material of the considered stiffener.

R_{eHp} : Minimum yield stress, in N/mm^2, of the material of the considered plate.

A_{s-n50} : Net sectional area, in cm^2, of stiffener, without attached plating.

A_{p-n50} : Net sectional area, in cm^2, of attached plating.

1 GENERAL

1.1 Application

1.1.1

This appendix provides the criteria for obtaining the following ultimate longitudinal bending moment capacities:

- M_U to be used in the hull girder ultimate capacity check according to Ch 5, Sec 2,
- M_{UD} to be used in the hull girder residual strength capacity check according to Ch 5, Sec 3

1.1.2

The hull girder ultimate longitudinal bending moment capacity, M_U or M_{UD}, is defined as the maximum bending capacity of the hull girder beyond which the hull structure collapses. Hull girder failure is controlled by buckling, ultimate strength and yielding of longitudinal structural elements.

1.2 Methods

1.2.1 Incremental-iterative method

The hull girder ultimate bending capacity is to be assessed by the incremental-iterative method defined in [2].

1.2.2 Alternative methods

Principles for alternative methods for the calculation of the hull girder ultimate bending capacity; e.g. non-linear finite element analysis, are given in [3].

Application of alternative methods is to be agreed by the Society prior to commencement. Documentation of the analysis methodology and detailed comparison of its results are to be submitted for review and acceptance. The use of such methods may require the partial safety factors to be recalibrated.

1.3 Assumptions

1.3.1

The method for calculating the ultimate hull girder capacity is to identify the critical failure modes of all main longitudinal structural elements.

1.3.2

Structures compressed beyond their buckling limit have reduced load carrying capacity. All relevant failure modes for individual structural elements, such as plate buckling, torsional stiffener buckling, stiffener web buckling, lateral or global stiffener buckling; and their interactions, are to be considered in order to identify the weakest inter-frame failure mode.

1.3.3

Only vertical bending is considered. The effects of shear force, torsional loading, horizontal bending moment and lateral pressure are neglected.

1.3.4

For the calculation of the ultimate longitudinal bending moment capacity, M_{UD}, used in the hull girder residual strength check according to Ch 5, Sec 3, the structural members in way of the damage part are to be excluded from the members participating to the considered cross section strength.

2 INCREMENTAL-ITERATIVE METHOD

2.1 Assumptions

2.1.1

In applying the procedure described in [2.2], the following assumptions are generally to be made:

- The ultimate strength is calculated at hull transverse sections between two adjacent transverse webs.
- The hull girder transverse section remains plane during each curvature increment.
- The hull material has an elasto-plastic behaviour.
- The hull girder transverse section is divided into a set of elements, which are considered to act independently.

These elements are:

- Transversely framed plating panels and/or stiffeners with attached plating, whose structural behaviour is described in [2.3.1].
- Hard corners, constituted by plating crossing, whose structural behaviour is described in [2.3.2].
- According to the iterative procedure, the bending moment M_i acting on the transverse section at each curvature value χ_i is obtained by summing the contribution given by the stress σ acting on each element. The stress σ corresponding to the element strain, ε is to be obtained for each curvature increment from the non-linear load-end shortening curves σ-ε of the element.

These curves are to be calculated, for the failure mechanisms of the element, from the formulae specified in [2.2]. The stress, σ is selected as the lowest among the values obtained from each of the considered load-end shortening curves σ-ε.

The procedure is to be repeated until the value of the imposed curvature reaches the value χ_F in m^{-1}, in hogging and sagging condition, obtained from the following formula:

$$\chi_F = \pm 0.003 \frac{M_Y}{EI_{y-n50}}$$

where:

M_Y : Lesser of the values M_{Y1} and M_{Y2}, in kNm.

$M_{Y1} = 10^3\, R_{eH}\, Z_{B\text{-}n50}$.

$M_{Y2} = 10^3\, R_{eH}\, Z_{D\text{-}n50}$.

If the value χ_F is not sufficient to evaluate the peaks of the curve M-χ, the procedure is to be repeated until the value of the imposed curvature permits the calculation of the maximum bending moments of the curve.

2.2 Procedure

2.2.1 General

The curve M-χ is to be obtained by means of an incremental-iterative approach, summarised in the flow chart in Figure 1.

In this procedure, the ultimate hull girder bending moment capacity, M_U is defined as the peak value of the curve with vertical bending moment M versus the curvature χ of the ship cross section as shown in Figure 1. The curve is to be obtained through an incremental-iterative approach.

Each step of the incremental procedure is represented by the calculation of the bending moment M_i which acts on the hull transverse section as the effect of an imposed curvature χ_i.

For each step, the value χ_i is to be obtained by summing an increment of curvature, $\Delta\chi$ to the value relevant to the previous step χ_{i-1}. This increment of curvature corresponds to an increment of the rotation angle of the hull girder transverse section around its horizontal neutral axis.

This rotation increment induces axial strains, ε in each hull structural element, whose value depends on the position of the element. In hogging condition, the structural elements above the neutral axis are lengthened, while the elements below the neutral axis are shortened, and vice-versa in sagging condition.

The stress σ induced in each structural element by the strain ε is to be obtained from the load-end shortening curve σ-ε of the element, which takes into account the behaviour of the element in the non-linear elasto-plastic domain.

The distribution of the stresses induced in all the elements composing the hull transverse section determines, for each step, a variation of the neutral axis position, since the relationship σ-ε is non-linear. The new position of the neutral axis relevant to the step considered is to be obtained by means of an iterative process, imposing the equilibrium among the stresses acting in all the hull elements.

Once the position of the neutral axis is known and the relevant stress distribution in the section structural elements is obtained, the bending moment of the section M_i around the new position of the neutral axis, which corresponds to the curvature χ_i imposed in the step considered, is to be obtained by summing the contribution given by each element stress.

The main steps of the incremental-iterative approach described above are summarised as follows (see also Figure 1):

a) Step 1: Divide the transverse section of hull into stiffened plate elements.

b) Step 2: Define stress-strain relationships for all elements as shown in Table 1.

c) Step 3: Initialise curvature χ_1 and neutral axis for the first incremental step with the value of incremental curvature (i.e. curvature that induces a stress equal to 1% of yield strength in strength deck) as:

$$\chi_1 = \Delta\chi = 0.01\frac{R_{eH}}{E}\frac{1}{z_D - z_n}$$

where:

z_D : Z coordinate, in m, of strength deck at side, with respect to reference coordinate defined in Ch 1, Sec 4, [3.6]

d) Step 4: Calculate for each element the corresponding strain, $\varepsilon_i = \chi\ (z_i - z_n)$ and the corresponding stress σ_i.

e) Step 5: Determine the neutral axis z_{NA_cur} at each incremental step by establishing force equilibrium over the whole transverse section as:

$\Sigma A_{i\text{-}n50}\, \sigma_i = \Sigma A_{j\text{-}n50}\, \sigma_j$ (i-th element is under compression, j-th element under tension).

f) Step 6: Calculate the corresponding moment by summing the contributions of all elements as:

$$M_U = \sum \sigma_{Ui}\, A_{i-n50}\, \left|(z_i - z_{NA\_cur})\right|$$

g) Step 7: Compare the moment in the current incremental step with the moment in the previous incremental step. If the slope in M-χ relationship is less than a negative fixed value, terminate the process and define the peak value of M_U. Otherwise, increase the curvature by the amount of $\Delta\chi$ and go to Step 4.

2.2.2 Modelling of the hull girder cross section

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder ultimate strength.

Sniped stiffeners are also to be modelled, taking account that they do not contribute to the hull girder strength.

The structural members are categorised into a stiffener element, a stiffened plate element or a hard corner element.

The plate panel including web plate of girder or side stringer is idealised into either a stiffened plate element, an attached plate of a stiffener element or a hard corner element.

The plate panel is categorised into the following two kinds:

- Longitudinally stiffened panel of which the longer side is in the longitudinal direction, and
- Transversely stiffened panel of which the longer side is in the perpendicular direction to the longitudinal direction.

a) Hard corner element:

Hard corner elements are sturdier elements composing the hull girder transverse section, which collapse mainly according to an elasto-plastic mode of failure (material yielding); they are generally constituted by two plates not lying in the same plane.

The extent of a hard corner element from the point of intersection of the plates is taken equal to 20 t_{n50} on transversely stiffened panel and to 0.5 s on a longitudinally stiffened panel, see Figure 2.

where:

t_{n50} : Net offered thickness of the plate, in mm.

s : Spacing of the adjacent longitudinal stiffener, in m.

Bilge, sheer strake-deck stringer elements, girder-deck connections and face plate-web connections on large girders are typical hard corners.

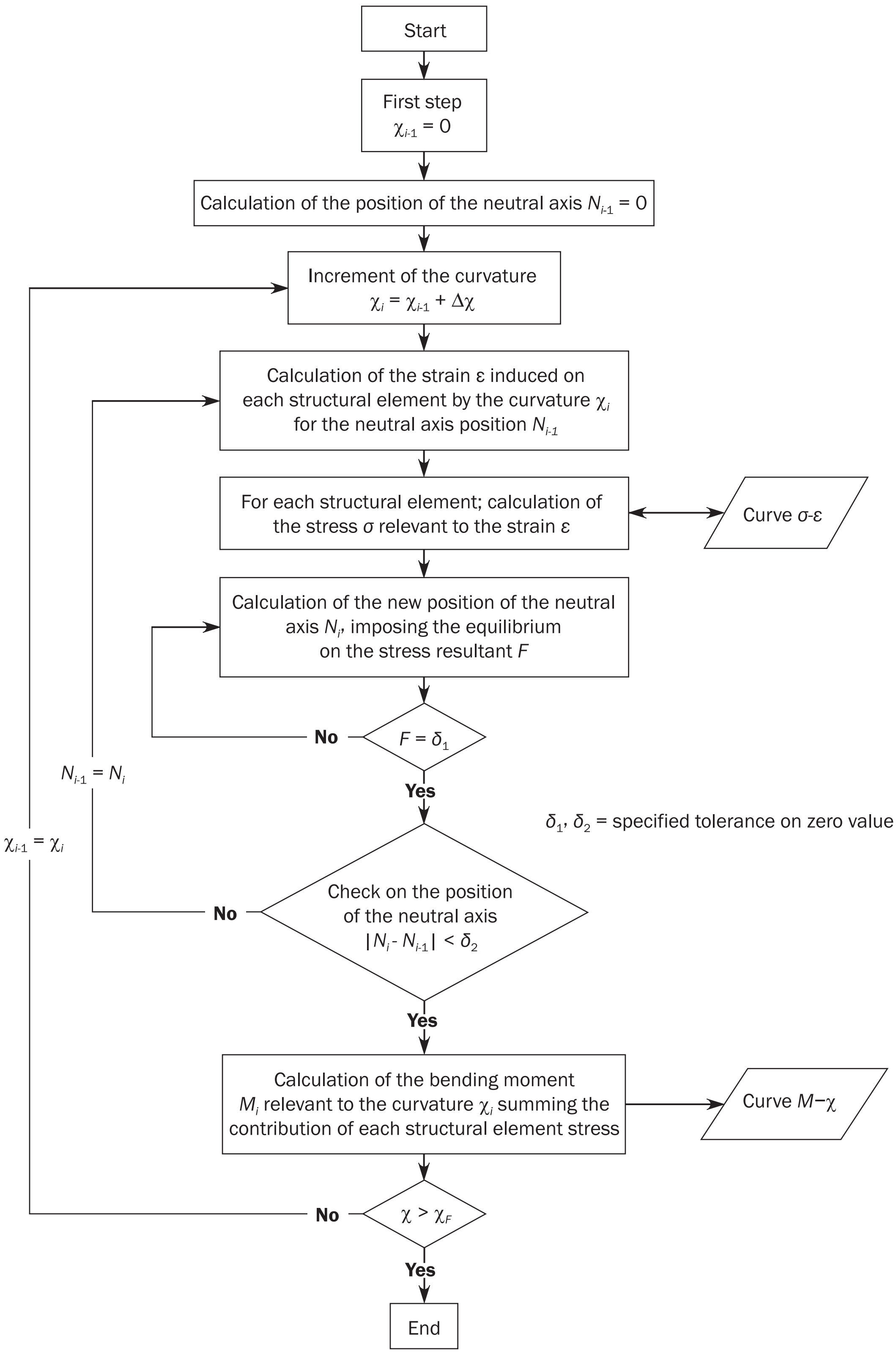
b) Stiffener element:

The stiffener constitutes a stiffener element together with the attached plate.

The attached plate width is in principle:

- Equal to the mean spacing of the stiffener when the panels on both sides of the stiffener are longitudinally stiffened, or
- Equal to the width of the longitudinally stiffened panel when the panel on one side of the stiffener is longitudinally stiffened and the other panel is of the transversely stiffened, see Figure 2.

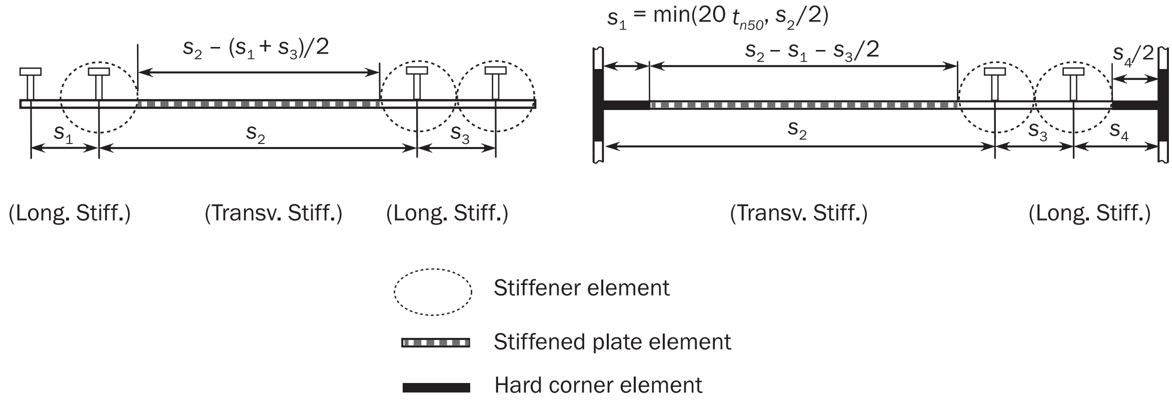
Figure 1 : Flow chart of the procedure for the evaluation of the curve *M*-χ



c) Stiffened plate element:

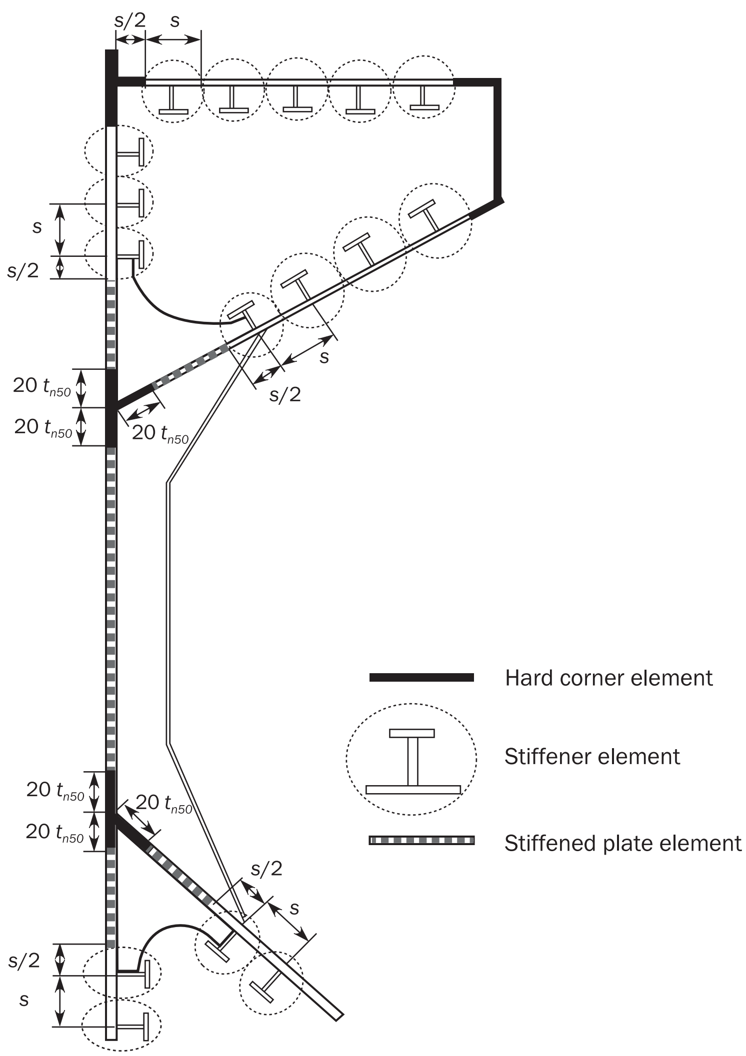
The plate between stiffener elements, between a stiffener element and a hard corner element or between hard corner elements is to be treated as a stiffened plate element, see Figure 2.

Figure 2 : Extension of the breadth of the attached plating and hard corner element



The typical examples of modelling of hull girder section are illustrated in Figure 3 and Figure 4. Notwithstanding the foregoing principle, these figures are to be applied to the modelling in the vicinity of upper deck, sheer strake and hatch side girder.

Figure 3 : Examples of the configuration of stiffened plate elements, stiffener elements and hard corner elements on a hull section



- In case of the knuckle point as shown in Figure 5, the plating area adjacent to knuckles in the plating with an angle greater than 30 deg is defined as a hard corner. The extent of one side of the corner is taken equal to 20 t_{n50} on transversely framed panels and to 0.5 *s* on longitudinally framed panels from the knuckle point.
- Where the plate members are stiffened by non-continuous longitudinal stiffeners, the non-continuous stiffeners are considered only as dividing a plate into various elementary plate panels.
- Where the opening is provided in the stiffened plate element, the openings are to be considered in accordance with Ch 5, Sec 1, [1.2.9].
- Where attached plating is made of steels having different thicknesses and/or yield stresses, an average thickness and/or average yield stress obtained from the following formula are to be used for the calculation.

$$t_{n50} = \frac{t_{1-n50}s_1 + t_{2-n50}s_2}{s} \qquad R_{eHp} = \frac{R_{eHp1}\, t_{1-n50}\, s_1 + R_{eHp2}\, t_{2-n50}\, s_2}{t_{n50}s}$$

where R_{eHp1}, R_{eHp2}, $t_{1\text{-}n50}$, $t_{2\text{-}n50}$, s_1, s_2 and s are shown in Figure 6.

Figure 4 : Extension of the breadth of the attached plating and hard corner element

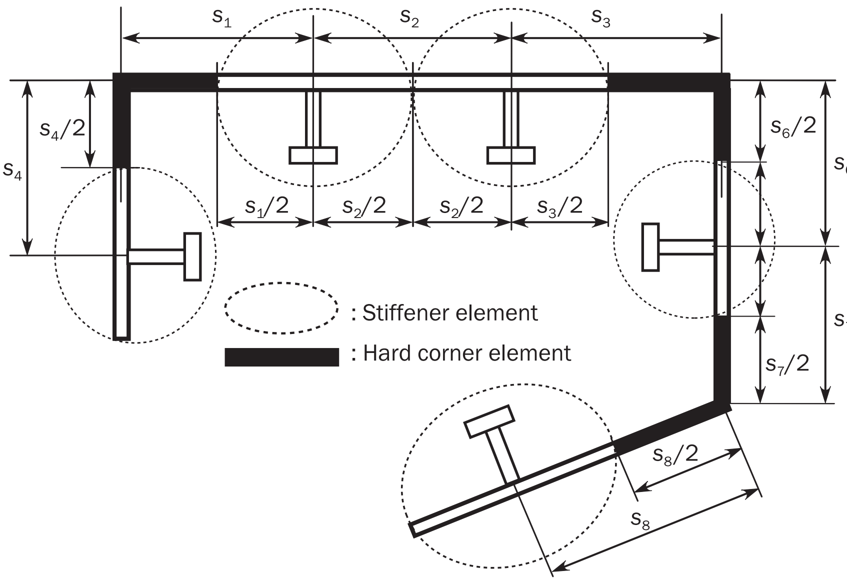


Figure 5 : Plating with knuckle point

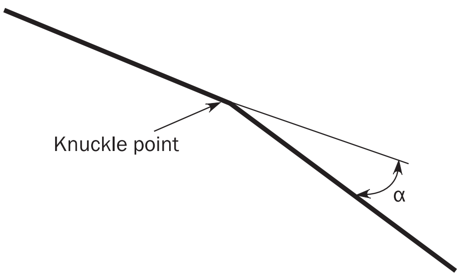
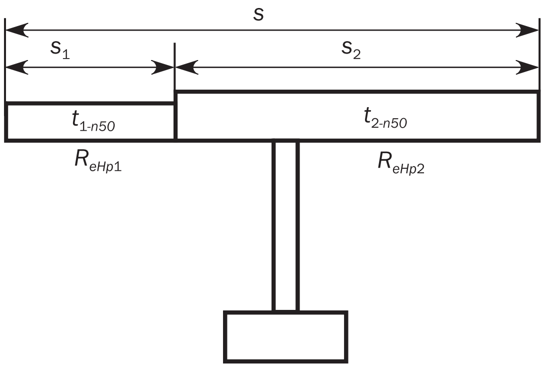


Figure 6 : Element with different thickness and yield strength



PART 1 CHAPTER 5 APPENDIX 2

2.3 Load-end shortening curves

2.3.1 Stiffened plate element and stiffener element

Stiffened plate element and stiffener element composing the hull girder transverse sections may collapse following one of the modes of failure specified in Table 1.

- Where the plate members are stiffened by non-continuous longitudinal stiffeners, the stress of the element is to be obtained in accordance with [2.3.3] to [2.3.8], taking into account the non-continuous longitudinal stiffener.

In calculating the total forces for checking the hull girder ultimate strength, the area of non-continuous longitudinal stiffener is to be assumed as zero.

- Where the opening is provided in the stiffened plate element, the considered area of the stiffened plate element is to be obtained by deducting the opening area from the plating in calculating the total forces for checking the hull girder ultimate strength. The consideration of the opening is in accordance with the requirement in Ch 5, Sec 1, [1.2.9].
- For stiffened plate element, the effective width of plate for the load shortening portion of the stress-strain curve is to be taken as full plate width, i.e. to the intersection of other plate or longitudinal stiffener – neither from the end of the hard corner element nor from the attached plating of stiffener element, if any. In calculating the total forces for checking the hull girder ultimate strength, the area of the stiffened plate element is to be taken between the hard corner element and the stiffener element or between the hard corner elements, as applicable.

Table 1 : Modes of failure of stiffened plate element and stiffener element

Element	Mode of failure	Curve σ-ε defined in
Lengthened stiffened plate element or stiffener element	Elasto-plastic collapse	[2.3.3]
Shortened stiffener element	Beam column buckling Torsional buckling Web local buckling of flanged profiles Web local buckling of flat bars	[2.3.4] [2.3.5] [2.3.6] [2.3.7]
Shortened stiffened plate element	Plate buckling	[2.3.8]

2.3.2 Hard corner element

The relevant load-end shortening curve σ-ε is to be obtained for lengthened and shortened hard corners according to [2.3.3].

2.3.3 Elasto-plastic collapse of structural elements

The equation describing the load-end shortening curve σ-ε for the elasto-plastic collapse of structural elements composing the hull girder transverse section is to be obtained from the following formula, valid for both positive (shortening) and negative (lengthening) strains, see Figure 7:

$\sigma = \Phi R_{eHA}$

where:

R_{eHA} : Equivalent minimum yield stress, in N/mm², of the considered element, obtained by the following formula:

$$R_{eHA} = \frac{R_{eHp} A_{p-50} + R_{eHs} A_{s-n50}}{A_{p-n50} + A_{s-n50}}$$

Φ : Edge function, equal to:

$\Phi = -1$ for $\varepsilon < -1$

$\Phi = \varepsilon$ for $-1 \leq \varepsilon \leq 1$

$\Phi = 1$ for $\varepsilon > 1$

ε : Relative strain, equal to:

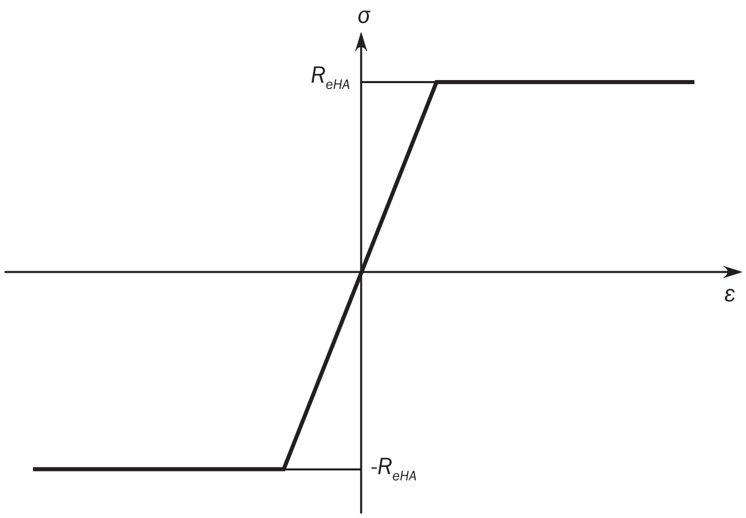
$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_Y}$$

ε_E : Element strain.

ε_Y : Strain at yield stress in the element, equal to:

$$\varepsilon_Y = \frac{R_{eHA}}{E}$$

Figure 7 : Load-end curve σ-ε for elasto plastic collapse



2.3.4 Beam column buckling

The equation describing the load-end shortening curve σ_{CR1}-ε for the beam column buckling of stiffeners composing the hull girder transverse section is to be obtained from the following formula, see Figure 8:

$$\sigma_{CR1} = \Phi\sigma_{C1}\frac{A_{s-n50} + A_{pE-n50}}{A_{s-n50} + A_{p-n50}}$$

where:

Φ : Edge function, as defined in [2.3.3].

σ_{C1} : Critical stress, in N/mm^2, equal to:

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon} \quad \text{for} \quad \sigma_{E1} \le \frac{R_{eHB}}{2}\varepsilon$$

$$\sigma_{C1} = R_{eHB}\left(1 - \frac{R_{eHB}\,\varepsilon}{4\sigma_{E1}}\right) \quad \text{for} \quad \sigma_{E1} > \frac{R_{eHB}}{2}\varepsilon$$

R_{eHB} : Equivalent minimum yield stress, in N/mm^2, of the considered element, obtained by the following formula:

$$R_{eHB} = \frac{R_{eHp}\,A_{pEI-n50}\,\ell_{pE} + R_{eHs}\,A_{s-n50}\,\ell_{sE}}{A_{pEI-n50}\,\ell_{pE} + A_{s-n50}\,\ell_{sE}}$$

$A_{pEI-n50}$: Effective area, in cm^2, equal to:
$A_{pEI-n50} = 10\, b_{E1}\, t_{n50}$

ℓ_{pE} : Distance, in mm, measured from the neutral axis of the stiffener with attached plate of width b_{E1} to the bottom of the attached plate.

ℓ_{sE} : Distance, in mm, measured from the neutral axis of the stiffener with attached plating of width b_{E1} to the top of the stiffener.

ε : Relative strain, as defined in [2.3.3].

σ_{E1} : Euler column buckling stress, in N/mm², equal to:

$$\sigma_{E1} = \pi^2 E \frac{I_{E-n50}}{A_{E-n50}\, \ell^2} 10^{-4}$$

$I_{E\text{-}n50}$: Net moment of inertia of stiffeners, in cm⁴, with attached plating of width b_{E1}.

$A_{E\text{-}n50}$: Net area, in cm², of stiffeners with attached plating of width b_E.

b_{E1} : Effective width corrected for relative strain, in m, of the attached plating, equal to:

$$b_{E1} = \frac{s}{\beta_E} \quad \text{for} \quad \beta_E > 1.0$$

$$b_{E1} = s \quad \text{for} \quad \beta_E \le 1.0$$

β_E : $\beta_E = 10^3 \dfrac{s}{t_{n50}} \sqrt{\dfrac{\varepsilon R_{eHp}}{E}}$

A_{pE-n50} : Net sectional area, in cm², of attached plating of width b_E, equal to:

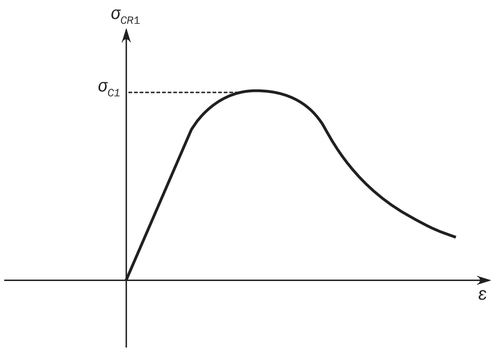
$$A_{pE\text{-}n50} = 10\, b_E\, t_{n50}$$

b_E : Effective width, in m, of the attached plating, equal to:

$$b_E = \left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2}\right) s \quad \text{for} \quad \beta_E > 1.25$$

$$b_E = s \quad \text{for} \quad \beta_E \le 1.25$$

Figure 8 : Load-end shortening curve σ_{CR1}-ε for beam column buckling



2.3.5 Torsional buckling

The equation describing the load-end shortening curve σ_{CR2}-ε for the flexural-torsional buckling of stiffeners composing the hull girder transverse section is to be obtained according to the following formula, see Figure 9.

$$\sigma_{CR2} = \Phi \frac{A_{S-n50}\, \sigma_{C2} + A_{p-n50}\, \sigma_{CP}}{A_{S-n50} + A_{p-n50}}$$

where:

Φ : Edge function, as defined in [2.3.3].

σ_{C2} : Critical stress, in N/mm², equal to:

$$\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon} \quad \text{for} \quad \sigma_{E2} \le \frac{R_{eHs}}{2}\varepsilon$$

$$\sigma_{C2} = R_{eHs}\left(1 - \frac{R_{eHs}\,\varepsilon}{4\sigma_{E2}}\right) \quad \text{for} \quad \sigma_{E2} > \frac{R_{eHs}}{2}\varepsilon$$

σ_{E2} : Euler torsional buckling stress, in N/mm², taken as σ_{ET} in Ch 8, Sec 5, [2.3.4]

ε : Relative strain, as defined in [2.3.3].

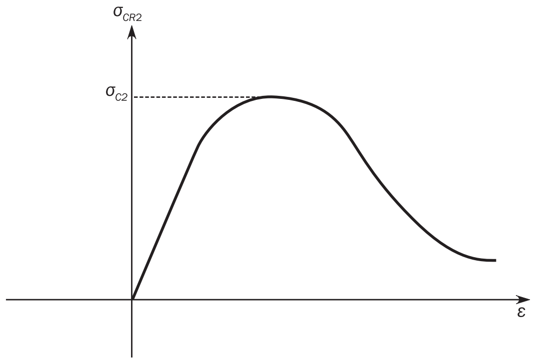
σ_{CP} : Buckling stress of the attached plating, in N/mm², equal to:

$$\sigma_{CP} = \left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2}\right) R_{eHp} \quad \text{for} \quad \beta_E > 1.25$$

$$\sigma_{CP} = R_{eHp} \quad \text{for} \quad \beta_E \le 1.25$$

β_E : Coefficient, as defined in [2.3.4].

Figure 9 : Load-end shortening curve σ_{CR2}-ε for flexural-torsional buckling



2.3.6 Web local buckling of stiffeners made of flanged profiles

The equation describing the load-end shortening curve σ_{CR3}-ε for the web local buckling of flanged stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi \frac{10^3\ b_E\ t_{n50}\ R_{eHp} + (h_{we}\ t_{w-n50} + b_f\ t_{f-n50})\ R_{eHs}}{10^3\ st_{n50} + h_w\ t_{w-n50} + b_f\ t_{f-n50}}$$

where:

Φ : Edge function, as defined in [2.3.3].

b_E : Effective width, in m, of the attached shell plating, as defined in [2.3.4].

h_{we} : Effective height, in mm, of the web, equal to:

$$h_{we} = \left(\frac{2.25}{\beta_w} - \frac{1.25}{\beta_w^2}\right) h_w \quad \text{for} \quad \beta_w \ge 1.25$$

$$h_{we} = h_w \quad \text{for} \quad \beta_w < 1.25$$

β_w : $\beta_w = \dfrac{h_w}{t_{w-n50}} \sqrt{\dfrac{\varepsilon\ R_{eHs}}{E}}$

ε : Relative strain, as defined in [2.3.3].

2.3.7 Web local buckling of stiffeners made of flat bars

The equation describing the load-end shortening curve σ_{CR4}-ε for the web local buckling of flat bar stiffeners composing the hull girder transverse section is to be obtained from the following formula, see Figure 10:

$$\sigma_{CR4} = \Phi \frac{A_{P-n50}\ \sigma_{CP} + A_{s-n50}\ \sigma_{C4}}{A_{p-n50} + A_{s-n50}}$$

where:

Φ : Edge function, as defined in [2.3.3].

σ_{CP} : Buckling stress of the attached plating, in N/mm², as defined in [2.3.5].

σ_{C4} : Critical stress, in N/mm², equal to:

$$\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon} \qquad \text{for } \sigma_{E4} \le \frac{R_{eHs}}{2}\varepsilon$$

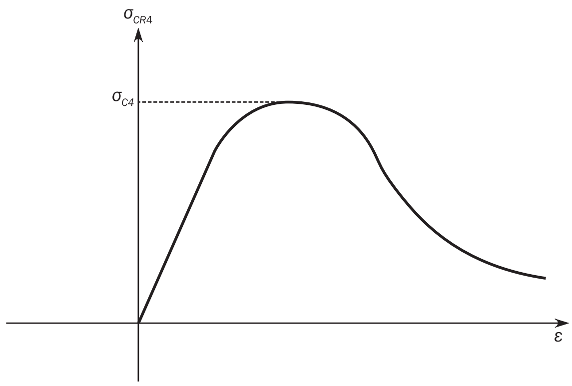
$$\sigma_{C4} = R_{eHs}\left(1 - \frac{R_{eHs}\,\varepsilon}{4\sigma_{E4}}\right) \quad \text{for } \sigma_{E4} > \frac{R_{eHs}}{2}\varepsilon$$

σ_{E4} : Local Euler buckling stress, in N/mm², equal to:

$$\sigma_{E4} = 160000\left(\frac{t_{w-n50}}{h_w}\right)^2$$

ε : Relative strain, as defined in [2.3.3].

Figure 10 : Load-end shortening curve σ_{CR4}-ε for web local buckling



2.3.8 Plate buckling

The equation describing the load-end shortening curve σ_{CR5}-ε for the buckling of transversely stiffened panels composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR5} = min\begin{cases} R_{eHp}\Phi \\ \Phi R_{eHp}\left[\frac{s}{\ell}\left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2}\right) + 0.1\left(1 - \frac{s}{\ell}\right)\left(1 + \frac{1}{\beta_E^2}\right)^2\right] \end{cases}$$

where:

Φ : Edge function, as defined in [2.3.3].

β_E : $\beta_E = 10^3\,\frac{s}{t_{n50}}\sqrt{\frac{\varepsilon\,R_{eHp}}{E}}$

s : Plate breadth, in m, taken as the spacing between the stiffeners.

ℓ : Longer side of the plate, in m.

3 ALTERNATIVE METHODS

3.1 General

3.1.1

The bending moment-curvature relationship, M-χ, may be established by alternative methods. Such models are to consider all the relevant effects important to the non-linear response with due considerations of:

a) Non-linear geometrical behaviour.

b) Inelastic material behaviour.

c) Geometrical imperfections and residual stresses (geometrical out-of-flatness of plate and stiffeners).

d) Simultaneously acting loads:

- Bi-axial compression.
- Bi-axial tension.
- Shear and lateral pressure.

e) Boundary conditions.

f) Interactions between buckling modes.

g) Interactions between structural elements such as plates, stiffeners, girders, etc.

h) Post-buckling capacity.

i) Overstressed elements on the compression side of hull girder cross section possibly leading to local permanent sets/buckle damages in plating, stiffeners etc (double bottom effects or similar).

3.2 Non-linear finite element analysis

3.2.1

Advanced non-linear finite element analyses models may be used for the assessment of the hull girder ultimate capacity. Such models are to consider the relevant effects important to the non-linear responses with due consideration of the items listed in [3.1.1].

3.2.2

Particular attention is to be given to modelling the shape and size of geometrical imperfections. It is to be ensured that the shape and size of geometrical imperfections trigger the most critical failure modes.

PART 1 CHAPTER 6

HULL LOCAL SCANTLING

Table of Contents

SECTION 1
GENERAL

1 APPLICATION

1.1 Application

1.1.1

This chapter applies to hull structure over the full length of the ship including fore end, cargo hold region, machinery space and aft end, the side shell above the freeboard deck, engine casing, exposed decks of superstructure and internal decks except those inside superstructure and deckhouse.

1.1.2

This chapter provides requirements for evaluation of plating, stiffeners and Primary Supporting Members (PSM) subject to lateral pressure, local loads and to hull girder loads, as applicable. Requirements are specified for:

- Load application in Ch 6, Sec 2.
- Minimum thickness of plates, stiffeners and PSM in Ch 6, Sec 3.
- Plating in Ch 6, Sec 4.
- Stiffeners in Ch 6, Sec 5.
- PSM and pillars in Ch 6, Sec 6.

In addition, other requirements not related to defined design load sets, are provided.

1.1.3 Required scantlings

The offered net scantling is to be greater than or equal to the required scantlings based on requirements provided in this chapter.

1.1.4 Additional local strength requirements

Additional local strength requirements are provided in Ch 10 considering bow impact loads, bottom slamming loads and sloshing loads, and for fore end, machinery space and aft end.

1.2 Acceptance criteria

1.2.1

Acceptance criteria set to be selected based on design load as follows:

- AC-S for design load S; static loads.
- AC-SD for design load S+D; combination of static and dynamic loads.

SECTION 2
LOAD APPLICATION

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

1 LOAD COMBINATION

1.1 Hull girder bending

1.1.1 Normal stresses

The normal stress σ_{hg}, in N/mm², induced by acting vertical and horizontal bending moments at the position being considered is given as follow. This stress is to be calculated for each design load set, as defined in [2] covering all dynamic load cases defined in Ch 4 in combination with M_{sw} both in hogging and in sagging.

$$\sigma_{hg} = \left(\frac{M_{sw} + M_{wv-LC}}{I_{y-n50}}\,(z - z_n) - \frac{M_{wh-LC}}{I_{z-n50}}\,y\right) 10^{-3}$$

where:

M_{sw} : Still water bending moment, in kNm, as defined in Ch 4, Sec 4, [2.2] in accordance with the considered design load scenario in Ch 4, Sec 7, Table 1.

M_{wv-LC} : Vertical wave bending moment, in kNm, of the considered dynamic load case, as defined in Ch 4, Sec 4, [3.5.2] in accordance with the considered design load scenario in Ch 4, Sec 7, Table 1, at the considered longitudinal position.

M_{wh-LC} : Horizontal wave bending moment, in kNm, of the considered dynamic load case, as defined in Ch 4, Sec 4, [3.5.4] in accordance with the considered design load scenario in Ch 4, Sec 7, Table 1, at the considered longitudinal position.

I_{y-n50} : Net vertical hull girder moment of inertia, at the longitudinal position being considered, in m⁴.

I_{z-n50} : Net horizontal hull girder moment of inertia, at the longitudinal position being considered, in m⁴.

y : Transverse coordinate of load calculation point, in m.

z : Vertical coordinate of the load calculation point under consideration, in m.

z_n : Distance from the baseline to the horizontal neutral axis, in m.

1.2 Lateral pressures

1.2.1 Static and dynamic pressures in intact conditions

The static and dynamic lateral pressures in intact condition induced by the sea and the various types of cargoes, ballast and other liquids are to be considered. Applied loads will depend on the location of the elements under consideration, and the adjacent type of compartments.

1.2.2 Lateral pressure in flooded conditions

Watertight boundaries of compartments not intended to carry liquids, excluding hull envelope, are to be subjected to lateral pressure in flooded conditions.

1.3 Pressure combination

1.3.1 Elements of the outer shell

If the compartment adjacent to the outer shell is intended to carry liquids, the static and dynamic lateral pressures to be considered are the differences between the internal pressures and the external sea pressures at the corresponding draught.

If the compartment adjacent to the outer shell is not intended to carry liquids, the internal pressures and external sea pressures are to be considered independently.

1.3.2 Elements other than those of the outer shell

Except as specified in [1.3.1], the static and dynamic lateral pressures on an element separating two adjacent compartments are those obtained considering the two compartments individually loaded.

2 DESIGN LOAD SETS

2.1 Application of load components

2.1.1 Application

These requirements apply to:

- Plating and stiffeners along the full length of the ship.
- PSM outside the cargo hold region.

2.1.2 Load components

The static and dynamic load components are to be determined in accordance with Ch 4, Sec 7, Table 1.

Radius of gyration, k_r, and metacentric height, GM, are to be in accordance with Ch 4, Sec 3, Table 1 and Ch 4, Sec 3, Table 2 for the considered loading conditions specified in the design load sets given in Table 1.

2.1.3 Design load sets for plating, stiffeners and PSM

Design load sets for plating, stiffeners and primary supporting members are given in Table 1.

In addition, the design load sets for primary supporting members of bulk carriers with length L less than 150 m and of oil tankers within the cargo hold region are given respectively in Pt 2, Ch 1, Sec 4, [4.2] and in Pt 2, Ch 2, Sec 3, [1.2].

Table 1 : Design load sets

Item	Design load set	Load component	Draught	Design load	Loading condition
External shell and exposed deck	SEA-1	P_{ex}, P_D	T_{SC}	S+D	Full Load condition (1)
	SEA-2	P_{ex}	T_{SC}	S	Harbour condition (2)
Water ballast tank (oil tanker and bulk carrier)	WB-1	$P_{in} - P_{ex}$ (3)	T_{BAL}	S+D	Normal ballast condition
	WB-2	$P_{in} - P_{ex}$ (3)	T_{BAL}	S+D	Normal ballast condition Water ballast exchange
	WB-3	$P_{in} - P_{ex}$ (3)	$0.25T_{SC}$	S	Harbour/test condition

Item	Design load set	Load component	Draught	Design load	Loading condition
Water ballast tank (bulk carrier) and bulk cargo hold assigned as ballast hold	WB-4	$P_{in} - P_{ex}$ **(3)**	T_{BAL-H} **(7)**	S+D	Heavy ballast condition
	WB-5 **(4)**	$P_{in} - P_{ex}$ **(3)**	T_{BAL-H} **(7)**	S+D	Heavy ballast condition Water ballast exchange
	WB-6 **(5)**	P_{in}	-	S	Harbour/test condition
Cargo oil tank	OT-1	P_{in}	T_{SC}	S+D	Full Load condition
	OT-2	P_{in}	$0.6T_{SC}$	S+D	Partial load condition
	OT-3	P_{in}	-	S	Harbour/Test condition
Bulk cargo hold	BC-1	P_{in}	T_{SC}	S+D	Homogeneous loading, fully filled
	BC-2	P_{in}	-	S	
	BC-3	P_{in}	T_{SC}	S+D	Homogeneous heavy cargo, partially filled (BC-A, B ships)
	BC-4	P_{in}	-	S	
	BC-5	P_{in}	T_{SC}	S+D	Alternate light cargo, fully filled (BC-A ships)
	BC-6	P_{in}	-	S	
	BC-7	P_{in}	T_{SC}	S+D	Alternate heavy cargo, partially filled (BC-A ships.)
	BC-8	P_{in}	-	S	
Other tanks (fuel oil tank, fresh water tank)	TK-1	$P_{in} - P_{ex}$ **(3)**	T_{BAL}	S+D	Normal ballast condition
	TK-2	$P_{in} - P_{ex}$ **(3)**	$0.25T_{SC}$	S	Harbour/test condition
Compartments not carrying liquids	FD-1 **(6)**	P_{in}	T_{SC}	S+D	Flooded condition
	FD-2 **(6)**	P_{in}	-	S	Flooded condition
Exposed deck, internal decks or platforms	DL-1 **(8)**	P_{dl}, F_U	T_{BAL}	S+D	Normal ballast condition
	DL-2 **(8)**	P_{dl}, F_U	-	S	Harbour condition

(1) For bulk carrier BC-A and BC-B, full load condition means 'homogeneous heavy cargo'.
(2) For external shell only.
(3) P_{ex} is to be considered for external shell only.
(4) Not to be applied to bulk cargo hold assigned as ballast hold.
(5) Bulk cargo hold only.
(6) FD-1 and FD-2 are not applicable to external shell and corrugations of transverse vertically corrugated bulkhead separating cargo holds. Requirement in flooded conditions of transverse corrugated bulkhead are given in Pt 2, Ch 1, Sec 3, [3].
(7) Minimum draught among heavy ballast conditions is to be used.
(8) Distributed or concentrated loads only. Need not be combined with simultaneously occurring green sea pressure.

SECTION 3
MINIMUM THICKNESSES

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

1 PLATING

1.1 Minimum thickness requirements

1.1.1

The net thickness of plating in mm, is to comply with the appropriate minimum thickness requirements given in Table 1.

Table 1 : Minimum net thickness for plating

Element	Location	Area	Net thickness
Shell	Keel	-	$7.5 + 0.03\ L_2$
	Bottom Side shell Bilge	Fore Part	$6.5 + 0.03\ L_2$
		Machinery space Aft part	$7.0 + 0.03\ L_2$
		Elsewhere	$5.5 + 0.03\ L_2$
Breasthook		Fore part	6.5
Deck	Weather deck, strength deck, internal tank boundary	-	$4.5 + 0.02\ L_2$
	Platform deck	Machinery space	$2.8 + 0.0067\ s$
		Elsewhere	6.5
Inner bottom (1)	-	Machinery space	$6.6 + 0.024\ L_2$
		Elsewhere	$5.5 + 0.03\ L_2$
Longitudinal bulkheads of bulk carriers	Inner side, hopper tank top, top wing tank longitudinal bulkhead	Cargo hold region	$0.7\ L_2^{1/2}$
Bulkheads	Internal tank boundary, Transverse/longitudinal watertight bulkhead	-	$4.5 + 0.02\ L_2$
	Non-tight bulkhead, Wash bulkhead, Bulkheads between dry spaces.	-	$4.5 + 0.01\ L_2$
	Pillar bulkheads in fore and aft peaks	-	7.5
Other members	Diaphragms in lower/upper stool	-	$5.0 + 0.015\ L_2$
	Engine casing (in the cargo hold region)	Cargo hold region	5.5
	Engine casing (in way of accommodation)	Accommodation	4.0
	Other plates in general	-	$4.5 + 0.01\ L_2$
(1) Applicable for both tight and non tight members			

2 STIFFENERS AND TRIPPING BRACKETS

2.1 Minimum thickness requirements

2.1.1

The net thickness of the web and face plate, if any, of stiffeners and tripping brackets in mm, is to comply with the minimum net thickness given in Table 2.

In addition, the net thickness of the web of stiffeners and tripping brackets, in mm, is to be:

- Not less than 40% of the net required thickness of the attached plating, to be determined according to Ch 6, Sec 4.
- Less than twice the net offered thickness of the attached plating.

Table 2 : Minimum net thickness for stiffeners and tripping brackets

Element	Location	Net thickness
Stiffeners and attached end brackets	Watertight boundary	$3.5 + 0.015\, L_2$
	Other structure	$3.0 + 0.015\, L_2$
Cargo hold side frames webs of single side bulk carriers	Foremost hold [(1)]	$6.0 + 0.026\, L$
	Other holds [(1)]	$5.2 + 0.023\, L$
Tripping brackets		$5.0 + 0.015\, L_2$
(1) *L* needs not to be taken greater than 200 m		

3 PRIMARY SUPPORTING MEMBERS

3.1 Minimum thickness requirements

3.1.1

The net thickness of web plating and flange of primary supporting members in mm, is to comply with the minimum net thickness given in Table 3.

Table 3 : Minimum net thickness for primary supporting members

Element	Location		Net thickness
Double bottom centreline girder	Machinery space		$1.55\, L_2^{1/3} + 3.5$
	Elsewhere		$5.5 + 0.025\, L_2$
Other bottom girder	Machinery space		$1.7\, L_2^{1/3} + 1.0$
	Fore part of ships with $L \geq 150$ m		$0.7\, L_2^{1/2}$
	Elsewhere and fore part of ships with $L < 150$ m		$5.5 + 0.02\, L_2$
Girders bounding a duct keel	Machinery space		$0.8\, L_2^{1/2} + 2.5$
Bottom floor	Machinery space		$1.7\, L_2^{1/3} + 1.0$
	Fore part		$0.7\, L_2^{1/2}$
	Elsewhere		$0.6\, L_2^{1/2}$
Aft peak floor	-		$0.7\, L_2^{1/2}$
Other primary supporting member	Aft part / fore part		$0.7\, L_2^{1/2}$
	Elsewhere	In oil cargo tanks	$5.5 + 0.015\, L_2$
		For other cases	$0.6\, L_2^{1/2}$

SECTION 4
PLATING

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

α_p : Correction factor for the panel aspect ratio to be taken as follow but not to be taken greater than 1.0.

$$\alpha_p = 1.2 - \frac{b}{2.1\ a}$$

a : Length of plate panel, in mm, as defined in Ch 3, Sec 7, [2.2.2].

b : Breadth of plate panel, in mm, as defined in Ch 3, Sec 7, [2.2.2].

P : Design pressure for the considered design load set, see Ch 6, Sec 2, [2], calculated at the load calculation point defined in Ch 3, Sec 7, [2.2], in kN/m^2.

σ_{hg} : Hull girder bending stress, in N/mm^2, as defined in Ch 6, Sec 2, [1.1], calculated at the load calculation point as defined in Ch 3, Sec 7, [2.2].

χ : Coefficient taken equal to:

- In intact condition:
  - χ = 0.70 for inner bottom and hopper of bulk carriers,
  - χ = 1.00 for other cases.
- In flooded condition:
  - χ = 1.00 for collision bulkheads for acceptance criteria set AC-S,
  - χ = 0.95 for collision bulkheads for acceptance criteria set AC-SD,
  - χ = 1.15 for other watertight boundaries of compartments.

1 PLATING SUBJECTED TO LATERAL PRESSURE

1.1 Yielding check

1.1.1 Plating

The net thickness, t in mm, is not to be taken less than the greatest value for all applicable design load sets, as defined in Ch 6, Sec 2, [2.1.3], given by:

$$t = 0.0158\ \alpha_p\ b\sqrt{\frac{|P|}{\chi\ C_a\ R_{eH}}}$$

where:

C_a : Permissible bending stress coefficient for plate taken equal to:

$$C_a = \beta - \alpha\frac{|\sigma_{hg}|}{R_{eH}}$$, not to be taken greater than $C_{a\text{-}max}$.

β : Coefficient as defined in Table 1.

α : Coefficient as defined in Table 1.

C_{a-max} : Maximum permissible bending stress coefficient as defined in Table 1.

Table 1 : Definition β, α and C_{a-max}

Acceptance criteria set	Structural member		β	α	C_{a-max}
AC-S	Longitudinal strength members	Longitudinally stiffened plating	0.9	0.5	0.8
		Transversely stiffened plating	0.9	1.0	0.8
	Other members		0.8	0	0.8
AC-SD	Longitudinal strength members	Longitudinally stiffened plating	1.05	0.5	0.95
		Transversely stiffened plating	1.05	1.0	0.95
	Other members		1.0	0	1.0

1.2 Plating of corrugated bulkheads

1.2.1 Cold and hot formed corrugations

The net thicknesses, t in mm, of the web and flange plates of corrugated bulkheads are not to be taken less than the greatest value calculated for all applicable design load sets, as defined in Ch 6, Sec 2, [2.1.3], given by:

$$t = 0.0158\, b_p \sqrt{\frac{|P|}{C_{CB}\, R_{eH}}}$$

where:

b_p : Breadth of plane corrugation plating:

$b_p = a$ for flange plating, in mm, as defined in Ch 3, Sec 6, Figure 21.

$b_p = c$ for web plating, in mm, as defined in Ch 3, Sec 6, Figure 21.

C_{CB} : Permissible bending stress coefficient for corrugated bulkhead plating taken equal to:

- For acceptance criteria set AC-S for transverse corrugated bulkheads and vertically corrugated longitudinal bulkheads.

  $C_{CB} = 0.75$

- For acceptance criteria set AC-SD for transverse corrugated bulkheads and vertically corrugated longitudinal bulkheads.

  $C_{CB} = 0.90$

- For horizontally corrugated longitudinal bulkheads, without being greater than C_{CB-max}.

$$C_{CB} = \beta_{CB} - \alpha_{CB} \frac{|\sigma_{hg}|}{R_{eH}}$$

β_{CB} : Coefficient as defined in Table 2.

α_{CB} : Coefficient as defined in Table 2.

C_{CB-max} : Maximum permissible bending stress coefficient as defined in Table 2.

Table 2 : Definition β_{CB}, α_{CB} and C_{CB-max}

Acceptance criteria set	Structural member	β_{CB}	α_{CB}	C_{CB-max}
AC-S	Horizontally corrugated longitudinal bulkheads	0.90	0.50	0.75
AC-SD	Horizontally corrugated longitudinal bulkheads	1.05	0.50	0.90

1.2.2 Built-up corrugations

For built-up corrugations, with flange and web plate of different thickness, the net thickness, t_1 in mm, is to be taken as the greatest value calculated for all applicable design load sets, as defined in Ch 6, Sec 2, [2.1.3], given by:

$$t_1 = \sqrt{\frac{0.0005\, b_P^2\, |P|}{C_{CB}\, R_{eH}} - t_2^2}$$

where:

t_1 : Net thickness of the thicker plating, either flange or web, in mm.

t_2 : Net thickness of the thinner plating, either flange or web, in mm.

b_P : Breadth of thicker plate, either flange or web, in mm.

C_{CB} : Permissible bending stress coefficient as defined in [1.2.1].

2 SPECIAL REQUIREMENTS

2.1 Minimum thickness of keel plating

2.1.1

The net thickness of the keel plating is not to be taken less than the offered net thickness of the adjacent 2 m width bottom plating, measured from the edge of the keel strake.

The width of the keel is defined in Ch 3, Sec 6, [7.2.1].

2.2 Bilge plating

2.2.1 Definition of bilge area

The definition of bilge area is given in Ch 1, Sec 4, [3.8.1].

2.2.2 Bilge plate thickness within 0.4 *L* amidships

The net thickness of bilge plating is not to be taken less than the offered net thickness for the adjacent bottom shell or adjacent side shell plating, whichever is greater.

The net thickness of curved bilge plating, t, in mm, is not to be taken less than:

$$t = 6.45 \times 10^{-4}\,(P_{ex}\, s_b)^{0.4}\, R^{0.6}$$

where:

P_{ex} : Design sea pressure for the design load set SEA-1 as defined in Ch 6, Sec 2, [2.1.3] calculated at the lower turn of the bilge, in kN/m^2.

R : Effective bilge radius in mm.

$$R = R_0 + 0.5\,(\Delta s_1 + \Delta s_2)$$

R_0 : Radius of curvature, in mm. See Figure 1.

Δs_1 : Distance between the lower turn of bilge and the outermost bottom longitudinal, in mm, see Figure 1. Where the outermost bottom longitudinal is within the curvature, this distance is to be taken as zero.

Δs_2 : Distance between the upper turn of bilge and the lowest side longitudinal, in mm, see Figure 1. Where the lowest side longitudinal is within the curvature, this distance is to be taken as zero.

s_b : Distance between transverse stiffeners, webs or bilge brackets, in mm.

Longitudinally stiffened bilge plating is to be assessed as regular stiffened plating. The bilge thickness is not to be less than the minimum value obtained by [1.1.1] and [2.2.2]. A bilge keel is not considered as an effective 'longitudinal stiffening' member and unless other longitudinal stiffeners are fitted, this requirement has to be applied.

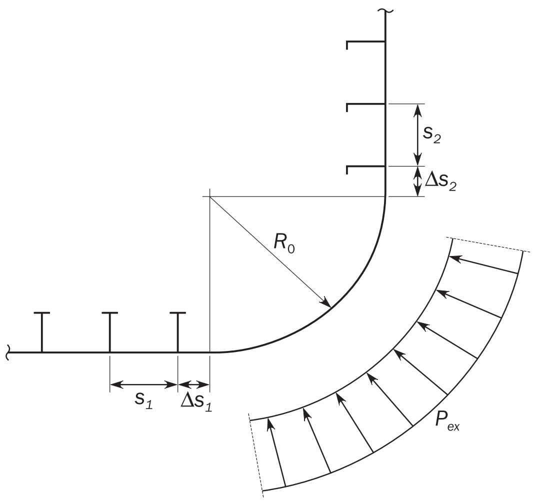
2.2.3 Bilge plate thickness outside 0.4 *L* amidships

For transversely stiffened bilge plating outside 0.4 *L* amidships, the bilge plate thickness requirement is to be specially considered based on evaluation of support provided by the hull form and internal stiffening arrangements. Outside of 0.4 *L* amidships, the bilge plating thickness and arrangement are to comply with the requirements to side shell or bottom plating in the same region. Effect of increased loading in the forward region is to be specially considered.

2.2.4 Transverse extension of bilge minimum plate thickness

Where a plate seam is located in the straight plate just below the lowest stiffener on the side shell, any increased thickness required for the bilge plating does not have to be extended to the adjacent plate above the bilge provided the plate seam is not more than $s_2/4$ below the lowest side longitudinal. Similarly, for the flat part of adjacent bottom plating, any increased thickness for the bilge plating does not have to be extended to the adjacent plate provided that the plate seam is not more than $s_1/4$ beyond the outboard bottom longitudinal. For definition of s_1 and s_2, see Figure 1.

Figure 1 : Transverse stiffened bilge plating



2.2.5 Hull envelope framing in bilge area

For transversely stiffened bilge plating, a longitudinal is to be fitted at the bottom and at the side close to the position where the curvature of the bilge plate starts. The scantling of those longitudinals are to be not less than the one of the closer adjacent stiffener. The distance between the lower turn of bilge and the outermost bottom longitudinal, Δs_1, is generally not to be greater than one-third of the spacing between the two outermost bottom longitudinals, s_1. Similarly, the distance between the upper turn of the bilge and the lowest side longitudinal, Δs_2, is generally not to be greater than one-third of the spacing between the two lowest side longitudinals, s_2. See Figure 1.

2.3 Side shell plating

2.3.1 Fender contact zone

The net thickness, *t* in mm, of the side shell plating within the fender contact zone as specified in [2.3.2] is not to be taken less than:

$$t = 26\left(\frac{b}{1000} + 0.7\right)\left(\frac{BT_{SC}}{R_{eH}{}^2}\right)^{0.25}$$

2.3.2 Application of fender contact zone requirement

The application extends within the cargo hold region as defined in Ch 1, Sec 1, [2.4.3], from the ballast draught T_{BAL} to 0.25 T_{SC} (minimum 2.2 m) above T_{SC}.

2.4 Sheer strake

2.4.1 General

The minimum width of the sheer strake is defined in Ch 3, Sec 6, [8.2.4].

2.4.2 Welded sheer strake

The net thickness of a welded sheer strake is not to be less than the offered net thickness of the adjacent 2 m width side plating, provided this plating is located entirely within the top wing tank or double side tank as the case may be.

2.4.3 Rounded sheer strake

The net thickness of a rounded sheer strake is not to be less than:

- The offered net thickness of the adjacent 2 m width deck plating, or
- The offered net thickness of the adjacent 2 m width side plating,

whichever is greater.

2.5 Deck stringer plating

2.5.1

The minimum width of deck stringer plating is defined in Ch 3, Sec 6, [9.1.2].

2.5.2

Within 0.6 L of amidships, the net thickness of the deck stringer plate is not to be less than the offered net thickness of the adjacent deck plating.

2.6 Supporting structure in way of corrugated bulkheads

2.6.1 General

Requirements for the arrangement of bulkhead as given in Ch 3, Sec 6, [10.4] are to be considered together with [2.6.2] to [2.6.4].

2.6.2 Lower stool

a) The net thickness of the stool top plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation. The extension of the top plate beyond the corrugation is not to be less than the as-built flange thickness of the corrugation.

b) The net thickness of the stool side plate, within the region of the corrugation depth from the stool top plate, is not to be less than the corrugated bulkhead flange net required thickness at the lower end and is to be of at least the same material yield strength. The net thickness may be reduced to 90% of corrugation flange thickness if continuity is provided between the corrugation web and supporting brackets inside the stool as defined in (c).

c) Continuity between corrugation web and lower stool supporting brackets is to be maintained inside the stool. Alternatively, lower stool supporting brackets inside the stool are to be aligned with every knuckle point of corrugation web.

d) The net thickness of supporting bracket is not to be less than 80% of the required net thickness of the corrugation webs and is to be of at least the same material yield strength.

e) The net thickness of supporting floors is not to be less than the net required thickness of the stool side plating (excluding the application of GRAB requirements as defined in Pt 2, Ch 1, Sec 6) connected to the inner bottom and is to be of at least the same material yield strength. If material of different yield strength is used, the required thickness is to be adjusted by the ratio of the two material factors *k*, as defined in Ch 3, Sec 1, [2.2.1].

f) Where a lower stool is fitted, particular attention is to be given to the through-thickness properties, and arrangements for continuity of strength, at the connection of the bulkhead stool to the inner bottom. For requirements for plates with specified through-thickness properties, see Ch 3, Sec 1, [2.5].

2.6.3 Upper stool

a) The net thickness of the stool bottom plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation. The extension of the top plate beyond the corrugation is not to be less than the as-built flange thickness of the corrugation.

b) The net thickness of the lower portion of stool side plating is not to be less than 80% of the upper part of the bulkhead plating as required by [1.2] and Pt 2, Ch 1, Sec 3, [3.1], as applicable, whichever is the greater, where the same material is used. If material of different yield strength is used, the required thickness is to be adjusted by the ratio of the two material factors *k* as defined in Ch 3, Sec 1, [2.2.1].

2.6.4 Local supporting structure in way of corrugated bulkheads without a lower stool

a) The net thickness of the supporting floors and pipe tunnel beams in way of a corrugated bulkhead are not to be less than the required net thickness of the corrugation flanges and are to be of at least the same material yield strength. The inner bottom and hopper tank in way of the corrugation is to be of at least the same material yield strength as the attached corrugation, and Z grade steel as defined in Ch 3, Sec 1, [2.5.1] is to be used unless through thickness properties are documented for approval.

b) Brackets/carlings arranged in line with the corrugation web are to have a depth of not less than 0.5 times the corrugation depth and a net thickness not less than 80% of the net thickness of the corrugation webs and are to be of at least the same material yield strength. Where support is provided by gussets with shedder plates instead of brackets/carlings, the height of the gusset plate, see h_G in Pt 2, Ch 1, Sec 3, Figure 5, is to be at least equal to the corrugation depth. The gusset plates are to be fitted in line with and between the corrugation flanges. The net thickness of the gusset and shedder plates is not to be less than 100% and 80%, respectively, of the net thickness of the corrugation flange and is to be of at least the same material yield strength.

2.7 Aft peak bulkhead

2.7.1

The net thickness of the aft peak bulkhead plating in way of the stern tube penetration is to be at least 1.6 times the required thickness for the bulkhead plating.

SECTION 5
STIFFENERS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

d_{shr} : Effective shear depth, in mm, as defined in Ch 3, Sec 7, [1.4.3].

ℓ_{bdg} : Effective bending span, in m, as defined in Ch 3, Sec 7, [1.1.2].

ℓ_{shr} : Effective shear span, in m, as defined in Ch 3, Sec 7, [1.1.3].

P : Design pressure for the design load set being defined in Ch 6, Sec 2 and calculated at the load calculation point defined in Ch 3, Sec 7, [3.2], in kN/m^2.

χ : Coefficient taken equal to:

- In intact condition:
  - χ = 0.90 for inner bottom and hopper of bulk carriers,
  - χ = 1.00 for other cases.
- In flooded condition: χ as defined in Ch 6, Sec 4 for flooded condition.

1 STIFFENERS SUBJECT TO LATERAL PRESSURE

1.1 Yielding check

1.1.1 Web plating

The minimum net web thickness, t_w in mm, is not to be taken less than the greatest value calculated for all applicable design load sets as defined in Ch 6, Sec 2, [2], given by:

$$t_w = \frac{f_{shr}\ |P|\ s\ \ell_{shr}}{d_{shr}\ \chi\ C_t\ \tau_{eH}} \quad \text{with } \chi\ C_t \text{ not to be taken greater than 1.0.}$$

where:

f_{shr} : Shear force distribution factor taken as:

- For continuous stiffeners with fixed ends, f_{shr} is not to be taken less than:
  - f_{shr} = 0.5 for horizontal stiffeners and upper end of vertical stiffeners.
  - f_{shr} = 0.7 for lower end of vertical stiffeners.
- For stiffeners with reduced end fixity, variable load or being part of grillage, the requirement in [1.2] applies.

C_t : Permissible shear stress coefficient for the design load set being considered, taken as:

- C_t = 0.75 for acceptance criteria set AC-S.
- C_t = 0.90 for acceptance criteria set AC-SD.

1.1.2 Section modulus

The minimum net section modulus, Z in cm^3, is not to be taken less than the greatest value calculated for all applicable design load sets as defined in Ch 6, Sec 2, [2.1.3], given by:

$$Z = \frac{|P|\, s\, \ell_{bdg}^{2}}{f_{bdg}\, \chi\, C_s\, R_{eH}}$$

where:

f_{bdg} : Bending moment factor taken as:

- For continuous stiffeners with fixed ends, f_{bdg} is not to be taken higher than:
  - f_{bdg} = 12 for horizontal stiffeners and upper end of vertical stiffeners.
  - f_{bdg} = 10 for lower end of vertical stiffeners.
- For stiffeners with reduced end fixity, variable load or being part of grillage, the requirement in [1.2] applies.

C_s : Permissible bending stress coefficient as defined in Table 1 for the design load set being considered.

σ_{hg} : Hull girder bending stress, in N/mm^2, as defined in Ch 6, Sec 2, [1.1], calculated at the load calculation point as defined in Ch 3, Sec 7, [3.2].

β_s : Coefficient as defined in Table 2.

α_s : Coefficient as defined in Table 2.

C_{s-max} : Coefficient as defined in Table 2.

Table 1 : Definition of C_s

Sign of hull girder bending stress, σ_{hg}	Lateral pressure acting on	Coefficient C_s
Tension (positive)	Stiffener side	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than C_{s-max}
Compression (negative)	Plate side	
Tension (positive)	Plate side	$C_s = C_{s-max}$
Compression (negative)	Stiffener side	

Table 2 : Definition of β_s, α_s and C_{s-max}

Acceptance criteria set	Structural member	β_s	α_s	C_{s-max}
AC-S	Longitudinal strength member	0.85	1.0	0.75
	Transverse or vertical member	0.75	0	0.75
AC-SD	Longitudinal strength member	1.0	1.0	0.9
	Transverse or vertical member	0.9	0	0.9

1.1.3 Group of stiffeners

Scantlings of stiffeners based on requirements in [1.1.1] and [1.1.2] may be decided based on the concept of grouping designated sequentially placed stiffeners of equal scantlings on a single stiffened panel. The scantling of the group is to be taken as the greater of the following:

- The average of the required scantling of all stiffeners within a group.
- 90% of the maximum scantling required for any one stiffener within the group.

1.1.4 Plate and stiffener of different materials

When the minimum specified yield stress of a stiffener exceeds the minimum specified yield stress of the attached plate by more than 35%, the following criterion is to be satisfied:

$$R_{eH-S} \le \left(R_{eH-P} - \frac{\alpha_S\, |\sigma_{hg}|}{\beta_S}\right)\frac{Z_P}{Z} + \frac{\alpha_S\, |\sigma_{hg}|}{\beta_S}$$

where:

R_{eH-S} : Minimum specified yield stress of the material of the stiffener, in N/mm^2.

R_{eH-P} : Minimum specified yield stress of the material of the attached plate, in N/mm^2.

σ_{hg} : Hull girder bending stress, in N/mm^2, as defined in Ch 6, Sec 2, [1.1] with $|\sigma_{hg}|$ not to be taken less than 0.4 R_{eH-P}.

Z : Net section modulus, in way of face plate/free edge of the stiffener, in cm^3.

Z_P : Net section modulus, in way of the attached plate of stiffener, in cm^3.

α_s, β_s : Coefficients defined in Table 2.

1.2 Beam analysis

1.2.1 Direct analysis

The maximum normal bending stress, σ and shear stress, τ in a stiffener using net properties with reduced end fixity, variable load or being part of grillage are to be determined by direct calculations taking into account:

- The distribution of static and dynamic pressures and forces, if any.
- The number and position of intermediate supports (e.g. decks, girders, etc).
- The condition of fixity at the ends of the stiffener and at intermediate supports.
- The geometrical characteristics of the stiffener on the intermediate spans.

1.2.2 Stress criteria

The stress is to comply with the following criteria where the coefficients C_t and C_s, are defined in [1.1.1] and [1.1.2].

- $\tau \leq \chi C_t \tau_{eH}$
- $\sigma \leq \chi C_s R_{eH}$

SECTION 6
PRIMARY SUPPORTING MEMBERS AND PILLARS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

P : Design pressure for the design load set being considered as defined in Ch 6, Sec 2 and calculated at the load calculation point as defined in Ch 3, Sec 7, [4.1.1], in kN/m^2.

ℓ_{bdg} : Effective bending span, as defined in Ch 3, Sec 7, [1.1.6], in m.

ℓ_{shr} : Effective shear span, as defined in Ch 3, Sec 7, [1.1.7], in m.

χ : Coefficient taken equal to:

- In intact condition:
  - χ = 0.90 for inner bottom and hopper of bulk carriers,
  - χ = 1.00 for other cases.
- In flooded condition: χ as defined in Ch 6, Sec 4 for flooded condition.

1 GENERAL

1.1 Application

1.1.1

The requirements of this section apply to primary supporting members subjected to lateral pressure and concentrated loads and pillars subjected to compressive axial loads. The yielding check is to be carried out for such members subjected to specific loads.

2 PRIMARY SUPPORTING MEMBERS WITHIN CARGO HOLD REGION

2.1 Flooded condition

2.1.1

The requirements in this sub-article apply to the primary supporting members of watertight boundaries other than outer shell or tank boundaries, subject to lateral pressure in flooded condition.

2.1.2

The verification against flooded condition is to be made by using the pressure and hull girder loads for the appropriate design load set as defined in Ch 6, Sec 2 and the scantling requirements given in [3.2].

2.2 Bulk carriers

2.2.1 Bulk carriers having a length *L* of 150m and above

The scantlings of primary supporting members within the cargo hold region are to be verified by FE structural analysis as defined in Ch 7.

2.2.2 Bulk carriers having a length *L* less than 150m

The scantlings of primary supporting members within the cargo hold region are to comply with the requirements given in Pt 2, Ch 1, Sec 4, [4]. Alternatively, the scantlings of such members may be verified by direct strength assessment as deemed appropriate by the Society.

2.3 Oil tankers

2.3.1

Scantlings of primary supporting members within the cargo hold region are to comply with the requirements given in Pt 2, Ch 2, Sec 3, [1] and are to be verified by FE structural analysis, as defined in Ch 7.

3 PRIMARY SUPPORTING MEMBERS OUTSIDE CARGO HOLD REGION

3.1 Application

3.1.1

The requirements of this article apply to primary supporting members, subjected to lateral pressure within the fore part, aft part and machinery space.

3.2 Scantling requirements

3.2.1 Net section modulus

The net section modulus, Z_{n50} in cm^3, of primary supporting members subjected to lateral pressure is not to be taken less than the greatest value for all applicable design load sets defined in Ch 6, Sec 2, [2], given by:

$$Z_{n50} = 1000 \frac{|P|\ S\ \ell_{bdg}^2}{\chi\ f_{bdg}\ C_s\ R_{eH}}$$

where:

f_{bdg} : Bending moment distribution factor, as given in Table 2.

C_s : Permissible bending stress coefficient for the acceptance criteria set, as given in Table 1.

3.2.2 Net shear area

The net shear area, $A_{shr\text{-}n50}$ in cm^2, of primary supporting members subjected to lateral pressure is not to be taken less than the greatest value for all applicable design load sets defined in Ch 6, Sec 2, [2], given by:

$$A_{shr-n50} = 10 \frac{f_{shr}\ |P|\ S\ \ell_{shr}}{\chi\ C_t\ \tau_{eH}}$$

where:

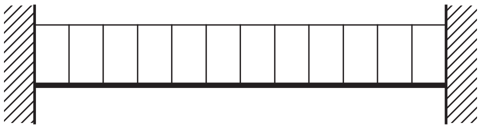
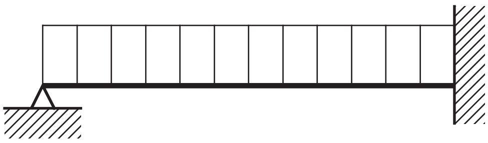
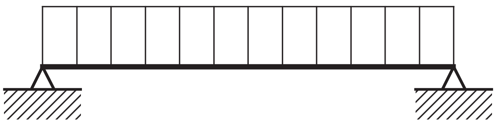
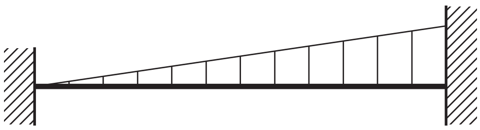
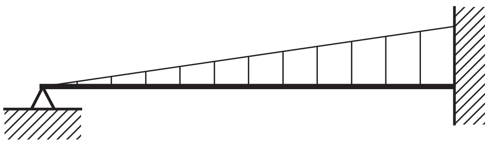
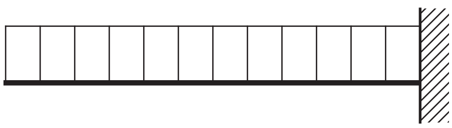
f_{shr} : Shear force distribution factor, as given in Table 2.

C_t : Permissible shear stress coefficient for the acceptance criteria set being considered, as given in Table 1.

Table 1 : Permissible bending and shear stress coefficients for primary supporting members

Acceptance criteria set	Structure attached to primary supporting member	C_s and C_t
AC-S	All boundaries, including decks and flats	0.70
AC-SD	All boundaries, including decks and flats	0.85

Table 2 : Bending moment and shear force factors, f_{bdg} and f_{shr}

Load and boundary condition				**Bending moment and shear force distribution factors (based on load at mid span, where load varies)**		
Position				**1**	**2**	**3**
Load model	**1** **Support**	**2** **Field**	**3** **Support**	f_{bdg1} f_{shr1}	f_{bdg2} -	f_{bdg3} f_{shr3}
A				12.0 0.50	24.0 -	12.0 0.50
B				- 0.38	14.2 -	8.0 0.63
C				- 0.50	8.0 -	- 0.50
D				15.0 0.30	23.3 -	10.0 0.70
E				- 0.20	16.8 -	7.5 0.80
F				- -	- -	2.0 1.0

Note 1: The bending moment distribution factor, f_{bdg} for the support positions is applicable for a distance of 0.2 ℓ_{bdg} from the end of the effective bending span of the primary supporting member.

Note 2: The shear force distribution factor, f_{shr} for the support positions is applicable for a distance of 0.2 ℓ_{shr} from the end of the effective shear span of the primary supporting member.

Note 3: Application of f_{bdg} and f_{shr}:

The section modulus requirement within 0.2 ℓ_{bdg} from the end of the effective span is to be determined using the applicable f_{bdg1} and f_{bdg3}, however f_{bdg} is not to be taken greater than 12.

The section modulus of mid-span area is to be determined using f_{bdg} = 24, or f_{bdg2} from the table if lesser.

The shear area requirement of end connections within 0.2 ℓ_{shr} from the end of the effective span is to be determined using f_{shr} = 0.5 or the applicable f_{shr1} or f_{shr3}, whichever is greater.

For models A through F, the value of f_{shr} may be gradually reduced outside of 0.2 ℓ_{shr} towards 0.5 f_{shr} at mid-span, where f_{shr} is the greater value of f_{shr1} and f_{shr3}.

3.3 Advanced calculation methods

3.3.1 Direct analysis

Where complex grillage structures are employed or cross ties are fitted in side shell primary supporting members, the scantlings are to be determined by direct calculation taking into account:

- The distribution of still water and wave pressure and forces, if any.
- The number and position of intermediate supports (e.g. decks, girders, etc).
- The condition of fixity at the ends of the primary supporting members and at intermediate supports.
- The geometrical characteristics of the primary supporting members on the intermediate spans.

3.3.2 Analysis criteria

The calculated stresses are to comply with the following criteria where the coefficients C_t and C_s, are defined in [3.2]:

- $\sigma \le \chi C_s R_{eH}$
- $\tau \le \chi C_t \tau_{eH}$

where:

τ : Shear stress in member, in N/mm², based on t_{n50}.

σ : Normal stress in member, in N/mm², based on t_{n50}.

4 PILLARS

4.1 Pillars subjected to compressive axial load

4.1.1 Criteria

The maximum applied compressive axial load on a pillar, F_{pill}, in kN, is to be taken as the greatest value calculated for all applicable design load sets defined in Ch 6, Sec 2, [2], and is given by the following formula:

$$F_{pill} = Pb_{a-sup}\ \ell_{a-sup} + F_{pill-upr}$$

where:

$b_{a\text{-}sup}$: Mean breadth of area supported, in m.

$\ell_{a\text{-}sup}$: Mean length of area supported, in m.

$F_{pill\text{-}upr}$: Axial load from pillar including axial load from pillars above, in kN, if any.

$A_{pill\text{-}n50}$: Net cross section area of the pillar, in cm².

The buckling check of the pillar is to be performed according to Ch 8, Sec 4, [5.1], with σ_{av} in N/mm², as defined in Ch 8, Sec 5, [3.1] given by:

$$\sigma_{av} = 10\frac{F_{pill}}{A_{pill-n50}}$$

4.2 Pillars subject to tensile axial load

4.2.1 Criteria

Pillars and PSM members subjected to tensile axial load are to satisfy the criteria given in [3.3.2].

PART 1 CHAPTER 7

DIRECT STRENGTH ANALYSIS

Table of Contents

SECTION 1
STRENGTH ASSESSMENT

1 GENERAL

1.1 Application

1.1.1

This chapter provides requirements applicable to ships having rule length L of 150 m or above to assess the scantlings of the hull structure using finite element analysis.

1.1.2

The finite element analysis consists of three parts:

a) Cargo hold analysis to assess the strength of longitudinal hull girder structural members, primary supporting structural members and bulkheads.

b) Fine mesh analysis to assess detailed stress levels in local structural details.

c) Very fine mesh analysis to assess the fatigue capacity of the structural details according to Ch 9.

1.1.3

The strength assessment performed with finite element analysis is to verify that the scantlings comply with the acceptance criteria specified in this chapter for:

- Cargo hold structural analysis performed in accordance with Ch 7, Sec 2.
- Local structural analysis performed in accordance with Ch 7, Sec 3.

1.1.4

Strength assessment based on finite element analysis is applicable for the entire cargo hold region.

1.1.5

The analysis is to verify the following:

a) Stress levels are within the acceptance criteria for yielding.

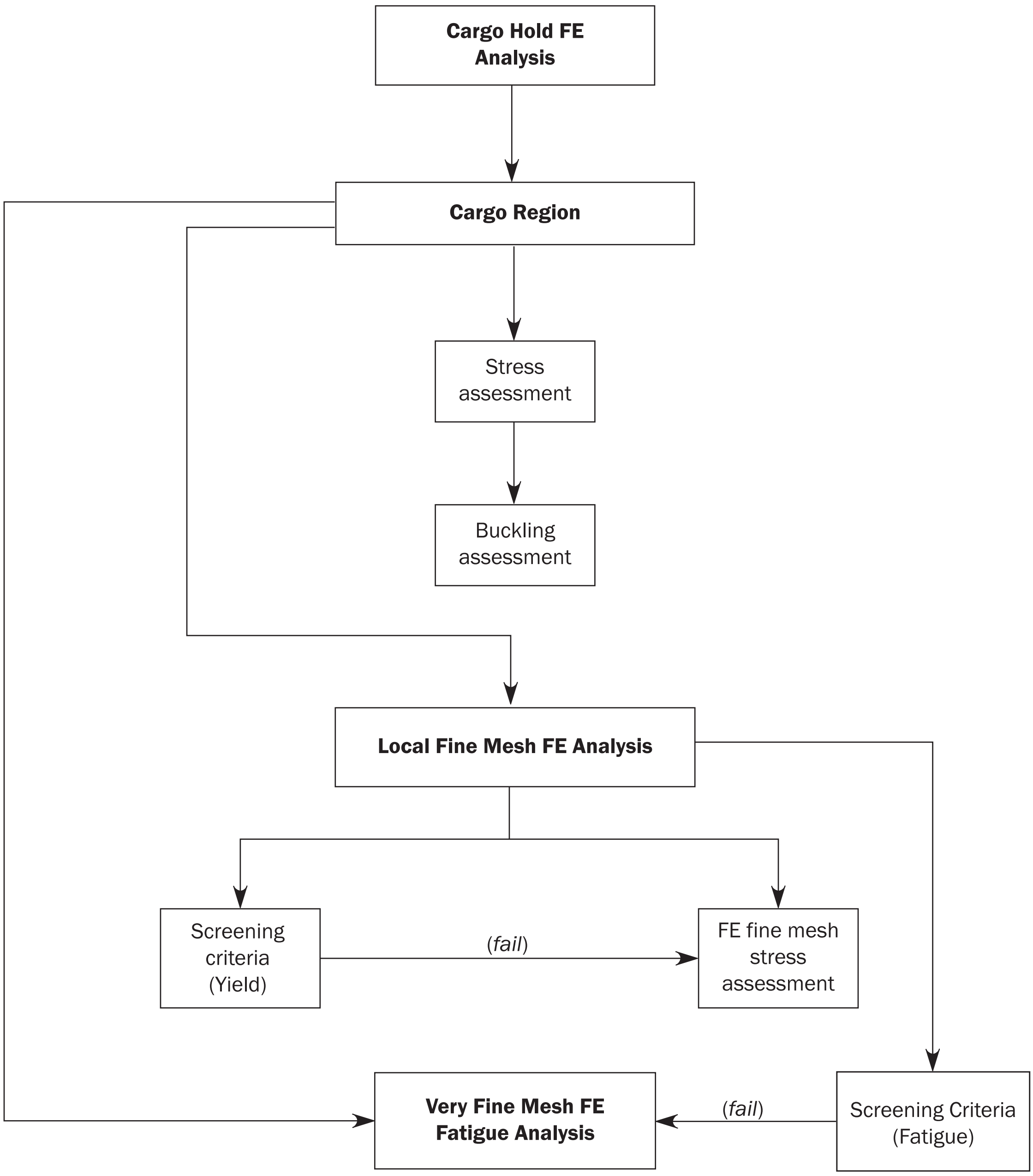
b) Buckling capability of plates and stiffened panels are within the acceptance criteria for bucking defined in Ch 8.

c) Fatigue capacity of structural details is within the acceptance criteria defined in Ch 9.

1.1.6

A flow diagram showing the minimum requirement of finite element analysis is shown in Figure 1.

Figure 1 : Flow diagram of finite element analysis



2 NET SCANTLING

2.1 Net scantling application

2.1.1

FE models for cargo hold FE analyses, local fine mesh FE analysis and very fine mesh FE analyses, are to be based on the net scantling approach, applying a corrosion addition of 0.5 t_c as defined in Ch 3, Sec 2, Table 1.

All buckling capacity assessment are to be based on corrosion addition t_c, as defined in Ch 3, Sec 2, Table 1.

3 FINITE ELEMENT TYPES

3.1 Used finite element types

3.1.1

The structural assessment is to be based on linear finite element analysis of three dimensional structural models. The general types of finite elements to be used in the finite element analysis are given in Table 1.

Table 1 : Types of finite element

Type of finite element	Description
Rod (or truss) element	Line element with axial stiffness only and constant cross sectional area along the length of the element.
Beam element	Line element with axial, torsional and bi-directional shear and bending stiffness and with constant properties along the length of the element.
Shell (or plate) element	Shell element with in-plane stiffness and out-of-plane bending stiffness with constant thickness.

3.1.2

Two node line elements and four node shell elements are, in general, considered sufficient for the representation of the hull structure. The mesh requirements given in this chapter are based on the assumption that these elements are used in the finite element models. However, higher order elements may also be used.

4 SUBMISSION OF RESULTS

4.1 Detailed report

4.1.1

A detailed report of the structural analysis is to be submitted by the designer/builder to demonstrate compliance with the specified structural design criteria. This report is to include the following information:

a) List of plans used including dates and versions.

b) Detailed description of structural modelling including all modelling assumptions and any deviations in geometry and arrangement of structure compared with plans.

c) Plots to demonstrate correct structural modelling and assigned properties.

d) Details of material properties, plate thickness, beam properties used in the model.

e) Details of boundary conditions.

f) Details of all loading conditions reviewed with calculated hull girder shear force, bending moment and torsional moment distributions.

g) Details of applied loads and confirmation that individual and total applied loads are correct.

h) Plots and results that demonstrate the correct behaviour of the structural model under the applied loads.

i) Summaries and plots of global and local deflections.

j) Summaries and sufficient plots of stresses to demonstrate that the design criteria are not exceeded in any member.

k) Plate and stiffened panel buckling analysis and results.

l) Tabulated results showing compliance, or otherwise, with the design criteria.

m) Proposed amendments to structure where necessary, including revised assessment of stresses, buckling and fatigue properties showing compliance with design criteria.

n) Reference of the finite element computer program, including its version and date.

5 COMPUTER PROGRAMS

5.1 Use of computer programs

5.1.1

Any finite element computation program complying with Ch 1, Sec 3 may be employed to determine the stress and deflection of the hull structure, provided that the combined effects of bending, shear, axial and torsional deformations are considered.

SECTION 2
CARGO HOLD STRUCTURAL STRENGTH ANALYSIS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

M_{sw} : Permissible vertical still water bending moment, in kNm, as defined in Ch 4, Sec 4.

M_{wv} : Vertical wave bending moment, in kNm, in hogging or sagging condition, as defined in Ch 4, Sec 4.

M_{wh} : Horizontal wave bending moment, in kNm, as defined in Ch 4, Sec 4.

M_{wt} : Wave torsional moment in seagoing condition, in kNm, as defined in Ch 4, Sec 4.

Q_{sw} : Permissible still water shear force, in kN, at the considered bulkhead position, as provided in Ch 4, Sec 4.

Q_{wv} : Vertical wave shear force, in kN, as defined in Ch 4, Sec 4.

$x_{b\text{-}aft}$, $x_{b\text{-}fwd}$: X-coordinate, in m, of respectively the aft and forward bulkhead of the mid-hold.

x_{aft} : *X*-coordinate, in m, of the aft end support of the FE model.

x_{fore} : *X*-coordinate, in m, of the fore end support of the FE model.

x_i : *X*-coordinate, in m, of web frame station *i*.

Q_{aft} : Vertical shear force, in kN, at aft bulkhead of mid-hold as defined in [4.4.6].

Q_{fwd} : Vertical shear force, in kN, at fore bulkhead of mid-hold as defined in [4.4.6].

$Q_{targ\text{-}aft}$: Target shear force, in kN, at the aft bulkhead of mid-hold as defined in [4.3.3].

$Q_{targ\text{-}fwd}$: Target shear force, in kN, at the forward bulkhead of mid-hold as defined in [4.3.3].

1 OBJECTIVE AND SCOPE

1.1 General

1.1.1

The cargo hold structural strength analysis is used for the assessment of scantlings of longitudinal hull girder structural members, primary supporting members and bulkheads within the cargo hold region. This section gives the requirements for cargo hold structural strength analysis.

1.1.2

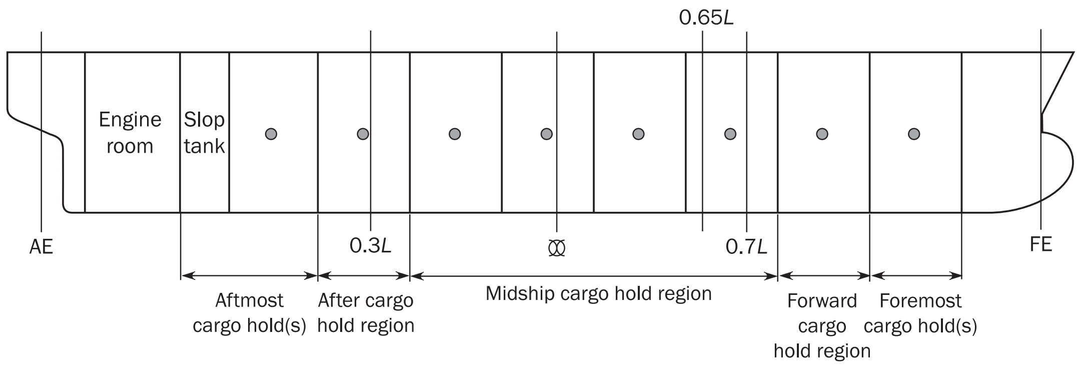
Cargo hold structural strength analysis is mandatory within the cargo hold region including the aft bulkhead of the aftmost cargo hold and the collision bulkhead. The evaluation areas are defined in [5.1].

1.1.3

For the purpose of FE structural assessment and load application, the cargo hold region contains the following cargo hold regions, which may vary depending on the ship length and cargo hold arrangement, as defined in Figure 1:

- Midship cargo hold region,
- Forward cargo hold region,
- After cargo hold region,
- Foremost cargo hold(s),
- Aftmost cargo hold(s).

Figure 1 : Definition of cargo hold regions for FE structural assessment



Holds in the forward cargo hold region are defined as holds with their longitudinal centre of gravity position forward of 0.7 *L* from AE, except foremost cargo hold.
Holds in the midship cargo hold region are defined as holds with their longitudinal centre of gravity position at or forward of 0.3 *L* from AE and at or aft of 0.7 *L* from AE.
Holds in the after cargo hold region are defined as holds with their longitudinal centre of gravity position aft of 0.3 *L* from AE, except aftmost cargo hold.
Foremost cargo hold(s) is (are) defined as hold(s) in the foremost location of the cargo hold region.
Aftmost cargo hold(s) is (are) defined as hold(s) in the aftmost location of the cargo hold region.

1.2 Cargo hold structural strength analysis procedure

1.2.1 Procedure description

The structural FE analysis is to be performed in accordance with the following:

- Model: Three cargo hold model with:
    - Extent as given in [2.2]
    - Finite element types as given in [2.3]
    - Structural modelling as defined in [2.4]
- Boundary conditions as defined in [2.5]
- FE load combinations as defined in [3]
- Load application as defined in [4]
- Evaluation area as defined in [5.1]
- Strength assessment as defined in [5.2] and [5.3]

1.2.2 Mid-hold definition

For the purpose of the FE analysis, the mid-hold is defined as the middle hold(s) of the three cargo hold length FE model.

In case of foremost and aftmost cargo hold assessment, the mid-hold represents the foremost and aftmost cargo hold including the slop tank if any, respectively.

1.2.3 Scantling assessment

The scantling assessment is carried out according to Ch 7, Sec 1 for each individual cargo hold using the FE load combinations defined in Ch 4, Sec 8 applicable to the considered cargo hold. The FE analysis results are applicable to the evaluation area as defined in [5.1.1], of the considered cargo hold.

The individual transverse bulkhead structural elements, inclusive plating, stiffeners and horizontal stringers, are to be assessed considering two cargo hold finite element analyses, i.e. the analysis for the hold forward and the one for the hold aft of the considered transverse bulkhead.

2 STRUCTURAL MODEL

2.1 Members to be modelled

2.1.1

All main longitudinal and transverse structural elements are to be modelled. These include:

- Inner and outer shell,
- Deck,
- Double bottom floors and girders,
- Transverse and vertical web frames,
- Hatch coamings,
- Stringers,
- Transverse and longitudinal bulkhead structures,
- Other primary supporting members,
- Other structural members which contribute to hull girder strength.

All plates and stiffeners on the structure, including web stiffeners, are to be modelled. Brackets which contribute to primary supporting member strength and the size of which is not less than the typical mesh size (s-by-s) described in [2.4.2], are to be modelled.

2.2 Extent of model

2.2.1 Longitudinal extent

Except the foremost and aftermost cargo hold models, the longitudinal extent of the cargo hold FE model is to cover three cargo hold lengths. The transverse bulkheads at the ends of the model are to be modelled. Where corrugated transverse bulkheads are fitted, the model is to include the extent of the bulkhead stool structure forward and aft of the tanks/holds at the model ends. The web frames at the ends of the model are to be modelled. Typical finite element models representing the midship cargo hold region of different ship type configurations are shown in Figure 3 and Figure 4.

The foremost and the aftmost cargo holds are located at the middle of the FE models as follows:

- Foremost cargo hold: from the after bulkhead of the cargo hold no. 2 to the ship's foremost cross section where the reinforced ring or web frame remains continuous from the base line to the strength deck.
- Aftermost cargo hold: from the after bulkhead of the engine room to the forward bulkhead of no. N-1 cargo hold, where N is the number of holds or sets of holds numbered from forward to aft.

Examples of finite element models representing the foremost and aftermost cargo holds of different ship type configurations are shown in Figure 5 and Figure 6.

2.2.2 Hull form modelling

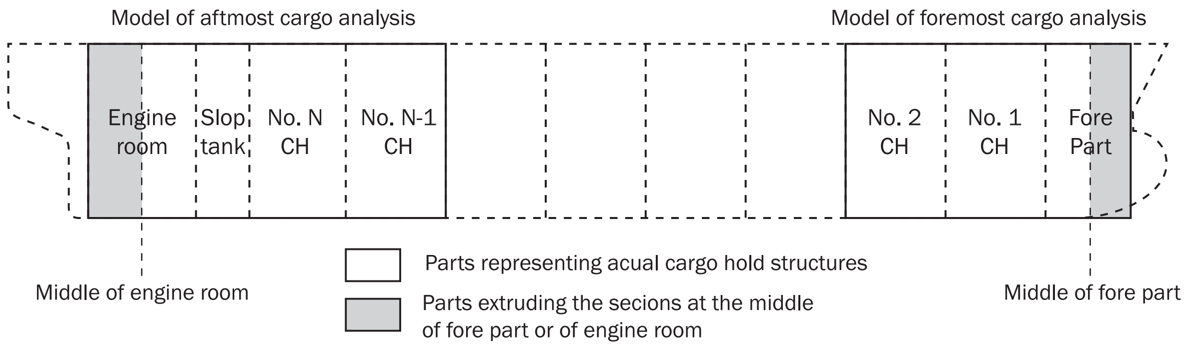
In general, the finite element model is to represent the geometry of the hull form. In the midship cargo hold region, the finite element model may be prismatic provided the mid-hold has a prismatic shape.

In the foremost cargo hold model, the hull form forward of the transverse section at the middle of the fore part up to the model end as defined in [2.2.1] may be modelled with a simplified geometry. The transverse section at the middle of the fore part up to the model end may be extruded out to the fore model end, as shown in Figure 2.

In the aftmost cargo hold model, the hull form aft of the middle of the machinery space may be modelled with a simplified geometry. The section at the middle of the machinery space may be extruded out to its aft bulkhead, as shown in Figure 2.

When the hull form is modelled by extrusion, the geometrical properties of the transverse section located at the middle of the considered space (fore or machinery space) are copied along the simplified model. The transverse web frames are to be considered along this extruded part with the same properties as the ones in the fore part or in the machinery space.

Figure 2 : Hull form simplification for foremost and aftmost cargo hold model



2.2.3 Transverse extent

Both port and starboard sides of the ship are to be modelled.

2.2.4 Vertical extent

The full depth of the ship is to be modelled including primary supporting members above the upper deck, trunks, forecastle and/or cargo hatch coaming, if any.

The superstructure or deck house in way of the machinery space and the bulwark are not required to be included in the model.

2.3 Finite element types

2.3.1

Shell elements are to be used to represent plates.

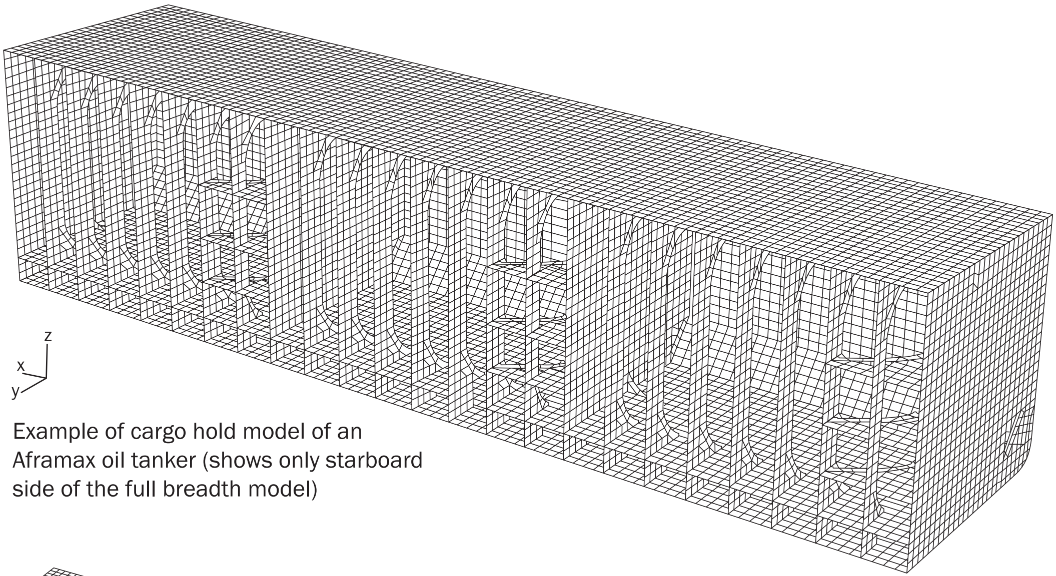
2.3.2

All stiffeners are to be modelled with beam elements having axial, torsional, bi-directional shear and bending stiffness. The eccentricity of the neutral axis is to be modelled.

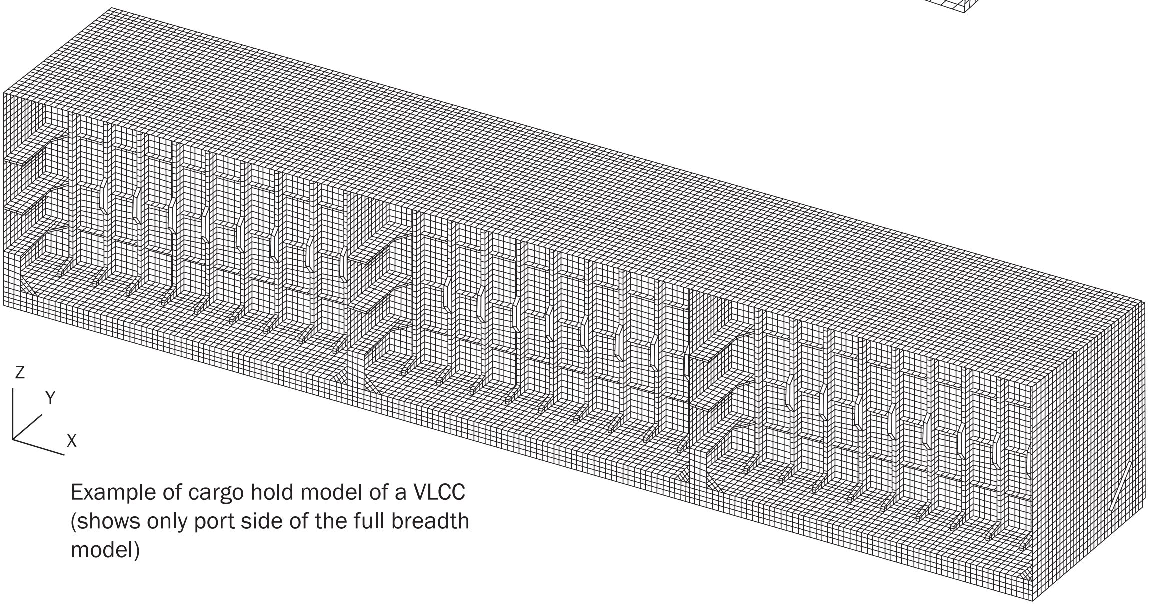
2.3.3

Face plates of primary supporting members and brackets are to be modelled using rod or beam elements.

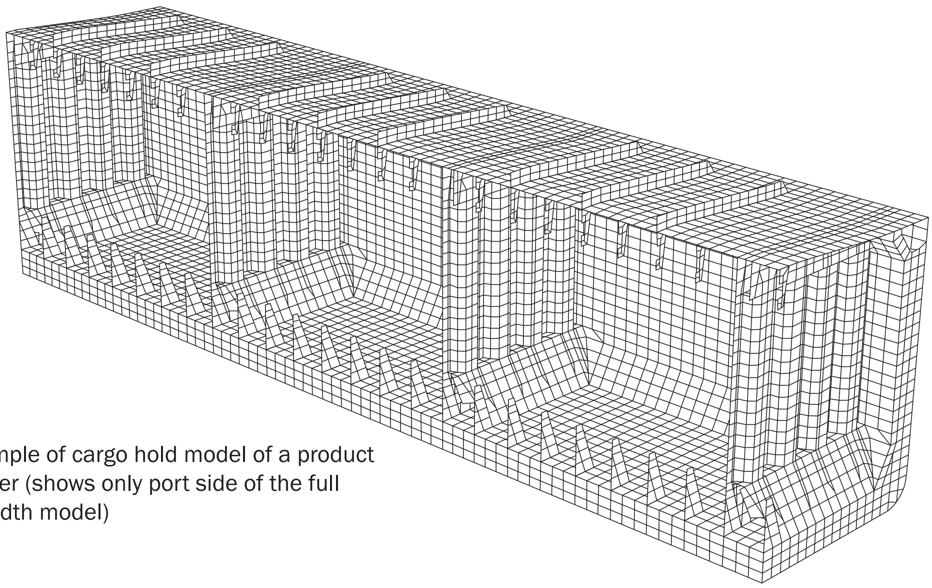
Figure 3 : Example of 3 cargo hold model within midship region of oil tankers



Example of cargo hold model of an Aframax oil tanker (shows only starboard side of the full breadth model)

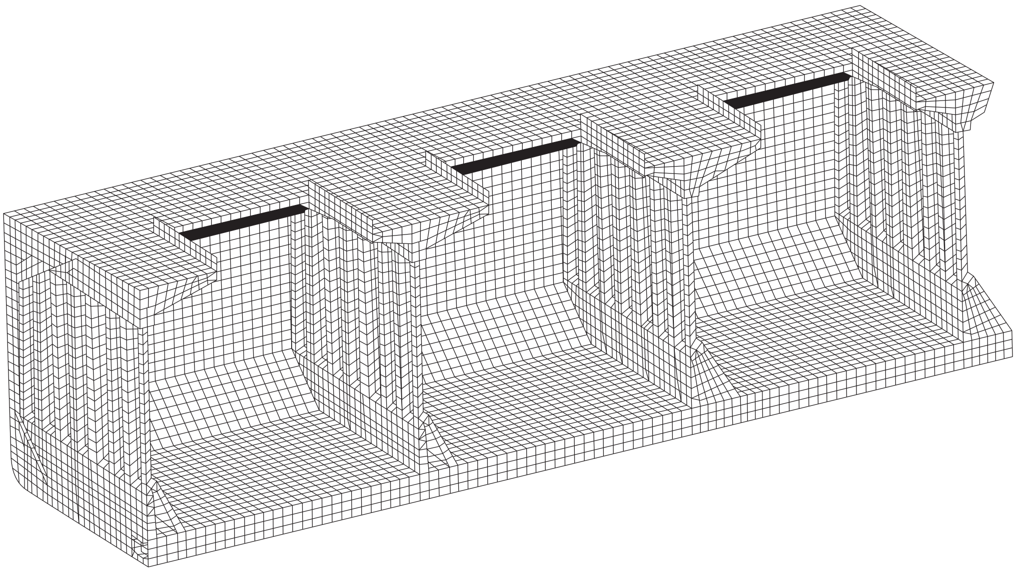


Example of cargo hold model of a VLCC (shows only port side of the full breadth model)



Example of cargo hold model of a product tanker (shows only port side of the full breadth model)

Figure 4 : Example of 3 cargo hold model within midship region of a bulk carrier



Example of cargo hold model of a bulk carrier (shows only port side of the full breadth model)

Figure 5 : Example of FE model for the foremost cargo hold structure of an oil tanker

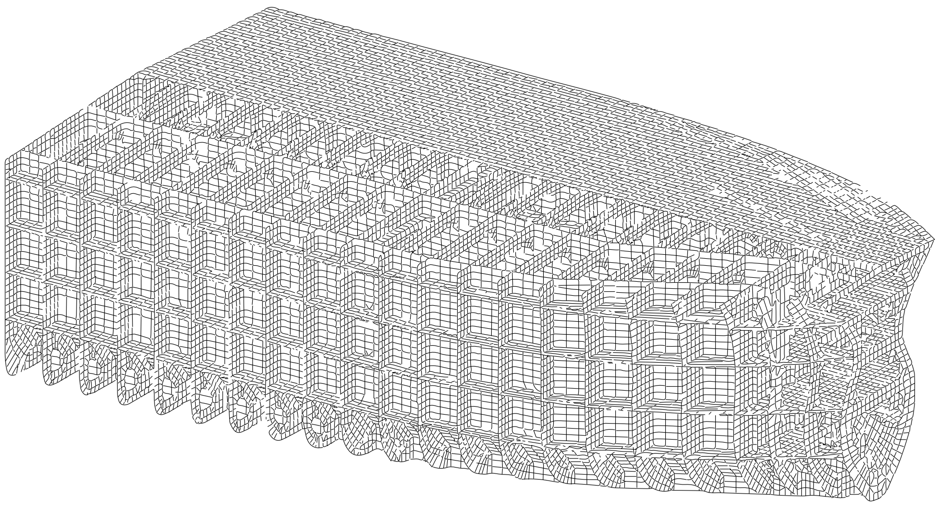


Figure 6 : Example of FE model for the aftermost cargo hold structure of a bulk carrier

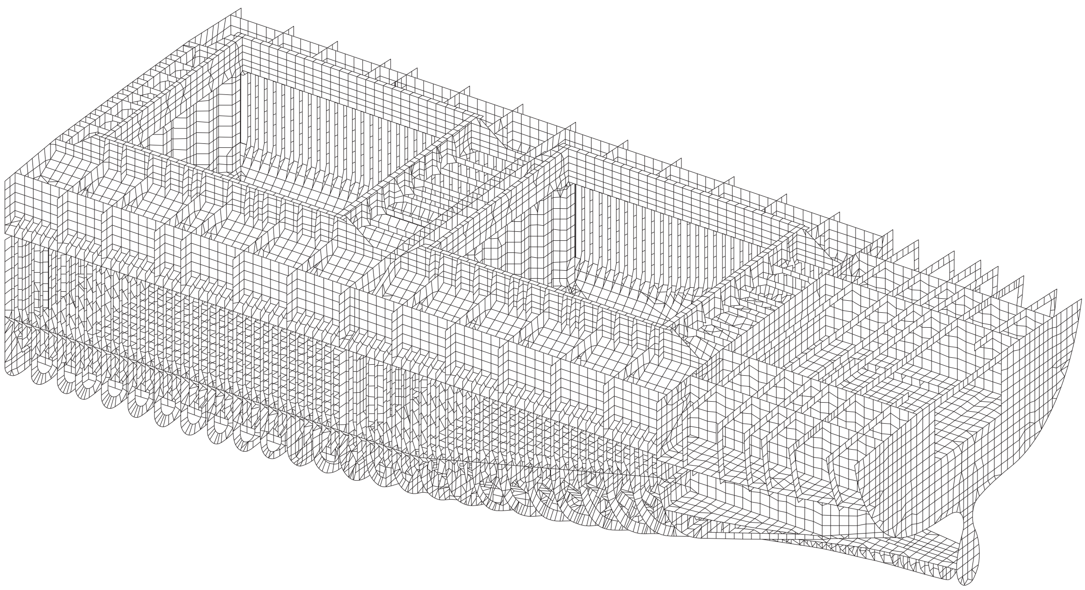


Figure 7 : Typical finite element mesh on web frame

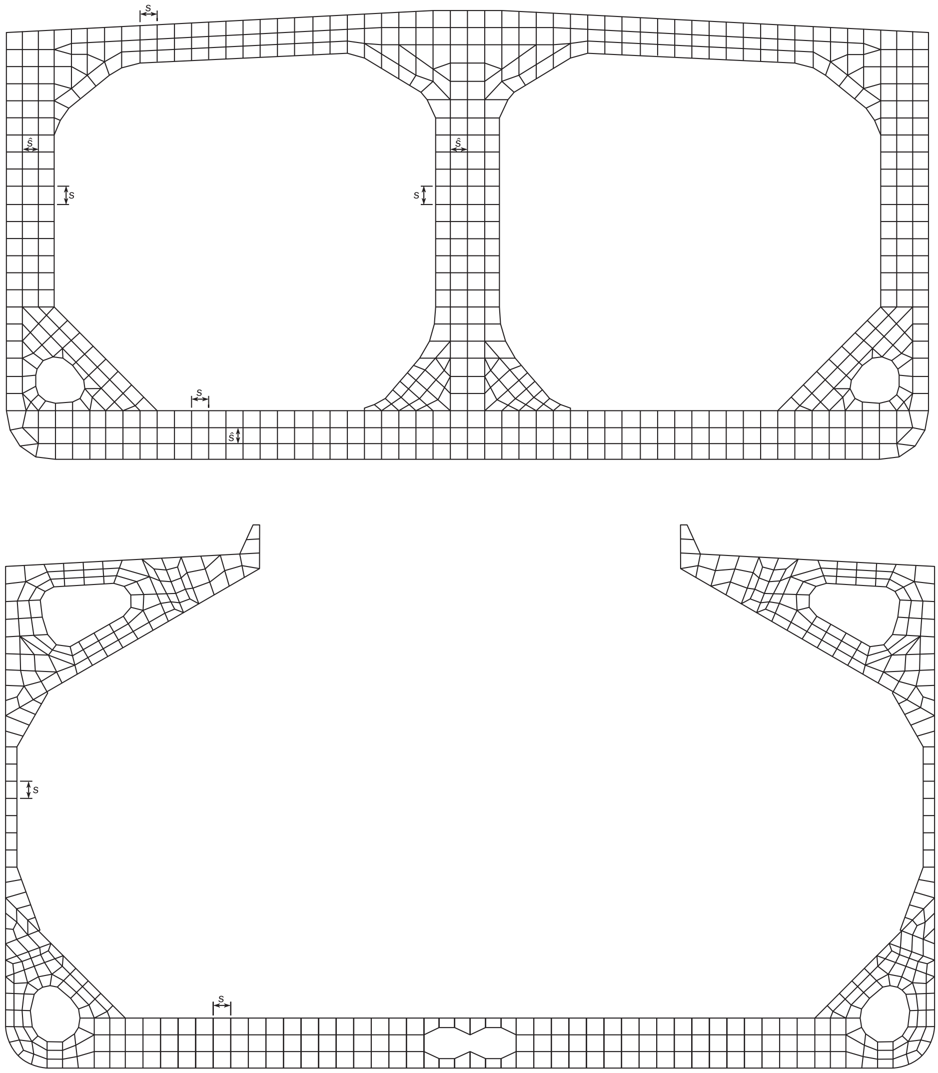
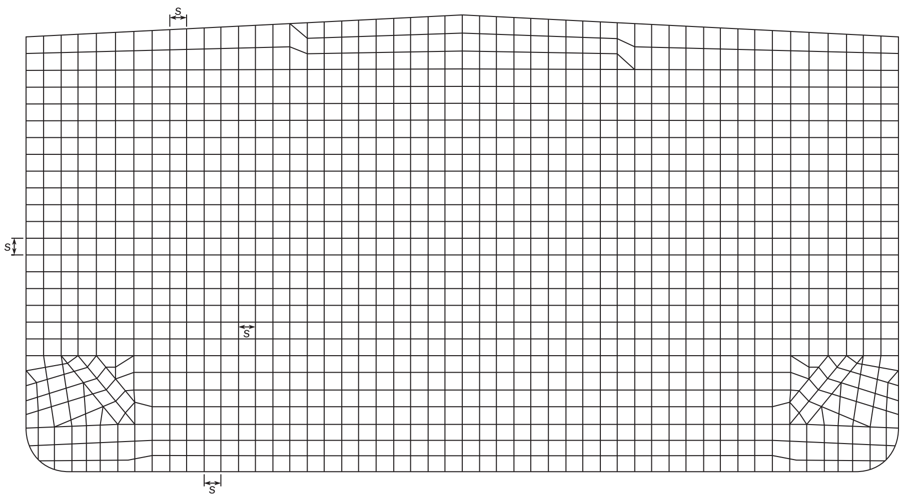


Figure 8 : Typical finite element mesh on transverse bulkhead



s = Stiffener spacing

2.4 Structural modelling

2.4.1 Aspect ratio

The aspect ratio of the shell elements is in general not to exceed 3. The use of triangular shell elements is to be kept to a minimum. Where possible, the aspect ratio of shell elements in areas where there are likely to be high stresses or a high stress gradient is to be kept close to 1 and the use of triangular elements is to be avoided.

2.4.2 Mesh

The shell element mesh is to follow the stiffening system as far as practicable, hence representing the actual plate panels between stiffeners. In general, the shell element mesh is to satisfy the following requirements:

a) One element between every longitudinal stiffener, see Figure 7. Longitudinally, the element length is not to be greater than 2 longitudinal spaces with a minimum of three elements between primary supporting members.

b) One element between every stiffener on transverse bulkheads, see Figure 8.

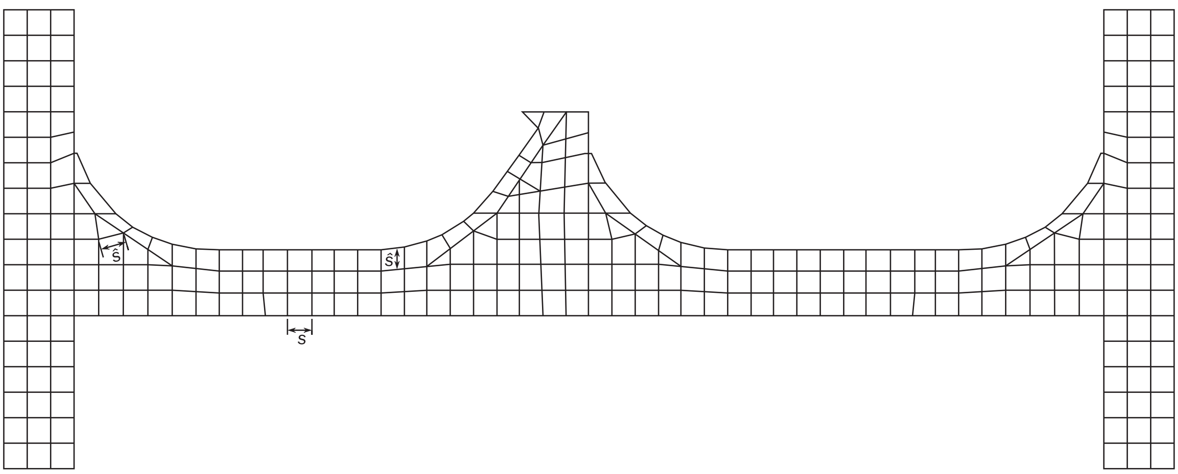
c) One element between every web stiffener on transverse and vertical web frames, cross ties and stringers, see Figure 7 and Figure 9.

d) At least 3 elements over the depth of double bottom girders, floors, transverse web frames, vertical web frames and horizontal stringers on transverse bulkheads. For cross ties, deck transverse and horizontal stringers on transverse wash bulkheads and longitudinal bulkheads with a smaller web depth, modelling using 2 elements over the depth is acceptable provided that there is at least 1 element between every web stiffener. For a single side bulk carrier, 1 element over the depth of side frames is acceptable. The mesh size of adjacent structure is to be adjusted accordingly.

e) The mesh on the hopper tank web frame and the topside web frame is to be fine enough to represent the shape of the web ring opening, as shown in Figure 7.

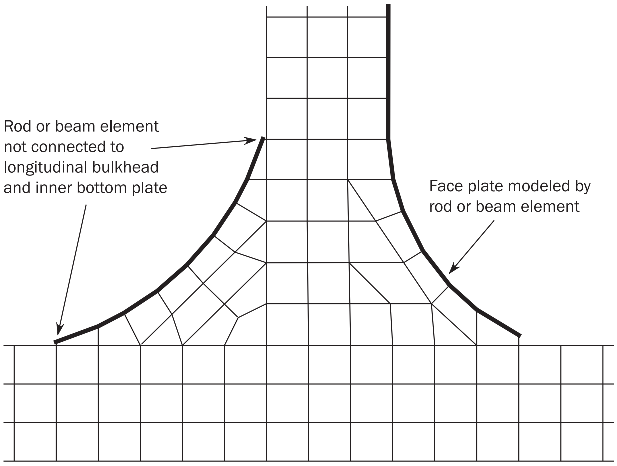
f) The curvature of the free edge on large brackets of primary supporting members is to be modelled to avoid unrealistic high stress due to geometry discontinuities. In general, a mesh size equal to the stiffener spacing is acceptable. The bracket toe may be terminated at the nearest nodal point provided that the modelled length of the bracket arm does not exceed the actual bracket arm length. The bracket flange is not to be connected to the plating, as shown in Figure 10. The modelling of the tapering part of the flange is to be in accordance with [2.4.8]. An example of acceptable mesh is shown in Figure 10. A finer mesh is to be used for the determination of detailed stress at the bracket toe, as given in Ch 7, Sec 3.

Figure 9 : Typical finite element mesh on horizontal transverse stringer on transverse bulkhead



s = Stiffener spacing

Figure 10 : Typical finite element mesh on transverse web frame main bracket



2.4.3 Finer mesh

Where the geometry cannot be adequately represented in the cargo hold model and the stress exceeds the cargo hold mesh acceptance criteria, a finer mesh may be used for such geometry to demonstrate satisfactory scantlings. The mesh size required for such analysis can be governed by the geometry. In such cases, the average stress within an area equivalent to that specified in [2.4] is to comply with the requirements given in [5.2].

2.4.4 Corrugated bulkhead

Diaphragms in the stools, supporting structure of corrugated bulkheads and internal longitudinal and vertical stiffeners on the stool plating are to be included in the model. Modelling is to be carried out as follows:

a) The corrugation is to be modelled with its geometric shape.

b) The mesh on the flange and web of the corrugation is in general to follow the stiffener spacing inside the bulkhead stool.

c) The mesh on the longitudinal corrugated bulkhead is to follow longitudinal positions of transverse web frames, where the corrections to hull girder vertical shear forces are applied in accordance with [4.4.7].

d) The aspect ratio of the mesh in the corrugation is not to exceed 2 with a minimum of 2 elements for the flange breadth and the web height.

e) Where difficulty occurs in matching the mesh on the corrugations directly with the mesh on the stool, it is acceptable to adjust the mesh on the stool in way of the corrugations.

f) For a corrugated bulkhead without an upper stool and/or lower stool, it may be necessary to adjust the geometry in the model. The adjustment is to be made such that the shape and position of the corrugations and primary supporting members are retained. Hence, the adjustment is to be made on stiffeners and plate seams if necessary.

g) When corrugated bulkhead is subjected to liquid cargo or ballast, dummy rod elements with a cross sectional area of 1 mm^2 are to be modelled at the corrugation knuckle between the flange and the web. Dummy rod elements are to be used as minimum at the two corrugation knuckles closest to the intersection between:

- Transverse and longitudinal bulkheads,
- Transverse bulkhead and inner hull,
- Transverse bulkhead and side shell.

h) Manholes in diaphragms are to be modelled according to [2.4.9].

2.4.5

Example of mesh arrangements of the cargo hold structure are shown in Figure 11 to Figure 14.

Figure 11 : Example of FE mesh arrangements of cargo hold structure for a bulk carrier

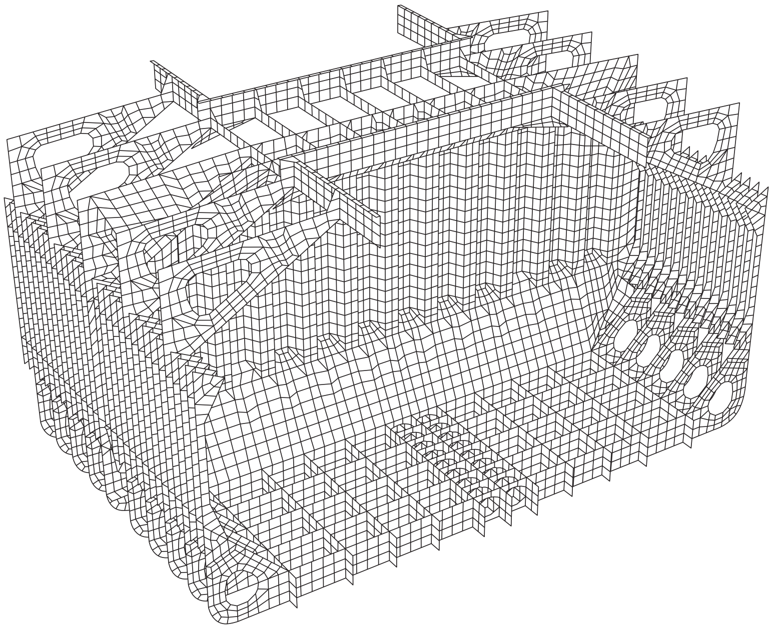


Figure 12 : Example of FE mesh on transverse corrugated bulkhead structure for a product tanker

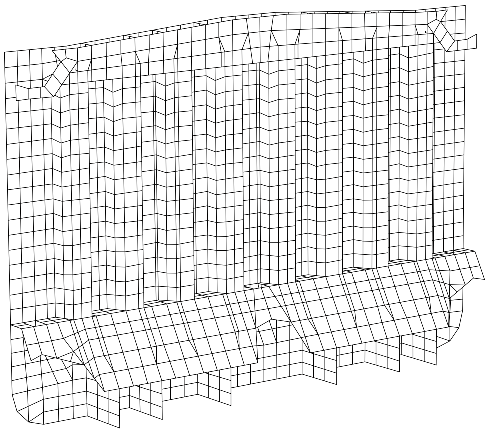


Figure 13 : Example of FE mesh arrangements of cargo tank structure for an aframax tanker

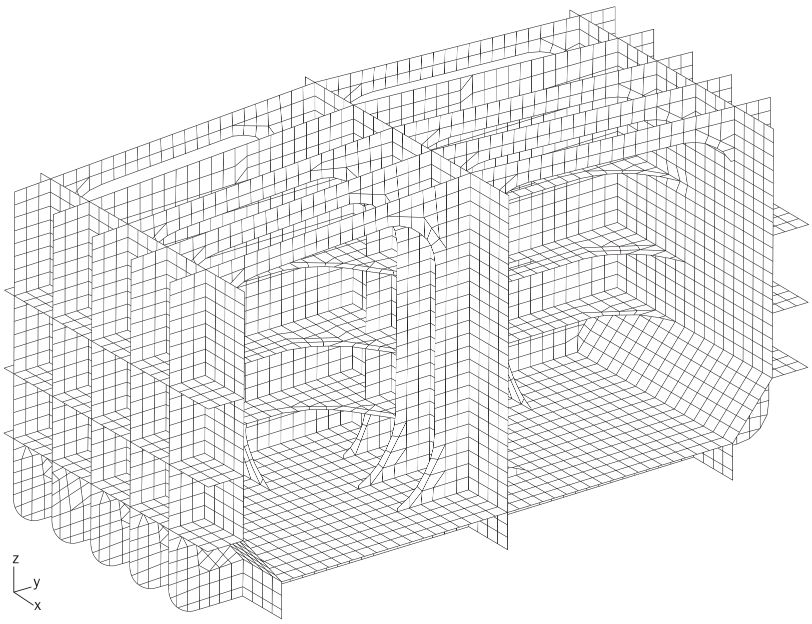
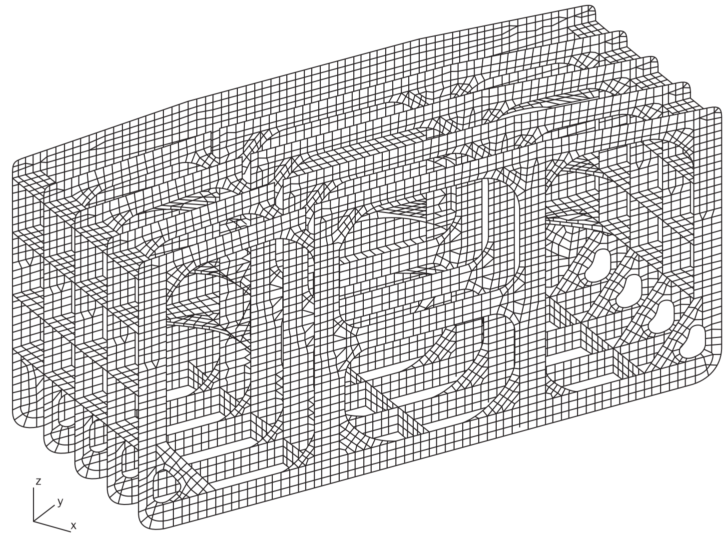
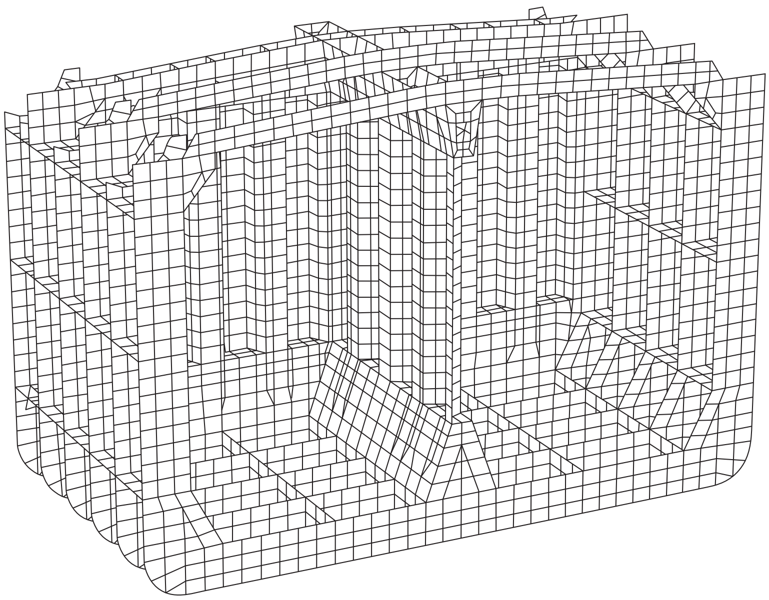


Figure 14 : Examples of FE mesh arrangements of cargo tank structure for VLCC and product tanker





2.4.6 Sniped stiffener

Non continuous stiffeners are to be modelled as continuous stiffeners, i.e. the height web reduction in way of the snip ends are not to be modelled.

2.4.7 Web stiffeners of primary supporting members

Web stiffeners of primary supporting members are to be modelled. Where these stiffeners are not in line with the primary FE mesh, it is sufficient to place the line element along the nearby nodal points provided that the adjusted distance does not exceed 0.2 times the stiffener spacing under consideration. The stresses and buckling utilisation factors obtained need not be corrected for the adjustment. Buckling stiffeners on large brackets, deck transverses and stringers parallel to the flange are to be modelled. These stiffeners may be modelled using rod elements.

2.4.8 Face plate of primary supporting member

The effective cross sectional area at the curved part of the face plate of primary supporting members and brackets is to be calculated in accordance with Ch 3, Sec 7. The cross sectional area of a rod or beam element representing the tapering part of the face plate is to be based on the average cross sectional area of the face plate in way of the element length.

2.4.9 Openings

Methods of representing openings in webs of primary supporting members are to be in accordance with Table 1 except for manholes which are to be modelled by removing the adequate elements.

Table 1 : Representation of openings in primary supporting member webs

Criteria	Modelling decision
$h_o/h < 0.5$ and $g_o < 2.0$	Openings do not need to be modelled
$h_o/h \geq 0.5$ or $g_o \geq 2.0$	The geometry of the opening is to be modelled

where:

$$g_o = \left(1 + \frac{\ell_o^2}{2.6(h - h_o)^2}\right)$$

ℓ_o : Length of opening parallel to primary supporting member web direction, in m, see Figure 15. For sequential openings where the distance, d_o between openings is less than 0.25 h, the length ℓ_o is to be taken as the length across openings as shown in Figure 16.

h_o : Height of opening parallel to depth of web, in m, see Figure 15 and Figure 16.

h : Height of web of primary supporting member in way of opening, in m, see Figure 15 and Figure 16.

Figure 15 : Openings in web

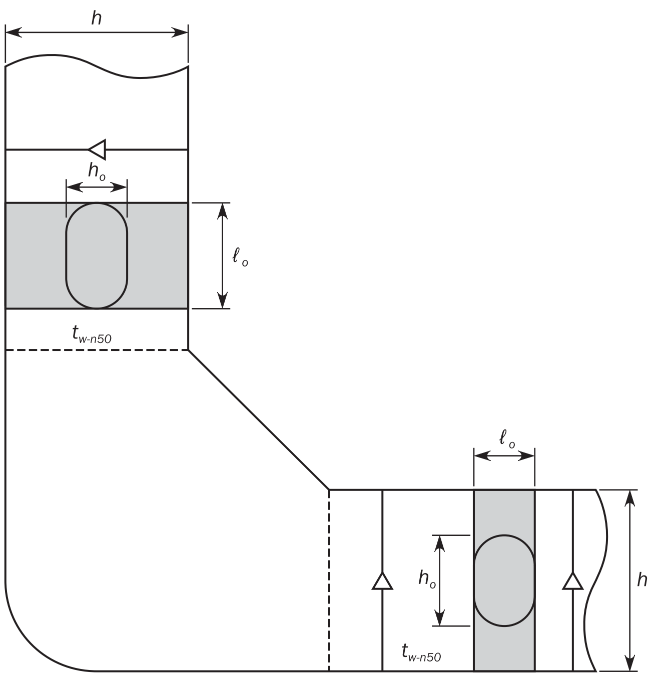
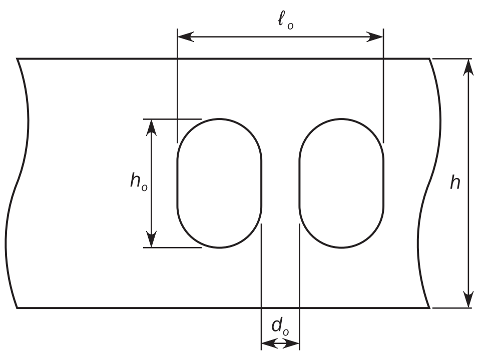


Figure 16 : Length lo for sequential openings with $d_o < h/4$



2.5 Boundary conditions

2.5.1 General

All boundary conditions described in this section are in accordance with the global coordinate system defined in Ch 4, Sec 1.

2.5.2 Application

The boundary conditions given [2.5.3] are applicable to cargo hold finite element model analyses in cargo hold region.

2.5.3 Boundary conditions

The boundary conditions consist of the rigid links at model ends, point constraints and end-beams. The rigid links connect the nodes on the longitudinal members at the model ends to an independent point at neutral axis in centreline. The boundary conditions to be applied at the ends of the cargo hold FE model, except for the foremost cargo hold, are given in Table 2. For the foremost cargo hold analysis, the boundary conditions to be applied at the ends of the cargo hold FE model are given in Table 3.

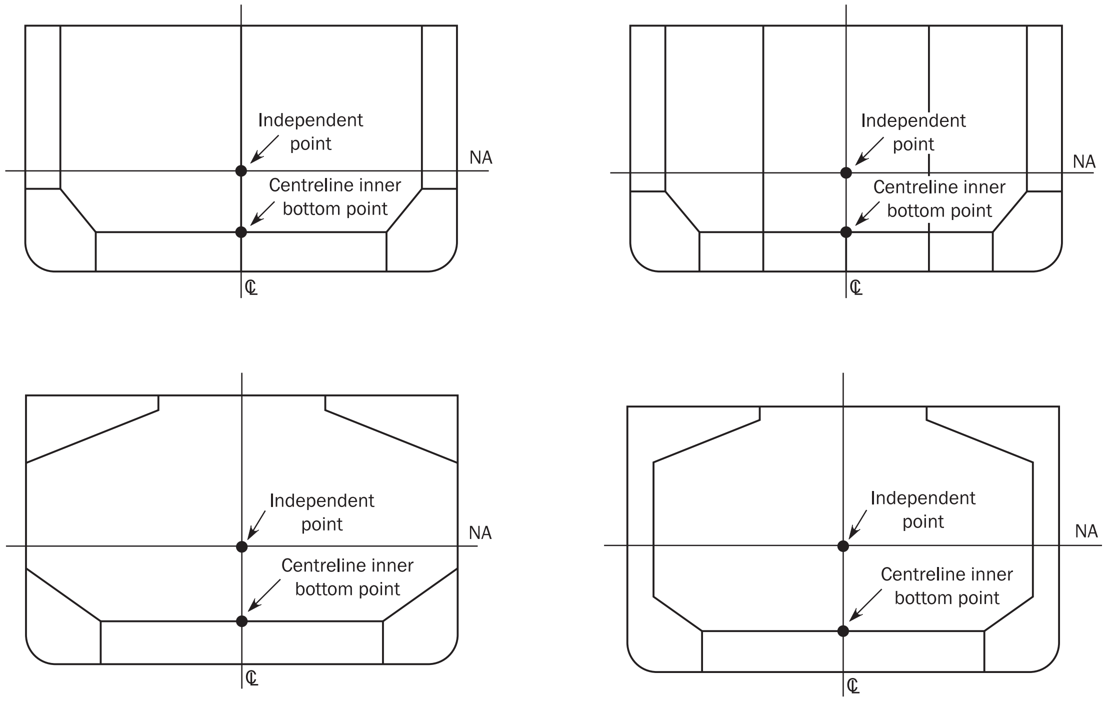
Table 2 : Boundary constraints at model ends except the foremost cargo hold models

Location	Translation			Rotation		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Aft End						
Independent point	-	Fix	Fix	$M_{T\text{-}end}$	-	-
Cross section	-	Rigid link	Rigid link	Rigid link	-	-
	End beam, see [2.5.4]					
Fore End						
Independent point	-	Fix	Fix	Fix	-	-
Intersection of centreline and inner bottom	Fix	-	-	-	-	-
Cross section	-	Rigid link	Rigid link	Rigid link	-	-
	End beam, see [2.5.4]					
Note 1: [-] means no constraint applied (free). Note 2: See Figure 17.						

Table 3 : Boundary constraints at model ends of the foremost cargo hold model

Location	Translation			Rotation		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Aft End						
Independent point	-	Fix	Fix	Fix	-	-
Intersection of centreline and inner bottom	Fix	-	-	-	-	-
Cross section	-	Rigid link	Rigid link	Rigid link	-	-
	End beam, see [2.5.4]					
Fore End						
Independent point	-	Fix	Fix	$M_{T\text{-}end}$	-	-
Cross section	-	Rigid link	Rigid link	Rigid link	-	-
Note 1: [-] means no constraint applied (free). Note 2: See Figure 17. Note 3: Boundary constraints in fore end are to be located at the most forward reinforced ring or web frame which remains continuous from the base line to the strength deck.						

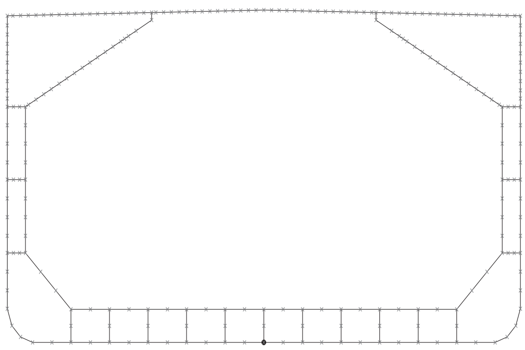
Figure 17 : Boundary conditions applied at the model end sections



2.5.4 End constraint beams

End constraint beams are to be modelled at the both end sections of the model along all longitudinally continuous structural members and along the cross deck plating of bulk carriers. An example of end beams at one end for a double hull bulk carrier is shown in Figure 18.

Figure 18 : End constraint beams for a bulk carrier



The properties of beams are calculated at fore and after sections separately and all beams at each end section have identical properties as follows:

- Net moment of inertia: $I_{yy\text{-}n50} = I_{zz\text{-}n50} = I_{xx\text{-}n50}$ (J) = 1/25 of the vertical hull girder moment of inertia of fore/aft end cross sections based on the net FE model.
- Net cross sectional area: $A_{y\text{-}n50}$ and $A_{z\text{-}n50}$ = 1/80 of the fore/aft end cross sectional areas based on the net FE model.

where:

$I_{yy\text{-}n50}$: Moment of inertia about local beam Y axial, in m^4.

$I_{zz\text{-}n50}$: Moment of inertia about local beam Z axial, in m^4.

$I_{xx\text{-}n50}$ (J) : Torsional inertia, in m^4.

$A_{y\text{-}n50}$: Shear area in local beam Y direction, in m^2.

$A_{z\text{-}n50}$: Shear area in local beam Z direction, in m^2.

3 FE LOAD COMBINATIONS

3.1 Design Load combinations

3.1.1 FE load combination definition

A FE load combination is defined as a loading pattern, a draught, a value of still water bending and shear force, associated with a given dynamic load case.

3.1.2 Mandatory load combinations

For cargo hold structural strength analysis, the design load combinations specified in Ch 4, Sec 8 are to be used for considered ship type and considered cargo hold regions.

Each design load combination given in Ch 4, Sec 8 consists of a loading pattern and dynamic load cases as given in Ch 4, Sec 2. Each load combination requires the application of the structural weight, internal and external pressures and hull girder loads. For seagoing condition, both static and dynamic load components (S+D) are applied. For harbour and tank testing condition, only static load components (S) are applied.

3.1.3 Additional loading conditions

Where the loading conditions specified by the designer are not covered by the load combinations given in Ch 4, Sec 8, these additional loading conditions are to be examined according to the procedure in [4].

4 LOAD APPLICATION

4.1 General

4.1.1 Structural weight

Effect of the weight of hull structure is to be included in static loads, but is not to be included in dynamic loads. Density of steel is to be taken as given in Ch 4, Sec 6.

4.1.2 Sign convention

Unless otherwise mentioned in this Section, the sign of moments and shear force is to be in accordance with the sign convention defined in Ch 4, Sec 1.

4.2 External and internal loads

4.2.1 External pressure

External pressure is to be calculated for each load case in accordance with Ch 4, Sec 5. External pressures include static sea pressure, wave pressure and green sea pressure.

The forces applied on the hatch cover by the green sea pressure are to be distributed along the top of the corresponding hatch coamings. The total force acting on the hatch cover is determined by integrating the hatch cover green sea pressure as defined in Ch 4, Sec 5, [5]. Then the total force is to be distributed to the total length of the hatch coamings using the average line load. The effect of the hatch cover self weight is to be ignored in the loads applied to the ship structure.

4.2.2 Internal pressure

Internal pressure is to be calculated for each load case in accordance with Ch 4, Sec 6 for design load scenarios given in Ch 4, Sec 7, Table 1. Internal pressures include static dry and liquid cargo, ballast and other liquid pressure, setting pressure on relief valve and dynamic pressure of dry and liquid cargo, ballast and other liquid pressure due to acceleration.

4.2.3 Pressure application on FE element

Constant pressure, calculated at the element's centroid, is applied to the shell element of the loaded surfaces, e.g. outer shell and deck for external pressure and tank/hold boundaries for internal pressure. Alternately, pressure can be calculated at element nodes applying linear pressure distribution within elements.

4.3 Hull girder loads

4.3.1 General

Each loading condition is to be associated with its corresponding hull girder loads which is to be applied to the model according to the procedure described in [4.4] for shear force and bending moment and in [4.5] for torsional moment. The hull girder loads are the combinations of still water hull girder loads and wave induced hull girder loads as specified in Ch 4, Sec 8. For each required FE load combination, the wave induced hull girder loads are to be calculated with the Load Combination Factors (LCFs), specified in Ch 4, Sec 2.

4.3.2 Target hull girder vertical bending moment

The target hull girder vertical bending moment, M_{v-targ}, in kNm, at a longitudinal position for a given FE load combination is taken as:

$$M_{v-targ} = C_{BM-LC}\ M_{sw} + M_{wv-LC}$$

where:

C_{BM-LC} : Percentage of permissible still water bending moment applied for the load combination under consideration as given in Ch 4, Sec 8,

M_{sw} : Permissible still water bending moments in kNm, at the considered longitudinal position for seagoing and harbour conditions as defined in Ch 4, Sec 4, [2.2.2] and Ch 4, Sec 4, [2.2.3] respectively.

M_{wv-LC} : Vertical wave bending moment in kNm, for the dynamic load case under consideration, calculated in accordance with Ch 4, Sec 4, [3.5.2].

The values of M_{v-targ} are taken as:

- Midship cargo hold region: the maximum hull girder bending moment within the mid-hold(s) for each individual cargo hold for each given FE load combination as defined in Ch 4, Sec 8.
- Outside midship cargo hold region: the values at all web frame and transverse bulkhead positions of the FE model under consideration.

Both $C_{BM-LC}\ M_{sw}$ *and* M_{wv-LC} are either in sagging or in hogging condition according to the FE load combinations given in the tables of Ch 4, Sec 8.

4.3.3 Target hull girder shear force

The target hull girder vertical shear force at the aft and forward transverse bulkheads of the mid-hold, $Q_{targ-aft}$ and $Q_{targ-fwd}$, in kN, for a given FE load combination is taken as:

- $Q_{fwd} \geq Q_{aft}$:

$$Q_{targ-aft} = C_{SF-LC} \cdot Q_{sw-neg} - \Delta Q_{swa} + f_\beta |C_{QW}| Q_{wv-neg}$$

$$Q_{targ-fwd} = C_{SF-LC} \cdot Q_{sw-pos} + \Delta Q_{swf} + f_\beta |C_{QW}| Q_{wv-pos}$$

- $Q_{fwd} < Q_{aft}$:

$$Q_{targ-aft} = C_{SF-LC} \cdot Q_{sw-pos} + \Delta Q_{swa} + f_\beta |C_{QW}| Q_{wv-pos}$$

$$Q_{targ-fwd} = C_{SF-LC} \cdot Q_{sw-neg} - \Delta Q_{swf} + f_\beta |C_{QW}| Q_{wv-neg}$$

where:

Q_{fwd}, Q_{aft}: Vertical shear forces, in kN, due to the local loads respectively at the forward and aft bulkhead position of the mid-hold, as defined in [4.4.7].

C_{SF-LC} : Percentage of permissible still water shear force as given in Ch 4, Sec 8, for the FE load combination under consideration.

Q_{sw-pos}, Q_{sw-neg}: Positive and negative permissible still water shear forces, in kN, at any longitudinal position for seagoing and harbour conditions as defined in Ch 4, Sec 4, [2.3.3] and Ch 4, Sec 4, [2.3.4] respectively.

ΔQ_{swf} : Shear force correction, in kN, for the considered FE loading pattern at the forward bulkhead taken as:

- For bulk carriers:

  Minimum of the absolute values of ΔQ_{mdf} as defined in Ch 5, Sec 1, [3.6.1] calculated at forward bulkhead for the mid-hold and the value calculated at aft bulkhead of the forward cargo hold taken as:

  $$\Delta Q_{swf} = Min(|\Delta Q_{mdf}|_{Mid}, |\Delta Q_{mdf}|_{Fwd})$$

- For oil tankers:

  $$\Delta Q_{swf} = 0$$

ΔQ_{swa} : Shear force correction, in kN, for the considered FE loading pattern at the aft bulkhead taken as:

- For bulk carriers:

  Minimum of the absolute values of ΔQ_{mdf} as defined in Ch 5, Sec 1, [3.6.1] calculated at aft bulkhead for the mid-hold and the value calculated at forward bulkhead of the aft cargo hold taken as:

  $$\Delta Q_{swa} = Min(|\Delta Q_{mdf}|_{Mid}, |\Delta Q_{mdf}|_{Aft})$$

- For oil tankers:

  $$\Delta Q_{swa} = 0$$

f_β : Wave heading factor, as given in Ch 4, Sec 4.

C_{QW} : Load combination factor for vertical wave shear force, as given in Ch 4, Sec 2.

Q_{wv-pos}, Q_{wv_neg}: Positive and negative vertical wave shear force, in kN, as defined in Ch 4, Sec 4, [3.2.1].

The values of $Q_{targ-aft}$ and $Q_{targ-fwd}$ are to be taken at after and forward transverse bulkheads of the mid-hold under consideration.

4.3.4 Target hull girder horizontal bending moment

The target hull girder horizontal bending moment, M_{h-targ}, in kNm, for a given FE load combination is taken as:

$$M_{h-targ} = M_{wh-LC}$$

where:

M_{wh-LC} : Horizontal wave bending moment, in kNm, for the dynamic load case under consideration, calculated in accordance with Ch 4, Sec 4, [3.5.4].

The values of M_{wh-LC} are taken as:

- Midship cargo hold region: the value calculated for the middle of the individual cargo hold under consideration.
- Outside midship cargo hold region: the values calculated at all web frame and transverse bulkhead positions of the FE model under consideration.

4.3.5 Target hull girder torsional moment

For bulk carriers only, the target hull girder torsional moment, $M_{wt-targ}$, in kNm, for the dynamic load cases OST and OSA is the value at the target location taken as:

$$M_{wt-targ} = M_{wt-LC}\ (x_{targ})$$

where:

$M_{wt-LC}\ (x)$: Wave torsional moment, in kNm, for the dynamic load case OST and OSA, defined in Ch 4, Sec 4, [3.5.5], calculated at x position.

x_{targ} : Target location for hull girder torsional moment taken as:

- For midship cargo hold region:
  - If $x_{mid} \le 0.531\ L$: after bulkhead of the mid-hold.
  - If $x_{mid} > 0.531\ L$: forward bulkhead of the mid-hold.
- Outside midship cargo hold region:

  The transverse bulkhead of mid-hold where the following formula is minimum:

$$\frac{M_{wt-LC}(x_{bhd})}{|M_{wt-LC}(x_{bhd})|} \cdot [M_{wt-LC}(x_{bhd}) - M_{T-FEM}(x_{bhd})]$$

x_{mid} : X-coordinate, in m, of the mid-hold centre.

x_{bhd} : X-coordinate, in m, of the after or forward transverse bulkhead of mid-hold.

For dynamic load cases of bulk carriers other than OST and OSA and for all dynamic load cases of oil tankers, hull girder torsional moment $M_{wt-targ}$, at middle of mid-hold is to be adjusted to zero.

4.4 Procedure to adjust hull girder shear forces and bending moments

4.4.1 General

The procedure given in this sub-article [4.4] describes how to adjust the hull girder horizontal bending moment, vertical force and vertical bending moment distribution on the three cargo hold FE model to achieve the required target values at required locations. The hull girder load target values are specified in [4.3].

The target locations for hull girder shear force are at the transverse bulkheads of the mid-hold. The final adjusted hull girder shear force at the target location should not exceed the target hull girder shear force.

The target location for hull girder bending moment is, in general, located at the centre of the mid-hold. If the maximum value of bending moment is not located at the centre of the mid-hold, the final adjusted maximum bending moment within the mid-hold is not to exceed the target hull girder bending moment.

4.4.2 Local load distribution

The following local loads are to be applied for the calculation of hull girder shear and bending moments:

a) Ship structural steel weight distribution over the length of the cargo hold model (static loads). The structural steel weight is to be calculated based on the FE model with a net thickness of 0.5 t_c deduction, as used in the cargo hold FE model.

b) Weight of cargo and ballast (static loads).

c) Static sea pressure, dynamic wave pressure and, where applicable, green sea load. For the harbour/tank testing load cases, only static sea pressure needs to be applied.

d) Dynamic cargo and ballast loads for seagoing load cases.

With the above local loads applied to the FE model, the FE nodal forces are obtained through FE loading procedure. The 3D nodal forces will then be lumped to each longitudinal station to generate the one dimension local load distribution. The longitudinal stations are located at transverse bulkheads/frames and typical longitudinal FE model nodal locations in between the frames according to the cargo hold model mesh size requirement. Any intermediate nodes created for modelling structural details are not treated as the longitudinal stations for the purpose of local load distribution. The nodal forces within half of forward and half of afterward of longitudinal station spacing are lumped to that station. The lumping process will be done for vertical and horizontal nodal forces separately to obtain the lumped vertical and horizontal local loads, f_{vi} and f_{hi}, at the longitudinal station i.

4.4.3 Hull girder forces and bending moment due to local loads

With the local load distribution, the hull girder load longitudinal distributions are obtained by assuming the model is simply supported at model ends. The reaction forces at both ends of the model and longitudinal distributions of hull girder shear forces and bending moments induced by local loads at any longitudinal station are determined by the following formulae:

$$R_{V\_fore} = -\frac{\sum_i (x_i - x_{aft})\ f_{vi}}{x_{fore} - x_{aft}} \qquad R_{V\_aft} = \sum_i f_{vi} + R_{V\_fore}$$

$$R_{H\_fore} = \frac{\sum_i (x_i - x_{aft})\ f_{hi}}{x_{fore} - x_{aft}} \qquad R_{H\_aft} = -\sum_i f_{hi} + R_{H\_fore}$$

$$F_l = \sum_i f_{li}$$

$$Q_{V\_FEM}\ (x_j) = R_{V\_aft} - \sum_i f_{vi} \qquad \text{when} \quad x_i < x_j$$

$$Q_{H\_FEM}\ (x_j) = R_{H\_aft} + \sum_i f_{hi} \qquad \text{when} \quad x_i < x_j$$

$$M_{V\_FEM}\ (x_j) = (x_j - x_{aft})\ R_{V\_aft} - \sum_i (x_j - x_i)\ f_{vi} \qquad \text{when} \quad x_i < x_j$$

$$M_{H\_FEM}\ (x_j) = (x_j - x_{aft})\ R_{H\_aft} + \sum_i (x_j - x_i)\ f_{hi} \qquad \text{when} \quad x_i < x_j$$

where:

R_{V_aft}, R_{V_fore}, R_{H_aft}, R_{H_fore} : Vertical and horizontal reaction forces at the aft and fore ends, in kN.

x_{aft} : *X*-coordinate of the aft end support, in m.

x_{fore} : *X*-coordinate of the fore end support, in m.

f_{vi} : Lumped vertical local load at longitudinal station *i* as defined in [4.4.2], in kN.

f_{hi} : Lumped horizontal local load at longitudinal station *i* as defined in [4.4.2], in kN.

F_l : Total net longitudinal force of the model, in kN.

f_{li} : Lumped longitudinal local load at longitudinal station *i* as defined in [4.4.2], in kN.

x_j : *X*-coordinate, in m, of considered longitudinal station *j*.

x_i : *X*-coordinate, in m, of longitudinal station *i*.

Q_{V_FEM} (x_j), Q_{H_FEM} (x_j), M_{V_FEM} (x_j), M_{H_FEM} (x_j) : Vertical and horizontal shear forces, in kN, and bending moments, in kNm, at longitudinal station x_j created by the local loads applied on the FE model. The sign convention for reaction forces is that a positive creates a positive shear force.

4.4.4 Longitudinal unbalanced force

In case total net longitudinal force of the model, F_l, is not equal to zero, the counter longitudinal force, $(F_x)_j$, is to be applied at one end of the model, where the translation on X-direction, δ_x, is fixed, by distributing longitudinal axial nodal forces to all hull girder bending effective longitudinal elements, as follows:

$$(F_x)_j = \frac{F_l}{A_{x-n50}} \frac{A_{j-n50}}{n_j}$$

where:

$(F_x)_j$: Axial force applied to a node of the *j*-th element, in kN.

F_l : Total net longitudinal force of the model, as defined in [4.4.3], in kN.

$A_{j\text{-}n50}$: Net cross sectional area of the *j*-th element, in m^2.

$A_{x\text{-}n50}$: Net cross sectional area of fore end section, in m^2,

$$A_{x-n50} = \sum_j A_{j-n50}$$

n_j : Number of nodal points of *j*-th element on the cross section, n_j = 1 for beam element, n_j = 2 for 4-node shell element.

4.4.5 Hull girder shear force adjustment procedure

The hull girder shear force adjustment procedure defined in this requirement applies to all FE load combinations given in Ch 4, Sec 8. The FE load combinations not directly covered by the load combination tables of Ch 4, Sec 8 are to be considered on a case by case basis.

The two following methods are to be used for the shear force adjustment:

- Method 1 (M1): for shear force adjustment at one bulkhead of the mid-hold as given in [4.4.6],
- Method 2 (M2): for shear force adjustment at both bulkheads of the mid-hold as given in [4.4.7].

For the considered FE load combination, the method to be applied is to be selected as follows:

- For maximum shear force load combination (Max SFLC), the method 1 applies at the bulkhead mentioned in Table 4 if the shear force after the adjustment with method 1 at the other bulkhead does not exceed the target value. Otherwise, the method 2 applies.
- For other shear force load combination:
    - The shear force adjustment is not requested when the shear forces at both bulkheads are lower or equal to the target values.
    - The method 1 applies when the shear force exceeds the target at one bulkhead and the shear force at the other bulkhead after the adjustment with method 1 does not exceed the target value. Otherwise the method 2 applies,
    - The method 2 applies when the shear forces at both bulkheads exceed the target values,

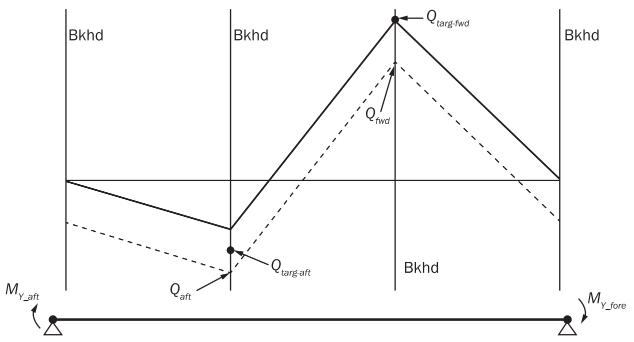
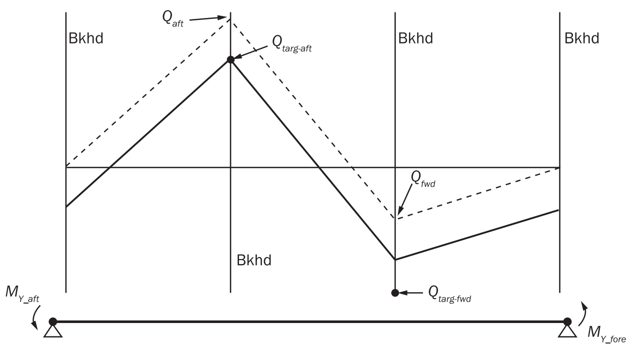
The “maximum shear force load combinations“ are marked as “Max SFLC“ in the load combination tables of Ch 4, Sec 8. The “other shear force load combinations“ are those which are not the maximum shear force load combinations. They are not marked in the load combination tables of Ch 4, Sec 8.

Table 4 : Mid-hold bulkhead location for shear force adjustment

Design loading conditions	Bulkhead location	M_{wv-LC}	Condition on Q_{fwd}	Mid-hold bulkhead for SF adjustment
Seagoing conditions	$x_{b-aft} > 0.5\ L$	< 0 (sagging)	$Q_{fwd} > Q_{aft}$	Fwd
			$Q_{fwd} \leq Q_{aft}$	Aft
		> 0 (hogging)	$Q_{fwd} > Q_{aft}$	Aft
			$Q_{fwd} \leq Q_{aft}$	Fwd
	$x_{b-fwd} < 0.5\ L$	< 0 (sagging)	$Q_{fwd} > Q_{aft}$	Aft
			$Q_{fwd} \leq Q_{aft}$	Fwd
		> 0 (hogging)	$Q_{fwd} > Q_{aft}$	Fwd
			$Q_{fwd} \leq Q_{aft}$	Aft
	$x_{b-aft} \leq 0.5\ L$ and $x_{b-fwd} \geq 0.5\ L$	-	-	(1)
Harbour and testing conditions	whatever the location	-	-	(1)

(1) For the FE load combinations covered by the load combination tables of Ch 4, Sec 8, the bulkhead where the shear force adjustment is to be done is indicated in those tables.

Table 5 : Vertical shear force adjustment by application of vertical bending moments M_{Y_aft} and M_{Y_fore} for method 1

Vertical shear force diagram	Target position in mid-hold
	Forward bulkhead
	Aft bulkhead

——— Vertical shear force after adjustment

- - - - - - - - Vertical shear force due to local loads

4.4.6 Method 1 for shear force adjustment at one bulkhead

The required adjustments in shear force at following transverse bulkheads of the mid-hold are given by:

- Aft bulkhead:

$$M_{Y\_aft} = M_{Y\_fore} = \frac{(x_{fore} - x_{aft})}{2}(Q_{targ-aft} - Q_{aft})$$

- Forward bulkhead

$$M_{Y\_aft} = M_{Y\_fore} = \frac{(x_{fore} - x_{aft})}{2}(Q_{targ-fwd} - Q_{fwd})$$

where:

M_{Y_aft}, M_{Y_fore}: Vertical bending moment, in kNm, to be applied at the aft and fore ends in accordance with [4.4.10], to enforce the hull girder vertical shear force adjustment as shown in Table 5. The sign convention is that of the FE model axis.

Q_{aft} : Vertical shear force, in kN, due to local loads at aft bulkhead location of mid-hold, x_{b_aft}, resulting from the local loads calculated according to [4.4.3].

Since the vertical shear force is discontinued at the transverse bulkhead location, Q_{aft} is the maximum absolute shear force between the stations located right after and right forward of the aft bulkhead of mid-hold.

Q_{fwd} : Vertical shear force, in kN, due to local loads at the forward bulkhead location of mid-hold, x_{b-_fwd}, resulting from the local loads calculated according to [4.4.3].

Since the vertical shear force is discontinued at the transverse bulkhead location, Q_{fwd} is the maximum absolute shear force between the stations located right after and right forward of the forward bulkhead of mid-hold.

4.4.7 Method 2 for vertical shear force adjustment at both bulkheads

The required adjustments in shear force at both transverse bulkheads of the mid-hold are to be made by applying:

- Vertical bending moments, M_{Y_aft}, M_{Y_fore} at model ends and,
- Vertical loads at the transverse frame positions as shown in Table 7 in order to generate vertical shear forces, ΔQ_{aft} and ΔQ_{fwd}, at the transverse bulkhead positions.

Table 6 shows examples of the shear adjustment application due to the vertical bending moments and to vertical loads.

$$M_{Y\_aft} = \frac{x_{fore} - x_{aft}}{2} \cdot \frac{Q_{targ-fwd} - Q_{fwd} + Q_{targ-aft} - Q_{aft}}{2}$$

$$M_{Y\_fore} = M_{Y\_aft}$$

$$\Delta Q_{fwd} = \frac{Q_{targ-fwd} - Q_{fwd} - (Q_{targ-aft} - Q_{aft})}{2}$$

$$\Delta Q_{aft} = -\Delta Q_{fwd}$$

where:

M_{Y_aft}, M_{Y_fore}: Vertical bending moment, in kNm, to be applied at the aft and fore ends in accordance with [4.4.10], to enforce the hull girder vertical shear force adjustment. The sign convention is that of the FE model axis.

ΔQ_{aft} : Adjustment of shear force, in kN, at aft bulkhead of mid-hold.

ΔQ_{fwd} : Adjustment of shear force, in kN, at fore bulkhead of mid-hold.

The above adjustments in shear forces, ΔQ_{aft} and ΔQ_{fwd}, at the transverse bulkhead positions are to be generated by applying vertical loads at the transverse frame positions as shown in Table 7. For bulk carriers, the transverse frame positions correspond to the floors. Vertical correction loads are not to be applied to any transverse tight bulkheads, any frames forward of the forward cargo hold and any frames aft of the aft cargo hold of the FE model.

The vertical loads to be applied to each transverse frame to generate the increase/decrease in shear force at the bulkheads may be calculated as shown in Table 7. In case of uniform frame spacing, the amount of vertical force to be distributed at each transverse frame may be calculated in accordance with Table 8.

Table 6 : Target and required shear force adjustment by applying vertical forces

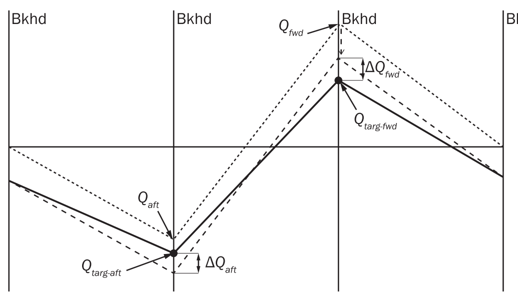
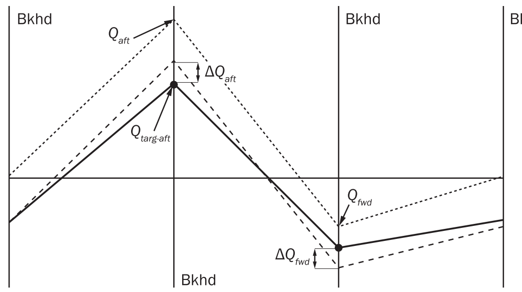
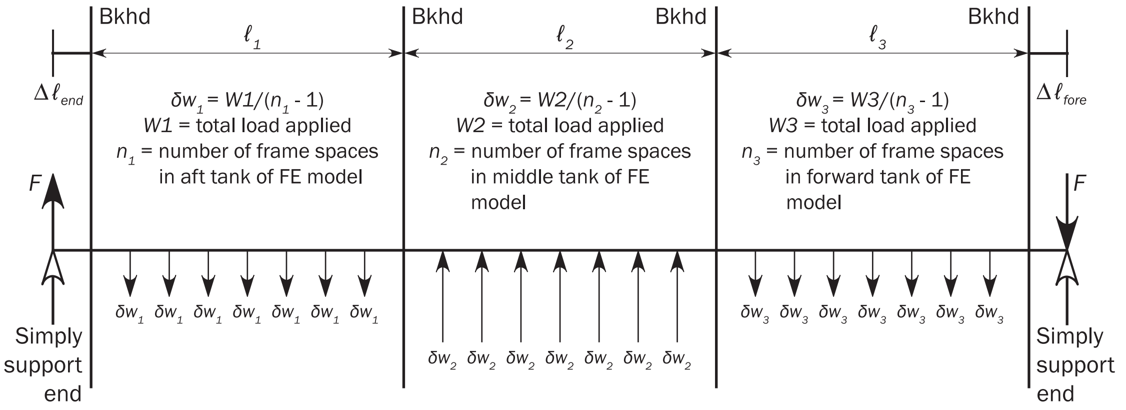
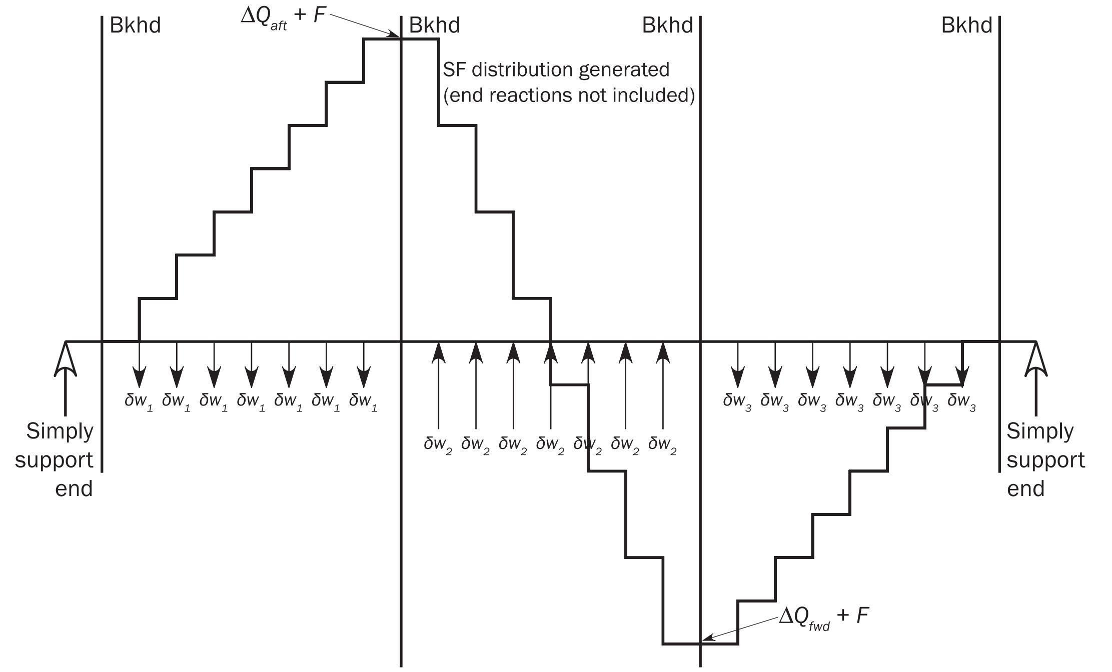
<table>
<tr><th rowspan="2">Vertical shear force diagram</th><th>Aft Bhd</th><th>Fore Bhd</th></tr>
<tr><th>SF target</th><th>SF target</th></tr>
<tr><td>
</td><td>$Q_{targ\text{-}aft}$ (-ve)</td><td>$Q_{targ\text{-}fwd}$ (+ve)</td></tr>
<tr><td>
</td><td>$Q_{targ\text{-}aft}$ (+ve)</td><td>$Q_{targ\text{-}fwd}$ (-ve)</td></tr>
<tr><td colspan="3">Vertical shear force after both adjustments
Vertical shear force after adjustment by use of M_{Y_aft} and M_{Y_fore}
Vertical shear force due to local loads</td></tr>
<tr><td colspan="3">Note 1: -ve means negative.
Note 2: +ve means positive.</td></tr>
</table>

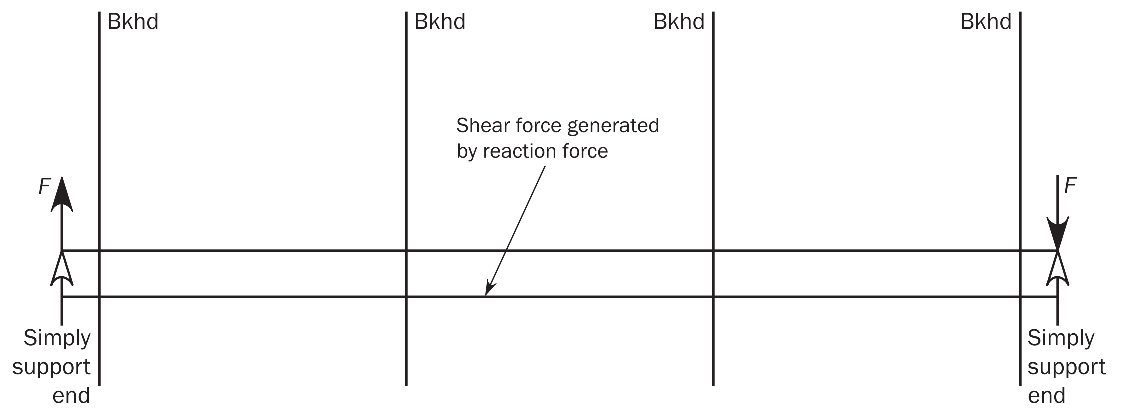
Table 7 : Distribution of adjusting vertical force at frames and resulting shear force distributions



Note: Transverse bulkhead frames not loaded
Frames beyond aft transverse bulkhead of aft most tank and forward bulkhead of forward most tank not loaded
F = Reaction load generated by supported ends



Shear Force distribution due to adjusting vertical force at frames



Note: $F = 0$ if $\ell_1 = \ell_3$ and $\Delta\ell_{fore} = \Delta\ell_{end}$, and loads are symmetrical about mid-length of model

Note 1: For definition of symbols, see Table 8.

Table 8 : Formulae for calculation of vertical loads for adjusting vertical shear forces

$\delta w_1 = \dfrac{\Delta Q_{aft}\ (2\ell - \ell_2 - \ell_3) + \Delta Q_{fwd}\ (\ell_2 + \ell_3)}{(n_1 - 1)\ (2\ell - l_1 - 2\ell_2 - \ell_3)}$	$F = 0.5\left(\dfrac{W1\ (\ell_2 + \ell_1) - W3\ (\ell_2 + \ell_3)}{\ell}\right)$
$\delta w_2 = \dfrac{(W1 + W3)}{(n_2 - 1)} = \dfrac{(\Delta Q_{aft} - \Delta Q_{fwd})}{(n_2 - 1)}$	
$\delta w_3 = \dfrac{-\Delta Q_{fwd}\ (2\ell - \ell_1 - \ell_2) - \Delta Q_{aft}\ (\ell_1 + \ell_2)}{(n_3 - 1)\ (2\ell - \ell_1 - 2\ell_2 - \ell_3)}$	
where: ℓ_1 : Length of aft cargo hold of model, in m. ℓ_2 : Length of mid-hold of model, in m. ℓ_3 : Length of forward cargo hold of model, in m. ΔQ_{aft} : Required adjustment in shear force, in kN, at aft bulkhead of middle hold, see [4.4.7]. ΔQ_{fwd} : Required adjustment in shear force, in kN, at fore bulkhead of middle hold, see [4.4.7]. F : End reactions, in kN, due to application of vertical loads to frames. $W1$: Total evenly distributed vertical load, in kN, applied to aft hold of FE model, $(n_1 - 1)\ \delta w_1$. $W2$: Total evenly distributed vertical load, in kN, applied to mid-hold of FE model, $(n_2 - 1)\ \delta w_2$. $W3$: Total evenly distributed vertical load, in kN, applied to forward hold of FE model, $(n_3 - 1)\ \delta w_3$. n_1 : Number of frame spaces in aft cargo hold of FE model. n_2 : Number of frame spaces in mid-hold of FE model. n_3 : Number of frame spaces in forward cargo hold of FE model. δw_1 : Distributed load, in kN, at frame in aft cargo hold of FE model. δw_2 : Distributed load, in kN, at frame in mid-hold of FE model. δw_3 : Distributed load, in kN, at frame in forward cargo hold of FE model. $\Delta\ell_{end}$: Distance, in m, between end bulkhead of aft cargo hold to aft end of FE model. $\Delta\ell_{fore}$: Distance, in m, between fore bulkhead of forward cargo hold to forward end of FE model. ℓ : Total length, in m, of FE model including portions beyond end bulkheads: $= \ell_1 + \ell_2 + \ell_3 + \Delta\ell_{end} + \Delta\ell_{fore}$	
Note 1: Positive direction of loads, shear forces and adjusting vertical forces in the formulae is in accordance with Table 6 and Table 7. Note 2: $W1 + W3 = W2$. Note 3: The above formulae are only applicable if uniform frame spacing is used within each hold. The length and frame spacing of individual cargo holds may be different.	

If non-uniform frame spacing is used within each cargo hold, the average frame spacing ℓ_{av-i} is used to calculate the average distributed frame loads δw_{av-i}, according to Table 8, where i = 1, 2, 3 for each hold.

Then δw_{av-i} is redistributed to the non-uniform frame as follows:

$$\delta w_i^k = \delta w_{av-i} \frac{\ell^k_{av-i}}{\ell_{av-i}} \qquad k=1, 2, ..., \quad n_i - 1 \quad \text{, for each frame in cargo hold i, i=1, 2, 3}$$

where:

ℓ_{av-i} : Average frame spacing, in m, calculated as ℓ_i / n_i, in cargo hold i with i = 1, 2, 3.

ℓ_i : Length, in m, of the cargo hold i with i = 1, 2, 3 as defined in Table 8.

n_i : Number of frame spacing in cargo hold i with i = 1, 2, 3 as defined in Table 8.

δw_{av-i} : Average uniform frame spacing, in m, distributed force calculated according to Table 8 with the average frame spacing ℓ_{av-i} in cargo hold i with i = 1, 2, 3.

δw_i^k : Distributed load, in kN, for non-uniform frame k in cargo hold i.

$\ell^k{}_{av-i}$: Equivalent frame spacing, in m, for each frame k with k = 1, 2,..., n_i - 1, in cargo hold i, taken as:

$$\ell^k{}_{av-i} = \ell_i^1 - \frac{\ell_{av-i}\ \ell_i^1}{\ell_i^1 + \ell_i^{n_i}} + \frac{\ell_i^2}{2} \quad \text{for k = 1 (first frame), in cargo hold i}$$

$$\ell^k{}_{av-i} = \frac{\ell_i^k}{2} + \frac{\ell_i^{k+1}}{2} \quad \text{for k = 2, 3, ..., } n_1 \text{ - 2, in cargo i}$$

$$\ell^k{}_{av-i} = \ell_i^{n_i} - \frac{\ell_{av-i}\ \ell_i^{n_i}}{\ell_i^1 + \ell_i^{n_i}} + \frac{\ell_i^{n_i-1}}{2} \quad \text{for k = } n_i \text{ - 1 (last frame), in cargo i}$$

ℓ_i^k : Frame spacing, in m, between the frame k - 1 and k in the cargo hold i:

The required vertical load δw_i for a uniform frame spacing or δw_i^k for non-uniform frame spacing, are to be applied by following the shear flow distribution at the considered cross section, as described in Ch 5, App 1. For a frame section under vertical load δw_i, the shear flow, q_f, at the middle point of the element is calculated as:

$$q_{f-k} = \frac{\delta w_i}{I_{y-n50}} Q_{k-n50}$$

where:

$q_{f\text{-}k}$: Shear flow calculated at the middle of the k-th element of the transverse frame, in N/mm.

δw_i : Distributed load at each transverse frame location for i-th cargo hold, i = 1, 2, 3, as defined in Table 8, in N.

$I_{y\text{-}n50}$: Moment of inertia of the hull girder cross section, in mm^4.

$Q_{k\text{-}n50}$: First moment about neutral axis of the accumulative section area starting from the open end (shear stress free end) of the cross section to the point s_k for shear flow $q_{f\text{-}k}$, in mm^3, taken as;

$$Q_{k-n50} = \int_0^{s_k} z_{neu}\ t_{n50}\ ds$$

z_{neu} : Vertical distance from the integral point, s, to the vertical neutral axis.

t_{n50} : Net thickness, in mm, of the plate at the integral point of the cross section.

The distributed shear force at j-th FE grid of the transverse frame, $F_{j\text{-}grid}$, is obtained from the shear flow of the connected elements as following:

$$F_{j-gird} = \sum_{k=1}^{n} q_{f-k} \frac{\ell_k}{2}$$

where:

ℓ_k : Length of the k-th element of the transverse frame connected to the grid j, in mm.

n : Total number of elements connect to the grid j.

The shear flow has direction along the cross section and therefore the distributed force, $F_{j\text{-}grid}$, is a vector force. For vertical hull girder shear correction, the vertical and horizontal force components calculated with above mentioned shear flow method need to be applied to the cross section.

4.4.8 Procedure to adjust vertical and horizontal bending moments for midship cargo hold region

In case the target vertical bending moment needs to be reached, an additional vertical bending moment is to be applied at both ends of the cargo hold FE model to generate this target value in the mid-hold of the model. This end vertical bending moment is given as follows:

$$M_{v-end} = M_{v-targ} - M_{v-peak}$$

where:

$M_{v\text{-}end}$: Additional vertical bending moment, in kNm, to be applied to both ends of FE model in accordance with [4.4.10].

$M_{v\text{-}targ}$: Hogging (positive) or sagging (negative) vertical bending moment, in kNm, as specified in [4.3.2].

$M_{v\text{-}peak}$: Maximum or minimum bending moment, in kNm, within the length of the mid-hold due to the local loads described in [4.4.3] and due to the shear force adjustment as defined in [4.4.5].

$M_{v\text{-}peak}$ is to be taken as the maximum bending moment if $M_{v\text{-}targ}$ is hogging (positive) and as the minimum bending moment if $M_{v\text{-}targ}$ is sagging (negative). $M_{v\text{-}peak}$ is to be calculated as follows based on a simply supported beam model:

$$M_{v-peak} = \text{Extremum}\left\{M_{V\_FEM}(x) + M_{lineload} + M_{Y\_aft}\left(2\frac{x - x_{aft}}{x_{fore} - x_{aft}} - 1\right)\right\}$$

$M_{V\_FEM}(x)$: Vertical bending moment, in kNm, at position x, due to the local loads as described in [4.4.3].

M_{Y_aft} : End bending moment, in kNm, to be taken as:

- When method 1 is applied: the value as defined in [4.4.6].
- When method 2 is applied: the value as defined in [4.4.7].
- Otherwise: $M_{Y\_aft} = 0$

$M_{lineload}$: Vertical bending moment, in kNm, at position x, due to application of vertical line loads at frames according to method 2, to be taken as:

$$M_{lineload} = -(x - x_{aft})\,F - \sum_i (x - x_i)\,\delta w_i \quad \text{when} \quad x_i < x$$

F : Reaction force, in kN, at model ends due to application of vertical loads to frames as defined in Table 7.

x : X-coordinate, in m, of frame in way of the mid-hold.

δw_i : vertical load, in kN, at web frame station i applied to generate required shear force.

In case the target horizontal bending moment needs to be reached, an additional horizontal bending moment is to be applied at the ends of the cargo tank FE model to generate this target value within the mid-hold. The additional horizontal bending moment is to be taken as:

$$M_{h-end} = M_{h-targ} - M_{h-peak}$$

where:

$M_{h\text{-}end}$: Additional horizontal bending moment, in kNm, to be applied to both ends of the FE model according to [4.4.10].

$M_{h\text{-}targ}$: Horizontal bending moment, as defined in [4.3.4].

$M_{h\text{-}peak}$: Maximum or minimum horizontal bending moment, in kNm, within the length of the mid-hold due to the local loads described in [4.4.3].

$M_{h\text{-}peak}$ is to be taken as the maximum horizontal bending moment if $M_{h\text{-}targ}$ is positive (starboard side in tension) and as the minimum horizontal bending moment if $M_{h\text{-}targ}$ is negative (port side in tension).

$M_{h\text{-}peak}$ is to be calculated as follows based on a simply supported beam model:

$$M_{h-peak} = \text{Extremum}\{M_{H\_FEM}(x)\}$$

$M_{H\_FEM}(x)$: Horizontal bending moment, in kNm, at position x, due to the local loads as described in [4.4.3].

The vertical and horizontal bending moments are to be calculated over the length of the mid-hold to identify the position and value of each maximum/minimum bending moment.

4.4.9 Procedure to adjust vertical and horizontal bending moments outside midship cargo hold region

To reach the vertical hull girder target values at each frame and transverse bulkhead position, as defined in [4.3.2], the vertical bending moment adjustments, m_{vi}, are to be applied at web frames and transverse bulkhead positions of the finite element model, as shown in Figure 19. The vertical bending moment adjustment at each longitudinal location, i, is to be calculated as follows:

$$f(i) = -M_{v-targ}(i) + M_{V-FEM}(i) + M_{lineload}(i) + M_{Y-aft} \cdot \left(2 \cdot \frac{x_i - x_{aft}}{x_{fore} - x_{aft}} - 1\right)$$

$$m_{vi} = \frac{f(i) + f(i+1)}{2} - \sum_{j=0}^{i-1} m_{vj}$$

$$m_{v\_end} = -\sum_{j=0}^{n_t} m_{vj}$$

where:

i : Index corresponding to the i-th station, starting from i =1 at the aft end section up to n_t

n_t : Total number of longitudinal stations where the vertical bending moment adjustment, m_{vi}, is applied.

m_{vi} : Vertical bending moment adjustment, in kNm, to be applied at transverse frame or bulkhead at station i.

m_{v_end} : Vertical bending moment adjustment, in kNm, to be applied, at the fore end section (n_t+1 station).

m_{vj} : Argument of summation to be taken as:

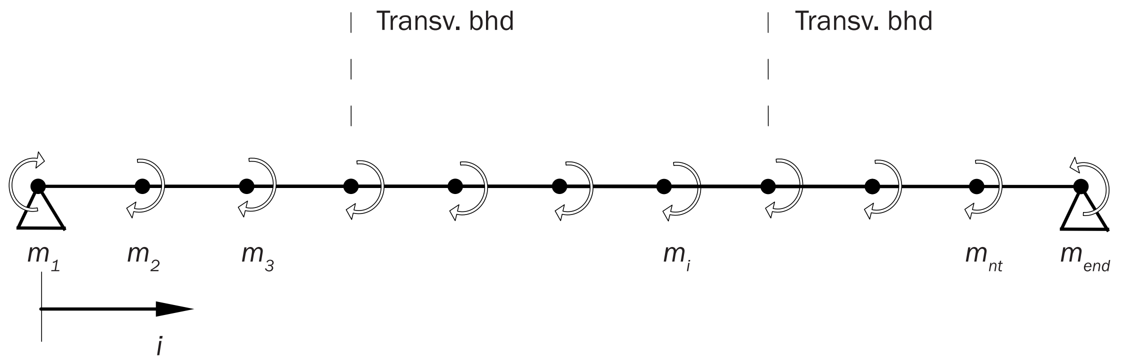
- m_{vo}= 0 when $j=0$
- $m_{vj} = m_{vi}$ when $j=i$

$M_{v\text{-}targ}(i)$: Required target vertical bending moment, in kNm, at station i, calculated in accordance with [4.3.2].

$M_{V\text{-}FEM}(i)$: Vertical bending moment distribution, in kNm, at station i due to local loads as given in [4.4.3].

$M_{lineload}(i)$:Vertical bending moment, in kNm, at station i, due to the line load for the vertical shear force correction as required in [4.4.8].

Figure 19 : Adjustments of bending moments outside midship cargo hold region.



m_{hi} can be substituted to m_{vi} in this figure

To reach the horizontal hull girder target values at each frame and transverse bulkhead position as defined in [4.3.4], the horizontal bending moment adjustments, m_{hi}, are to be applied at web frames and transverse bulkhead positions of the finite element model, as shown in Figure 19. The horizontal bending moment adjustment at each longitudinal location, i, is to be calculated as follows:

$$f(i) = M_{h-targ}(i) - M_{H-FEM}(i)$$

$$m_{hi} = \frac{f(i) + f(i+1)}{2} - \sum_{j=0}^{i-1} m_{hj}$$

$$m_{h\_end} = -\sum_{j=0}^{n_t} m_{hj}$$

where:

i : Longitudinal location for bending moment adjustments, m_{hi}.

n_t : Total number of longitudinal stations where the horizontal bending moment adjustment, m_{hi}, is applied.

m_{hi} : Horizontal bending moment adjustment, in kNm, to be applied at transverse frame or bulkhead at station i.

m_{h_end} : Horizontal bending moment adjustment, in kNm, to be applied at the fore end section (n_t+1 station).

m_{hj} : Argument of summation to be taken as:

- m_{ho} = 0 when $j=0$
- $m_{hj} = m_{hi}$ when $j=i$

$M_{h\text{-}targ}(i)$: Required target horizontal bending moment, in kNm, at station i, calculated in accordance with [4.3.4].

$M_{H\text{-}FEM}(i)$: Horizontal bending moment distribution, in kNm, at station i due to local loads as given in [4.4.3].

The vertical and horizontal bending moment adjustments, m_{vi} and m_{hi}, are to be applied at all web frames and bulkhead positions of the FE model. The adjustments are to be applied in FE model by distributing longitudinal axial nodal forces to all hull girder bending effective longitudinal elements in accordance with [4.4.10].

4.4.10 Application of bending moment adjustments on the FE model

The required vertical and horizontal bending moment adjustments are to be applied to the considered cross section of the cargo hold model by distributing longitudinal axial nodal forces to all hull girder bending effective longitudinal elements of the considered cross section according to Ch 5, Sec 1, [1.2] as follows:

- For vertical bending moment:

$$(F_x)_i = \frac{M_v}{I_{y-n50}} \frac{A_{i-n50}}{n_i} z_i$$

- For horizontal bending moment:

$$(F_x)_i = \frac{M_h}{I_{z-n50}} \frac{A_{i-n50}}{n_i} y_i$$

where:

M_v : Vertical bending moment adjustment, in kNm, to be applied to the considered cross section of the model.

M_h : Horizontal bending moment adjustment, in kNm, to be applied to the considered cross section the ends of the model.

$(F_x)_i$: Axial force, in kN, applied to a node of the i-th element.

$I_{y\text{-}n50}$: Hull girder vertical moment of inertia, in m^4, of the considered cross section about its horizontal neutral axis.

$I_{z\text{-}n50}$: Hull girder horizontal moment of inertia, in m^4, of the considered cross section about its vertical neutral axis.

Z_i : Vertical distance, in m, from the neutral axis to the centre of the cross sectional area of the *i*-th element.

Y_i : Horizontal distance, in m, from the neutral axis to the centre of the cross sectional area of the *i*-th element.

$A_{i\text{-}n50}$: Cross sectional area, in m^2, of the *i*-th element.

n_i : Number of nodal points of *i*-th element on the cross section, $n_i = 1$ for beam element, $n_i = 2$ for 4-node shell element.

For cross sections other than cross sections at the model end, the average area of the corresponding *i*-th elements forward and aft of the considered cross section is to be used.

4.5 Procedure to adjust hull girder torsional moments

4.5.1 General

The procedure in this sub-article describes how to adjust the hull girder torsional moment distribution on the cargo hold FE model to achieve the target torsional moment at the target location. The hull girder torsional moment target values are given in [4.3.5].

4.5.2 Torsional moment due to local loads

Torsional moment, in kNm, at longitudinal station *i* due to local loads, $M_{T\text{-}FEMi}$ in kNm, is determined by the following formula (see Figure 20):

$$M_{T-FEMi} = \sum_k [f_{hik}(z_{ik} - z_r)] - \sum_k (f_{vik} y_{ik})$$

where:

$M_{T\text{-}FEMi}$: Lumped torsional moment, in kNm, due to local load at longitudinal station *i*.

z_r : Vertical coordinate of torsional reference point, in m:

For bulk carrier, $z_r = 0$.

For oil tanker, $z_r = z_{sc}$, shear centre at the middle of the mid-hold.

f_{hik} : Horizontal nodal force, in kN, of node *k* at longitudinal station *i*.

f_{vik} : Vertical nodal force, in kN, of node *k* at longitudinal station *i*.

y_{ik} : *Y*-coordinate, in m, of node *k* at longitudinal station *i*.

z_{ik} : *Z*-coordinate, in m, of node *k* at longitudinal station *i*.

$M_{T\text{-}FEM0}$: Lumped torsional moment, in kNm, due to local load at aft end of the FE model (forward end for foremost cargo hold model), taken as:

$$M_{T-FEM0} = \sum_k [f_{h0k}(z_{0k} - z_r)] - \sum_k (f_{v0k}\, y_{0k}) + R_{H\_fwd}\,(z_{ind} - z_r) \text{ for foremost cargo hold model}$$

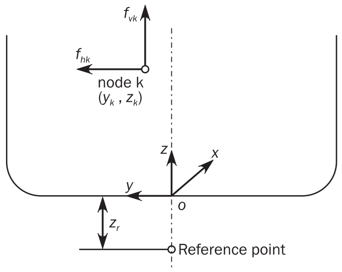
$$M_{T-FEM0} = \sum_k [f_{h0k}(z_{0k} - z_r)] - \sum_k (f_{v0k}\, y_{0k}) + R_{H\_aft}\,(z_{ind} - z_r) \text{ for the other cargo hold models}$$

R_{H_fwd} : Horizontal reaction forces, in kN, at the forward end, as defined in [4.4.3].

R_{H_aft} : Horizontal reaction forces, in kN, at the aft end, as defined in [4.4.3].

z_{ind} : Vertical coordinate, in m, of independent point as defined in [2.5.3].

Figure 20 : Station forces and acting location of torsional moment at section



4.5.3 Hull girder torsional moment

The hull girder torsional moment, $M_{T\text{-}FEM}$ (x_j) in kNm, is obtained by accumulating the station torsional moment from the aft end section (forward end for foremost cargo hold model) as follows:

$$M_{T-FEM}\ (x_j)\ =\ \sum_i M_{T-FEMi}$$

- when $x_i \geq x_j$ for foremost cargo hold model,
- when $x_i < x_j$ otherwise.

where:

$M_{T\text{-}FEM}$ (x_j): Hull girder torsional moment, in kNm, at longitudinal station x_j.

x_j : X-coordinate, in m, of considered longitudinal station j.

The torsional moment distribution given in [4.5.2], has a step at each longitudinal station.

4.5.4 Procedure to adjust hull girder torsional moment to target value

The torsional moment is to be adjusted by applying a hull girder torsional moment $M_{T\text{-}end}$ in kNm, at the independent point of the aft end section of the model (forward end for foremost cargo hold model), given as follows:

$$M_{T-end}\ =\ M_{wt-targ} - M_{T-FEM}\ (x_{targ})$$

where:

x_{targ} : X-coordinate, in m, of the target location for hull girder torsional moment, as defined in [4.3.5].

$M_{wt\text{-}targ}$: Target hull girder torsional moment, in kNm, specified in [4.3.5], to be achieved at the target location.

$M_{T\text{-}FEM}$ (x_{targ}): Hull girder torsional moment, in kNm, at target location due to local loads.

Due to the step of hull girder torsional moment at each longitudinal station, the hull girder torsional moment is to be selected from the values aft and forward of the target location as follows: Maximum value for positive torsional moment and minimum value for negative torsional moment.

4.6 Summary of hull girder load adjustments

4.6.1

The required methods of hull girder load adjustments for different cargo hold regions are given in Table 9.

Table 9 : Overview of hull girder load adjustments in FE analyses

	Midship cargo hold region	After and Forward cargo hold region	Aft most cargo holds	Foremost cargo holds
Adjustment of Vertical Shear Forces	See [4.4.5]			
Adjustment of Bending Moments	See [4.4.8]	See [4.4.9]		
Adjustment of Torsional Moment	See [4.5.4]			

5 ANALYSIS CRITERIA

5.1 General

5.1.1 Evaluation areas

Verification of results against the acceptance criteria is to be carried out within the longitudinal extent of the mid-hold, as shown in Figure 21 and Figure 22.

Figure 21 : Longitudinal extent of evaluation area for oil tanker

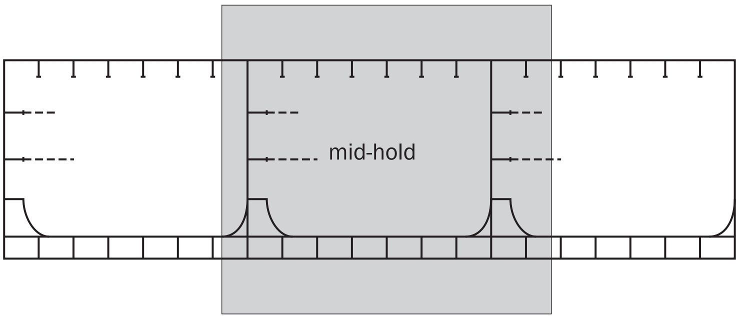
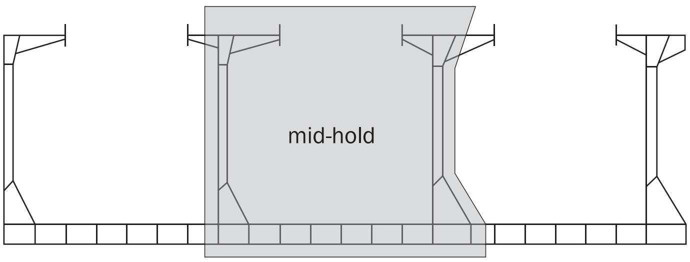


Figure 22 : Longitudinal extent of evaluation area for bulk carrier



5.1.2 Structural members

The following structural elements within the evaluation area are to be verified with the criteria given in [5.2] and [5.3]:

- All hull girder longitudinal structural members,
- All primary supporting structural members and bulkheads within the mid-hold,
- All structural members being part of the transverse bulkheads, such as:
    - For oil tanker: stringer, buttress structure, stool tanks, partial girders together with attached transverse structures,
    - For bulk carrier: stool tanks together with connected longitudinal girders and double bottom floors,
- All structural members being part of the collision bulkhead, and extending to one web frame spacing forward of the collision bulkhead,
- All structural members being part of the forward transverse bulkhead of the machinery space and all hull girder longitudinal structural members aft of this transverse bulkhead within the extent of 15% of the aftmost cargo hold length excluding slop tanks.

5.2 Yield strength assessment

5.2.1 Von Mises stress

For all plates of the structural members defined in [5.1.2], the von Mises stress, σ_{vm}, in N/mm², is to be calculated based on the membrane normal and shear stresses of the shell element. The stresses are to be evaluated at the element centroid of the mid-plane (layer), as follows:

$$\sigma_{vm} = \sqrt{\sigma_x^2 - \sigma_x \sigma_y + \sigma_y^2 + 3\tau_{xy}^2}$$

where:

σ_x, σ_y : Element normal membrane stresses, in N/mm².

τ_{xy} : Element shear stress, in N/mm².

5.2.2 Axial stress in beams and rod elements

For beams and rod elements, the axial stress, σ_{axial}, in N/mm², is to be calculated based on axial force alone. The axial stress is to be evaluated at the middle of element length.

5.2.3 Coarse mesh permissible yield utilisation factors

The coarse mesh permissible yield utilisation factors, λ_{yperm}, given in Table 10, are based on the mesh sizes and element types described in [2.3] to [2.4].

The yield utilisation factor resulting from element stresses of each structural component are not to exceed the permissible values as given in Table 10.

Table 10 : Coarse mesh permissible yield utilisation factor

Structural component	Coarse mesh permissible yield utilisation factor, λ_{yperm}
Plating of all longitudinal hull girder structural members, primary supporting structural members and bulkheads. Face plate of primary supporting members modelled using shell or rod elements. Dummy rod of corrugated bulkhead	1.0 (load combination S+D) 0.8 (load combination S)
Corrugation of vertically corrugated bulkheads with lower stool and horizontally corrugated bulkhead, under lateral pressure from liquid loads, for shell elements only. Supporting structure in way of lower end of corrugated bulkheads without lower stool (1).	0.90 (load combination S+D) 0.72 (load combination S)
Corrugation of vertically corrugated bulkheads without lower stool under lateral pressure from liquid loads and without lower stool, for shell elements only.	0.81 (load combination S+D) 0.65 (load combination S)
(1) Supporting structure for a transverse corrugated bulkhead refers to the structure in the longitudinal direction within half a web frame space forward and aft of the bulkhead, and within a vertical extent equal to the corrugation depth. Supporting structure for a longitudinal corrugated bulkhead refers to the structure in transverse direction within 3 longitudinal stiffener spacings from each side of the bulkhead, and within a vertical extent equal to the corrugation depth.	

5.2.4 Yield criteria

The structural elements given in [5.1.2] are to comply with the following criteria:

$$\lambda_y \le \lambda_{yperm}$$

where:

λ_y : Yield utilisation factor.

$\lambda_y = \frac{\sigma_{vm}}{R_Y}$ for shell elements in general.

$\lambda_y = \frac{|\sigma_{axial}|}{R_Y}$ for rod or beam elements in general.

σ_{vm} : Von Mises stress, in N/mm^2.

σ_{axial} : Axial stress in rod or beam element, in N/mm^2.

λ_{yperm} : Coarse mesh permissible yield utilisation factors defined in Table 10.

The yield check criteria is to be based on axial stress for the following members:

- The flange of primary supporting members,
- The intersections between the flange and web of the corrugations, according to [5.2.5].

Where the von Mises stress of the elements in the cargo hold FE model in way of the area under investigation by fine mesh exceeds the yield criteria, average von Mises stress, obtained from the fine mesh analysis, calculated over an area equivalent to the mesh size of the cargo hold finite element model is to satisfy the yield criteria above.

In way of cut-outs, yield utilisation factor is to be obtained with shear stress correction, as given in [5.2.6].

5.2.5 Corrugation of corrugated bulkhead

The stress in corrugation of corrugated bulkheads is to be evaluated based on:

a) The von Mises stress, σ_{vm}, in shell elements on the flange and web of the corrugation.

b) The axial stress, σ_{axial}, in dummy rod elements, modelled with unit cross sectional properties at the intersection between the flange and web of the corrugation.

5.2.6 Shear stress correction for cut-outs

Except as indicated in [5.2.7], the element shear stress in way of cut-outs in webs is to be corrected for loss in shear area in accordance with the following formula. The corrected element shear stress is to be used to calculate the von Mises stress of the element for verification against the yield criteria.

$$\tau_{cor} = \frac{h\ t_{mod-n50}}{A_{shr-n50}}\tau_{elem}$$

where:

τ_{cor} : Corrected element shear stress, in N/mm^2.

h : Height of web of girder, in mm, in way of opening, see Table 1. Where the geometry of the opening is modelled, h is to be taken as the height of web of the girder deducting the height of the modelled opening.

$t_{mod-n50}$: Modelled web thickness, in mm, in way of opening.

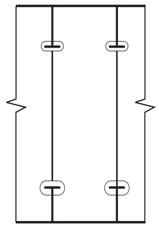
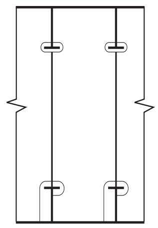
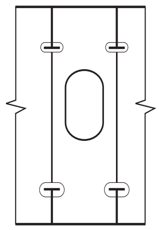
$A_{shr-n50}$: Effective net shear area of web, in mm^2, taken as the web area deducting the area lost of all openings, including slots for stiffeners, calculated in accordance with Ch 3, Sec 7, [1.4.8].

τ_{elem} : Element shear stress, in N/mm^2, before correction.

5.2.7 Exceptions for shear stress correction for openings

Correction of element shear stress due to presence of cut-outs is not required for cases given in Table 11 provided λ_y/C_r complies with the criteria given in [5.2.4].

Table 11 : Exceptions for shear stress correction

Identification	Figure	Difference between modelled shear area and the net effective shear area in % of the net effective shear area $\frac{A_{FEM-n50} - A_{shr-n50}}{A_{shr-n50}} \cdot 100\%$	Reduction factor for yield criteria, C_r
Upper and lower slots for local support stiffeners fitted with lugs or collar plates		< 15%	0.85
Upper or lower slots for local support stiffeners fitted with lugs or collar plates		< 20%	0.80
In way of opening; upper and lower slots for local support stiffeners fitted with collar plates		< 40%	0.60
$A_{shr-n50}$: Effective net shear area of the web, in mm^2, taken as the web area without the all opening areas and without the slots for stiffeners, in accordance with Ch 3, Sec 7, [1.4.8].			

5.3 Buckling strength assessment

5.3.1

All structural elements in FE analysis carried out in accordance with this Section are to be assessed individually against the buckling requirements as defined in Ch 8, Sec 4.

SECTION 3
LOCAL STRUCTURAL STRENGTH ANALYSIS

1 OBJECTIVE AND SCOPE

1.1 General

1.1.1

The local strength analysis of structural details is to be in accordance with the requirements given in this section.

1.1.2

The selection of critical locations on the structural members for fine mesh analysis is to be in accordance with this section.

1.1.3 Fine mesh analysis procedure

The details to be assessed by fine mesh analysis are to be modelled according to the requirements given in [4], under the FE load combinations defined in [5] and to comply with the criteria given in [6].

1.1.4 Scope of local structural strength verification

The fine mesh verification is to be performed as follows:

- Fine mesh analysis for the structural details given in [2],
- Screening procedure according to [3].

2 LOCAL AREAS TO BE ASSESSED BY FINE MESH ANALYSIS

2.1 List of mandatory structural details

2.1.1 List of structural details

In the midship cargo hold region, the following structural details are to be assessed according to the fine mesh analysis procedure defined in [1.1.3]:

a) Hopper knuckles for ship with double side as given in [2.1.2],

b) Side frame end brackets and lower hopper knuckle for single side bulk carrier as given in [2.1.3],

c) Large openings as given in [2.1.4],

d) Connections of deck and double bottom longitudinal stiffeners to transverse bulkhead as given in [2.1.5],

e) Connections of corrugated bulkhead to adjoining structure as given in [2.1.6].

For each above mentioned structural detail, one fine mesh model is required within all the cargo hold models covering the midship cargo hold region. The selection of the location of this fine mesh model is to be based on requirements given from [2.1.2] to [2.1.6] from all cargo hold analyses in the midship cargo hold region.

2.1.2 Hopper knuckles for ship with double side

Fine mesh analysis is to be carried out for the lower and upper hopper knuckles of either welded or bent type, in way of a typical transverse web frame, as indicated in Figure 1.

For double side arrangements without the hopper plating, i.e. where the inner hull longitudinal bulkhead is fitted directly to the inner bottom, fine mesh analysis is to be carried out for the heel of the transverse web frame.

The transverse web frame which, in the cargo hold analysis, has the maximum yield utilisation factor, λ_y, in knuckle is to be selected for the fine mesh analysis.

2.1.3 Side frame end brackets and lower hopper knuckle for single side bulk carrier

Fine mesh analysis is to be carried out for the lower hopper knuckle of either welded or bent type, lower and upper end bracket of side frame, as indicated in Figure 2.

The side frame which in the cargo hold analysis has the maximum yield utilisation factor, λ_y, in end bracket joints is to be selected for the fine mesh analysis.

Figure 1 : Mandatory areas at hopper knuckles for ships with double side

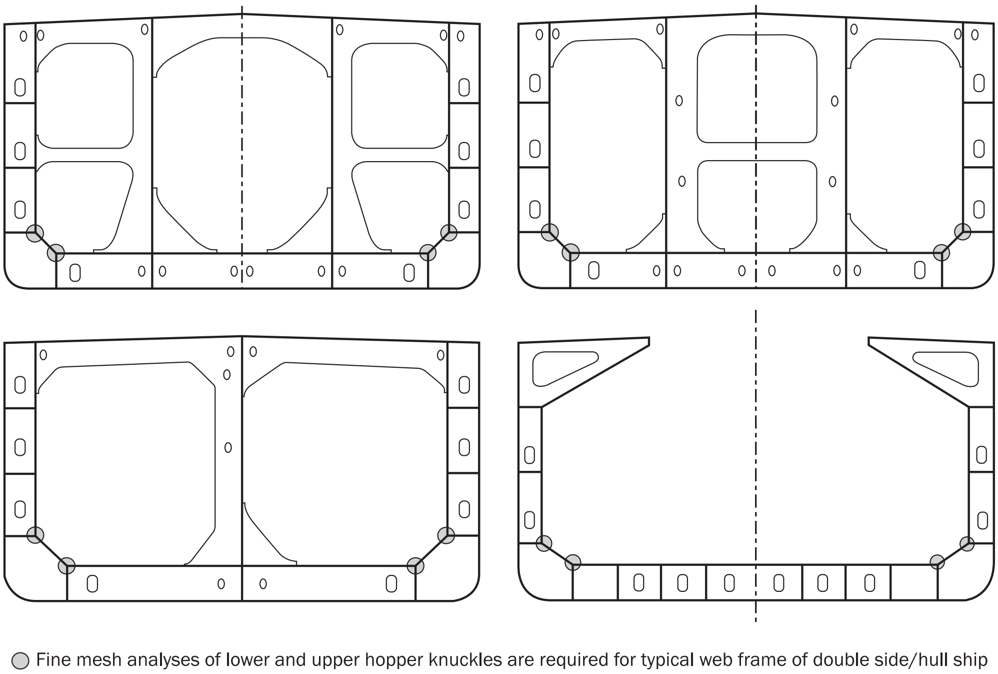
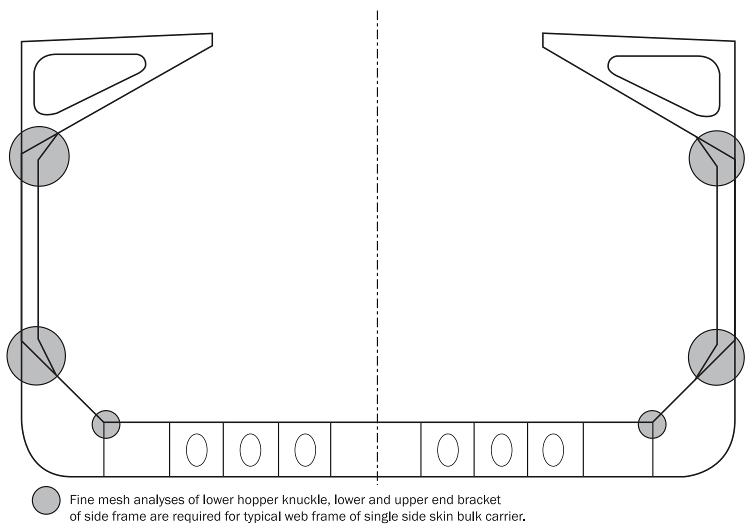


Figure 2 : Mandatory areas at lower upper knuckle and side frame end brackets for single side bulk carrier



2.1.4 Large openings

Large openings in way of primary supporting members, for which their geometry is required to be represented in the cargo hold model in accordance with Ch 7, Sec 2, [2.4.9], are to be assessed by fine mesh analysis.

The structural member in way of the large openings having the maximum yield utilisation factor, λ_y, in the cargo hold analysis is to be selected for the fine mesh analysis.

2.1.5 Connections between deck and double bottom longitudinal stiffeners and adjoining structures of transverse bulkhead

Fine mesh analysis is to be carried out for the connections of deck and double bottom longitudinal stiffeners and adjoining structures of transverse bulkhead, either plane or corrugated bulkhead. The adjoining structures of transverse bulkhead include the structural members in way of the bulkhead, the partial deck girders and partial double bottom girders, if any.

For example, the following structural members are to be assessed, some of them being shown in Figure 3:

- At least one pair of connections between inner and outer bottom longitudinal stiffeners and adjoining structures of transverse bulkhead.
- At least one pair of connections between inner and outer bottom longitudinal stiffeners and adjoining structures of adjacent floor to the transverse bulkhead.
- At least one connection between deck longitudinal stiffener (fitted above or below deck) and adjoining vertical structure of transverse oil tight bulkhead.
- Connection between deck longitudinal partial girder on top of transverse oil tight bulkheads when fitted and adjoining vertical structure of transverse oil tight bulkhead.
- Connection between bottom longitudinal partial girder in way of transverse oil tight bulkheads when fitted and adjoining vertical structure of transverse oil tight bulkhead.

The selection of the connections between longitudinal and vertical stiffeners to be analysed is to be based on the maximum relative deflection between supports, i.e. between floor and transverse bulkhead or between deck transverse and transverse bulkhead. Where there is a significant variation in end connection arrangement between stiffeners or scantlings, analyses of additional connections may be required by the Society.

2.1.6 Connections between corrugation and adjoining lower structure

Fine mesh analysis is to be carried out for connections between corrugation and adjoining lower supporting structures. For example, the following structural members, as shown in Figure 4, are to be assessed:

- Connection of the corrugation and supporting structure in way of lower stool shelf plate.
- Connection of the corrugation and lower supporting structure to inner bottom if no lower stool is fitted.
- Connection of the corrugation and the upper corner of the gusset plate if shedder plate with a gusset plate is fitted at top of the lower stool.

The corrugation unit as defined in Ch 8, Sec 4, [3.3.2] which, in the cargo hold analysis, has the maximum yield utilisation factor, λ_y, in way of the corrugation connection, is to be selected for the fine mesh analysis.

Where there is a significant variation in the arrangement of supporting structure of the corrugation, analysis of additional locations may be required by the Society.

For ships with both longitudinal and transverse corrugated bulkheads, fine mesh analysis is required for the connection between corrugations and supporting structure in way of the lower stool shelf plate or inner bottom, if no lower stool is fitted, at the intersection between longitudinal and transverse corrugated bulkheads.

Figure 3 : Examples of mandatory areas at connections between double bottom and deck longitudinals and adjoining structure of transverse bulkhead

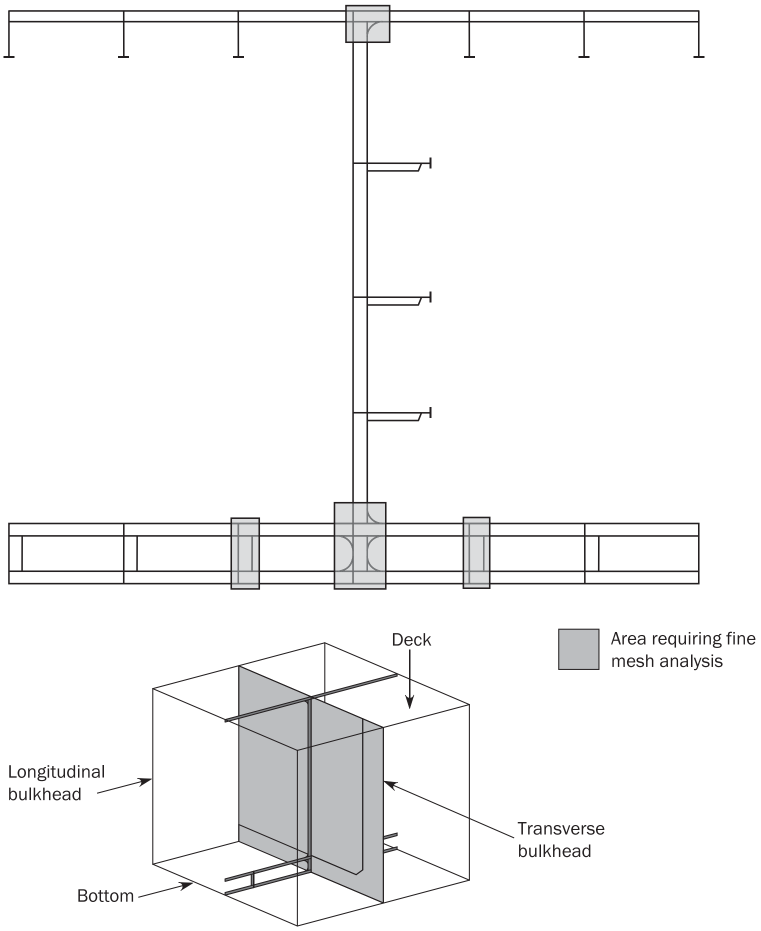
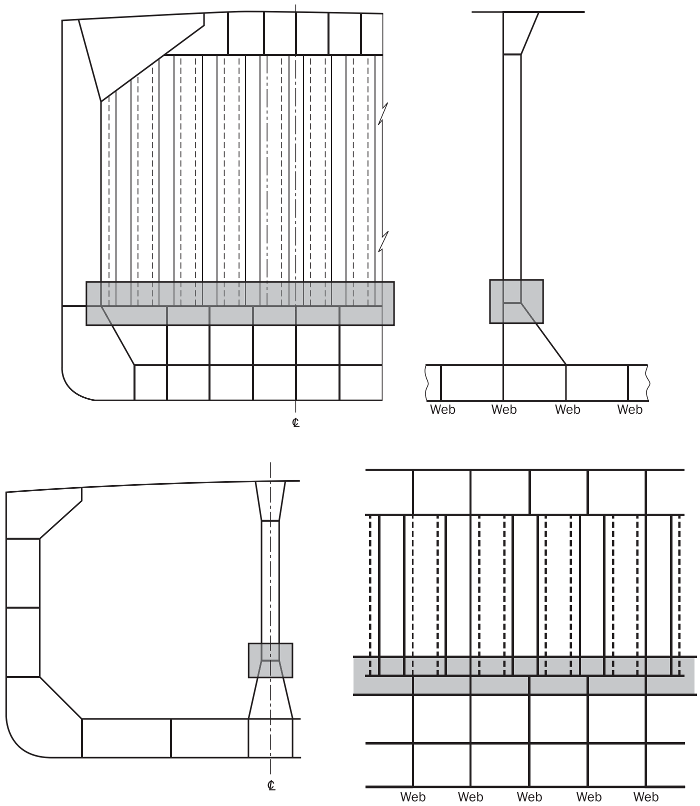


Figure 4 : Mandatory areas at connections between corrugations and adjoining lower stool



3 SCREENING PROCEDURE

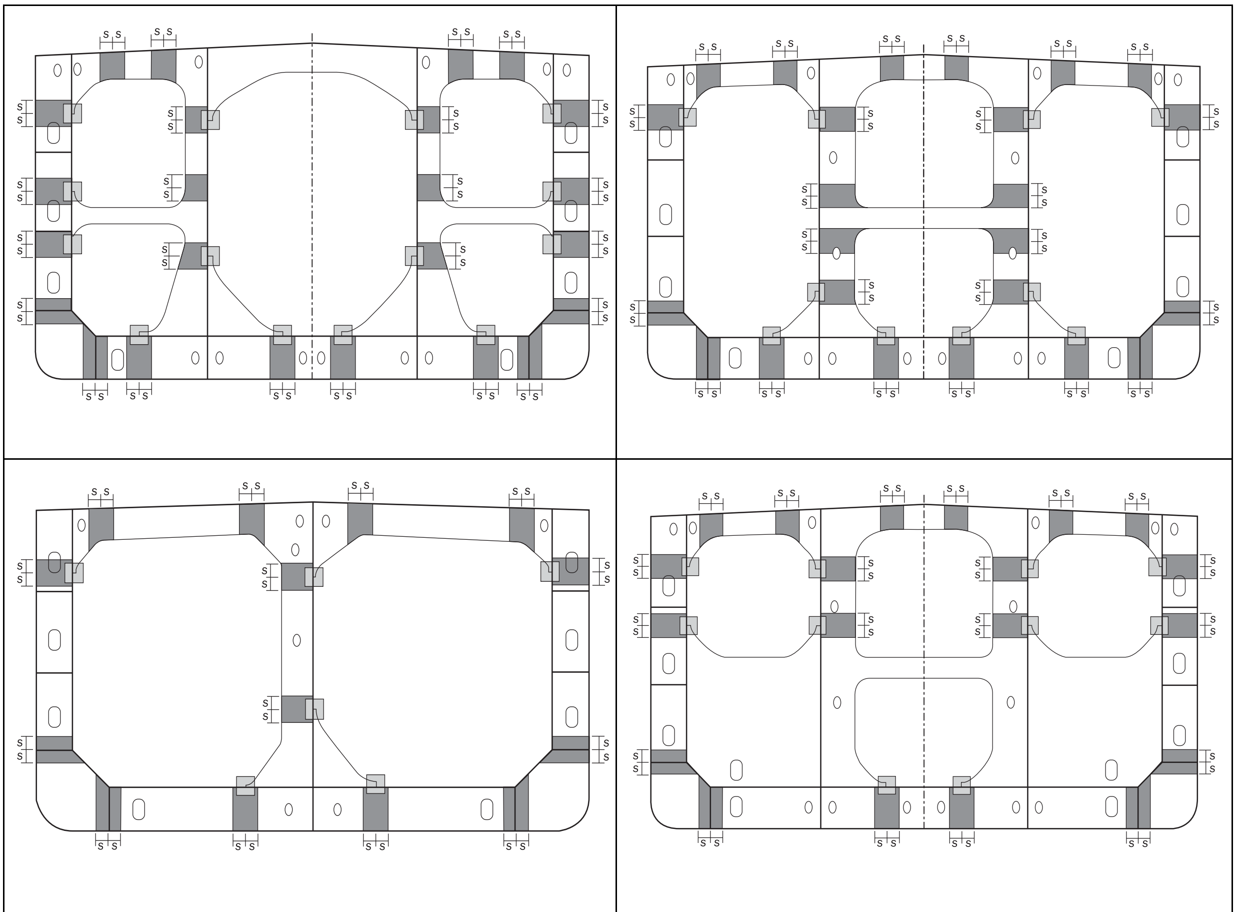
3.1 Screening areas

3.1.1

The structural details subject to this screening procedure are checked in the following ship areas:

- Within the full cargo hold region for the details given in [3.2.1],
- Outside midship cargo hold region for the details given in [3.2.2].

Table 1 : Screening areas of transverse web frame in oil tanker



	Bracket toes	
	Openings (shaded regions)	
	Other Openings (unshaded regions)	Screening check to be performed except if: $h_o/h < 0.35$ and $g_o < 1.2$, and, each end of the opening forms a semi circle arc (i.e. radius of opening equal to $b/2$). h_o, h and g_o is defined in Ch 7, Sec 2, [2.4.9], b is the smallest of the length and breadth of the opening.

3.2 List of structural details

3.2.1 Cargo hold region

The following structural details and areas in the cargo hold region are to be evaluated by screening:

a) Openings in way of web of primary supporting members, such as transverse web frame as indicated in Table 1 and Table 2, horizontal stringers as indicated in Table 3, floors and longitudinal girders in double bottom.

b) Bracket toes on transverse web frame as indicated in Table 1 and Table 2, horizontal stringer and transverse plane bulkhead connected to double bottom or buttress structure specified in Table 3.

c) Heels of transverse bulkhead horizontal stringers specified in Table 3.

d) Connections of transverse lower stool to double bottom girders and longitudinal lower stool to double bottom floors as indicated in Figure 5.

e) Connection of lower hopper to transverse lower stool structure as indicated in Figure 5.

f) Connection of topside tank to inner side as indicated in Figure 6.

g) Connection of corrugation and upper supporting structure to upper stool as indicated in Figure 7.

h) Hatch corner area, such as the hatch coaming end bracket, the hatch corner and the hatch end beam connection as indicated in Figure 8.

Within each group of the structural details having the same geometry and the same relative location inside the cargo region, the screening verification can be performed for the detail for which the yield utilisation factor, λ_y, is maximum

Table 2 : Screening areas for transverse web frame in bulk carrier

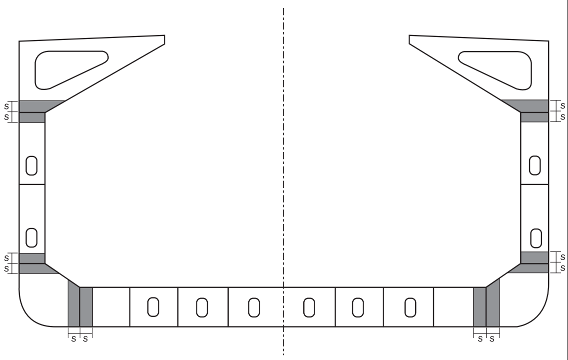
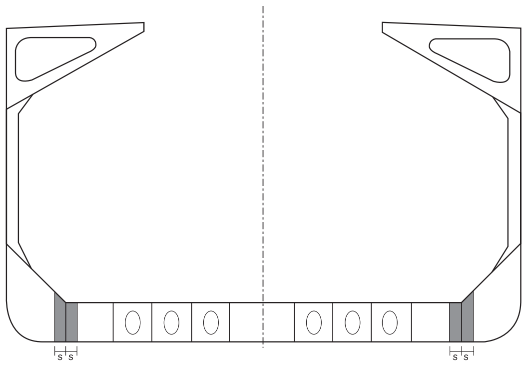
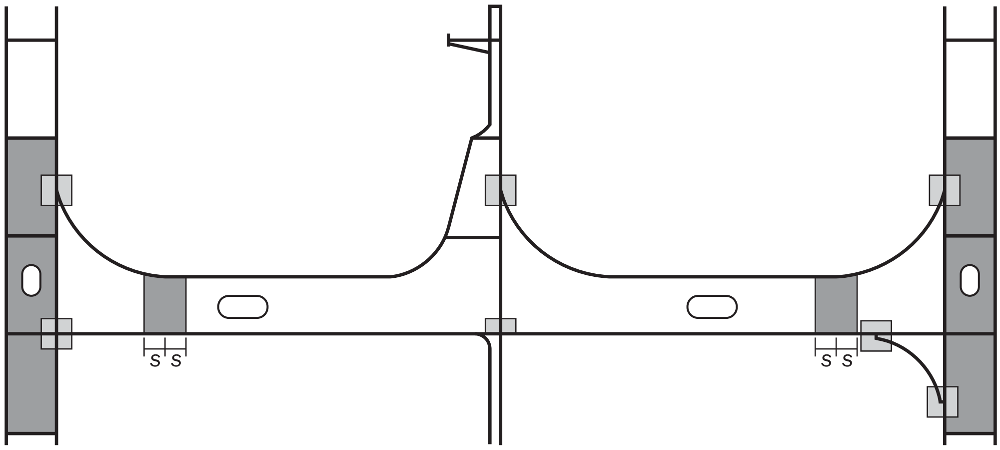
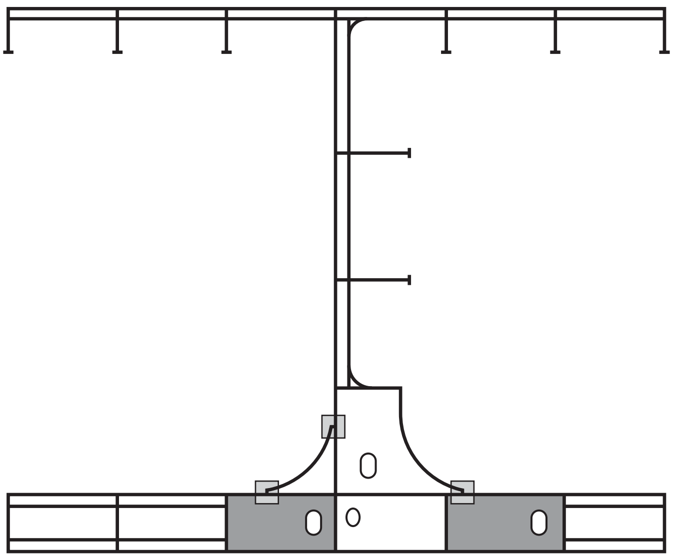
		
(light grey box)	Bracket toes	
(dark grey box)	Openings (shaded regions)	
(white box)	Other Openings (unshaded regions)	Screening check to be performed except if: h_o/h < 0.35 and g_o < 1.2, and, each end of the opening forms a semi circle arc (i.e. radius of opening equal to $b/2$). h_o, h and g_o is defined in Ch 7, Sec 2, [2.4.9], b is the smallest of the length and breadth of the opening.

Table 3 : Screening areas for horizontal stringer and transverse bulkhead to double bottom connections in oil tanker





(light grey box)	Bracket toes and heels	
(dark grey box)	Openings (shaded regions)	
(white box)	Other Openings (unshaded regions)	Screening check to be performed except if: $h_o/h < 0.35$ and $g_o < 1.2$, and, each end of the opening forms a semi circle arc (i.e. radius of opening equal to $b/2$). h_o, h and g_o is defined in Ch 7, Sec 2, [2.4.9], b is the smallest of the length and breadth of the opening.

Figure 5 : Screening areas at connections of lower stool to inner bottom and hopper tank

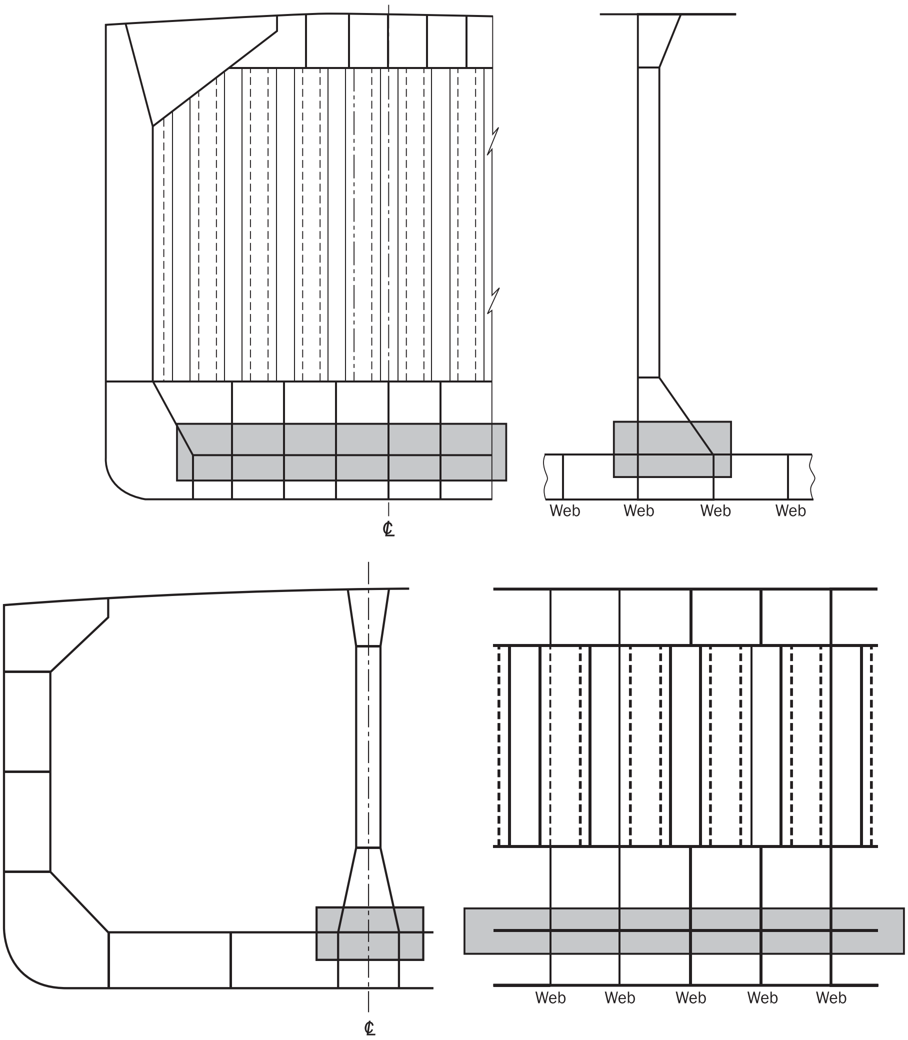


Figure 6 : Screening areas at connections of topside tank to inner side

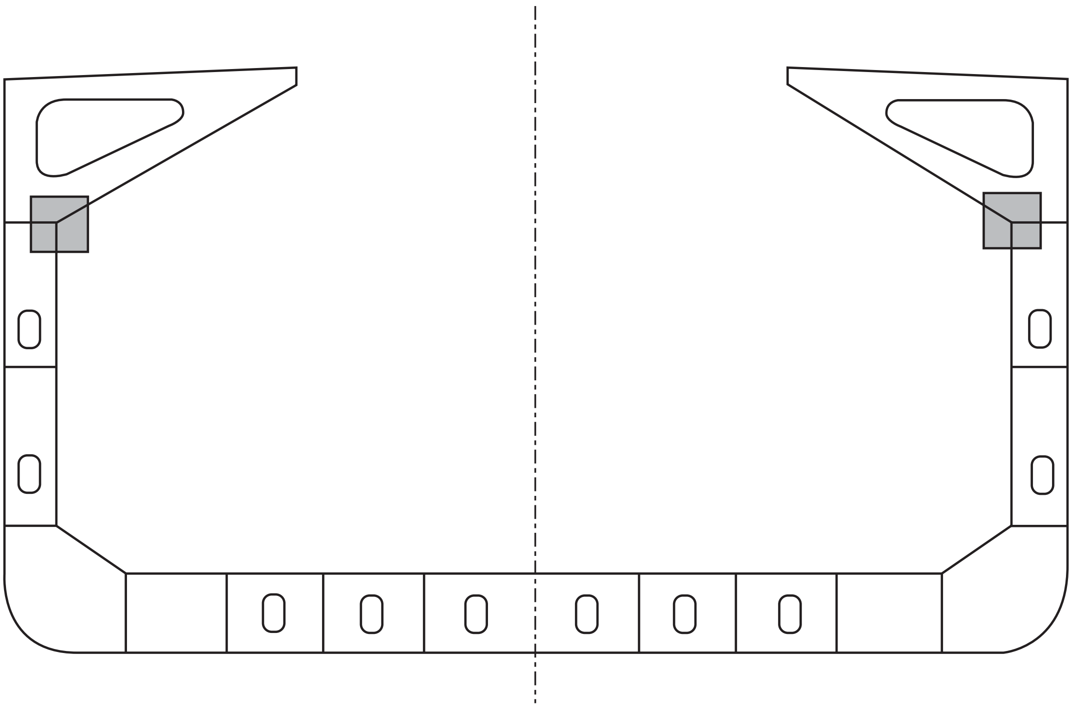


Figure 7 : Screening areas at connection of corrugation and upper supporting structure to upper stool

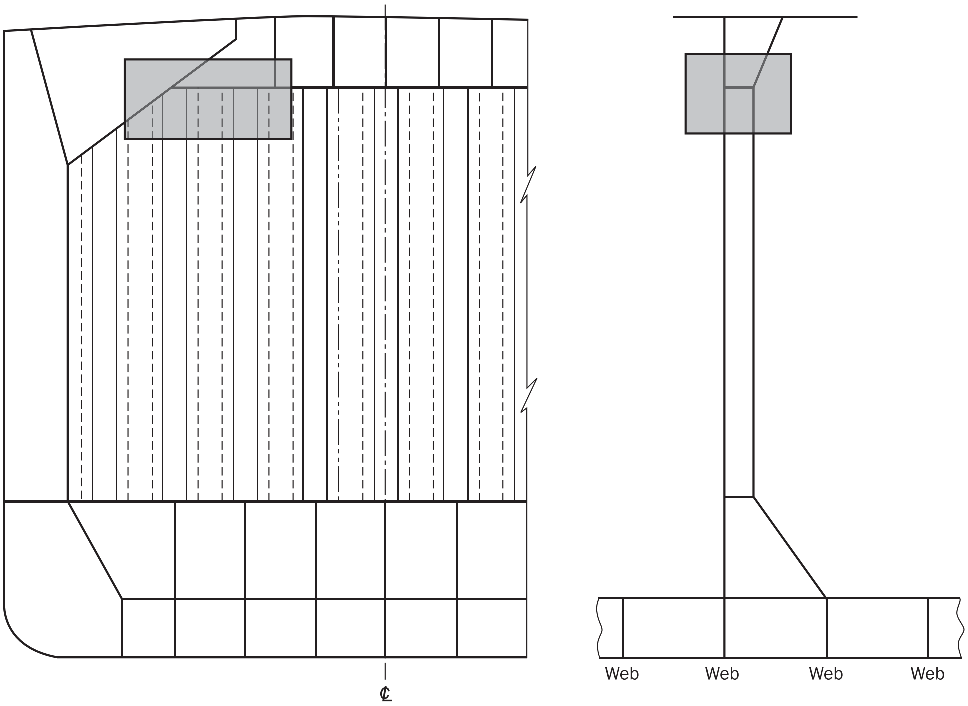
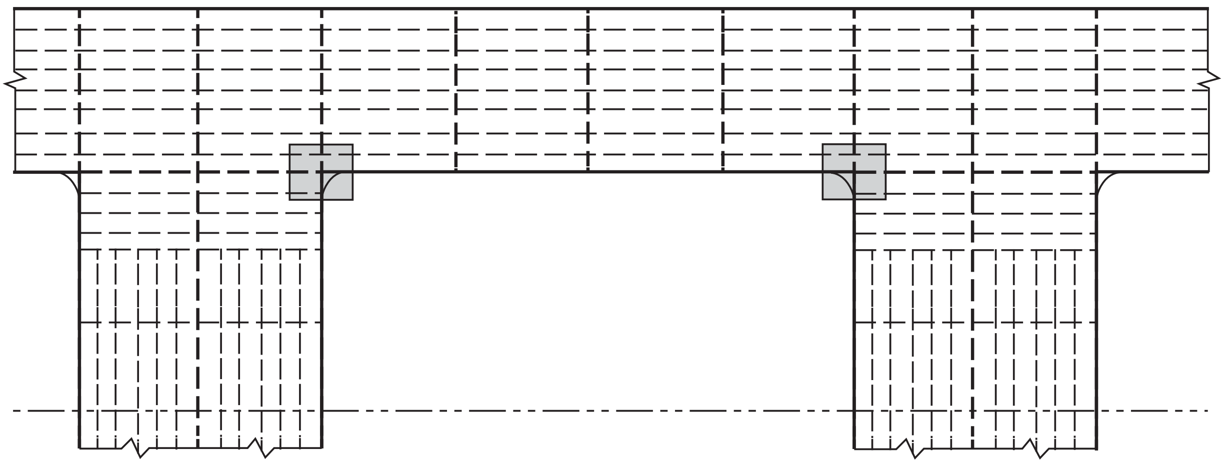


Figure 8 : Screening areas at hatch corner in bulk carrier



3.2.2 Outside midship cargo hold region

The following structural details outside midship cargo hold region are to be evaluated by screening:

a) Hopper knuckle, as defined in [2.1.2] and [2.1.3],

b) Side frame end bracket, as defined in [2.1.3],

c) Large openings, as defined in [2.1.4],

d) Connections of corrugation to adjoining structure, as defined in [2.1.6],

The above mentioned structural details to be screened are to be similar in its geometry, its proportion and its relative location to the corresponding detail modelled in fine mesh in the midship cargo hold region.

When the above mentioned structural details outside the midship cargo hold region are different from the corresponding detail modelled in fine mesh in the midship cargo hold region, a fine mesh analysis is to be performed for the detail located where the yield utilisation factor, λ_y, is maximum for structural details having the same geometry and the same relative location,

When it is deemed necessary, the Society may request a fine mesh analysis to be performed according to [1.1.3].

3.3 Screening criteria

3.3.1 Screening factors and permissible screening factors

The screening factors, λ_{sc}, and the permissible screening factors, λ_{scperm}, are given in Table 4 for the screening areas defined in [3.1].

Table 4 : Screening factors and permissible screening factors

Type of Details	Screening factors, λ_{sc}	Permissible screening factors, λ_{scperm}	
Within the whole cargo hold region		**S+D**	**S**
Openings in way of webs of primary supporting members, such as transverse web frame as indicated in Table 1 and Table 2, horizontal stringers as indicated in Table 3, floors and longitudinal girders in double bottom.	Table 5	1.70	1.36
Bracket toes on transverse web frames as indicated in Table 1 and Table 2, horizontal stringers and transverse plane bulkhead to double bottom connection or buttress structure specified in Table 3.	Table 6	1.50	1.20
Heels of transverse bulkhead horizontal stringers specified in Table 3.	Table 7	1.50	1.20
Connections of transverse lower stool to double bottom girders and longitudinal lower stool to double bottom floors as indicated in Figure 5. The connection of lower hopper to transverse lower stool structure as indicated in Figure 5. The connection of topside tank to inner side as indicated in Figure 6. The connection of corrugation and upper supporting structure to upper stool as indicated in Figure 7.	λ_y	$0.75\ \lambda_{yperm}$	
Hatch corner area.	λ_y	$0.95\ \lambda_{yperm}$	
Outside midship cargo hold region			
Hopper knuckle	$\lambda_{sc} = \dfrac{K_{sc} \cdot \sigma_c}{R_Y}$ **(1)**	$1.50\ f_f$	$1.20\ f_f$
Side frame end bracket **(2)**		$1.50\ f_f$	$1.20\ f_f$
Large openings		$1.70\ f_f$	$1.36\ f_f$
Connections of corrugation to adjoining structure		$1.50\ f_f$	$1.20 f_f$

where:

λ_y : Coarse mesh yield utilisation factor, as defined in Ch 7, Sec 2, [5.2.4].

λ_{yperm} : Coarse mesh permissible yield utilisation factor, as defined in Ch 7, Sec 2, [5.2.4].

K_{sc} : Screening stress concentration factor, taken as:

$$K_{sc} = \frac{\sigma_{FM}}{\sigma_{CM}}$$

σ_{FM} : Von Mises fine mesh stress, in N/mm^2, for the considered detail calculated in the midship cargo hold region according to [2].

σ_{CM} : Von Mises coarse mesh stress, in N/mm^2, for the considered detail calculated in the midship cargo hold region according to Ch 7, Sec 2.

σ_c : Von Mises coarse mesh stress, in N/mm^2, for the area in way of considered detail.

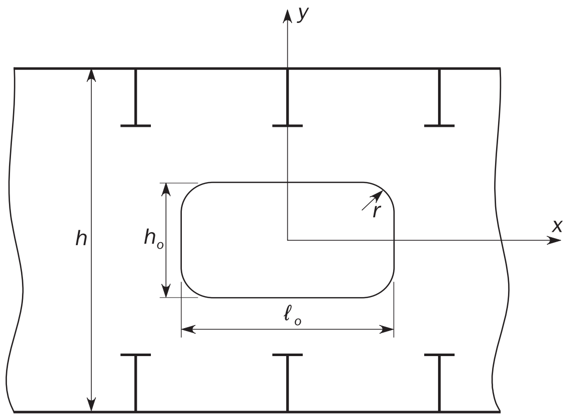
f_f : Fatigue factor defined in [6.2.1].

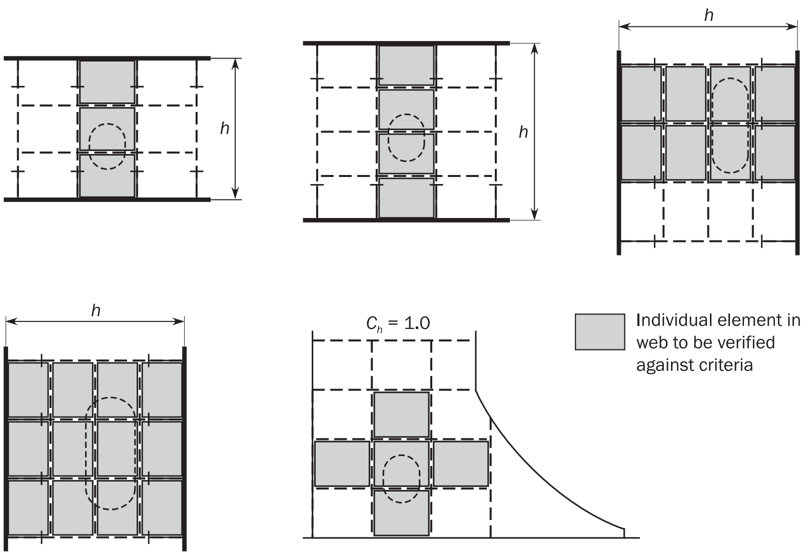
(1) For each screened detail, σ_{FM} and σ_{CM} are to be taken from the corresponding elements in the same plane position.

(2) For the side frame end brackets of single side bulk carrier, σ_{FM} and σ_{CM} are to be taken at the corresponding elements representing the flange of the end brackets.

Table 5 : Screening factor for openings in primary supporting members

λ_{sc}	: Screening factor taken as $\lambda_{sc} = 0.85 C_h \left(\lvert \sigma_x + \sigma_y \rvert + \left(2 + \left(\frac{\ell_0}{2r} \right)^{0.74} + \left(\frac{h_0}{2r} \right)^{0.74} \right) \lvert \tau_{xy} \rvert \right) \frac{k}{235}$
C_h	: Coefficient taken as (2): • For opening in web of PSM. $C_h = 1.0 - 0.23 \left(\frac{h_0}{h} \right) + 2.12 \left(\frac{h_0}{h} \right)^2$ • For opening in web of main bracket and buttress (see figures below). $C_h = 1.0$
r	: Radius of opening, in mm.
h_0	: Height of opening parallel to depth of web, in mm.
ℓ_0	: Length of opening parallel to girder web direction, in mm.
h	: Height of web of girder in way of opening, in mm.
σ_x	: Axial stress in element *x*-direction determined from cargo hold FE analysis according to the coordinate system shown, in N/mm^2.
σ_y	: Axial stress in element *y*-direction determined from cargo hold FE analysis according to the coordinate system shown, in N/mm^2.
τ_{xy}	: Element shear stress determined from cargo hold FE analysis (1), in N/mm^2.



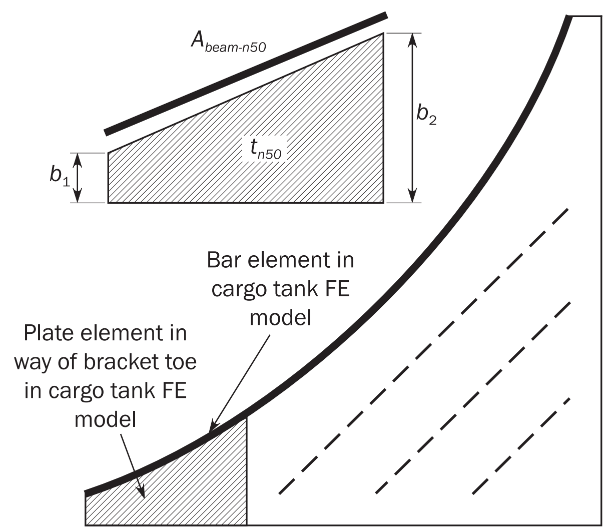


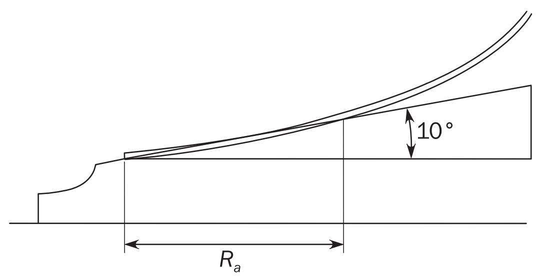
(1) The element shear stress is to be adjusted using the formula given in Ch 7, Sec 2, [5.2.6] prior to the evaluation of yield utilisation factor for verification against the screening criteria.

(2) Where the geometry of the opening is required to be modelled in accordance with Ch 7, Sec 2, [2.4.9], fine mesh FE analysis is to be carried out to determine the stress level and the screening criteria are not applicable.

Table 6 : Screening factor for bracket toes of primary supporting members

λ_{sc}	: Screening factor taken as: $$\lambda_{sc} = C_a\left(0.75\left(\frac{b_2}{b_1}\right)^{0.5}\sigma_{vm} + 0.55\left(\frac{A_{beam-n50}}{b_1\ t_{n50}}\right)^{0.5}\lvert\sigma_{beam}\rvert\right)\frac{k}{235}$$
C_a	: Coefficient taken as: $$C_a = 1.0 - 0.2\left(\frac{R_a}{1400}\right)^2$$
b_1, b_2	: Height of shell element in way of bracket toe in cargo hold FE model, in mm.
$A_{beam\text{-}n50}$	: Sectional area of beam or rod element in cargo hold FE model representing the face plate of bracket, in mm^2.
σ_{beam}	: Beam or rod element axial stress determined from cargo hold FE analysis, in N/mm^2.
σ_{vm}	: Von Mises stress of shell element in way of bracket toe determined from cargo hold FE analysis, in N/mm^2.
t_{n50}	: Net thickness of shell element in way of bracket toe, in mm.
R_a	: Leg length, in mm, not to be taken as greater than 1400 mm.





3.3.2 Screening criteria

Stresses in areas defined in [3.1], calculated for all applicable FE load combinations given in [5], are to be checked against the following screening criteria.

$\lambda_{sc} \leq \lambda_{scperm}$

where:

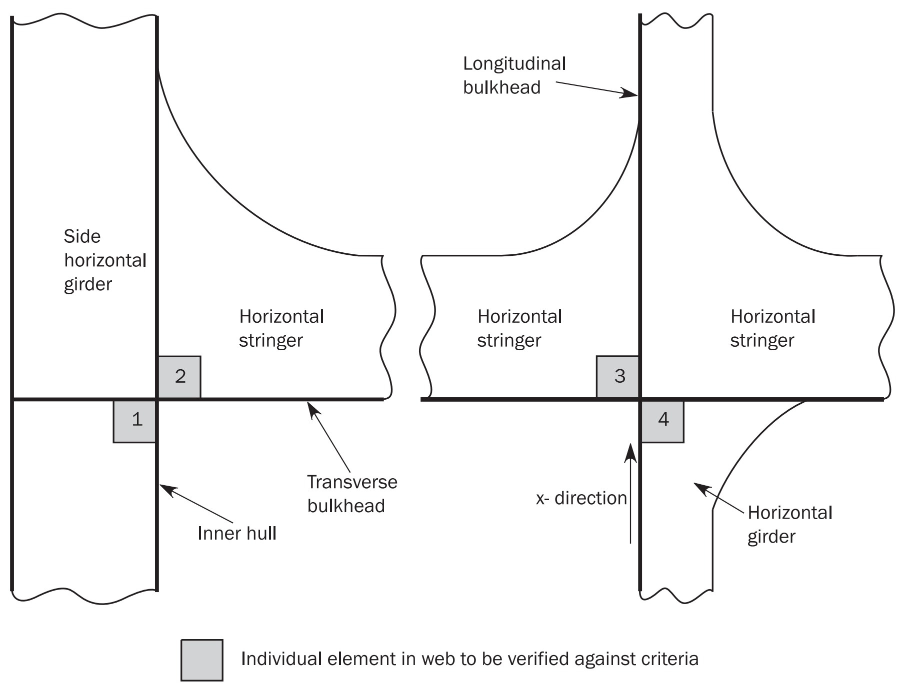
λ_{sc} : Screening factor defined in [3.3.1]

λ_{scperm} : Permissible screening factor defined in [3.3.1]

Where the screening criteria are not met, fine mesh analysis of the corresponding structural detail is required and to be performed according to [1.1.3].

Table 7 : Screening factor for heels of transverse bulkhead horizontal stringers

λ_{sc}	: Screening factor taken as: • For heels at side horizontal girder and transverse bulkhead horizontal stringer, at the locations 1, 2 and 3 in figure below. $\lambda_{sc} = 3.0\ \sigma_{vm}\ \dfrac{k}{235}$ • For heel at longitudinal bulkhead horizontal stringer, at the location 4 in figure below. $\lambda_{sc} = 5.2\ \lvert\sigma_x\rvert\ \dfrac{k}{235}$
σ_x	: Axial stress in element *x* direction determined from cargo hold FE analysis in accordance with the coordinate system shown, in N/mm^2.
σ_{vm}	: Von Mises stress of shell element in way of heel determined from cargo hold FE analysis, in N/mm^2.



▢	Individual element in web to be verified against criteria.

4 STRUCTURAL MODELLING

4.1 General

4.1.1

Evaluation of detailed stresses requires the use of refined finite element mesh in way of areas of high stress. This fine mesh analysis can be carried out by fine mesh zones incorporated into the cargo hold model. Alternatively, separate local FE model with fine mesh zones in conjunction with the boundary conditions obtained from the cargo hold model may be used.

4.2 Extent of model

4.2.1

If a separate local fine mesh model is used, its extent is to be such that the calculated stresses at the areas of interest are not significantly affected by the imposed boundary conditions. The boundary of the fine mesh model is to coincide with primary supporting members in the cargo hold model, such as web frame, girders, stringers and floors.

4.3 Mesh size

4.3.1

The mesh size in the fine mesh zones is not to be greater than 50 × 50 mm.

4.3.2

The extent of the fine mesh zone is not to be less than 10 elements in all directions from the area under investigation. A smooth transition of mesh density from fine mesh zone to the boundary of the fine mesh model is to be maintained.

4.4 Elements

4.4.1

All plating within the fine mesh zone is to be represented by shell elements. The aspect ratio of elements within the fine mesh zone is to be kept as close to 1 as possible. Variation of mesh density within the fine mesh zone and the use of triangular elements are to be avoided. In all cases, the elements within the fine mesh model are to have an aspect ratio not exceeding 3. Distorted elements, with element corner angles of less than 45° or greater than 135°, are to be avoided. Stiffeners inside the fine mesh zone are to be modelled using shell elements. Stiffeners outside the fine mesh zones may be modelled using beam elements.

4.4.2

Where fine mesh analysis is required for main bracket end connections, including the end connection of hold frames of single skin bulk carriers, the fine mesh zone is to be extended at least 10 elements in all directions from the area subject to assessment, see Figure 9.

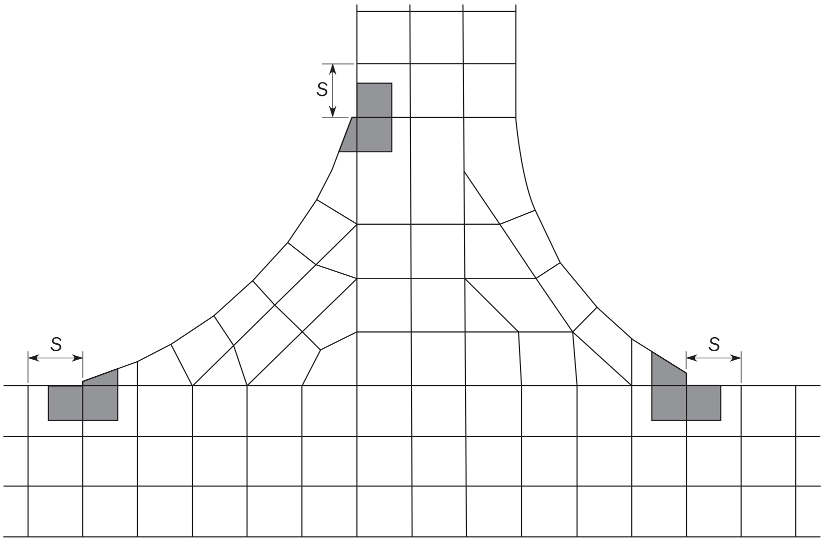
4.4.3

Where fine mesh analysis is required for an opening, the first two layers of elements around the opening are to be modelled with mesh size not greater than 50 × 50 mm. A smooth transition from the fine mesh to the coarser mesh is to be maintained. Edge stiffeners which are welded directly to the edge of an opening are to be modelled with shell elements. Web stiffeners close to an opening may be modelled using rod or beam elements located at a distance of at least 50 mm from the edge of the opening. Example of fine mesh zone around an opening is shown in Figure 10.

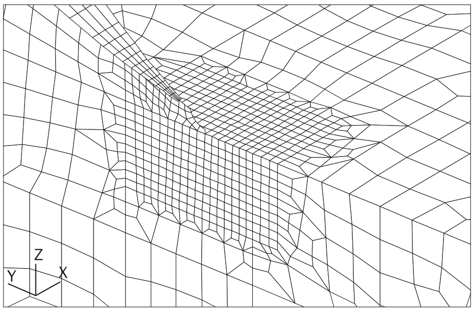
4.4.4

Face plates of openings, primary supporting members and associated brackets are to be modelled with at least two elements across their width on either side.

Figure 9 : Fine mesh zone around bracket toes



Fine mesh zone
Element size ≤50 mm × 50 mm
Extent - at least 10 elements in all directions
Face plate modelled by plate elements



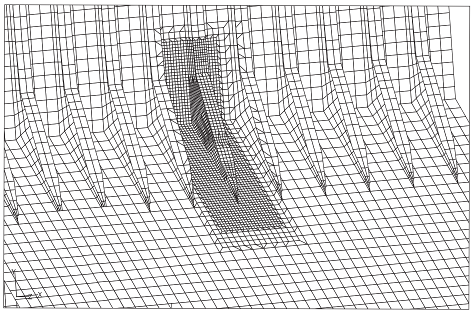
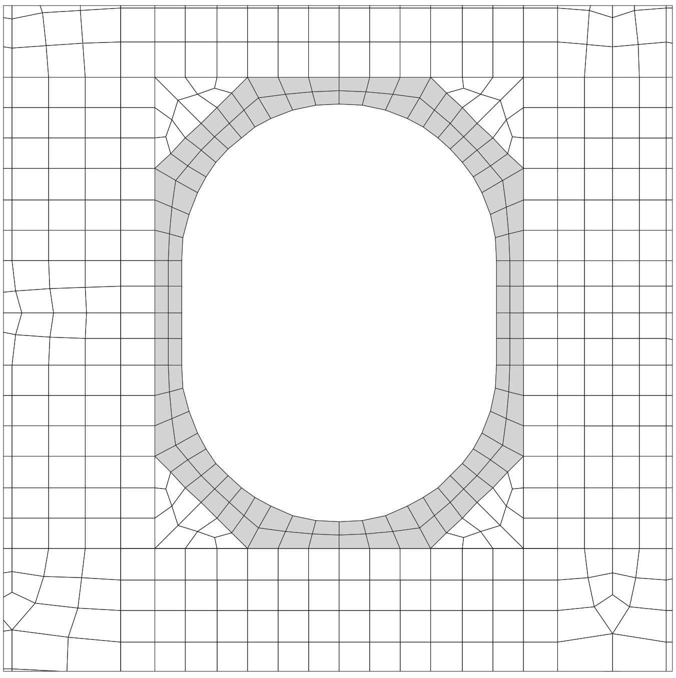


Figure 10 : Fine mesh zone around an opening



Fine mesh zone:
Element size ≤50 mm × 50 mm

4.5 Transverse web frames

4.5.1

In addition to the requirements of [4.2] to [4.4], the modelling requirements in this sub-section are applicable to the analysis of a typical transverse web frame.

4.5.2

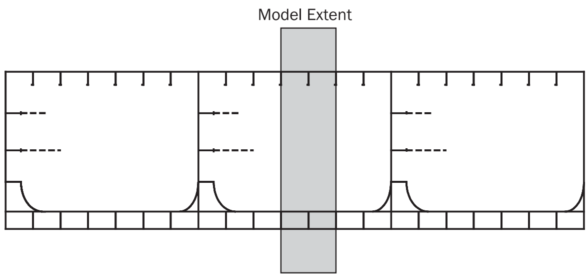
Where a FE sub model is used, the model is to have an extent of at least 1+1 web frame spaces, i.e. one web frame space extending either side of the transverse web frame under investigation. For bulk carriers, the web frame space is the longer space of web frames in the upper wing and the lower hopper tanks. The transverse web frames forward and aft of the web frame under investigation need not be included in the sub model.

4.5.3

The full depth and full breadth of the ship are to be modelled, see Figure 11.

Figure 12 shows a close up view of the finite element mesh at the lower part of the vertical web and backing brackets.

Figure 11 : Example of extent of local model for fine mesh analysis of web frame bracket connections and openings



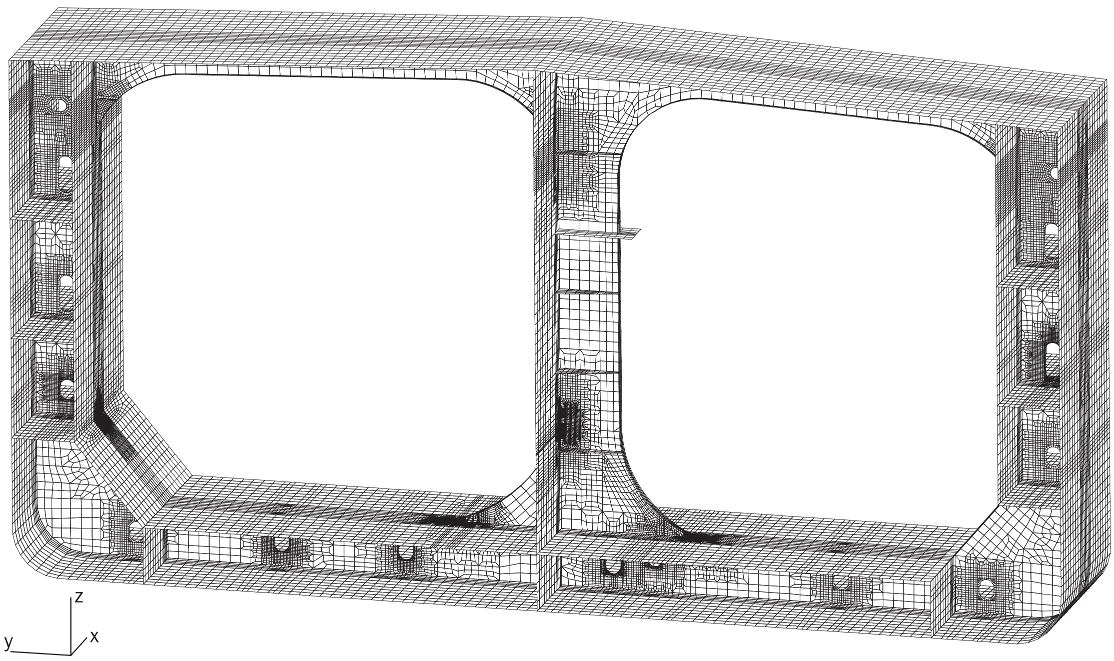
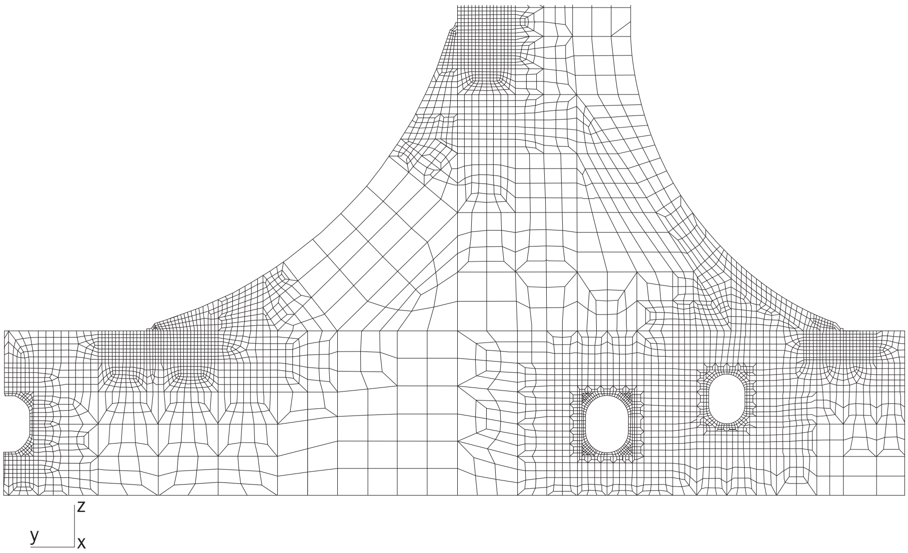
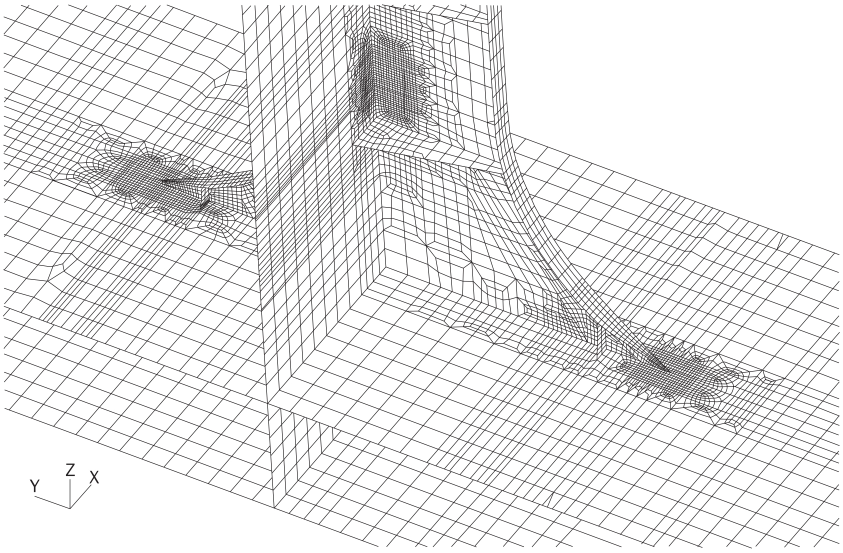


Figure 12 : Close-up view of finite element mesh at the lower part of a transverse web frame





4.6 Transverse bulkhead stringers, buttress and adjacent web frame

4.6.1

In addition to the requirements of [4.2] to [4.4], the modelling requirements in this sub-section are applicable to the analysis of transverse bulkhead structures and adjacent web frame.

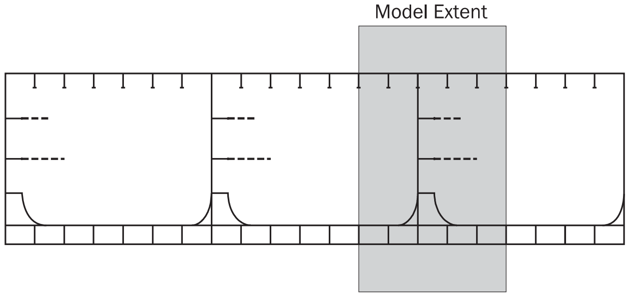
4.6.2

Due to the structural interaction among the transverse bulkhead, horizontal stringers, web frames, deck and double bottom, it is recommended that the FE local model represents a full section of the hull. Longitudinally, the ends of the model should be extended at least one web frame space beyond the areas that require investigation, see Figure 13.

4.6.3

Alternatively, it is acceptable to use a number of local models, as shown in Figure 14, to analyse different parts of the structure. For the analysis of the transverse bulkhead horizontal stringers the full breadth of the ship are to be modelled. For the analysis of buttress structure, the local model width should be at least 4+4 longitudinal spaces, i.e. four longitudinal spaces at each side of the buttress.

Figure 13 : Example of local model for fine mesh analysis of transverse bulkhead and adjacent structure



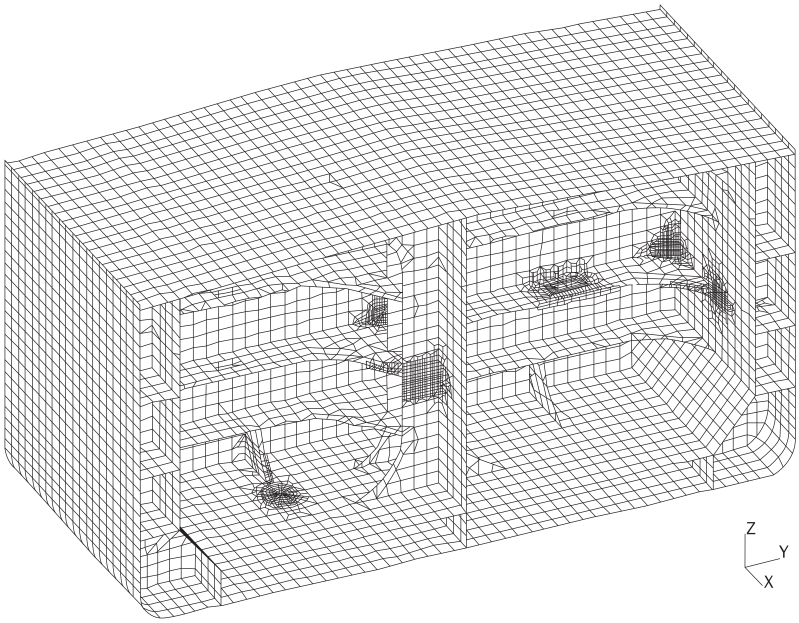
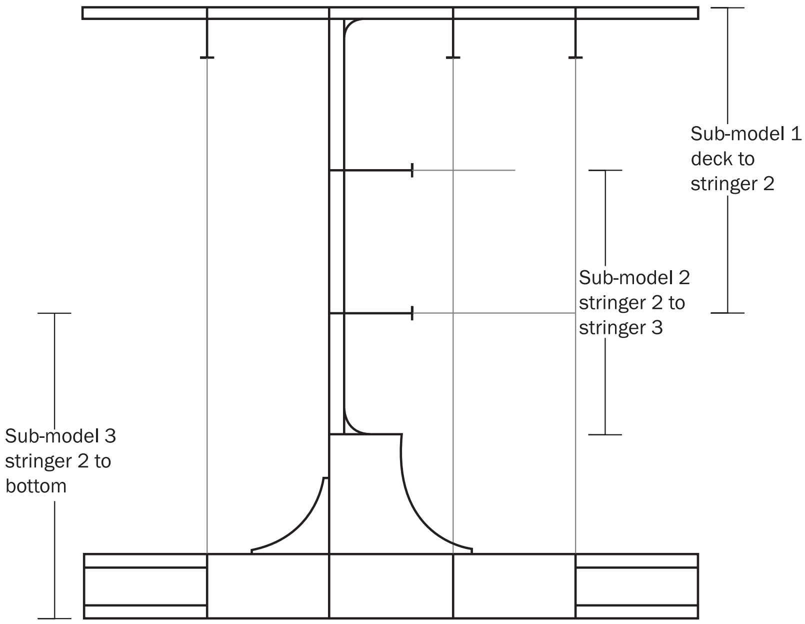


Figure 14 : Example of local analysis of transverse bulkhead structure using local models



4.6.4

Figure 15 shows the finite element mesh on a transverse bulkhead horizontal stringer. Figure 16 shows the local model for the analysis of buttress connections to transverse bulkhead and double bottom structure, and openings.

Figure 15 : Example of finite element mesh on transverse bulkhead horizontal stringer

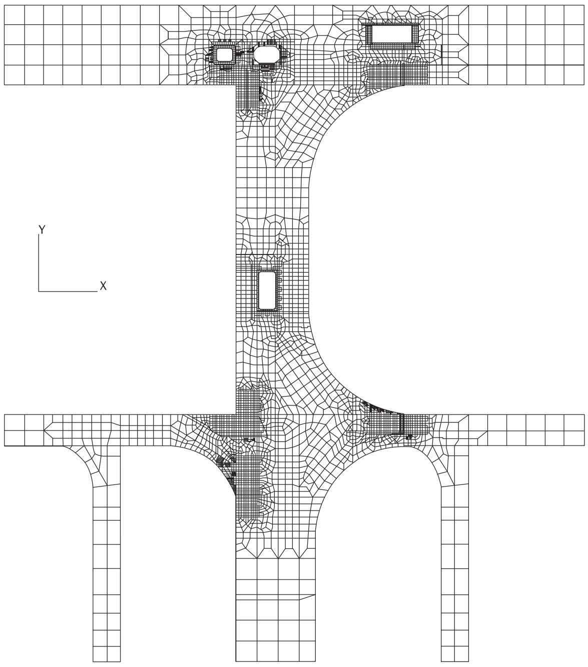
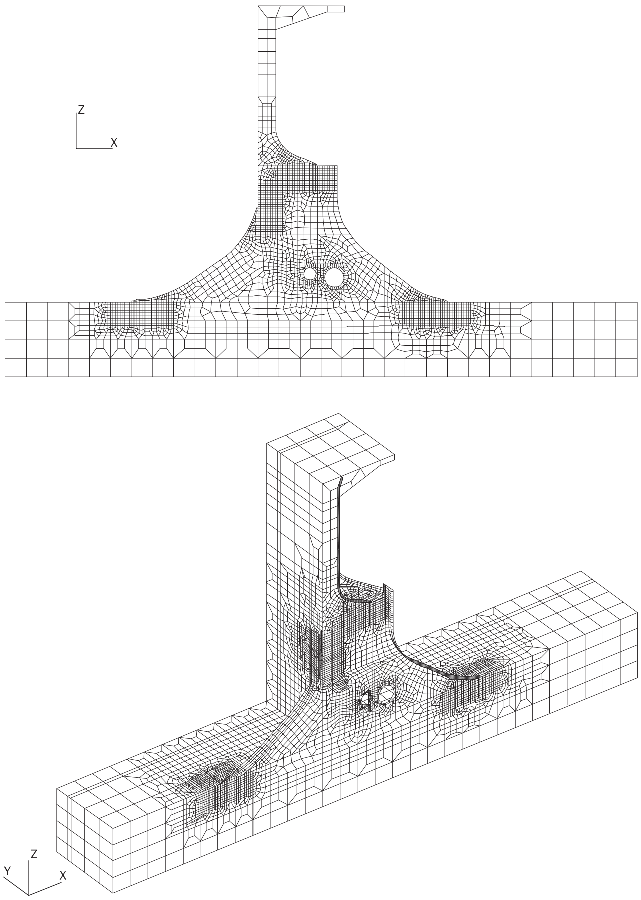


Figure 16 : Example of local model for the analysis of buttress connections to bulkhead and double bottom structure, showing port half of model



4.7 Deck, double bottom longitudinal and adjoining transverse bulkhead vertical stiffeners

4.7.1

In addition to the requirements of [4.2] to [4.4], the modelling requirements in this sub-section are applicable specifically to the analysis of longitudinal and vertical stiffener end connections and attached web stiffeners.

4.7.2

Where a local FE model is used, each end of the model is to be extended longitudinally at least two web frame spaces from the areas under investigation. The model width is to be at least 2+2 longitudinal spaces. Figure 17 shows the longitudinal extent of the local model for the analysis of deck and double bottom longitudinal stiffeners and adjoining transverse bulkhead vertical stiffener.

4.7.3

The web of the longitudinal stiffeners outside of the fine mesh zone should be represented by at least 3 shell elements across its depth. Similar size elements should be used to represent the plating of the bottom shell and inner bottom. The flange of the longitudinal stiffeners and face plate of brackets should be modelled with at least two shell elements across its width at one side.

4.7.4

The mesh size and extent of the fine mesh zone is to be in accordance with [4.3.1], see also Figure 17.

4.8 Corrugated bulkheads

4.8.1

In addition to the requirements of [4.2] to [4.4], the modelling requirements in this sub-article are applicable to the analysis of connections of corrugated bulkheads to lower stool and the connection between lower stool and inner bottom.

4.8.2

The minimum extents of the local model are as follows, see also Figure 18:

a) Vertically, the model is to be extended from the bottom of the ship to a level at least 2 m above the corrugation and lower stool connection. The upper boundary of the local model is to coincide with the horizontal mesh line of the cargo hold FE model for the purpose of applying boundary displacements, see [4.2].

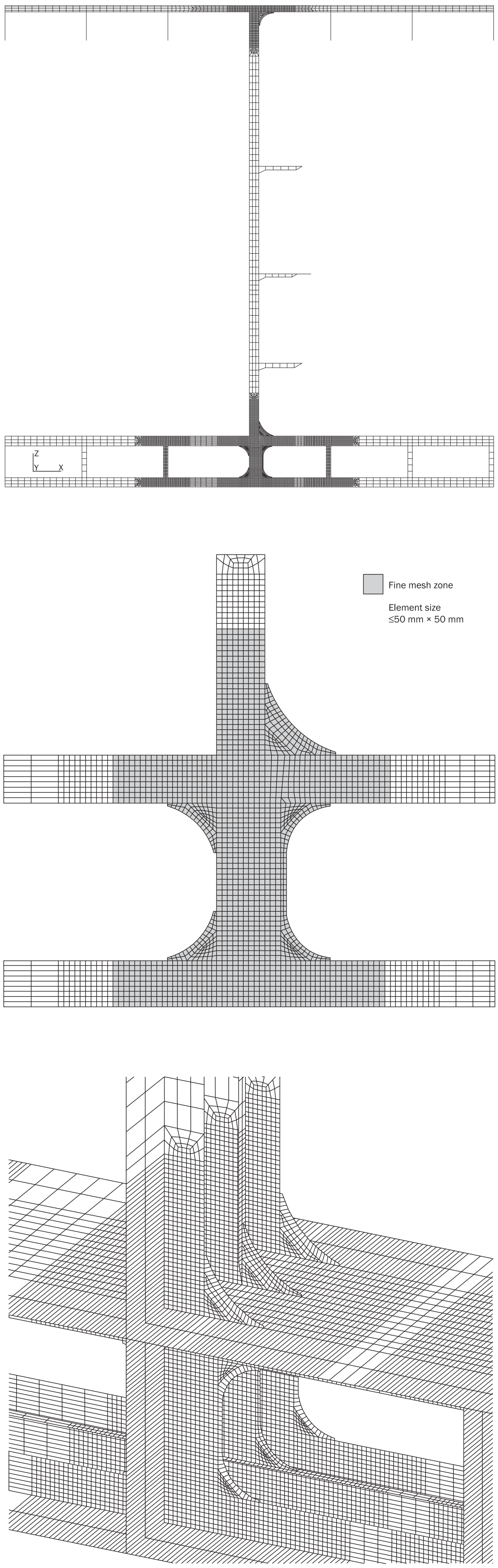
b) For transverse corrugated bulkheads, the local model is to be extended transversely to the nearest diaphragm web in the lower stool on each side of the fine mesh zone (i.e. the local model covers two lower stool transverse web/diaphragm spaces). The end diaphragms need not be modelled.

c) For the longitudinal corrugated bulkheads, the local model is to be extended to the nearest web frame on each side of the fine mesh zone (i.e. the local model covers two frame spaces). The end web frames need not be modelled.

d) For the corrugation and lower stool connection located close to the intersection of transverse and longitudinal corrugated bulkheads, such as for product tanker, the local model is to cover the structure between the diaphragms (in transverse direction) and web frames (in longitudinal direction) closest to the detail, whichever is relevant. In addition the local model is to be extended at least one diaphragm/web frame outside the intersection between the transverse stool and the longitudinal stool.

e) For lower stool to inner bottom connection, the connection between inner bottom, lower stool plate, diaphragm and double bottom girder, where applicable, is the centre of the fine mesh zone.

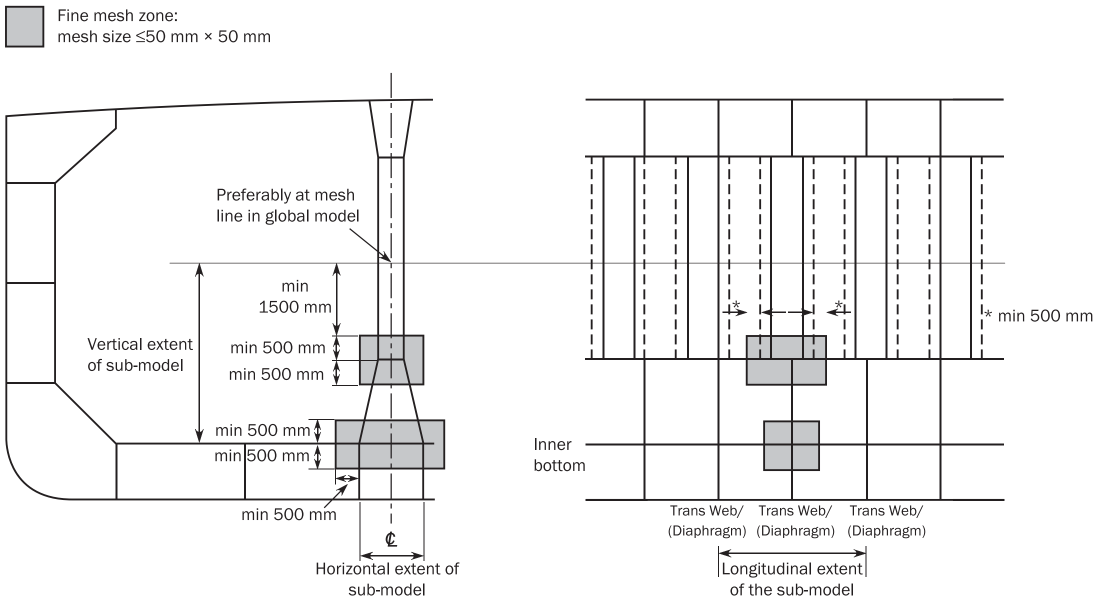
Figure 17 : Example of local model for fine mesh analysis of end connections and web stiffeners of deck and double bottom longitudinals



4.8.3

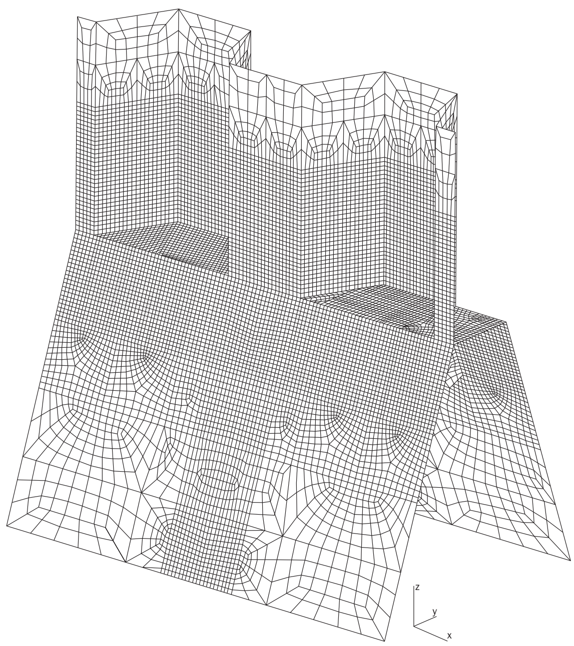
For corrugation connection, the fine mesh zone is to cover at least the corrugation flange under investigation, the adjacent corrugation webs and a further extension of 500 mm from each end of the corrugation web, i.e. the fine mesh zone covers at least four corrugation knuckles, see Figure 18 and Figure 19. The mesh size within the fine mesh zone is not to be greater than 50 × 50 mm.

Figure 18 : Extent of local model and fine mesh zone for the analysis of corrugated bulkhead connection to lower stool and inner bottom



Above figures show extent of local model and fine mesh zone on longitudinal corrugated bulkhead connection to lower stool. Similar extent applies to transverse corrugated bulkhead.
The model extents shown above are the minimum extents.

Figure 19 : Example of partial local model for the analysis of connection of corrugated bulkhead to lower stool



4.8.4

Diaphragm webs, brackets inside the lower stool and vertical stiffeners on the stool side plate are to be modelled at their actual positions within the extent of the local model. Shell elements are to be used for modelling of diaphragm, bracket and stiffener webs. Shell elements are be used to represent the flange of stiffeners and brackets in the fine mesh zone.

4.8.5

Stiffeners on the lower stool plate are to be represented by beam elements.

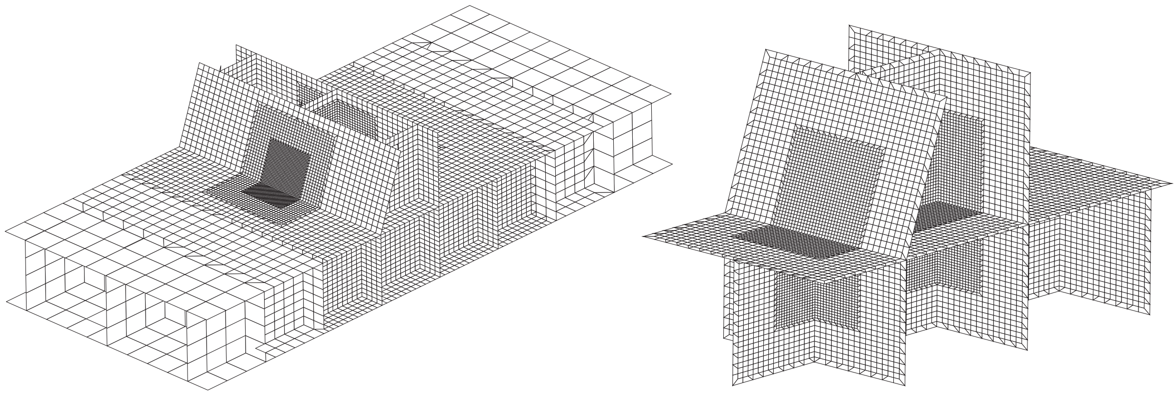
4.8.6

Figure 19 shows the details of finite element local model for the fine mesh analysis of longitudinal bulkhead to lower stool connection.

4.8.7

Figure 20 shows the details finite element local model for the fine mesh analysis of lower stool to inner bottom connection.

Figure 20 : Example of partial local model for the analysis of connection of lower stool to inner bottom



4.9 Hatch corner structures

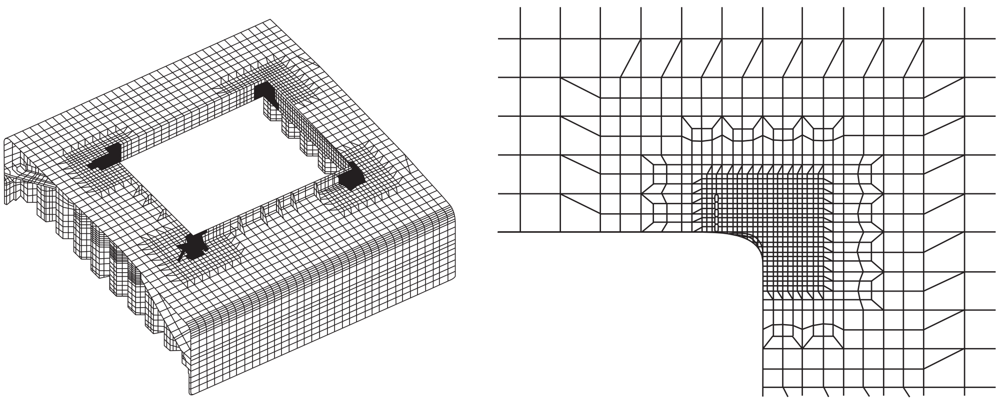
4.9.1

In addition to the requirements of [4.2] to [4.4], the modelling requirements in this sub-article are applicable to the analysis of hatch corner structures.

4.9.2

The high stress areas, such as the hatch coaming end bracket, the hatch corner and the hatch end beam connection, need to be analysed by fine mesh model. The fine mesh zones should cover these areas, see Figure 21.

Figure 21 : Example of local model for the analysis of hatch opening structures



5 FE LOAD COMBINATIONS

5.1 General

5.1.1

The fine mesh detailed stress analysis is to be carried out for all FE load combinations applied to the corresponding cargo hold analysis.

5.2 Application of loads and boundary conditions

5.2.1 General

Where a separate local model is used for the fine mesh detailed stress analysis, the nodal displacements from the cargo tank model are to be applied to the corresponding boundary nodes on the local model as prescribed displacements. Alternatively, equivalent nodal forces from the cargo tank model may be applied to the boundary nodes.

Where there are nodes on the local model boundaries which are not coincident with the nodal points on the cargo tank model, it is acceptable to impose prescribed displacements on these nodes using multi-point constraints. The use of linear multi-point constraint equations connecting two neighbouring coincident nodes is considered sufficient.

All local loads, including any loads applied for hull girder bending moment and/or shear force corrections, in way of the structure represented by the separate local finite element model are to be applied to the model.

6 ANALYSIS CRITERIA

6.1 Stress assessment

6.1.1 General

Stress assessment of the fine mesh analysis is to be carried out for the FE load combinations specified in Ch 4, Sec 8.

6.1.2 Reference stress

Reference stress is von Mises stress, σ_{vm}, which is to be calculated based on the membrane normal and shear stresses of the shell element evaluated at the element centroid. The stresses are to be evaluated at the mid plane of the element.

6.1.3 Permissible stress

The maximum permissible stresses are based on the mesh size of 50 × 50 mm as specified in [4.1] to [4.4]. Where a smaller mesh size is used, an area weighted von Mises stress calculated over an area equal to the specified mesh size may be used to compare with the permissible stresses. The averaging is to be based only on elements with their entire boundary located within the desired area. The average stress is to be calculated based on stresses at element centroid; stress values obtained by interpolation and/or extrapolation are not to be used. Stress averaging is not to be carried across structural discontinuities and abutting structure.

6.2 Acceptance criteria

6.2.1

Verification of stress results against the acceptance criteria is to be carried out in accordance with [6.1].

The structural assessment is to demonstrate that the stress complies with the following criteria:

$\lambda_f \leq \lambda_{fperm}$

where:

λ_f : Fine mesh yield utilisation factor.

$$\lambda_f = \frac{\sigma_{vm}}{R_Y} \quad \text{for shell elements in general}$$

$$\lambda_f = \frac{|\sigma_{axial}|}{R_Y} \quad \text{for rod or beam elements in general}$$

σ_{vm} : Von Mises stress, in N/mm^2.

σ_{axial} : Axial stress in rod element, in N/mm^2.

λ_{fperm} : Permissible fine mesh utilisation factor, taken as:

- Element not adjacent to weld:
  - λ_{fperm} = 1.70 f_f for S+D
  - λ_{fperm} = 1.36 f_f for S
- Element adjacent to weld:
  - λ_{fperm} = 1.50 f_f for S+D
  - λ_{fperm} = 1.20 f_f for S

f_f : Fatigue factor, taken as:

- f_f = 1.0 in general,
- f_f = 1.2 for details defined in Ch 9, Sec 2, Table 1, complying with the fatigue assessment criteria.

Note 1: The maximum permissible stresses are based on the mesh size of 50 × 50 mm. Where a smaller mesh size is used, an average von Mises stress calculated in accordance with [6.1] over an area equal to the specified mesh size may be used to compare with the permissible stresses.

Note 2: Average von Mises stress is to be calculated based on weighted average against element areas:

$$\sigma_{vm-av} = \frac{\sum_1^n A_i \, \sigma_{vm-i}}{\sum_1^n A_i}$$

where:

$\sigma_{vm\text{-}av}$ is the average von Mises stress.

Note 3: Stress averaging is not to be carried across structural discontinuities and abutting structure.

6.2.2 Lower stool not fitted to a transverse or longitudinal corrugated bulkhead

Where a lower stool is not fitted to a transverse or longitudinal corrugated bulkhead, the permissible stresses given in [6.2.1] are to be reduced by 10% for the areas under investigation by fine mesh analysis.

PART 1 CHAPTER 8

BUCKLING

Table of Contents

SECTION 1
GENERAL

1 INTRODUCTION

1.1 Assumption

1.1.1

This chapter contains the strength criteria for buckling and ultimate strength of local supporting members, primary supporting members and other structures such as pillars, corrugated bulkheads and brackets. These criteria are to be applied as specified in Ch 6 for hull local scantlings and in Ch 7 for direct strength analysis.

1.1.2

For each structural member, the characteristic buckling strength is to be taken as the most unfavourable/critical buckling failure mode.

1.1.3

Unless otherwise specified, the scantling requirements of structural members in this chapter are based on net scantling obtained by removing t_c from the gross offered thickness, where t_c is defined in Ch 3, Sec 3.

1.1.4

In this chapter, compressive and shear stresses are to be taken as positive, tension stresses are to be taken as negative.

2 APPLICATION

2.1 Scope

2.1.1

The buckling checks are to be performed according to:

- Ch 8, Sec 2 for the slenderness requirements of plates, longitudinal and transverse stiffeners, primary supporting members and brackets.
- Ch 8, Sec 3 for the prescriptive buckling requirements of plates, longitudinal and transverse stiffeners, supporting members and other structures.
- Ch 8, Sec 4 for the buckling requirements of the FE analysis for the plates, stiffened panels and other structures.
- Ch 8, Sec 5 for the buckling capacity of prescriptive and FE buckling requirements.

2.1.2 Stiffener

The buckling check of the stiffeners referred to in this Chapter is applicable to the stiffener fitted along the long edge of the buckling panel.

2.1.3 Enlarged stiffener

Enlarged stiffeners, with or without web stiffening, used for Permanent Means of Access (PMA) are to comply with the following requirements:

a) Slenderness requirements for primary supporting members as follows:
   - For enlarged stiffener web, see item (a) of Ch 8, Sec 2, [4.1.1].
   - For enlarged stiffener flange, see item (b) of Ch 8, Sec 2, [4.1.1] and Ch 8, Sec 2, [5.1].
   - For stiffeners fitted on enlarged stiffener web, see Ch 8, Sec 2, [3.1.1] and Ch 8, Sec 2, [3.1.3].

b) Buckling strength of prescriptive requirements as follows:
   - For enlarged stiffener web, see Ch 8, Sec 3, [3.2].
   - For stiffeners fitted on enlarged stiffener web, see Ch 8, Sec 3, [3.1] and Ch 8, Sec 3, [3.3].

c) All structural elements used for PMA are to be complied with for the buckling requirements of the FE analysis in Ch 8, Sec 4 when applicable.

d) Buckling strength of longitudinal PMA platforms without stiffeners fitted on enlarged stiffener web is to be checked using the criteria for local supporting members in Ch 8, Sec 3, [3.1] and Ch 8, Sec 3, [3.3].

3 DEFINITIONS

3.1 General

3.1.1 Buckling definition

'Buckling' is used as a generic term to describe the strength of structures, generally under in-plane compressions and/or shear and lateral load. The buckling strength or capacity can take into account the internal redistribution of loads depending on the load situation, slenderness and type of structure.

3.1.2 Buckling capacity

Buckling capacity based on this principle gives a lower bound estimate of ultimate capacity, or the maximum load the panel can carry without suffering major permanent set.

Buckling capacity assessment utilises the positive elastic post-buckling effect for plates and accounts for load redistribution between the structural components, such as between plating and stiffeners. For slender structures, the capacity calculated using this method is typically higher than the ideal elastic buckling stress (minimum Eigen value). Accepting elastic buckling of structural components in slender stiffened panels implies that large elastic deflections and reduced in-plane stiffness will occur at higher buckling utilisation levels.

3.1.3 Assessment methods

The buckling assessment is carried out according to one of the two methods taking into account different boundary condition types:

- Method A: All the edges of the elementary plate panel are forced to remain straight (but free to move in the in-plane directions) due to the surrounding structure/neighbouring plates.
- Method B: The edges of the elementary plate panel are not forced to remain straight due to low in-plane stiffness at the edges and/or no surrounding structure/neighbouring plates.

3.2 Buckling utilisation factor

3.2.1

The utilisation factor, η, is defined as the ratio between the applied loads and the corresponding ultimate capacity or buckling strength.

3.2.2

For combined loads, the utilisation factor, η_{act}, is to be defined as the ratio of the applied equivalent stress and the corresponding buckling capacity, as shown in Figure 1, and is to be taken as:

$$\eta_{act} = \frac{W_{act}}{W_u} = \frac{1}{\gamma_c}$$

where:

W_{act} : Applied equivalent stress due to the combined membrane stresses, in N/mm²:

$$W_{act} = \sqrt{\sigma_x^2 + \sigma_y^2 + \tau^2} \quad \text{for plate}$$

$$W_{act} = \sigma_a + \sigma_b + \sigma_w \quad \text{for stiffener}$$

σ_x : Membrane stress applied in *x* direction, in N/mm².

σ_y : Membrane stress applied in *y* direction, in N/mm².

τ : Membrane shear stress applied in *xy* plane, in N/mm².

σ_a : Actual stress in the stiffener as defined in Ch 8, Sec 5, [2.3], in N/mm².

σ_b : Bending stress in the stiffener as defined in Ch 8, Sec 5, [2.3], in N/mm².

σ_w : Warping stress in the stiffener as defined in Ch 8, Sec 5, [2.3], in N/mm².

W_u : Equivalent buckling capacity, in N/mm², to be taken as:

$$W_u = \sqrt{\sigma_{cx}^2 + \sigma_{cy}^2 + \tau_c^2} \quad \text{for plate}$$

$$W_u = \frac{R_{eH-S}}{S} \quad \text{for stiffener}$$

σ_{cx}, σ_{cy}, τ_c: Critical stress, in N/mm², defined in Ch 8, Sec 5, [2.2] for plates and in Ch 8, Sec 5, [2.3] for stiffeners.

R_{eH-S} : Specified minimum yield stress of the stiffener, in N/mm².

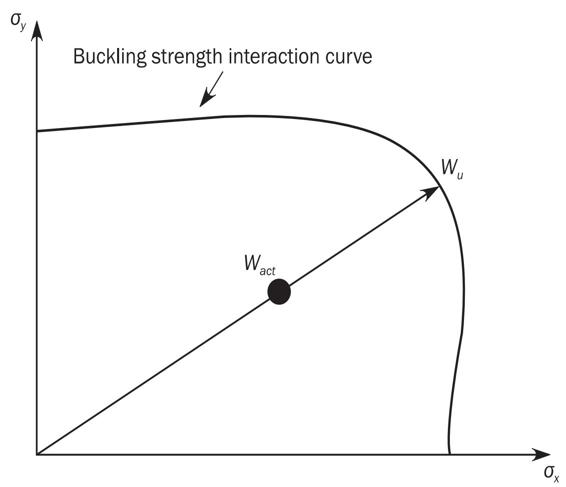
S : Partial safety factor as defined in Ch 8, Sec 5.

γ_c : Stress multiplier factor at failure.

For each typical failure mode, the corresponding capacity of the panel is calculated by applying the actual stress combination and then increasing or decreasing the stresses proportionally until collapse.

Figure 1 illustrates the buckling capacity and the buckling utilisation factor of a structural member subject to σ_x and σ_y stresses.

Figure 1 : Example of buckling capacity and buckling utilisation factor



3.3 Allowable buckling utilisation factor

3.3.1 General structural elements

The allowable buckling utilisation factor is defined in Table 1.

Table 1 : Allowable buckling utilisation factor

Structural component	η_{all}, Allowable buckling utilisation factor
Plates and stiffeners Stiffened and unstiffened panels Vertically stiffened side shell plating of single side skin bulk carrier Web plate in ways of openings	1.00 for load combination: S+D 0.80 for load combination: S
Struts, pillars and cross ties	0.75 for load combination: S+D 0.65 for load combination: S
Corrugation of vertically corrugated bulkheads with lower stool and horizontally corrugated bulkhead, under lateral pressure from liquid loads, for shell elements only. Supporting structure in way of lower end of corrugated bulkheads without lower stool.	0.90 for load combination: S+D 0.72 for load combination: S
Corrugation of vertically corrugated bulkheads without lower stool under lateral pressure from liquid loads, for shell elements only.	0.81 for load combination: S+D 0.65 for load combination: S
Note 1: Supporting structure for a transverse corrugated bulkhead refers to the structure in longitudinal direction within half a web frame space forward and aft of the bulkhead, and within a vertical extent equal to the corrugation depth. Note 2: Supporting structure for a longitudinal corrugated bulkhead refers to the structure in transverse direction within three longitudinal stiffener spacings from each side of the bulkhead, and within a vertical extent equal to the corrugation depth.	

3.4 Buckling acceptance criteria

3.4.1

A structural member is considered to have an acceptable buckling strength if it satisfies the following criterion:

$\eta_{act} \le \eta_{all}$

where:

η_{act} : Buckling utilisation factor based on the applied stress, defined in [3.2.2].

η_{all} : Allowable buckling utilisation factor as defined in [3.3].

SECTION 2
SLENDERNESS REQUIREMENTS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

$b_{f\text{-}out}$: Maximum distance, in mm, from mid thickness of the web to the flange edge, as shown in Figure 1.

h_w : Depth of stiffener web, in mm, as shown in Figure 1.

ℓ_b : Effective length of edge of bracket, in mm, as defined in Table 3.

ℓ : Length of stiffener between effective supports, in m.

s_{eff} : Effective width of attached plate of stiffener, in mm, taken equal to:

$s_{eff} = 0.8\ s$

t_f : Net flange thickness, in mm.

t_p : Net thickness of plate, in mm.

t_w : Net web thickness, in mm.

1 STRUCTURAL ELEMENTS

1.1 General

1.1.1

All structural elements are to comply with the applicable slenderness and proportion requirements given in [2] to [4].

2 PLATES

2.1 Net thickness of plate panels

2.1.1

The net thickness of plate panels is to satisfy the following criteria:

$$t_p \geq \frac{b}{C}\sqrt{\frac{R_{eH}}{235}}$$

where:

C : Slenderness coefficient taken as:

C = 100 for hull envelope and cargo and tank boundaries.

C = 125 for other structures.

R_{eH} : Specified minimum yield stress of the plate material, in N/mm^2.
The mild steel value may be used in this slenderness criterion provided the requirements specified in Sec 3 and Sec 4 are satisfied for the strake assumed in mild steel material.

This requirement does not apply to transversely stiffened bilge plates and radius gunwale.

3 STIFFENERS

3.1 Proportions of stiffeners

3.1.1 Net thickness of all stiffener types

The net thickness of stiffeners is to satisfy the following criteria:

a) Stiffener web plate:

$$t_w \geq \frac{h_w}{C_w}\sqrt{\frac{R_{eH}}{235}}$$

b) Flange:

$$t_f \geq \frac{b_{f-out}}{C_f}\sqrt{\frac{R_{eH}}{235}}$$

where:

C_w, C_f : Slenderness coefficients given in Table 1.

Figure 1 : Stiffener scantling parameters

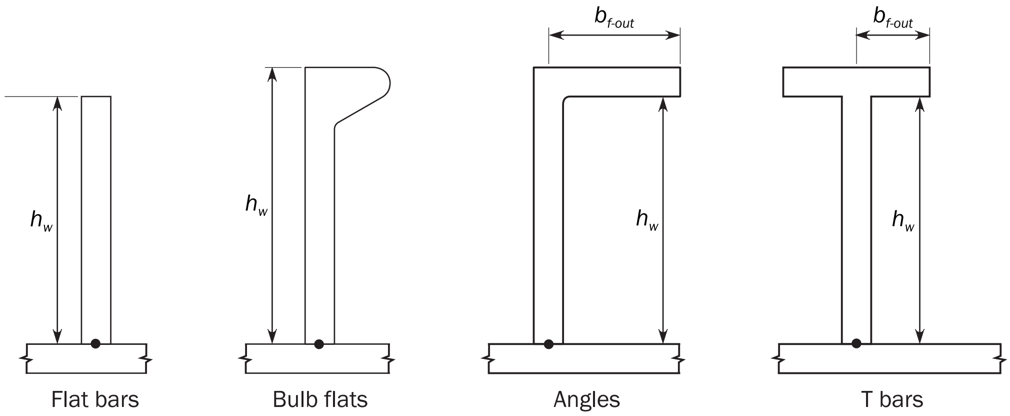


Table 1 : Slenderness coefficients

Type of Stiffener	C_w	C_f
Angle bars	75	12
T-bars	75	12
Bulb bars	45	-
Flat bars	22	-

3.1.2 Net dimensions of angle and T-bars

The total flange breadth b_f in mm, for angle and T-bars is to satisfy the following criterion:

$$b_f \geq 0.25 h_w$$

3.1.3 Bending stiffness of stiffeners

The net moment of inertia, in cm^4, about the neutral axis parallel to the effective attached plate of stiffener, s_{eff}, is not to be less than the minimum value given by:

$$I_{st} \geq C\,\ell^2 A_{eff}\frac{R_{eH}}{235}$$

where:

A_{eff} : Net sectional area of stiffener including effective attached plate, s_{eff}, in cm^2.

R_{eH} : Specified minimum yield stress of the material of the attached plate, in N/mm^2.

C : Slenderness coefficient taken as:

C = 1.43 for longitudinal stiffeners including sniped stiffeners.

C = 0.72 for other stiffeners.

4 PRIMARY SUPPORTING MEMBERS

4.1 Proportions and stiffness

4.1.1 Proportions of web plate and flange

The net thicknesses of the web plates and flanges of primary supporting members are to satisfy the following criteria:

a) Web plate:

$$t_w \geq \frac{s_w}{C_w}\sqrt{\frac{R_{eH}}{235}}$$

b) Flange:

$$t_f \geq \frac{b_{f-out}}{C_f}\sqrt{\frac{R_{eH}}{235}}$$

where:

s_w : Plate breadth, in mm, taken as the spacing of the web stiffeners.

C_w : Slenderness coefficient for the web plate taken as:

$C_w = 100$

C_f : Slenderness coefficient for the flange taken as:

$C_f = 12$

4.1.2 Deck transverse primary supporting members

The net moment of inertia for deck transverse primary supporting members, $I_{psm-n50}$, in cm^4, supporting deck longitudinals subject to axial compressive hull girder stress, is to comply, within its central half of the bending span, with the following criterion:

$$I_{psm-n50} \geq 300\,\frac{\ell_{bdg}^4}{S^3 s}\,I_{st}$$

where:

$I_{psm-n50}$: Net moment of inertia, in cm^4, of deck transverse primary supporting member, with effective width of attached plate equal to 0.8S.

ℓ_{bdg} : Effective bending span of deck transverse primary supporting member, in m, as defined in Ch 3, Sec 7.

S : Spacing of deck transverse primary supporting members, in m, as defined in Ch 3, Sec 7.

I_{st} : Moment of inertia of deck stiffeners within the central half of the bending span, in cm^4, as given in [3.1.3].

4.2 Web stiffeners of primary supporting members

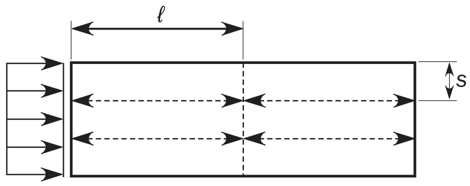
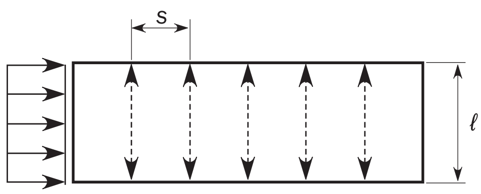
4.2.1 Proportions of web stiffeners

The net thickness of web and flange of web stiffeners fitted on primary supporting members is to satisfy the requirements specified in [3.1.1] and [3.1.2].

4.2.2 Bending stiffness of web stiffeners

The net moment of inertia, in cm^4, of web stiffener, I_{st}, fitted on primary supporting members, with effective attached plate, s_{eff}, is not to be less than the minimum moment of inertia defined in Table 2.

Table 2 : Stiffness criteria for web stiffeners

Stiffener arrangement		Minimum moment of inertia of web stiffeners, in cm^4
A	Web stiffeners fitted along the PSM span 	$I_{st} \geq C\ \ell^2\ A_{eff}\ \dfrac{R_{eH}}{235}$
B	Web stiffeners fitted normal to the PSM span 	$I_{st} \geq 1.14\ \ell\ s^2\ t_w \left(2.5\ \dfrac{1000\ell}{s} - 2\ \dfrac{s}{1000\ell}\right)\dfrac{R_{eH}}{235}\ 10^{-5}$

where:

C : Slenderness coefficient to be taken as:
C = 1.43 for longitudinal stiffeners including sniped stiffeners.
C = 0.72 for other stiffeners.

ℓ : Length of web stiffener, in m.
For web stiffeners welded to local supporting members, the length is to be measured between the flanges of the local support members.
For sniped web stiffeners, the length is to be measured between the lateral supports, e.g. the total distance between the flanges of the primary supporting member as shown for stiffener arrangement B.

A_{eff} : Net section area of web stiffener including effective attached plate, s_{eff}, in cm^2.

t_w : Net web thickness of the primary supporting member, in mm.

R_{eH} : Specified minimum yield stress of the material of the web plate of the primary supporting member, in N/mm^2.

5 BRACKETS

5.1 Tripping brackets

5.1.1 Unsupported flange length

The unsupported length of the flange of the primary supporting member, in m, i.e. the distance between tripping brackets, is not to be greater than:

$$S_b = b_f\ C \sqrt{\frac{A_{f-n50}}{\left(A_{f-n50} + \dfrac{A_{w-n50}}{3}\right)}\left(\frac{235}{R_{eH}}\right)}$$

, but need not be less than $S_{b\text{-}min}$.

where:

b_f : Flange breadth of primary supporting members, in mm.

C : Slenderness coefficient taken as:

C = 0.022 for symmetrical flanges.

C = 0.033 for asymmetrical flanges.

$A_{f\text{-}n50}$: Net cross sectional area of flange, in cm^2.

$A_{w\text{-}n50}$: Net cross sectional area of the web plate, in cm^2.

R_{eH} : Specified minimum yield stress of the PSM material, in N/mm^2.

$S_{b\text{-}min}$: Minimum unsupported flange length taken as:

$S_{b\text{-}min}$ = 3.0 m for the cargo tank/hold region, on tank/hold boundaries or the hull envelope including external decks.

$S_{b\text{-}min}$ = 4.0 m for other areas.

5.1.2 Edge stiffening

Tripping brackets on primary supporting members are to be stiffened by a flange or edge stiffener if the effective length of the edge, ℓ_b as defined in Table 3, in mm, is greater than:

$$\ell_b = 75t_b$$

where:

t_b : Bracket net web thickness, in mm.

5.2 End brackets

5.2.1 Proportions

The net web thickness of end brackets, in mm, subject to compressive stresses is not to be less than:

$$t_b = \frac{d_b}{C}\sqrt{\frac{R_{eH}}{235}}$$

where:

d_b : Depth of brackets, in mm, as defined in Table 3.

C : Slenderness coefficient as defined in Table 3.

R_{eH} : Specified minimum yield stress of the end bracket material, in N/mm^2.

5.3 Edge reinforcement

5.3.1 Edge reinforcements of bracket edges

The depth of stiffener web, h_w in mm, of edge stiffeners in way of bracket edges is not to be less than:

$$h_w = C\,\ell_b\sqrt{\frac{R_{eH}}{235}} \quad \text{or 50 mm, whichever is greater.}$$

where:

C : Slenderness coefficient taken as:

C = 75 for end brackets.

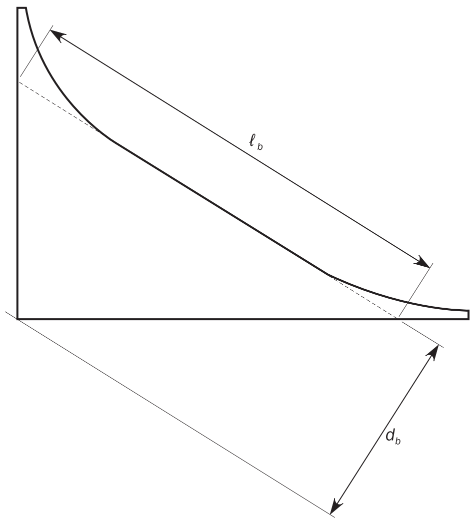
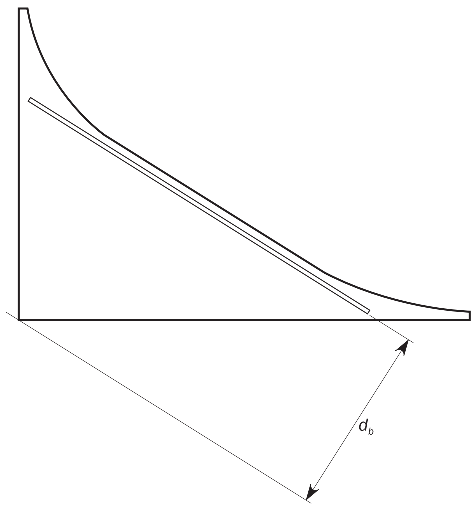
C = 50 for tripping brackets.

R_{eH} : Specified minimum yield stress of the stiffener material, in N/mm^2.

5.3.2 Proportions of edge stiffeners

The net thickness of the web plate and flange of the edge stiffener is to satisfy the requirements specified in [3.1.1] and [3.1.2].

Table 3 : Buckling coefficient, *C*, for proportions of brackets

Mode	*C*
Brackets without edge stiffener 	$C = 20\left(\frac{d_b}{\ell_b}\right) + 16$ where: $0.25 \leq \frac{d_b}{\ell_b} \leq 1.0$
Brackets with edge stiffener 	$C = 70$

6 OTHER STRUCTURES

6.1 Pillars

6.1.1 Proportions of I-section pillars

For I-sections, the thickness of the web plate and the flange thickness are to comply with requirements specified in [3.1.1] and [3.1.2].

6.1.2 Proportions of box section pillars

The thickness of thin walled box sections is to comply with the requirements specified in item (a) of [3.1.1].

6.1.3 Proportions of circular section pillars

The net thickness, t, of circular section pillars, in mm, is to comply with the following criterion:

$$t \geq \frac{r}{50}$$

where:

r : Mid thickness radius of the circular section, in mm.

6.2 Edge reinforcement in way of openings

6.2.1 Depth of edge stiffener

When fitted as shown in Figure 2, the depth of web, h_w in mm, of edge stiffeners in way of openings is not to be less than:

$$h_w = C\,\ell\,\sqrt{\frac{R_{eH}}{235}}$$ or 50 mm, whichever is greater.

where:

C : Slenderness coefficient taken as:

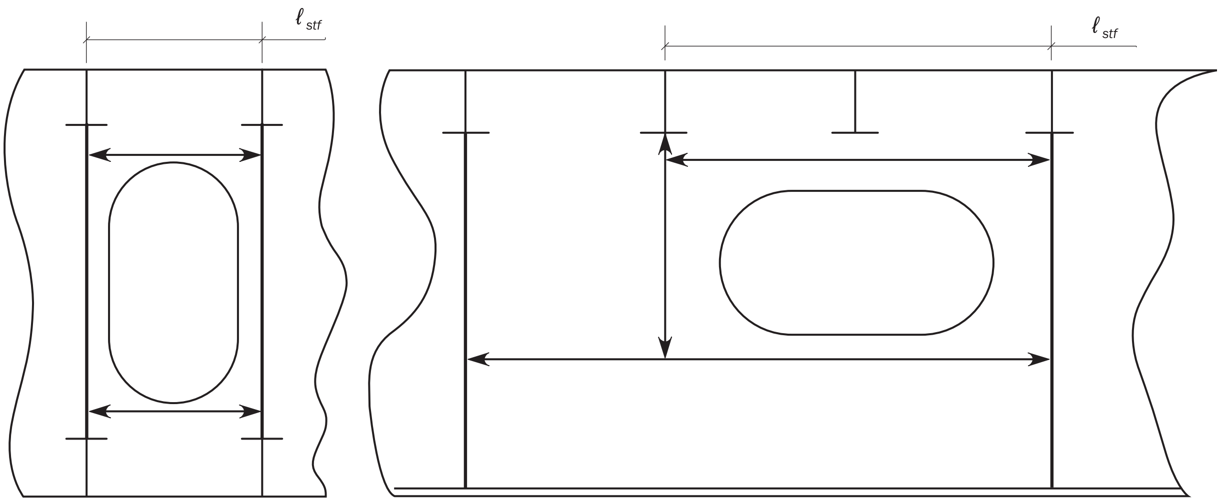
$C = 50$

R_{eH} : Specified minimum yield stress of the edge stiffener material, in N/mm^2.

6.2.2 Proportions of edge stiffeners

The net thickness of the web plate and flange of the edge stiffener is to satisfy the requirements specified in [3.1.1] and [3.1.2].

Figure 2 : Typical edge reinforcements



SECTION 3
PRESCRIPTIVE BUCKLING REQUIREMENTS

SYMBOLS

η_{all} : Allowable buckling utilisation factor, as defined in Ch 8, Sec 1, [3.3].

EPP : Elementary Plate Panel as defined in Ch 3, Sec 7, [2.1].

LCP : Load calculation point as defined in Ch 3, Sec 7, [2.2.2] and Ch 3, Sec 7, [3.2].

1 GENERAL

1.1 Scope

1.1.1

This section applies to plate panels and stiffeners subject to hull girder compression and shear stresses. In addition the following structural members subject to compressive stresses are to be checked:

- Corrugation of transverse vertically corrugated bulkhead.
- Corrugation of longitudinal corrugated bulkhead.
- Strut.
- Pillar.
- Cross tie.

1.1.2

The hull girder buckling strength requirements apply along the full length of the ship.

1.1.3 Design load sets

The buckling checks are to be performed for all design load sets defined in Ch 6, Sec 2, [2], both in intact and in flooded conditions with pressure combination defined in Ch 6, Sec 2, [1.3].

For each design load set, for all dynamic load cases, the lateral pressure is to be determined according to Ch 4 at the load calculation point defined in Ch 3, Sec 7, and is to be applied together with the hull girder stress combinations given in [2.2].

1.2 Equivalent plate panel

1.2.1

In longitudinal stiffening arrangement, when the plate thickness varies over the width b, of a plate panel, the buckling check is to be performed for an equivalent plate panel width, combined with the smaller plate thickness, t_1. The width of this equivalent plate panel, b_{eq}, in mm, is defined by the following formula:

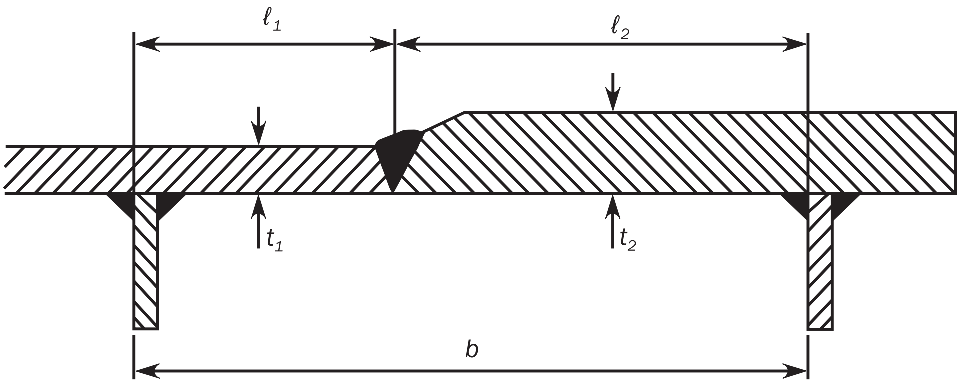
$$b_{eq} = \ell_1 + \ell_2 \left(\frac{t_1}{t_2}\right)^{1.5}$$

where:

ℓ_1 : Width of the part of the plate panel with the smaller plate thickness, t_1, in mm, as defined in Figure 1.

ℓ_2 : Width of the part of the plate panel with the greater plate thickness, t_2, in mm, as defined in Figure 1.

Figure 1 : Plate thickness change over the width



1.2.2

In transverse stiffening arrangement, when a EPP is made with different thicknesses, the buckling check of the plate and stiffeners is to be made for each thickness considered constant on the EPP, the stresses and pressures being estimated for the EPP at the LCP.

1.2.3 Materials

When the plate panel is made of different materials, the minimum yield strength is to be used for the buckling assessment.

2 HULL GIRDER STRESS

2.1 General

2.1.1

The hull girder bending stresses, σ_{hg}, in N/mm², are determined according to Ch 6, Sec 2.

2.1.2

The hull girder shear stresses, τ_{hg}, in N/mm², in the plate i are determined as follows:

$$\tau_{hg} = \frac{Q_{Tot}(x)\ q_{vi}}{t_{i-n50}} 10^3$$

where:

$Q_{Tot}(x)$: Total vertical shear force, in kN, at the ship longitudinal location x, taken as the greater of the following values:

- For the design load combination S+D
  - For seagoing operations:

    $$Q_{Tot}(x) = |Q_{sw} + Q_{wv-LC}|$$

  - For flooded conditions at sea for bulk carriers having a length L of 150 m or above:

    $$Q_{Tot}(x) = |Q_{sw-f} + Q_{wv-LC}|$$

- For the design load combination S

- For harbour/sheltered water operations:

$$Q_{Tot}(x) = |Q_{sw-p}|$$

q_{vi} : Contribution ratio in way of the plate *i*, as defined in Ch 5, Sec 1, [3.2.1].

t_{i-n50} : Net thickness of the plate *i*, in mm as defined in Ch 5, Sec 1, [3.2.1], used for shear stress calculation.

Q_{sw} : Permissible positive or negative still water shear force for seagoing operation, in kN, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.3.3].

Q_{sw-p} : Permissible positive or negative still water shear force for harbour/sheltered operation, in kN, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.3.4].

Q_{sw-f} : Permissible positive or negative still water shear force in flooded condition at sea, in kN, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.3.5].

Q_{wv-LC} : Vertical wave shear force in seagoing condition, in kN, in intact or flooded conditions at the hull transverse section considered for the considered dynamic load case, defined in Ch 4, Sec 4, [3.5.3].

2.2 Stress combinations

2.2.1

Each elementary plate panel and stiffeners are to satisfy the criteria defined in [3] with the following stress combinations:

a) Longitudinal stiffening arrangement:

- Stress combination 1 with:

$$\sigma_x = \sigma_{hg}$$
$$\sigma_y = 0$$
$$\tau = 0.7\tau_{hg}$$

- Stress combination 2 with:

$$\sigma_x = 0.7\sigma_{hg}$$
$$\sigma_y = 0$$
$$\tau = \tau_{hg}$$

b) Transverse stiffening arrangement:

- Stress combination 1 with:

$$\sigma_x = 0$$
$$\sigma_y = \sigma_{hg}$$
$$\tau = 0.7\tau_{hg}$$

- Stress combination 2 with:

$$\sigma_x = 0$$
$$\sigma_y = 0.7\sigma_{hg}$$
$$\tau = \tau_{hg}$$

where:

σ_{hg} : Hull girder bending stress in the elementary plate panel or stiffener, as defined in [2.1.1], in N/mm².

τ_{hg} : Hull girder shear stress, in N/mm², in the elementary plate panel or stiffener attached plate as defined in [2.1.2].

3 BUCKLING CRITERIA

3.1 Overall stiffened panel

3.1.1

The buckling strength of overall stiffened panels is to satisfy the following criterion:

$\eta_{Overall} \leq \eta_{all}$

where:

$\eta_{Overall}$: Maximum utilisation factor as defined in Ch 8, Sec 5, [2.1].

3.2 Plates

3.2.1

The buckling strength of elementary plate panels is to satisfy the following criterion:

$\eta_{Plate} \leq \eta_{all}$

where:

η_{Plate} : Maximum plate utilisation factor calculated according to SP-A, as defined in Ch 8, Sec 5, [2.2].

For the determination of η_{Plate} of the vertically stiffened side shell plating of single side skin bulk carrier between hopper and topside tanks, the cases 9 and 12 of Ch 8, Sec 5, Table 3 corresponding to the shorter edge of the plate panel clamped are to be considered together with a mean σ_y stress and $\psi_y = 1$.

3.3 Stiffeners

3.3.1

The buckling strength of stiffeners or of side frames of single side skin bulk carriers is to satisfy the following criterion:

$\eta_{Stiffener} \leq \eta_{all}$

where:

$\eta_{Stiffener}$: Maximum stiffener utilisation factor, as defined in Ch 8, Sec 5, [2.3].

Note 1: This capacity check can only be fulfilled when the overall stiffened panel capacity, as defined in [3.1.1], is satisfied.

3.4 Vertically corrugated transverse and longitudinal bulkheads

3.4.1

The shear buckling strength of vertically corrugated transverse and longitudinal bulkheads is to satisfy the following criterion:

$\eta_{Shear} \leq \eta_{all}$

where:

η_{Shear} : Maximum shear corrugated bulkhead utilisation factor.

$$\eta_{Shear} = \frac{\tau_{bhd}}{\tau_c}$$

τ_{bhd} : Shear stress, in N/mm^2, in the bulkhead taken as

- For longitudinal bulkheads: hull girder shear stress defined in [2.1.2]
- For transverse bulkheads: shear stress in the corrugation defined in Pt 2, Ch 1, Sec 3, [3.2.1].

τ_c : Shear critical stress, in N/mm^2, as defined in Ch 8, Sec 5, [2.2.3].

3.5 Horizontally corrugated longitudinal bulkhead

3.5.1

Each corrugation, within the extension of half flange, web and half flange, is to satisfy the following criterion:

$\eta \leq \eta_{all}$

where:

η : Overall column utilisation factor, as defined in Ch 8, Sec 5, [3.1].

3.6 Struts, pillars and cross ties

3.6.1

The compressive buckling strength of struts, pillars and cross ties is to satisfy the following criterion:

$\eta \leq \eta_{all}$

where:

η : Maximum buckling utilisation factor of struts, pillars or cross ties, defined in Ch 8, Sec 5, [3.1].

SECTION 4
BUCKLING REQUIREMENTS FOR DIRECT STRENGTH ANALYSIS

SYMBOLS

η_{all} : Allowable buckling utilisation factor, as defined in Ch 8, Sec 1, [3.3].

α : Aspect ratio of the plate panel, defined in Ch 8, Sec 5.

1 GENERAL

1.1 Scope

1.1.1

The requirements of this Section apply for the buckling assessment of direct strength analysis subjected to compressive stress, shear stress and lateral pressure.

1.1.2

All structural elements in the FE analysis carried out according to Ch 7 are to be assessed individually. The buckling checks have to be performed for the following structural elements:

- Stiffened and unstiffened panels.
- Web plate in way of openings.
- Corrugated bulkhead.
- Vertically stiffened side shell of single side skin bulk carrier.
- Struts, pillars and cross ties.

2 STIFFENED AND UNSTIFFENED PANELS

2.1 General

2.1.1

The plate panel of hull structure is to be modelled as stiffened or unstiffened panel. Method A and Method B as defined in Ch 8, Sec 1, [3] are to be used according to Table 1 and Figure 1 to Figure 9.

2.1.2 Average thickness of plate panel

Where the plate thickness along a plate panel is not constant, the panel used for the buckling assessment is to be modelled according to Ch 7 with a weighted average thickness taken as:

$$t_{avr} = \frac{\sum_{1}^{n} A_i \ t_i}{\sum_{1}^{n} A_i}$$

where:

A_i : Area of the *i*-th plate element.

t_i : Net thickness of the *i*-th plate element.

n : Number of finite elements defining the buckling plate panel.

Table 1 : Structural members

Structural elements	Assessment method	Normal panel definition
Longitudinal structure, see Figure 1, Figure 5 and Figure 7		
Longitudinally stiffened panels Shell envelope Deck Inner hull Hopper tank side Longitudinal bulkheads	SP-A	Length: between web frames Width: between primary supporting members
Double bottom longitudinal girders in line with longitudinal bulkhead or connected to hopper tank side	SP-A	Length: between web frames Width: full web depth
Web of double bottom longitudinal girders not in line with longitudinal bulkhead or not connected to hopper tank side	SP-B	Length: between web frames Width: full web depth
Web of horizontal girders in double side space connected to hopper tank side	SP-A	Length: between web frames Width: full web depth
Web of horizontal girders in double side space not connected to hopper tank side	SP-B	Length: between web frames Width: full web depth
Web of single skin longitudinal girders or stringers	UP-B	Plate between local stiffeners/face plate/PSM
Transverse structure, see Figure 2, Figure 6 and Figure 8		
Web of transverse deck frames including brackets	UP-B	Plate between local stiffeners/face plate/PSM
Vertical web in double side space	SP-B	Length: full web depth Width: between primary supporting members
Irregularly stiffened panels, e.g. web panels in way of hopper tank and bilge	UP-B	Plate between local stiffeners/face plate/PSM
Double bottom floors	SP-B	Length: full web depth Width: between primary supporting members
Vertical web frame including brackets	UP-B	Plate between vertical web stiffeners/face plate/PSM
Cross tie web plate	UP-B	Plate between vertical web stiffeners/face plate/PSM
Transverse oil-tight and watertight bulkheads, see Figure 3 and transverse wash bulkheads, see Figure 4		
Regularly stiffened bulkhead panels inclusive the secondary buckling stiffeners perpendicular to the regular stiffener (such as carlings)	SP-A	Length: between primary supporting members Width: between primary supporting members
Irregularly stiffened bulkhead panels, e.g. web panels in way of hopper tank and bilge	UP-B	Plate between local stiffeners/face plate

Structural elements	Assessment method	Normal panel definition
Web plate of bulkhead stringers including brackets	UP-B	Plate between web stiffeners /face plate
Transverse corrugated bulkheads and cross deck, see Figure 9		
Upper/lower stool including stiffeners	SP-A	Length: between internal web diaphragms Width: length of stool side
Stool internal web diaphragm	UP-B	Plate between local stiffeners /face plate / PSM
Cross deck	SP-A	Plate between local stiffeners/ PSM
Note 1: SP and UP stand for stiffened and unstiffened panel respectively. Note 2: A and B stand for Method A and Method B respectively.		

2.1.3 Yield stress of the plate panel

The panel yield stress R_{eH_P} is taken as the minimum value of the specified yield stresses of the elements within the plate panel.

2.2 Stiffened panels

2.2.1

To represent the overall buckling behaviour, each stiffener with attached plate is to be modelled as a stiffened panel of the extent defined in Table 1.

2.2.2

If the stiffener properties or stiffener spacing varies within the stiffened panel, the calculations are to be performed separately for all configurations of the panels, i.e. for each stiffener and plate between the stiffeners. Plate thickness, stiffener properties and stiffener spacing at the considered location are to be assumed for the whole panel.

Figure 1 : Longitudinal plates for oil tankers

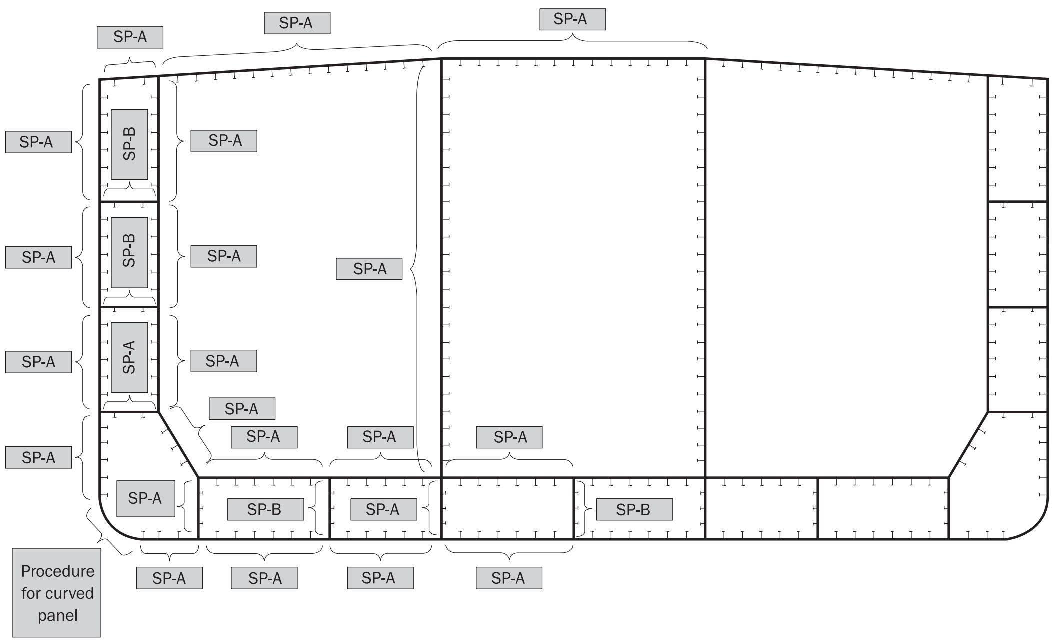


Figure 2 : Transverse web frames for oil tankers

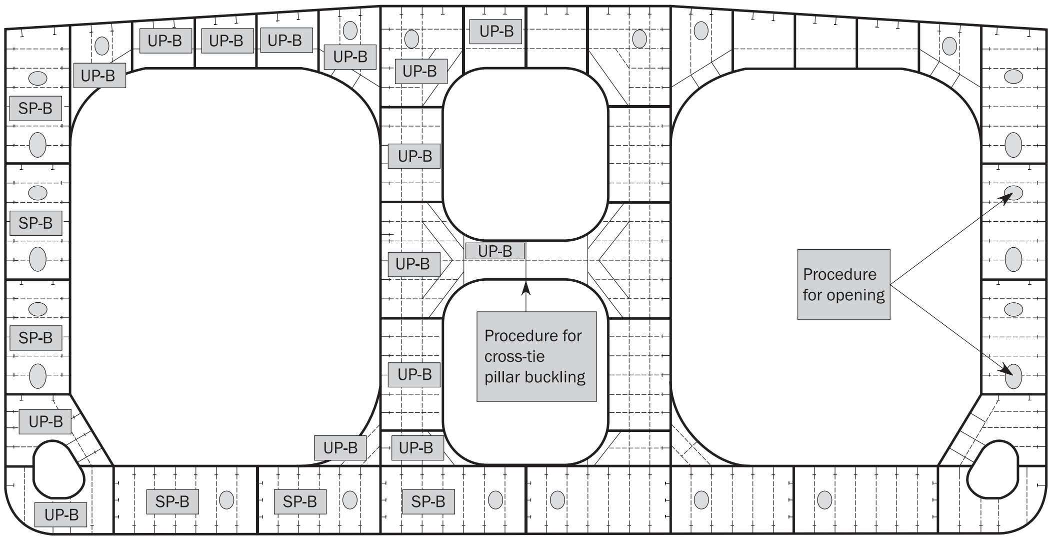


Figure 3 : Transverse bulkhead for oil tankers

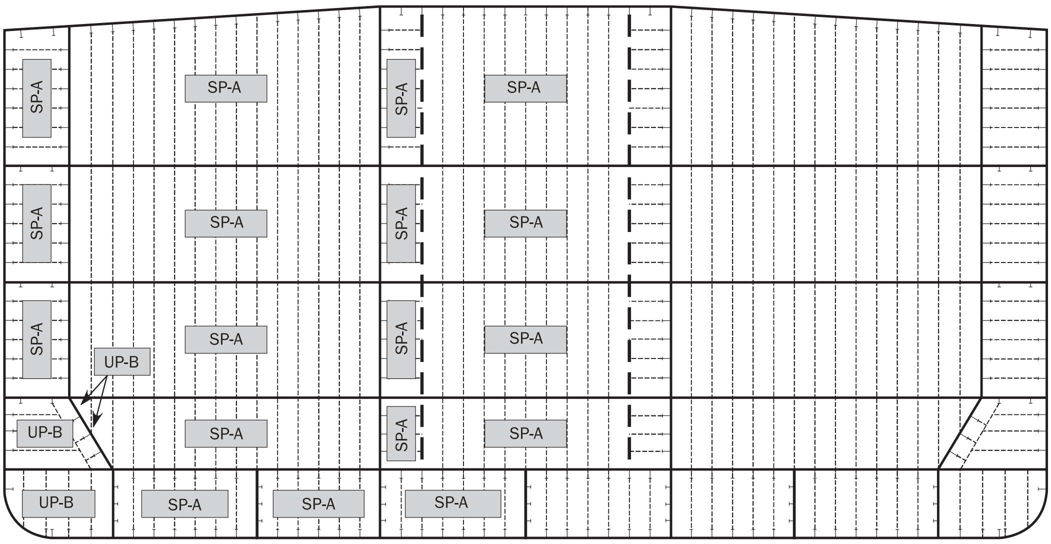


Figure 4 : Cross tie

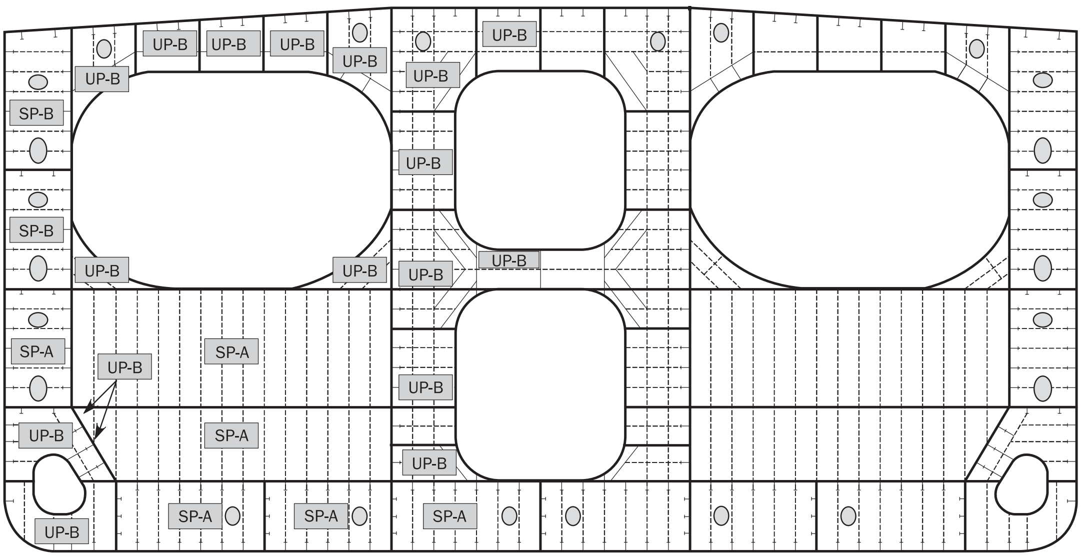


Figure 5 : Longitudinal plates for single hull bulk carrier

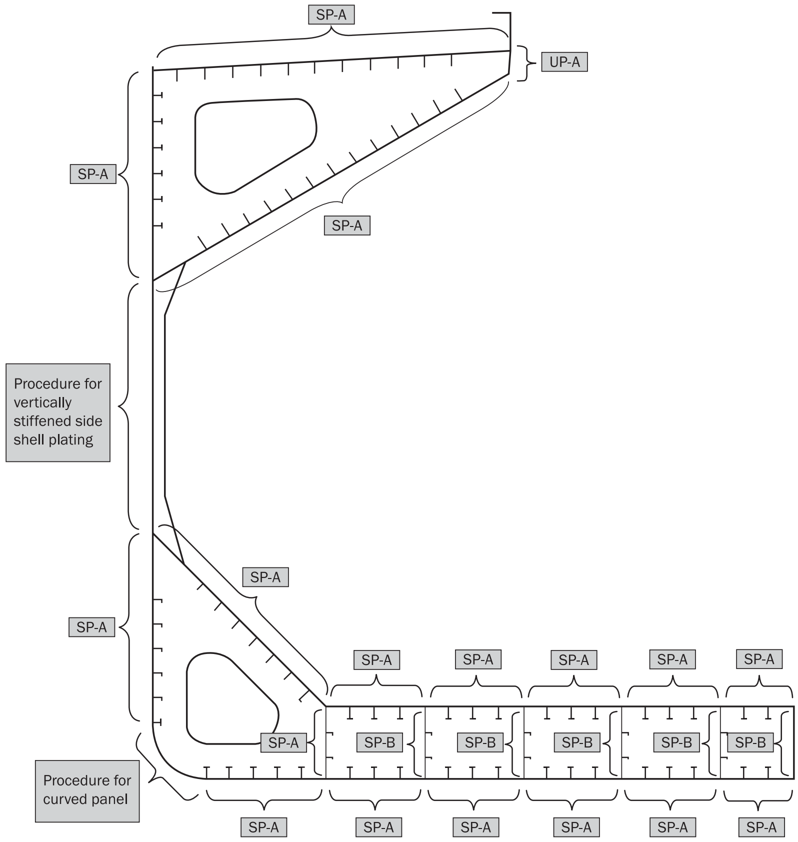


Figure 6 : Transverse web frames for single hull bulk carrier

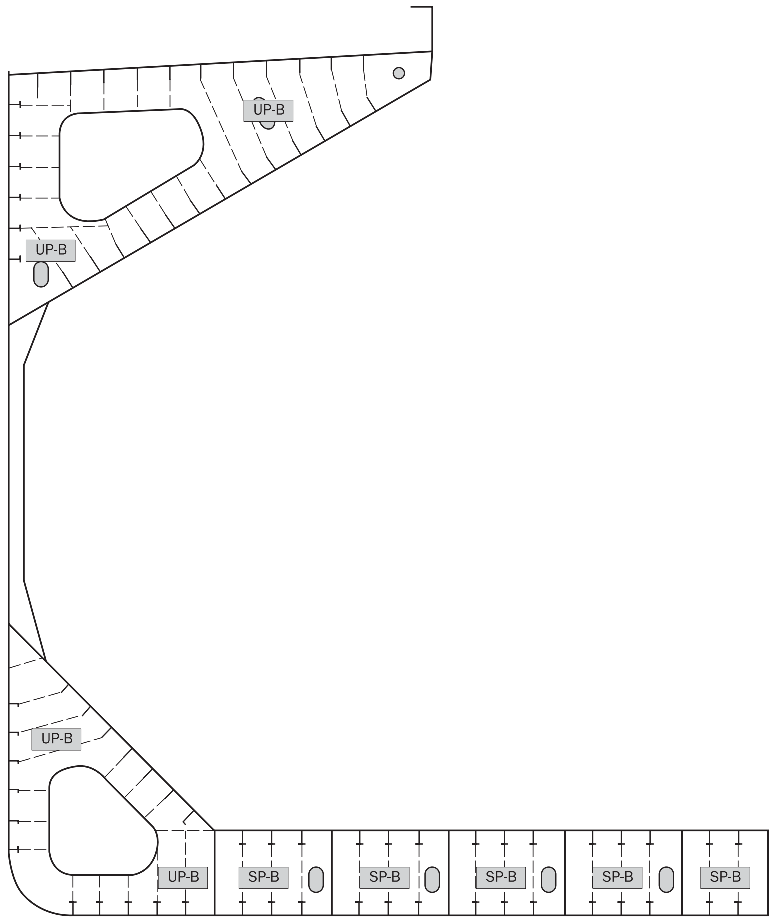


Figure 7 : Longitudinal plates for double hull bulk carrier

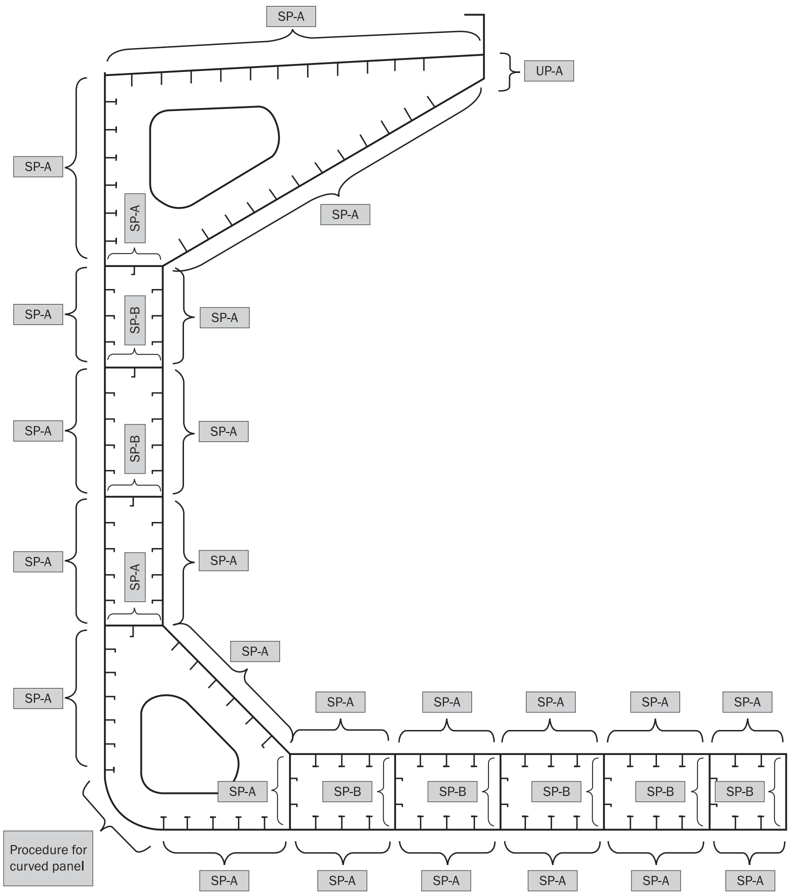


Figure 8 : Transverse web frames for double hull bulk carrier

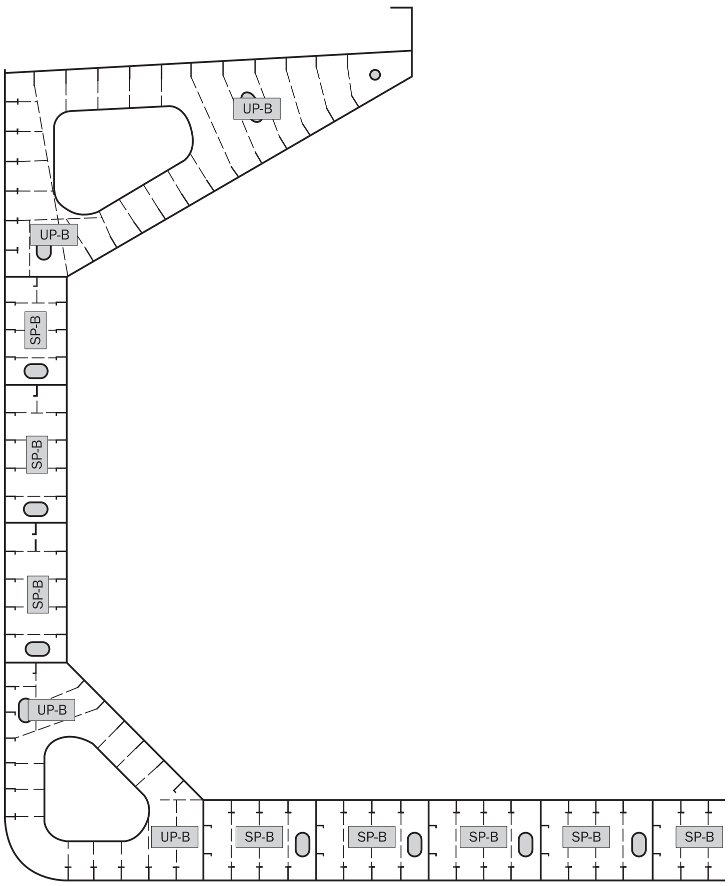
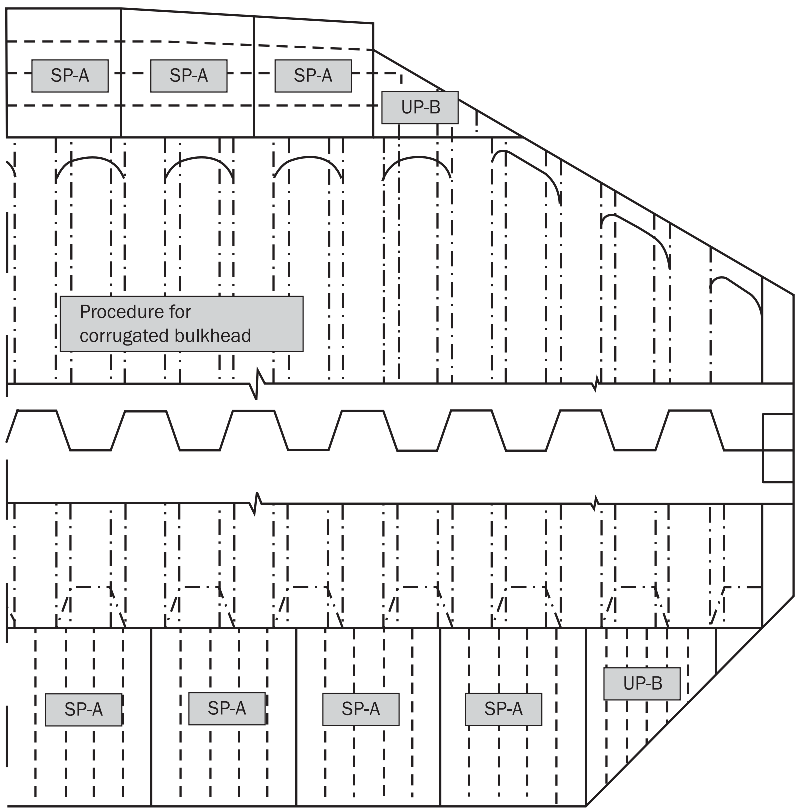
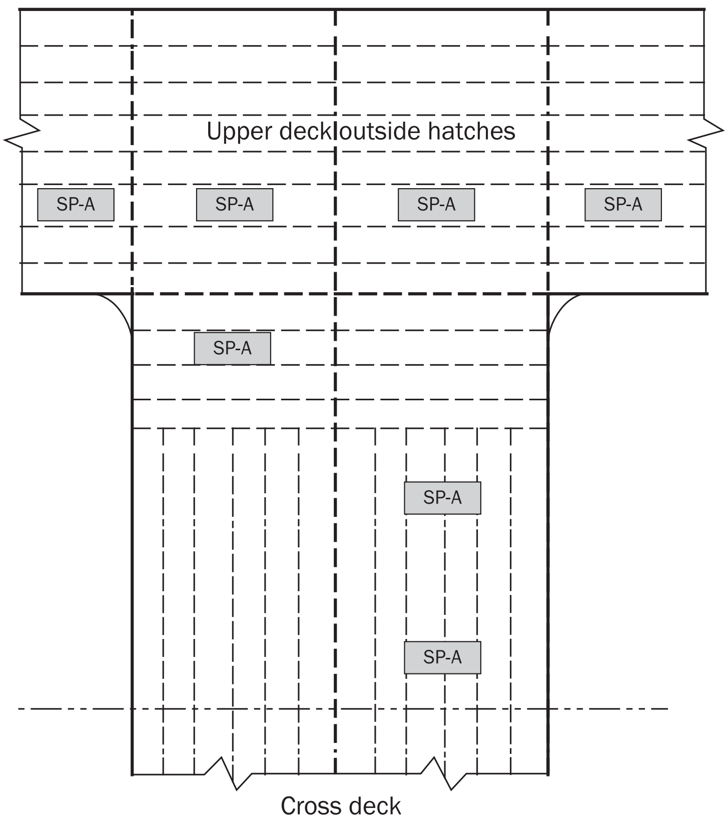


Figure 9 : Corrugated bulkhead and cross deck for bulk carriers





2.3 Unstiffened panels

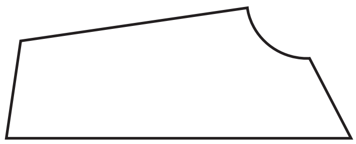
2.3.1 Irregular plate panel

In way of web frames, stringers and brackets, the geometry of the panel (i.e. plate bounded by web stiffeners/face plate) may not have a rectangular shape. In this case, an equivalent rectangular panel is to be defined according to [2.3.2] for irregular geometry and [2.3.3] for triangular geometry and to comply with buckling assessment.

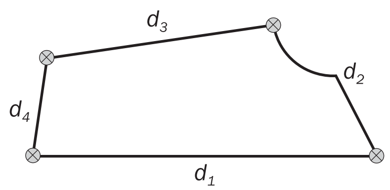
2.3.2 Modelling of an unstiffened panel with irregular geometry

Unstiffened panels with irregular geometry are to be idealised to equivalent panels for plate buckling assessment according to the following procedure:

a) The four corners closest to a right angle, 90 deg, in the bounding polygon for the plate are identified.

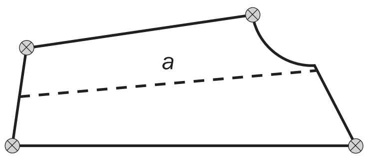


b) The distances along the plate bounding polygon between the corners are calculated, i.e. the sum of all the straight line segments between the end points.



c) The pair of opposite edges with the smallest total length is identified, i.e. minimum of $d_1 + d_3$ and $d_2 + d_4$

d) A line joins the middle points of the chosen opposite edges (i.e. a mid point is defined as the point at half the distance from one end). This line defines the longitudinal direction for the capacity model. The length of the line defines the length of the capacity model, *a* measured from one end point.



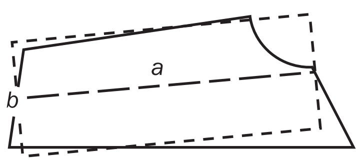
e) The length of shorter side, *b* in mm, is to be taken as:

$$b = A/a$$

where:

A : Area of the plate, in mm²

a : length defined in (d), in mm

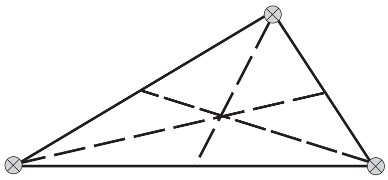


f) The stresses from the direct strength analysis are to be transformed into the local coordinate system of the equivalent rectangular panel. These stresses are to be used for the buckling assessment.

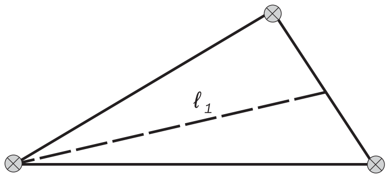
2.3.3 Modelling of an unstiffened plate panel with triangular geometry

Unstiffened panels with triangular geometry are to be idealised to equivalent panels for plate buckling assessment according to the following procedure:

a) Medians are constructed as shown below.



b) The longest median is identified. This median the length of which is ℓ_1 in mm, defines the longitudinal direction for the capacity model.

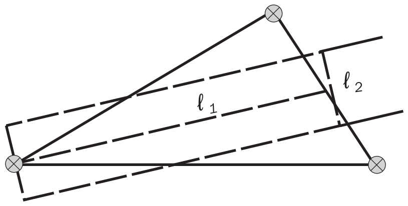


c) The width of the model, ℓ_2, in mm, is to be taken as:

$$\ell_2 = A/\ell_1$$

where:

A : Area of the plate, in mm²



d) The lengths of shorter side, b, and of the longer side, a, in mm, of the equivalent rectangular plate panel are to be taken as:

$$b = \frac{\ell_2}{C_{tri}}$$

$$a = \ell_1 \cdot C_{tri}$$

where:

$$C_{tri} = 0.4\frac{\ell_2}{\ell_1} + 0.6$$

e) The stresses from the direct strength analysis are to be transformed into the local coordinate system of the equivalent rectangular panel and are to be used for the buckling assessment of the equivalent rectangular panel.

2.4 Reference stress

2.4.1

The stress distribution is to be taken from the direct strength analysis and applied to the buckling model.

2.4.2

The reference stresses are to be calculated using the Stress based reference stresses as defined in App 1.

2.5 Lateral pressure

2.5.1

The lateral pressure applied to the direct strength analysis is also to be applied to the buckling assessment.

2.5.2

Where the lateral pressure is not constant over a buckling panel defined by a number of finite plate elements, an average lateral pressure, N/mm², is calculated using the following formula:

$$P_{avr} = \frac{\sum_{1}^{n} A_i \, P_i}{\sum_{1}^{n} A_i}$$

where:

A_i : Area of the *i*-th plate element, in mm².

P_i : Lateral pressure of the *i*-th plate element, in N/mm².

n : Number of finite elements in the buckling panel.

2.6 Buckling criteria

2.6.1 UP-A

The compressive buckling strength of UP-A is to satisfy the following criterion:

$\eta_{UP\text{-}A} \leq \eta_{all}$

where:

$\eta_{UP\text{-}A}$: Maximum plate utilisation factor, calculated according to Method A as defined in Ch 8, Sec 5, [2.2].

2.6.2 UP-B

The compressive buckling strength of UP-B is to satisfy the following criterion:

$\eta_{UP\text{-}B} \leq \eta_{all}$

where:

$\eta_{UP\text{-}B}$: Maximum plate utilisation factor, calculated according to Method B as defined in Ch 8, Sec 5, [2.2].

2.6.3 SP-A

The compressive buckling strength of SP-A is to satisfy the following criterion:

$\eta_{SP\text{-}A} \leq \eta_{all}$

where:

$\eta_{SP\text{-}A}$: Maximum stiffened panel utilisation factor taken as the maximum of:

- The overall stiffened panel capacity as defined in Ch 8, Sec 5, [2.1].
- The plate capacity calculated according to Method A as defined in Ch 8, Sec 5, [2.2].
- The stiffener buckling strength as defined in Ch 8, Sec 5, [2.3] considering separately the properties (thickness, dimensions), the pressures defined in [2.5.2] and the reference stresses of each EPP at both sides of the stiffener.

Note 1: The stiffener buckling capacity check can only be fulfilled when the overall stiffened panel capacity, as defined in Ch 8, Sec 5, [2.1], is satisfied.

2.6.4 SP-B

The compressive buckling strength of SP-B is to satisfy the following criterion:

$\eta_{SP\text{-}B} \leq \eta_{all}$

where:

$\eta_{SP\text{-}B}$: Maximum stiffened panel utilisation factor taken as the maximum of:

- The overall stiffened panel capacity as defined in Ch 8, Sec 5, [2.1].
- The plate capacity calculated according to Method B as defined in Ch 8, Sec 5, [2.2].
- The stiffener buckling strength as defined in Ch 8, Sec 5, [2.3] considering separately the properties (thickness, dimensions), the pressures defined in [2.5.2] and the reference stresses of each EPP at both sides of the stiffener.

Note 1: The stiffener buckling capacity check can only be fulfilled when the overall stiffened panel capacity, as defined in Ch 8, Sec 5, [2.1], is satisfied.

2.6.5 Web plate in way of openings

The web plate of primary supporting members with openings is to satisfy the following criterion:

$\eta_{opening} \leq \eta_{all}$

where:

$\eta_{opening}$: Maximum web plate utilisation factor in way of openings, as defined in Ch 8, Sec 5, [2.4].

3 CORRUGATED BULKHEAD

3.1 General

3.1.1

Three buckling failure modes are to be assessed on corrugated bulkheads:

- Corrugation overall column buckling.
- Corrugation flange panel buckling.
- Corrugation web panel buckling.

3.2 Reference stress

3.2.1

Each corrugation flange and web panel is to be assessed.

3.2.2

The membrane stresses at element centroid are to be used.

3.2.3

The maximum normal stress parallel to the corrugation, σ_x, is the maximum of the 2 following stresses:

- The normal stress parallel to the corrugation taken at $b/2$ from the corrugation ends,
- The normal stress parallel to the corrugation within the mid span of the corrugation.

When the corrugation end is fitted with a shedder plate, the normal stress parallel to the corrugation at end is to be taken at $b/2$ from the intersection of the shedder plate with the point at mid breadth of the flange or of the web, as the case may be.

The maximum shear stress is the shear stress which is maximum at the corrugation flange or web at the point $b/2$ from ends as defined above for the normal stress parallel to the corrugation.

The in plane stresses, σ_x and σ_y, and shear stress, τ, are to be taken as the element stresses averaged over the width of the considered member (flange or web) at the considered location.

When the stress value at $b/2$ from ends cannot be obtained directly from FE element, the stress at this location is to be obtained by interpolation. This interpolation is to be made on elements extending over a distance equal to $3b$ to a point located at $b/2$ from the end of the corrugation or from the intersection of the shedder plate if fitted, measured at the mid breadth of the flange or of the web. The interpolation of the in plane stresses, σ_x and σ_y, are to be made in accordance with Ch 8, App 1, [2.1].

The shear stress at $b/2$ is obtained by linear interpolation between the elements most close to '$b/2$' location.

For the application of this requirement, b is defined as follows:

b : Width of the considered member of the corrugation, i.e. flange or web.

3.2.4

Where more than one plate thicknesses are used for flange panel, maximum stress is to be obtained for each thickness range and to be checked with the buckling criteria for each thickness.

3.3 Overall column buckling

3.3.1

The overall buckling failure mode of corrugated bulkheads subjected to axial compression is to be checked for column buckling (e.g. horizontally corrugated bulkheads and vertically corrugated bulkheads subjected to local vertical forces).

Table 2 : Application of overall column buckling for corrugated bulkhead

Bulkhead orientation	Corrugation Orientation	
	Horizontal	Vertical
Longitudinal bulkhead	Required	Required, when subjected to local vertical forces (e.g. crane loads)
Transverse bulkhead	Required	

3.3.2

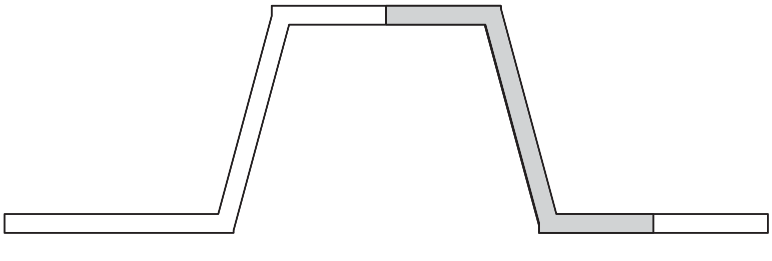
Each corrugation unit within the extension of half flange, web and half flange (i.e. single corrugation as shown in grey in Figure 10) is to satisfy the following criterion:

$\eta_{Overall} \leq \eta_{all}$

where:

$\eta_{Overall}$: Maximum overall column utilisation factor, as defined in Ch 8, Sec 5, [3.1.1] and Ch 8, Sec 5, [3.1.2], considered as a pillar with a unsupported length taken as the length of the corrugation.

Figure 10 : Single Corrugation



3.3.3

End constraint factor, f_{end} corresponding to pinned ends is to be applied except for fixed end support to be used in way of stool with width exceeding 2 times the depth of the corrugation.

3.4 Local buckling

3.4.1

The compressive buckling strength of a unit flange and a unit web of corrugation bulkheads is to satisfy the following criterion:

$\eta_{Corr} \le \eta_{all}$

where:

η_{Corr} : Maximum unit flange or unit web utilisation factor, as defined in Ch 8, Sec 5, [3.2.1].

Two stress combinations are to be considered for the application of the above criterion:

- The maximum normal stress parallel to the corrugation, σ_x, combined with the stress perpendicular to the corrugation, σ_y, and with the shear stress, τ, at the location where the maximum normal stress parallel to the corrugation occurs.
- The maximum shear stress, τ, combined with the normal stress parallel to the corrugation, σ_x, and with the stress perpendicular to the corrugation, σ_y, at the location where the maximum shear stress occurs.

The buckling assessment is to be performed for an aspect ratio α equal to 2, and for the thicknesses of the member where the maximum compressive/shear stress occurs (see [3.2.4]).

4 VERTICALLY STIFFENED SIDE SHELL OF SINGLE SIDE SKIN BULK CARRIER

4.1 Buckling criteria

4.1.1 Side shell plating

The compressive buckling strength of the vertically stiffened side shell plating of single side skin bulk carrier is to satisfy the following criterion:

$\eta_{vss} \le \eta_{all}$

where:

η_{vss} : Maximum vertically stiffened side shell plating utilisation factor calculated according to Method A as defined in Ch 8, Sec 5, [2.2.1] and for the cases 8, 9 and 12 of Ch 8, Sec 5, Table 3 corresponding to the shorter edge of the plate panel clamped, considering the following stress combinations:

- Pure vertical stress:
  - The maximum vertical stress of stress elements is used with

    $\alpha = 1$ and $\psi_x = 1$.
- Maximum vertical stress combined with longitudinal and shear stress:
  - The maximum vertical stress in the buckling panel plus the shear and longitudinal stresses at the location where the maximum vertical stress occurs is used with

    $\alpha = 2$ and $\psi_x = \psi_y = 1$.
  - The plate thickness to be considered in the buckling strength check is the one where the maximum vertical stress occurs.
- Maximum shear stress combined with longitudinal and vertical stress:

- The maximum shear stress in the buckling panel plus the longitudinal and vertical stresses at the location where maximum shear stress occurs is used with

  $\alpha = 2$ and $\psi_x = \psi_y = 1$.

- The plate thickness to be considered in the buckling strength check is the one where the maximum shear stress occurs.

- Distributed longitudinal stress associated with vertical and shear stress:
  - The actual size of the buckling panel is used to define α.
  - The average values for longitudinal, vertical and shear stresses are to be used.
  - $\psi_x = \psi_y = 1$.
  - The plate thickness to be considered in the buckling strength check is the minimum thickness of the buckling panel.

4.1.2 Side frames

The buckling strength of side frames of single side skin bulk carriers is to satisfy the following criterion:

$\eta_{Stiffener} \leq \eta_{all}$

where:

$\eta_{Stiffener}$: Maximum stiffener utilisation factor, as defined in Ch 8, Sec 5, [2.3].

5 STRUTS, PILLARS AND CROSS TIES

5.1 Buckling criteria

5.1.1

The compressive buckling strength of struts, pillars and cross ties is to satisfy the following criterion:

$\eta_{Pillar} \leq \eta_{all}$

where:

η_{Pillar} : Maximum utilisation factor of struts, pillars or cross ties, as defined in Ch 8, Sec 5, [3.1].

SECTION 5
BUCKLING CAPACITY

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

A_s : Net sectional area of the stiffener without attached plating, in mm^2.

a : Length of the longer side of the plate panel as defined in Table 3, in mm.

b : Length of the shorter side of the plate panel as defined in Table 3, in mm.

b_{eff} : Effective width of the attached plating of a stiffener, in mm, as defined in [2.3.5].

b_{eff1} : Effective width of the attached plating of a stiffener, in mm, without the shear lag effect taken as:

- For $\sigma_x > 0$
  - For prescriptive assessment:

    $$b_{eff1} = \frac{C_{x1}b_1 + C_{x2}b_2}{2}$$

  - For FE analysis:

    $$b_{eff1} = C_x b$$

- For $\sigma_x \leq 0$

  $$b_{eff1} = b$$

b_f : Breadth of the stiffener flange, in mm.

b_1, b_2 : Width of plate panel on each side of the considered stiffener, in mm.

C_{x1},C_{x2} : Reduction factor defined in Table 3 calculated for the EPP1 and EPP2 on each side of the considered stiffener according to case 1.

e_f : Distance from attached plating to centre of flange, in mm, as shown in Figure 1 to be taken as:

$e_f = h_w$ for flat bar profile.

$e_f = h_w - 0.5\ t_f$ for bulb profile.

$e_f = h_w + 0.5\ t_f$ for angle and Tee profiles.

F_{long} : Coefficient defined in [2.2.4].

F_{tran} : Coefficient defined in [2.2.5].

h_w : Depth of stiffener web, in mm, as shown in Figure 1.

ℓ : Span, in mm, of stiffener equal to spacing between primary supporting members or span of side frame equal to the distance between the hopper tank and top wing tank as defined in Pt 2, Ch 1, Sec 2, Figure 2.

R : Radius of curved plate panel, in mm.

R_{eH_P} : Specified minimum yield stress of the plate in N/mm^2.

R_{eH_S} : Specified minimum yield stress of the stiffener in N/mm^2.

S : Partial safety factor to be taken as:

- S = 1.1 for structures which are exposed to local concentrated loads (e.g. container loads on hatch covers, foundations).
- S = 1.15 for bulk carrier stiffeners located on the hatchway coamings, the sloping plate of the topside and hopper tanks, the inner bottom, the inner side if any, the side shell of single side skin construction and the top and bottom stools of transverse bulkheads.
- S = 1.0 for all other cases.

t_p : Net thickness of plate panel, in mm.

t_w : Net stiffener web thickness, in mm.

t_f : Net flange thickness, in mm.

x axis : Local axis of a rectangular buckling panel parallel to its long edge.

y axis : Local axis of a rectangular buckling panel perpendicular to its long edge.

α : Aspect ratio of the plate panel, defined in Table 3 to be taken as:

$$\alpha = \frac{a}{b}$$

β : Coefficient taken as:

$$\beta = \frac{1-\psi}{\alpha}$$

ω : Coefficient taken as:

$$\omega = min\ (3;\alpha)$$

σ_x : Stress applied on the edge along x axis of the buckling panel, in N/mm^2.

σ_y : Stress applied on the edge along y axis of the buckling panel, in N/mm^2.

σ_1 : Maximum stress, in N/mm^2.

σ_2 : Minimum stress, in N/mm^2.

σ_E : Elastic buckling stress, in N/mm^2 to be taken as:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{b}\right)^2$$

τ : Applied shear stress, in N/mm^2.

τ_c : Buckling strength in shear, in N/mm^2, as defined in [2.2.3].

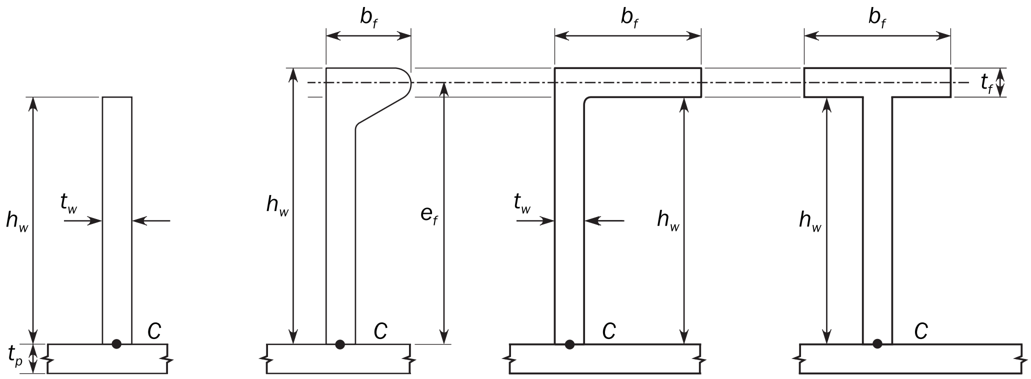
ψ : Edge stress ratio to be taken as:

$$\psi = \frac{\sigma_2}{\sigma_1}$$

γ : Stress multiplier factor acting on loads. When the factor is such that the loads reach the interaction formulae, $\gamma = \gamma_c$.

γ_c : Stress multiplier factor at failure.

Figure 1 : Stiffener cross sections



1 General

1.1 Scope

1.1.1

This section contains the methods for determination of the buckling capacity of plate panels, stiffeners, primary supporting members, struts, pillars, cross ties and corrugated bulkheads.

1.1.2

For the application of this section, the stresses σ_x, σ_y and τ applied on the structural members are defined in:

- Ch 8, Sec 3 for prescriptive requirements.
- Ch 8, Sec 4 for FE analysis requirements.

1.1.3 Ultimate buckling capacity

The ultimate buckling capacity is calculated by applying the actual stress combination and then increasing or decreasing the stresses proportionally until the interaction formulae defined in [2.1.1], [2.2.1], and [2.3.4] are equal to 1.0.

1.1.4 Buckling utilisation factor

The buckling utilisation factor of the structural member is equal to the highest utilisation factor obtained for the different buckling modes.

1.1.5 Lateral pressure

The lateral pressure is to be considered as constant in the buckling strength assessment.

2 Interaction Formulae

2.1 Overall stiffened panel capacity

2.1.1

The elastic stiffened panel limit state is based on the following interaction formula:

$$\frac{P_z}{c_f} = 1$$

where c_f and P_z are defined in [2.3.4].

2.2 Plate capacity

2.2.1 Plate limit state

The plate limit state is based on the following interaction formulae:

$$\frac{\gamma_{c1}\,\sigma_x\,S}{\sigma_{cx3}} = 1 \quad \text{for } \sigma_x \geq 0$$

$$\frac{\gamma_{c2}\,\sigma_y\,S}{\sigma_{cy3}} = 1 \quad \text{for } \sigma_y \geq 0$$

$$\frac{\gamma_{c3}|\tau|S}{\tau_c} = 1$$

$$\left[\left(\frac{\gamma_{c4}\,\sigma_x\,S}{\sigma_{cx1}}\right)^2 + \left(\frac{\gamma_{c4}\,\sigma_y\,S}{\sigma_{cy1}}\right)^2 - \left(\frac{\gamma_{c4}\,\sigma_x\,S}{\sigma_{cx1}}\right)\left(\frac{\gamma_{c4}\,\sigma_y\,S}{\sigma_{cy1}}\right)\right]\zeta + \left(\frac{\gamma_{c4}\,|\sigma_x|\,S}{\sigma_{cx2}} + \frac{\gamma_{c4}\,|\sigma_y|\,S}{\sigma_{cy2}}\right)(1-\zeta) = 1$$

with

$$\gamma_c = min(\gamma_{c1}, \gamma_{c2}, \gamma_{c3}, \gamma_{c4})$$

where:

σ_x, σ_y : Applied normal stress to the plate panel, in N/mm^2, to be taken as defined in [2.2.7].

τ : Applied shear stress to the plate panel, in N/mm^2.

ζ : Weighting factor to be taken as given in Table 1.

σ_{cx1}, σ_{cx2}, σ_{cx3}: Ultimate critical stresses, in N/mm^2, in direction parallel to the longer edge of the buckling panel as defined in [2.2.3].

σ_{cy1}, σ_{cy2}, σ_{cy3}: Ultimate critical stresses, in N/mm^2, in direction parallel to the shorter edge of the buckling panel as defined in [2.2.3].

τ_c : Ultimate critical shear stresses, in N/mm^2, as defined in [2.2.3].

γ_{c1}, γ_{c2}, γ_{c3}, γ_{c4}: Stress multiplier factors at failure for each of the above different limit states. γ_{c1} and γ_{c2} are only to be considered when $\sigma_x \geq 0$ and $\sigma_y \geq 0$ respectively.

Table 1 : Definition of weighting factor ζ and coefficients κ_{x1}, κ_{x2}, κ_{y1}, κ_{y2}

Applied Stress		ζ	κ_{x1}	κ_{x2}	κ_{y1}	κ_{y2}
$\sigma_x \geq 0$	$\sigma_y \geq 0$	$min\left[1\ ,\ 0.6\dfrac{min(5,\alpha)^{0.2}}{\beta_p^{\ 1/min(5,\alpha)}}\right]$	κ_{x3}		κ_{y3}	
$\sigma_x < 0$ or $\sigma_y < 0$		1.0	κ_{x4}	-	κ_{y4}	-

2.2.2 Reference degree of slenderness

The reference degree of slenderness is to be taken as:

$$\lambda = \sqrt{\frac{R_{eH\_P}}{K\sigma_E}}$$

where:

K : Buckling factor, as defined in Table 3 and Table 4.

2.2.3 Ultimate critical stresses

The ultimate critical stresses of plate panels are to be taken as:

$$\sigma_{cx1} = \kappa_{x1}\,R_{eH\_P} \qquad \sigma_{cx2} = \kappa_{x2}\,R_{eH\_P} \qquad \sigma_{cx3} = \kappa_{x3}\,R_{eH\_P}$$

$$\sigma_{cy1} = \kappa_{y1}\,R_{eH\_P} \qquad \sigma_{cy2} = \kappa_{y2}\,R_{eH\_P} \qquad \sigma_{cy3} = \kappa_{y3}\,R_{eH\_P}$$

The ultimate critical stress of plate panels subject to shear is to be taken as:

$$\tau_c = C_\tau \frac{R_{eH\_P}}{\sqrt{3}}$$

where:

κ_{x1}, κ_{x2}, κ_{y1}, κ_{y2}: Coefficients defined in Table 1.

κ_{x3}, κ_{x4}, κ_{y3}, κ_{y4}:Coefficients to be taken as:

$$\kappa_{x3} = \frac{C_x^2}{2\varsigma_{x\tau}}\left\{\sqrt{\left(\frac{1-\varsigma_{x\tau}}{C_x}\right)^2 - \frac{4\varsigma_{x\tau}}{C_x^2}\left[\varsigma_{x\tau}\left(\frac{\gamma_c|\tau|S}{\tau_c}\right)^2 + (1-\varsigma_{x\tau})\frac{\gamma_c|\tau|S}{\tau_c} - 1\right]} - \frac{1-\varsigma_{x\tau}}{C_x}\right\}$$

$$\kappa_{y3} = \frac{C_y^2}{2\varsigma_{y\tau}}\left\{\sqrt{\left(\frac{1-\varsigma_{y\tau}}{C_y}\right)^2 - \frac{4\varsigma_{y\tau}}{C_y^2}\left[\varsigma_{y\tau}\left(\frac{\gamma_c|\tau|S}{\tau_c}\right)^2 + (1-\varsigma_{y\tau})\frac{\gamma_c|\tau|S}{\tau_c} - 1\right]} - \frac{1-\varsigma_{y\tau}}{C_y}\right\}$$

$$\kappa_{x4} = \kappa_{y4} = \sqrt{1 - 3\left(\frac{\gamma_c|\tau|S}{R_{eH\_P}}\right)^2}$$

$$\varsigma_{x\tau} = \frac{1}{\sqrt{\beta_p}}$$

$$\varsigma_{y\tau} = \frac{min(5,\alpha)^{0.3}}{\sqrt{\beta_p}}$$

$$\beta_p = \frac{b}{t_p}\sqrt{\frac{R_{eH\_P}}{E}}$$

C_x, C_y, C_τ :Reduction factors, as defined in Table 3 and Table 4.

- For SP-A and UP-A, C_y is calculated according to Table 3 by using

  $$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

- For SP-B and UP-B, C_y is calculated according to Table 3 by using

  $$c_1 = 1$$

- For vertically stiffened single side skin of bulk carrier, C_y is calculated according to Table 3 by using

  $$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

- For corrugation of corrugated bulkheads, C_y is calculated according to Table 3 by using

  $$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

The boundary conditions for plates are to be considered as simply supported, see cases 1, 2 and 11 of Table 3. If the boundary conditions differ significantly from simple support, a more appropriate boundary condition can be applied according to the different cases of Table 3 subject to the agreement of the Society.

2.2.4 Correction factor F_{long}

The correction factor F_{long} depending on the edge stiffener types on the longer side of the buckling panel is defined in Table 2. An average value of F_{long} is to be used for plate panels having different edge stiffeners. For stiffener types other than those mentioned in Table 2, the value of c is to be agreed by the Society. In such a case, value of c higher than those mentioned in Table 2 can be used, provided it is verified by buckling strength check of panel using non-linear FE analysis and deemed appropriate by the Society.

Table 2 : Correction factor F_{long}

Structural element types			F_{long}	c
Unstiffened Panel			1.0	N/A
Stiffened Panel	Stiffener not fixed at both ends		1.0	N/A
	Stiffener fixed at both ends	Flat bar (1)	$F_{long} = c + 1$ for $\frac{t_w}{t_p} > 1$ $F_{long} = c\left(\frac{t_w}{t_p}\right)^3 + 1$ for $\frac{t_w}{t_p} \le 1$	0.10
		Bulb profile		0.30
		Angle profile		0.40
		T profile		0.30
		Girder of high rigidity (e.g. bottom transverse)	1.4	N/A
(1) t_w is the net web thickness, in mm, without the correction defined in [2.3.2].				

2.2.5 Correction factor F_{tran}

The correction factor F_{tran} is to be taken as:

- For transversely framed EPP of single side skin bulk carrier, between the hopper and top wing tank:
  - F_{tran} = 1.25 when the two adjacent frames are supported by one tripping bracket fitted in way of the adjacent plate panels.
  - F_{tran} = 1.33 when the two adjacent frames are supported by two tripping brackets each fitted in way of the adjacent plate panels.
  - F_{tran} = 1.15 elsewhere.
- For other cases: F_{tran} = 1

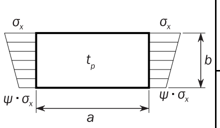
2.2.6 Curved plate panels

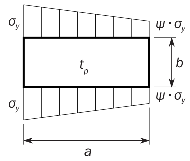
Table 4 applies to curved plate panels with $R/t_p \le 2500$. Otherwise, Table 3 is applicable.

For the application of Table 4, the stresses and coefficients are to be taken as:

- For $d \ge g$: $\sigma_{ax}=\sigma_x$, $\sigma_{tg}=\sigma_y$, $C_x=C_{ax}$ and $C_y=C_{tg}$.
- Otherwise : $\sigma_{ax}=\sigma_y$, $\sigma_{tg}=\sigma_x$, $C_x=C_{tg}$ and $C_y=C_{ax}$.

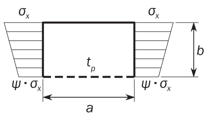
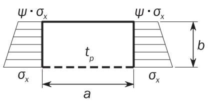
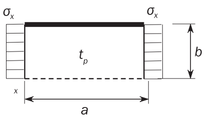
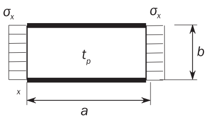
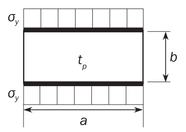
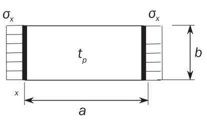
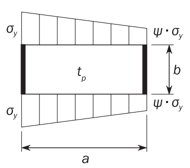
Table 3 : Buckling factor and reduction factor for plane plate panels

Case	Stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor C
1 	$1 \ge \psi \ge 0$		$K_x = F_{long}\dfrac{8.4}{\psi + 1.1}$	When $\sigma_x \le 0$: $C_x = 1$ When $\sigma_x > 0$: $C_x = 1$ for $\lambda \le \lambda_c$ $C_x = c\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > \lambda_c$ where: $c = (1.25 - 0.12\psi) \le 1.25$ $\lambda_c = \frac{c}{2}\left(1 + \sqrt{1 - \frac{0.88}{c}}\right)$
	$0 > \psi > -1$		$K_x = F_{long}[7.63 - \psi(6.26 - 10\psi)]$	
	$\psi \le -1$		$K_x = F_{long}[5.975(1-\psi)^2]$	

<table>
<tr><th>Case</th><th>Stress ratio ψ</th><th>Aspect ratio α</th><th>Buckling factor K</th><th>Reduction factor C</th></tr>
<tr><td rowspan="7">2

</td><td rowspan="3">$1 \geq \psi \geq 0$</td><td colspan="2">$K_y = F_{tran} \dfrac{2\left(1 + \dfrac{1}{\alpha^2}\right)^2}{1 + \psi + \dfrac{(1-\psi)}{100}\left(\dfrac{2.4}{\alpha^2} + 6.9 f_1\right)}$</td><td rowspan="7">When $\sigma_y \leq 0$:
$C_y = 1$
When $\sigma_y > 0$:
$C_y = c\left(\dfrac{1}{\lambda} - \dfrac{R + F^2 (H - R)}{\lambda^2}\right)$

where:
$c = (1.25 - 0.12\psi) \leq 1.25$
$R = \lambda(1 - \lambda/c)$ for $\lambda < \lambda_c$
$R = 0.22$ for $\lambda \geq \lambda_c$
$\lambda_c = 0.5c\ (1 + \sqrt{1 - 0.88/c})$
$F = \left[1 - \left(\dfrac{K}{0.91} - 1\right)/\lambda_p^2\right] c_1 \geq 0$
$\lambda_p^2 = \lambda^2 - 0.5$ for $1 \leq \lambda_p^2 \leq 3$
c_1 as defined in [2.2.3]
$H = \lambda - \dfrac{2\lambda}{c\ (T + \sqrt{T^2 - 4})} \geq R$
$T = \lambda + \dfrac{14}{15\lambda} + \dfrac{1}{3}$</td></tr>
<tr><td>$\alpha \leq 6$</td><td>$f_1 = (1 - \psi)(\alpha - 1)$</td></tr>
<tr><td>$\alpha > 6$</td><td>$f_1 = 0.6\left(1 - \dfrac{6\psi}{\alpha}\right)\left(\alpha + \dfrac{14}{\alpha}\right)$
but not greater than $14.5 - \dfrac{0.35}{\alpha^2}$</td></tr>
<tr><td rowspan="4">$0 > \psi \geq 1 - \dfrac{4\alpha}{3}$</td><td colspan="2">$K_y = \dfrac{200 F_{tran}(1 + \beta^2)^2}{(1 - f_3)(100 + 2.4\beta^2 + 6.9 f_1 + 23 f_2)}$</td></tr>
<tr><td>$\alpha > 6(1 - \psi)$</td><td>$f_1 = 0.6\left(\dfrac{1}{\beta} + 14\beta\right)$
but not greater than $14.5 - 0.35\beta^2$
$f_2 = f_3 = 0$</td></tr>
<tr><td>$3(1 - \psi) \leq \alpha \leq 6(1 - \psi)$</td><td>$f_1 = \dfrac{1}{\beta} - 1$
$f_2 = f_3 = 0$</td></tr>
<tr><td>$1.5(1 - \psi) \leq \alpha < 3(1 - \psi)$</td><td>$f_1 = \dfrac{1}{\beta} - (2 - \omega\beta)^4 - 9(\omega\beta - 1)\left(\dfrac{2}{3} - \beta\right)$
$f_2 = f_3 = 0$</td></tr>
</table>

Case	Stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor C
		$1-\psi \le \alpha < 1.5(1-\psi)$	• For $\alpha > 1.5$: $f_1 = 2\left(\frac{1}{\beta} - 16\left(1-\frac{\omega}{3}\right)^4\right)\left(\frac{1}{\beta}-1\right)$ $f_2 = 3\beta - 2$ $f_3 = 0$ • For $\alpha \le 1.5$: $f_1 = 2\left(\frac{1.5}{1-\psi} - 1\right)\left(\frac{1}{\beta}-1\right)$ $f_2 = \frac{\psi(1-16f_4^2)}{1-\alpha}$ $f_3 = 0$ $f_4 = (1.5 - Min(1.5;\alpha))^2$	
		$0.75(1-\psi) \le \alpha < 1-\psi$	$f_1 = 0$ $f_2 = 1 + 2.31(\beta-1) - 48\left(\frac{4}{3}-\beta\right)f_4^2$ $f_3 = 3f_4(\beta-1)\left(\frac{f_4}{1.81} - \frac{\alpha-1}{1.31}\right)$ $f_4 = (1.5 - Min(1.5;\alpha))^2$	
	$\psi < 1 - \frac{4\alpha}{3}$	$K_y = 5.972F_{tran}\frac{\beta^2}{1-f_3}$ where: $f_3 = f_5\left(\frac{f_5}{1.81} + \frac{1+3\psi}{5.24}\right)$ $f_5 = \frac{9}{16}(1 + Max(-1;\psi))^2$		

Case	Stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor C
3 	$1 \geq \psi \geq 0$		$K_x = \dfrac{4\,(0.425 + 1/\alpha^2)}{3\psi + 1}$	$C_x = 1$ for $\lambda \leq 0.7$ $C_x = \dfrac{1}{\lambda^2 + 0.51}$ for $\lambda > 0.7$
	$0 > \psi \geq -1$		$K_x = 4\,(0.425 + 1/\alpha^2)\,(1 + \psi) - 5\psi\,(1 - 3.42\psi)$	
4 	$1 \geq \psi \geq -1$		$K_x = \left(0.425 + \dfrac{1}{\alpha^2}\right)\dfrac{3 - \psi}{2}$	
5 	–	$\alpha \geq 1.64$	$K_x = 1.28$	
		$\alpha < 1.64$	$K_x = \dfrac{1}{\alpha^2} + 0.56 + 0.13\alpha^2$	
6 	–		$K_x = 6.97$	$C_x = 1$ for $\lambda \leq 0.83$ $C_x = 1,13\left(\dfrac{1}{\lambda} - \dfrac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
7 	–		$K_y = 4 + \dfrac{2.07}{\alpha^2} + \dfrac{0.67}{\alpha^4}$	$C_y = 1$ for $\lambda \leq 0.83$ $C_y = 1,13\left(\dfrac{1}{\lambda} - \dfrac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
8 	–	$\alpha \geq 4$	$K_x = 4$	$C_x = 1$ for $\lambda \leq 0.83$ $C_x = 1,13\left(\dfrac{1}{\lambda} - \dfrac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
		$\alpha < 4$	$K_x = 4 + 2.74\left[\dfrac{4 - \alpha}{3}\right]^4$	
9 	–		$K_y = K_y$ determined as per case 2	For $\alpha < 2$: $C_y = C_{y2}$ For $\alpha \geq 2$: $C_y = \left(1.06 + \dfrac{1}{10\alpha}\right)C_{y2}$ where: C_{y2} : C_y determined as per case 2

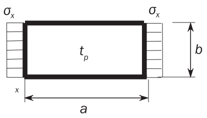
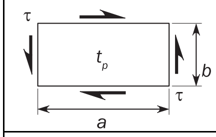
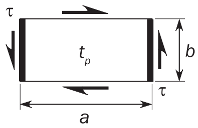
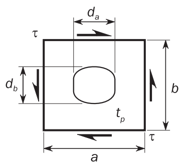
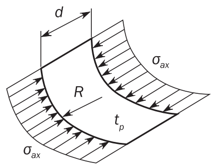
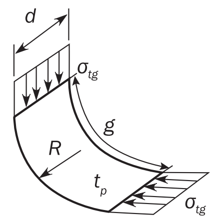
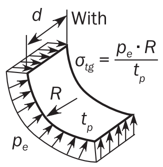
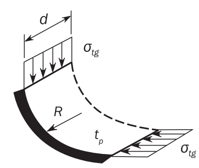
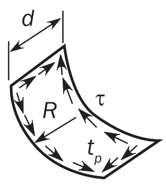
<table>
<tr><th>Case</th><th>Stress ratio ψ</th><th>Aspect ratio α</th><th>Buckling factor K</th><th>Reduction factor C</th></tr>
<tr><td rowspan="2">10
</td><td rowspan="2">–</td><td>$\alpha \geq 4$</td><td>$K_x = 6.97$</td><td rowspan="2">$C_x = 1$ for $\lambda \leq 0.83$
$C_x = 1,13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$
for $\lambda > 0.83$</td></tr>
<tr><td>$\alpha < 4$</td><td>$K_x = 6.97 + 3.1\left[\frac{4-\alpha}{3}\right]^4$</td></tr>
<tr><td>11
</td><td>–</td><td colspan="2">$K_\tau = \sqrt{3}\left[5.34 + \frac{4}{\alpha^2}\right]$</td><td rowspan="3">$C_\tau = 1$ for $\lambda \leq 0.84$
$C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$</td></tr>
<tr><td>12
</td><td>–</td><td colspan="2">$K_\tau = \sqrt{3}\left\{5.34 + Max\left[\frac{4}{\alpha^2}\ ;\ \frac{7.15}{\alpha^{2.5}}\right]\right\}$</td></tr>
<tr><td>13
</td><td>–</td><td colspan="2">$K_\tau = K_{\tau case11}\, r$
$K_{\tau case11}$: K_τ according to case 11
r : opening reduction factor taken as:
$r = \left(1 - \frac{d_a}{a}\right)\left(1 - \frac{d_b}{b}\right)$
with
$\frac{d_a}{a} \leq 0.7$ and $\frac{d_b}{b} \leq 0.7$</td></tr>
<tr><td colspan="5">Edge boundary conditions:
- - - - - - - - - Plate edge free.
———— Plate edge simply supported.
▬▬▬▬ Plate edge clamped.</td></tr>
<tr><td colspan="5">Note 1: Cases listed are general cases. Each stress component (σ_x,σ_y) is to be understood in local coordinates.</td></tr>
</table>

Table 4 : Buckling and reduction factor for curved plate panel with $R/t_p \le 2500$

Case	Aspect ratio	Buckling factor K	Reduction factor C
1 	$\frac{d}{R} \le 0.5\sqrt{\frac{R}{t_p}}$	$K = 1 + \frac{2}{3}\frac{d^2}{Rt_p}$	For general application: $C_{ax} = 1$ for $\lambda \le 0.25$; $C_{ax} = 1.233 - 0.933\lambda$ for $0.25 < \lambda \le 1$; $C_{ax} = 0.3/\lambda^3$ for $1 < \lambda \le 1.5$; $C_{ax} = 0.2/\lambda^2$ for $\lambda > 1.5$. For curved single fields, e.g. bilge strake, which are bounded by plane panels as shown in Ch 6, Sec 4, Figure 1: $C_{ax} = \frac{0.65}{\lambda^2} \le 1.0$
	$\frac{d}{R} > 0.5\sqrt{\frac{R}{t_p}}$	$K = 0.267\frac{d^2}{Rt_p}\left[3 - \frac{d}{R}\sqrt{\frac{t_p}{R}}\right] \ge 0.4\frac{d^2}{Rt_p}$	
2a  2b  p_e = external pressure in [N/mm²]	$\frac{d}{R} \le 1.63\sqrt{\frac{R}{t_p}}$	$K = \frac{d}{\sqrt{Rt_p}} + 3\frac{(Rt_p)^{0.175}}{d^{0.35}}$	For general application: $C_{tg} = 1$ for $\lambda \le 0.4$; $C_{tg} = 1.274 - 0.686\lambda$ for $0.4 < \lambda \le 1.2$; $C_{tg} = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$. For curved single fields, e.g. bilge strake, which are bounded by plane panels as shown in Ch 6, Sec 4, Figure 1: $C_{tg} = \frac{0.8}{\lambda^2} \le 1.0$
	$\frac{d}{R} > 1.63\sqrt{\frac{R}{t_p}}$	$K = 0.3\frac{d^2}{R^2} + 2.25\left(\frac{R^2}{d\ t_p}\right)^2$	
3 	$\frac{d}{R} \le \sqrt{\frac{R}{t_p}}$	$K = \frac{0.6d}{\sqrt{Rt_p}} + \frac{\sqrt{Rt_p}}{d} - 0.3\frac{Rt_p}{d^2}$	As in load case 2a.
	$\frac{d}{R} > \sqrt{\frac{R}{t_p}}$	$K = 0.3\frac{d^2}{R^2} + 0.291\left(\frac{R^2}{d\ t_p}\right)^2$	
4 	$\frac{d}{R} \le 8.7\sqrt{\frac{R}{t_p}}$	$K = \sqrt{3}\sqrt{28.3 + \frac{0.67\ d^3}{R^{1.5}\ t_p^{\ 1.5}}}$	$C_\tau = 1$ for $\lambda \le 0.4$; $C_\tau = 1.274 - 0.686\lambda$ for $0.4 < \lambda \le 1.2$; $C_\tau = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$
	$\frac{d}{R} > 8.7\sqrt{\frac{R}{t_p}}$	$K = \sqrt{3}\ \frac{0.28d^2}{R\sqrt{Rt_p}}$	

Explanations for boundary conditions:

- - - - - - - - - Plate edge free.

——— Plate edge simply supported.

▬▬▬ Plate edge clamped.

Note 1: For curved plate panels, the C-value need not be taken less than for the expanded plane panel.

2.2.7 Applied normal stress to plate panel

The normal stress, σ_x and σ_y, in N/mm^2, to be applied for the plate panel capacity calculation as given in [2.2.1] are to be taken as follows:

- For FE analysis, the reference stresses as defined in Ch 8, Sec 4, [2.4].
- For prescriptive assessment, the axial or transverse compressive stresses calculated according to Ch 8, Sec 3, [2.2.1], at load calculation points of the considered elementary plate panel, as defined in Ch 3, Sec 7, [2].
- For grillage analysis where the stresses are obtained based on beam theory, the stresses taken as:

$$\sigma_x = \frac{\sigma_{xb} + \nu\sigma_{yb}}{1-\nu^2}$$

$$\sigma_y = \frac{\sigma_{yb} + \nu\sigma_{xb}}{1-\nu^2}$$

where:

σ_{xb}, σ_{yb} : Stress, in N/mm^2, from grillage beam analysis respectively along x or y axis of the attached buckling panel.

The shear stress τ, in N/mm^2, to be applied for the plate panel capacity calculation as given in [2.2.1] are to be taken as follows:

- For FE analysis, the reference shear stresses as defined in Ch 8, Sec 4, [2.4].
- For prescriptive assessment, the shear stresses calculated according to Ch 8, Sec 3, [2.2.1], at load calculation points of the considered elementary plate panel, as defined in Ch 3, Sec 7, [2].
- For grillage beam analysis, $\tau = 0$ in the attached buckling panel.

2.3 Stiffeners

2.3.1 Buckling modes

The following buckling modes are to be checked:

- Stiffener induced failure (*SI*).
- Associated plate induced failure (*PI*).

2.3.2 Web thickness of flat bar

For accounting the decrease of the stiffness due to local lateral deformation, the effective web thickness of flat bar stiffener, in mm, is to be used in [2.3.4] for the calculation of the net sectional area, A_s, the net section modulus, *Z,* and the moment of inertia, *I*, of the stiffener and is taken as:

$$t_{w\_red} = t_w\left(1-\frac{2\pi^2}{3}\left(\frac{h_w}{s}\right)^2\left(1-\frac{b_{eff1}}{s}\right)\right)$$

2.3.3 Idealisation of bulb profile

Bulb profiles are to be considered as equivalent angle profiles, as defined in Ch 3, Sec 7, [1.4.1].

2.3.4 Ultimate buckling capacity

When $\sigma_a + \sigma_b + \sigma_w > 0$, the ultimate buckling capacity for stiffeners is to be checked according to the following interaction formula:

$$\frac{\gamma_c\ \sigma_a + \sigma_b + \sigma_w}{R_{eH}}S = 1$$

where:

σ_a : Effective axial stress, in N/mm², at mid span of the stiffener, acting on the stiffener with its attached plating.

$$\sigma_a = \sigma_x \frac{s\ t_p + A_s}{b_{eff1}\ t_p + A_s}$$

σ_x : Nominal axial stress, in N/mm², acting on the stiffener with its attached plating.

- For FE analysis, σ_x is the FE corrected stress as defined in [2.3.6] in the attached plating in the direction of the stiffener axis.
- For prescriptive assessment, σ_x is the axial stress calculated according to Ch 8, Sec 3, [2.2.1] at load calculation point of the stiffener, as defined in Ch 3, Sec 7, [3].
- For grillage beam analysis, σ_x is the stress acting along the x-axis of the attached buckling panel.

R_{eH} : Specified minimum yield stress of the material, in N/mm²:

$R_{eH} = R_{eH\_S}$ for stiffener induced failure (*SI*).

$R_{eH} = R_{eH\_P}$ for plate induced failure (*PI*).

σ_b : Bending stress in the stiffener, in N/mm²:

$$\sigma_b = \frac{M_0 + M_1}{1000Z}$$

Z : Net section modulus of stiffener, in cm³, including effective width of plating according to [2.3.5], to be taken as:

- The section modulus calculated at the top of stiffener flange for stiffener induced failure (*SI*).
- The section modulus calculated at the attached plating for plate induced failure (*PI*).

C_{PI} : Plate induced failure pressure coefficient:

$C_{PI} = 1$ if the lateral pressure is applied on the side opposite to the stiffener.

$C_{PI} = -1$ if the lateral pressure is applied on the same side as the stiffener.

C_{SI} : Stiffener induced failure pressure coefficient:

$C_{SI} = -1$ if the lateral pressure is applied on the side opposite to the stiffener.

$C_{SI} = 1$ if the lateral pressure is applied on the same side as the stiffener.

M_1 : Bending moment, in Nmm, due to the lateral load P:

$$M_1 = C_i \frac{|P| s \ell^2}{24 \times 10^3} \quad \text{for continuous stiffener}$$

$$M_1 = C_i \frac{|P| s \ell^2}{8 \times 10^3} \quad \text{for sniped stiffener}$$

P : Lateral load, in kN/m².

- For FE analysis, P is the average pressure as defined in Ch 8, Sec 4, [2.5.2] in the attached plating.
- For prescriptive assessment, P is the pressure calculated at load calculation point of the stiffener, as defined in Ch 3, Sec 7, [3].

C_i : Pressure coefficient:

$C_i = C_{SI}$ for stiffener induced failure (*SI*).

$C_i = C_{PI}$ for plate induced failure (*PI*).

M_0 : Bending moment, in Nmm, due to the lateral deformation w of stiffener:

$$M_0 = F_E \left(\frac{P_z\, w}{c_f - P_z} \right) \quad \text{with} \quad c_f - P_z > 0$$

F_E : Ideal elastic buckling force of the stiffener, in N.

$$F_E = \left(\frac{\pi}{\ell} \right)^2 E\, I\, 10^4$$

I : Moment of inertia, in cm^4, of the stiffener including effective width of attached plating according to [2.3.5]. I is to comply with the following requirement:

$$I \geq \frac{s\, t_p^3}{12 \times 10^4}$$

t_p : Net thickness of plate, in mm, to be taken as

- For prescriptive requirements: the mean thickness of the two attached plating panels,
- For FE analysis: the thickness of the considered EPP on one side of the stiffener.

P_z : Nominal lateral load, in N/mm^2, acting on the stiffener due to stresses, σ_x, σ_y and τ, in the attached plating in way of the stiffener mid span:

$$P_z = \frac{t_p}{s} \left(\sigma_{xl} \left(\frac{\pi\, s}{\ell} \right)^2 + 2c\, \gamma\, \sigma_y + \sqrt{2} \tau_1 \right)$$

$$\sigma_{xl} = \gamma\, \sigma_x \left(1 + \frac{A_s}{s t_p} \right) \quad \text{but not less than 0}$$

$$\tau_1 = \gamma |\tau| - t_p \sqrt{R_{eH\_p}\, E \left(\frac{m_1}{a^2} + \frac{m_2}{b^2} \right)} \quad \text{but not less than 0}$$

σ_y : Stress applied on the edge along y axis of the buckling panel, in N/mm^2, but not less than 0.

- For FE analysis, σ_y is the FE corrected stress as defined in [2.3.6] in the attached plating in the direction perpendicular to the stiffener axis.
- For prescriptive assessment, σ_y is the maximum compressive stress calculated according to Ch 8, Sec 3, [2.2.1], at load calculation points of the stiffener attached plating, as defined in Ch 3, Sec 7, [2].
- For grillage beam analysis, σ_y is the stress acting along the y-axis of the attached buckling panel.

τ : Applied shear stress, in N/mm^2.

- For FE analysis, τ is the reference shear stress as defined in Ch 8, Sec 4, [2.4.2] in the attached plating.
- For prescriptive assessment, τ is the shear stress calculated according to Ch 8, Sec 3, [2.2.1] at load calculation point of the stiffener attached plating, as defined in Ch 3, Sec 7, [2].
- For grillage beam analysis, $\tau = 0$ in the attached buckling panel.

m_1, m_2 : Coefficients taken equal to:

$m_1 = 1.47,\ m_2 = 0.49$ for $\alpha \geq 2$

$m_1 = 1.96,\ m_2 = 0.37$ for $\alpha < 2$

c : Factor taking into account the stresses in the attached plating acting perpendicular to the stiffener's axis:

$$c = 0.5(1+\psi) \quad \text{for} \quad 0 \leq \psi \leq 1$$

$$c = \frac{1}{2(1-\psi)} \quad \text{for} \quad \psi < 0$$

ψ : Edge stress ratio for case 2 according to Table 3.

w : Deformation of stiffener, in mm:

$$w = w_0 + w_1$$

w_0 : Assumed imperfection, in mm, to be taken as:

$w_0 = \ell / 1000$ in general.

$w_0 = -w_{na}$ for stiffeners sniped at both ends considering stiffener induced failure (*SI*).

$w_0 = w_{na}$ for stiffeners sniped at both ends considering plate induced failure (*PI*).

$w_{na:}$: Distance from the mid-point of attached plating to the neutral axis of the stiffener calculated with the effective width of the attached plating according to [2.3.5].

w_1 : Deformation of stiffener, in mm, at mid-point of stiffener span due to lateral load P. In case of uniformly distributed load, w_1 is to be taken as:

$$w_1 = C_i \frac{|P| s \ell^4}{384 \times 10^7\ EI} \quad \text{in general}$$

$$w_1 = C_i \frac{5|P| s \ell^4}{384 \times 10^7\ EI} \quad \text{for stiffeners sniped at both ends}$$

c_f : Elastic support provided by the stiffener, in N/mm^2:

$$c_f = F_E \left(\frac{\pi}{\ell}\right)^2 (1 + c_p)$$

$$c_p = \frac{1}{1 + \dfrac{0.91}{c_{xa}}\left(\dfrac{12I}{st_p^3}10^4 - 1\right)}$$

c_{xa} : Coefficient to be taken as:

$$c_{xa} = \left(\frac{\ell}{2s} + \frac{2s}{\ell}\right)^2 \quad \text{for} \quad \ell \geq 2s$$

$$c_{xa} = \left(1 + \left(\frac{\ell}{2s}\right)^2\right)^2 \quad \text{for} \quad \ell < 2s$$

σ_w : Stress due to torsional deformation, in N/mm^2, to be taken as:

$$\sigma_w = Ey_w\left(\frac{t_f}{2} + h_w\right)\Phi_0\left(\frac{\pi}{\ell}\right)^2\left(\frac{1}{1 - \dfrac{0.4R_{eH\_S}}{\sigma_{ET}}} - 1\right) \quad \text{for stiffener induced failure } (SI).$$

$$\sigma_w = 0 \quad \text{for plate induced failure } (PI).$$

y_w : Distance, in mm, from centroid of stiffener cross section to the free edge of stiffener flange, to be taken as:

$$y_w = \frac{t_w}{2} \quad \text{for flat bar.}$$

$$y_w = b_f - \frac{h_w t_w^2 + t_f b_f^2}{2A_s} \quad \text{for angle and bulb profiles.}$$

$$y_w = \frac{b_f}{2} \quad \text{for T profile.}$$

Φ_0 : Coefficient taken as:

$$\Phi_0 = \frac{\ell}{h_w} 10^{-3}$$

σ_{ET} : Reference stress for torsional buckling, in N/mm²:

$$\sigma_{ET} = \frac{E}{I_P}\left(\frac{\varepsilon \pi^2 I_\omega 10^2}{\ell^2} + 0.385 I_T\right)$$

I_P : Net polar moment of inertia of the stiffener, in cm⁴, about point C as shown in Figure 1, as defined in Table 5.

I_T : Net St. Venant's moment of inertia of the stiffener, in cm⁴, as defined in Table 5.

I_ω : Net sectional moment of inertia of the stiffener, in cm⁶, about point C as shown in Figure 1, as defined in Table 5.

ε : Degree of fixation.

$$\varepsilon = 1 + \frac{\left(\frac{\ell}{\pi}\right)^2 10^{-3}}{\sqrt{I_\omega\left(\frac{0.75s}{t_p^3} + \frac{e_f - 0.5t_f}{t_w^3}\right)}}$$

A_w : Net web area, in mm².

A_f : Net flange area, in mm².

Table 5 : Moments of inertia

	Flat bars (1)	Bulb, angle and T profiles
I_P	$\frac{h_w^3 t_w}{3\times10^4}$	$\left(\frac{A_w (e_f - 0.5t_f)^2}{3} + A_f e_f^2\right) 10^{-4}$
I_T	$\frac{h_w t_w^3}{3\times10^4}\left(1 - 0.63\frac{t_w}{h_w}\right)$	$\frac{(e_f - 0.5t_f) t_w^3}{3\times10^4}\left(1 - 0.63\frac{t_w}{e_f - 0.5t_f}\right) + \frac{b_f t_f^3}{3\cdot10^4}\left(1 - 0.63\frac{t_f}{b_f}\right)$
I_ω	$\frac{h_w^3 t_w^3}{36\times10^6}$	$\frac{A_f e_f^2 b_f^2}{12\times10^6}\left(\frac{A_f + 2.6A_w}{A_f + A_w}\right)$ for bulb and angle profiles. $\frac{b_f^3 t_f e_f^2}{12\times10^6}$ for T profiles.
(1)	t_w is the net web thickness, in mm. t_{w_red} as defined in [2.3.2] is not to be used in this table.	

2.3.5 Effective width of attached plating

The effective breadth of attached plating of stiffeners, b_{eff}, in mm, is to be taken as:

- For $\sigma_x > 0$:
  - For FE analysis,

    $$b_{eff} = min\ (C_x\ b, \chi_s\ s)$$

  - For prescriptive assessment,

    $$b_{eff} = min\left(\frac{C_{x1}\ b_1 + C_{x2}\ b_2}{2}, \chi_s\ s\right)$$

- For $\sigma_x \le 0$:
  - $b_{eff} = \chi_s\ s$

where:

χ_s : Effective breadth coefficient to be taken as:

$$\chi_s = min\left[\frac{1.12}{1 + \frac{1.75}{\left(\frac{\ell_{eff}}{s}\right)^{1.6}}};1.0\right] \quad \text{for} \quad \frac{\ell_{eff}}{s} \ge 1$$

$$\chi_s = 0.407\frac{\ell_{eff}}{s} \quad \text{for} \quad \frac{\ell_{eff}}{s} < 1$$

ℓ_{eff} : Effective length of the stiffener, in mm, taken as:

$\ell_{eff} = \frac{\ell}{\sqrt{3}}$ for stiffener fixed at both ends.

$\ell_{eff} = 0.75\ell$ for stiffener simply supported at one end and fixed at the other.

$\ell_{eff} = \ell$ for stiffener simply supported at both ends.

2.3.6 FE corrected stresses for stiffener capacity

When the reference stresses σ_x and σ_y obtained by FE analysis according to Ch 8, Sec 4, [2.4] are both compressive, they are to be corrected according to the following formulae:

- If $\sigma_x < \nu\sigma_y$:

  $$\sigma_{xcor} = 0$$

  $$\sigma_{ycor} = \sigma_y$$

- If $\sigma_y < \nu\sigma_x$:

  $$\sigma_{xcor} = \sigma_x$$

  $$\sigma_{ycor} = 0$$

- In the other cases:

  $$\sigma_{xcor} = \sigma_x - \nu\sigma_y$$

  $$\sigma_{ycor} = \sigma_y - \nu\sigma_x$$

2.4 Primary supporting members

2.4.1 Web plate in way of openings

The web plate of primary supporting members with openings is to be assessed for buckling based on the combined axial compressive and shear stresses.

The web plate adjacent to the opening on both sides is to be considered as individual unstiffened plate panels as shown in Table 6.

The interaction formula of [2.2.1] is to be used with:

- $\sigma_x = \sigma_{av}$
- $\sigma_y = 0$
- $\tau = \tau_{av}$

where:

σ_{av} : Weighted average compressive stress in the area of web plate being considered according to case 1, 2 or 3 in Table 3, in N/mm^2.

τ_{av} : Weighted average shear stress in the area of web plate being considered according to case 11 or 13 in Table 3, in N/mm^2.

For the application of the Table 6, the weighted average shear stress is to be taken as:

- Opening modelled in primary supporting members:
  - Configuration a) when using case 13:
    - In *P1* : $\tau_{av} = \tau_{av}(P1)\ (h-h_0)/h$
    - In *P2*: $\tau_{av} = \tau_{av}(P2)\ (h-h_0)/h$
  - Configuration b) when using case 11:
    - In *P1*: $\tau_{av} = \tau_{av}(P1)$
    - In *P2*: $\tau_{av} = \tau_{av}(P2)$
  - Configuration c):
    - In *P1* when using case 13: $\tau_{av} = \tau_{av}(P1)\ (h-h_0)/h$
    - In *P2* when using case 13: $\tau_{av} = \tau_{av}(P2)\ (h-h_0)/h$
    - In *P3* when using case 11: $\tau_{av} = \tau_{av}(P3)$
- Opening not modelled in primary supporting members:
  - Configuration a) when using case 13:
    - $\tau_{av} = \tau_{av}(\text{web})$
  - Configuration b) when using case 11:
    - In *P1*: $\tau_{av} = \tau_{av}(P1)\ h/(h-h_0)$
    - In *P2*: $\tau_{av} = \tau_{av}(P2)\ h/(h-h_0)$
  - Configuration c):
    - In *P1* when using case 13: $\tau_{av} = \tau_{av}(\text{web})$
    - In *P2* when using case 13: $\tau_{av} = \tau_{av}(\text{web})$
    - In *P3* when using case 11: $\tau_{av} = \tau_{av}(P3)\ h/(h-h_0)$

where:

h : Height, in m, of the web of the primary supporting member in way of the opening.

h_0 : Height in m, of the opening measured in the depth of the web.

$\tau_{av}(P1)$, $\tau_{av}(P2)$, $\tau_{av}(P3)$: Weighted average shear stress, in N/mm^2, within the areas *P1*, *P2* and *P3*, as shown in Table 6.

τ_{av}(web): Weighted average shear stress, in N/mm^2, in the area of the web marked with a dash rectangular shape, as shown in Table 6.

2.4.2 Reduction factors of web plate in way of openings

The reduction factors, C_x or C_y in combination with, C_τ of the plate panel(s) of the web adjacent to the opening is to be taken as shown in Table 6.

2.4.3

The equivalent plate panel of web plate of primary supporting members crossed by perpendicular stiffeners is to be idealised as shown in Figure 2.

3 Other Structures

3.1 Struts, pillars and cross ties

3.1.1 Buckling utilisation factor

The buckling utilisation factor, η, for axially compressed struts, pillars and cross ties is to be taken as:

$$\eta = \frac{\sigma_{av}}{\sigma_{cr}}$$

where:

σ_{av} : Average axial compressive stress in the member, in N/mm^2.

σ_{cr} : Minimum critical buckling stress, in N/mm^2, taken as:

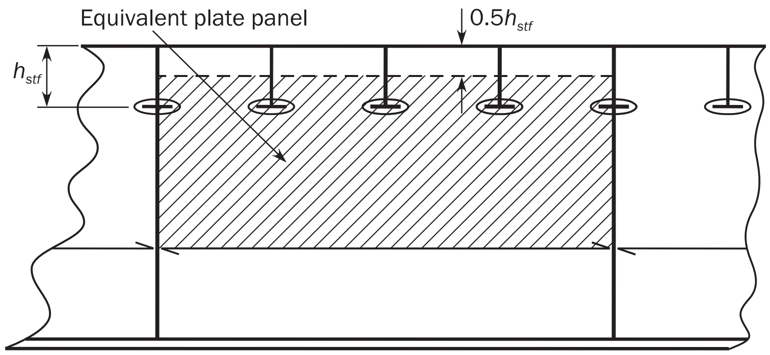
$$\sigma_{cr} = \sigma_E \quad \text{for} \quad \sigma_E \le 0.5 R_{eH\_S}$$

$$\sigma_{cr} = \left(1 - \frac{R_{eH\_S}}{4\sigma_E}\right) R_{eH\_S} \quad \text{for} \quad \sigma_E > 0.5 R_{eH\_S}$$

σ_E : Minimum elastic compressive buckling stress, in N/mm^2, according to [3.1.2] to [3.1.4].

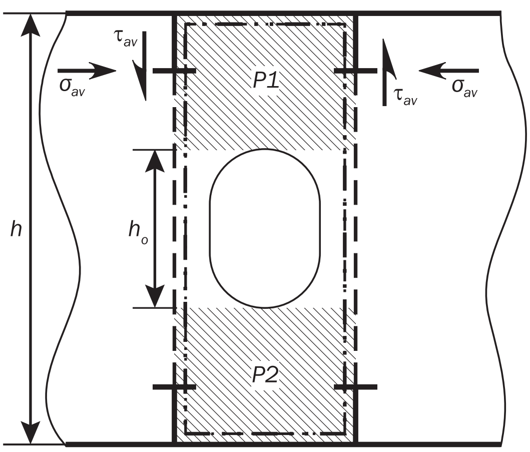
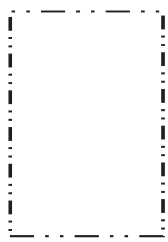
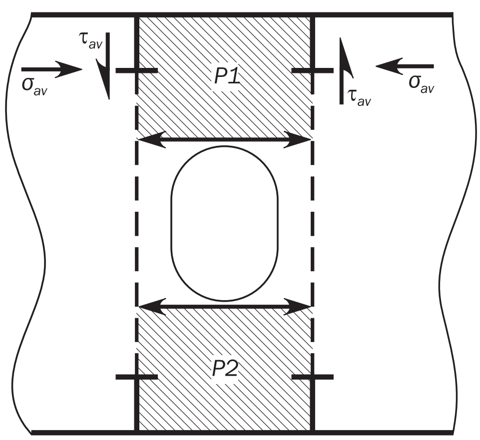
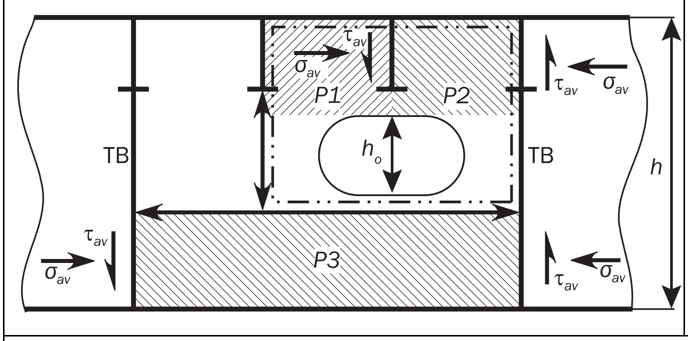
R_{eH_S} : Specified minimum yield stress of the considered member, in N/mm^2. For built up members, the lowest specified minimum yield stress is to be used.

Figure 2 : Web plate idealisation



The correction of panel breadth is applicable also for other slot configurations provided that the web or collar plate is attached to at least one side of the passing stiffener.

Table 6 : Reduction factors

Configuration	C_x, C_y	C_τ
(a) Without edge reinforcements: 	Separate reduction factors are to be applied to areas *P1* and *P2* using case 3 in Table 3, with edge stress ratio: $\psi = 1.0$	A common reduction factor is to be applied to areas *P1* and *P2* using case 13 in Table 3 for area marked: 
(b) With edge reinforcements: 	Separate reduction factors are to be applied for areas *P1* and *P2* using C_x for case 1 or C_y for case 2 in Table 3 with stress ratio: $\psi = 1.0$	Separate reduction factors are to be applied for areas *P1* and *P2* using case 11 in Table 3.
(c) Example of hole in web: 	Panels *P1* and *P2* are to be evaluated in accordance with (a). Panel *P3* is to be evaluated in accordance with (b).	
Note 1: Web panels to be considered for buckling in way of openings are shown shaded and numbered *P1*, *P2*, etc.		

3.1.2 Elastic column buckling stress

The elastic compressive column buckling stress, σ_{EC}, in N/mm^2 of members subject to axial compression is to be taken as:

$$\sigma_{EC} = \pi^2 E f_{end} \frac{I}{A\, \ell_{pill}^2} 10^{-4}$$

where:

I : Net moment of inertia about the weakest axis of the cross section, in cm^4.

A : Net cross sectional area of the member, in cm^2.

ℓ_{pill} : Length of the member, in m, taken as:

- For pillar and strut: unsupported length of the member
- For cross tie:
  - In centre tank: distance between the flanges of longitudinal stiffeners on the starboard and port longitudinal bulkheads to which the cross tie's horizontal stringer is attached.
  - In wing tank: distance between the flanges of longitudinal stiffeners on the longitudinal bulkhead to which the cross tie's horizontal stringer is attached, and the inner hull plating.

f_{end} : End constraint factor, taken as:

- For pillar and strut:
  - f_{end} = 1.0 where both ends are simply supported.
  - f_{end} = 2.0 where one end is simply supported and the other end is fixed.
  - f_{end} = 4.0 where both ends are fixed.
- For cross tie:
  - f_{end} = 2.0

A pillar end may be considered fixed when brackets of adequate size are fitted. Such brackets are to be supported by structural members with greater bending stiffness than the pillar.

3.1.3 Elastic torsional buckling stress

The elastic torsional buckling stress, σ_{ET}, in N/mm^2, with respect to axial compression of members is to be taken as:

$$\sigma_{ET} = \frac{GI_{sv}}{I_{pol}} + \frac{\pi^2 f_{end} Ec_{warp}}{I_{pol}\ \ell_{pill}^2} 10^{-4}$$

where:

I_{sv} : Net St. Venant's moment of inertia, in cm^4, see Table 7 for examples of cross sections.

I_{pol} : Net polar moment of inertia about the shear centre of cross section, in cm^4

$$I_{pol} = I_y + I_z + A\ (y_0^2 + z_0^2)$$

c_{warp} : Warping constant, in cm^6, see Table 7 for examples of cross sections.

ℓ_{pill} : Length of the member, in m as defined in [3.1.2].

y_0 : Transverse position of shear centre relative to the cross sectional centroid, in cm, see Table 7 for examples of cross sections.

z_0 : Vertical position of shear centre relative to the cross sectional centroid, in cm, see Table 7 for examples of cross sections.

A : Net cross sectional area, in cm^2, as defined in [3.1.2]

I_y : Net moment of inertia about y axis, in cm^4.

I_z : Net moment of inertia about z axis, in cm^4.

3.1.4 Elastic torsional/column buckling stress

For cross sections where the centroid and the shear centre do not coincide, the interaction between the torsional and column buckling mode is to be examined. The elastic torsional/column buckling stress, σ_{ETF}, with respect to axial compression is to be taken as:

$$\sigma_{ETF} = \frac{1}{2\zeta}\left[(\sigma_{EC}+\sigma_{ET}) - \sqrt{(\sigma_{EC}+\sigma_{ET})^2 - 4\zeta\,\sigma_{EC}\,\sigma_{ET}}\right]$$

where:

ζ : Coefficient taken as:

$$\zeta = 1 - \frac{(y_0^2 + z_0^2)\,A}{I_{pol}}$$

y_0 : Transverse position of shear centre relative to the cross sectional centroid, in cm, as defined in [3.1.3].

z_0 : Vertical position of shear centre relative to the cross sectional centroid, in cm, as defined in [3.1.3].

A : Net cross sectional area, in cm^2, as defined in [3.1.2].

I_{pol} : Net polar moment of inertia about the shear centre of cross section, in cm^4 as defined in [3.1.3].

σ_{EC} : Elastic column compressive buckling stress, as defined in [3.1.2].

σ_{ET} : Elastic torsional buckling stress, as defined in [3.1.3].

3.2 Corrugated bulkhead

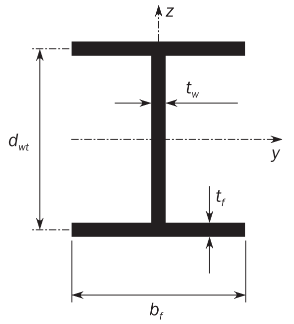
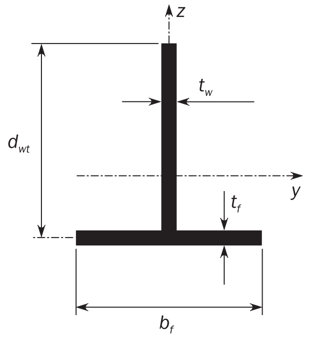
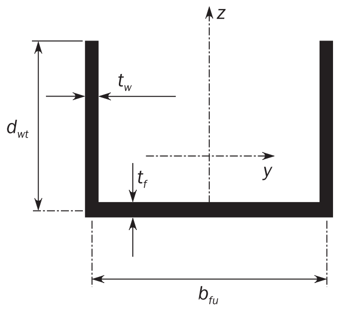
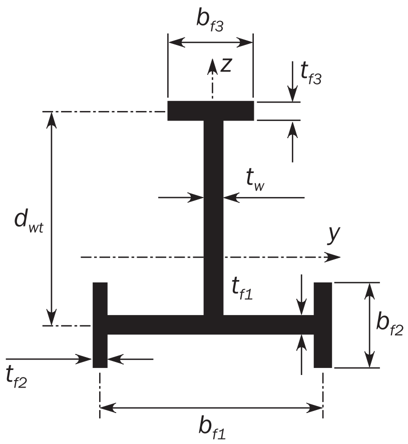
3.2.1

The buckling utilisation factor of flange and web of corrugation of corrugated bulkheads is based on the combination of in plane stresses and shear stress.

The interaction curve of [2.2.1] is to be used with the following coefficients:

- $\alpha = 2$
- $\psi_x = \psi_y = 1$

Table 7 : Cross sectional properties

	$I_{sv} = \frac{1}{3}\,(2b_f\,t_f^3 + d_{wt}\,t_w^3)\;10^{-4}$	cm^4
	$c_{warp} = \frac{d_{wt}^2\,b_f^3\,t_f}{24}\;10^{-6}$	cm^6
	$I_{sv} = \frac{1}{3}\,(b_f\,t_f^3 + d_{wt}\,t_w^3)\;10^{-4}$	cm^4
	$y_0 = 0$	cm
	$z_0 = -\frac{0.5d_{wt}^2\,t_w}{d_{wt}\,t_w + b_f\,t_f}\;10^{-1}$	cm
	$c_{warp} = \frac{b_f^3\,t_f^3 + 4d_{wt}^3\,t_w^3}{144}\;10^{-6}$	cm^6
	$I_{sv-n50} = \frac{1}{3}\,(b_{fu}\,t_f^3 + 2d_{wt}\,t_w^3)\;10^{-4}$	cm^4
	$y_0 = 0$	cm
	$z_0 = -\frac{d_{wt}^2\,t_w\,10^{-1}}{2d_{wt}\,t_w + b_f\,t_f} - \frac{0.5d_{wt}^2\,t_w\,10^{-1}}{d_{wt}\,t_w + b_{fu}\,t_f/6}$	cm
	$c_{warp} = \frac{b_{fu}^2\,d_{wt}^3\,t_w\,(3d_{wt}\,t_w + 2b_{fu}\,t_f)}{12(6d_{wt}\,t_w + b_{fu}\,t_f)}\;10^{-6}$	cm^6
	$I_{sv} = \frac{1}{3}\,(b_{f1}\,t_{f1}^3 + 2b_{f2}\,t_{f2}^3 + b_{f3}\,t_{f3}^3 + d_{wt}\,t_w^3)\;10^{-4}$	cm^4
	$y_0 = 0$	cm
	$z_0 = z_s - \frac{(b_{f3}\,d_{wt}\,t_{f3} + 0.5d_{wt}^2\,t_w)\;10^{-1}}{d_{wt}\,t_w + b_{f1}\,t_{f1} + 2b_{f2}\,t_{f2} + b_{f3}\,t_{f3}}$	cm
	$c_{warp} = \left(I_{f1}\,z_s^2 + \frac{I_{f2}\,b_{f1}^2}{200} + I_{f3}\left(\frac{d_{wt}}{10} - z_s\right)^2\right)$	cm^6
	$I_{f1} = \left(\frac{(b_{f1} - t_{f2})^3\,t_{f1}}{12} + \frac{b_{f2}\,t_{f2}\,b_{f1}^2}{2}\right)\;10^{-4}$	cm^4
	$I_{f2} = \frac{b_{f2}^3\,t_{f2}}{12}\;10^{-4}$	cm^4
	$I_{f3} = \frac{b_{f3}^3\,t_{f3}}{12}\;10^{-4}$	cm^4
	$z_s = \frac{I_{f3}\,d_{wt}}{I_{f1} + I_{f3}}\;10^{-1}$	cm

Note 1: All dimensions are in mm.

Note 2: Cross sectional properties are given for typical cross sections. Properties for other cross sections are to be determined by direct calculation.

APPENDIX 1
STRESS BASED REFERENCE STRESSES

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

a : Length, in mm, of the longer side of the plate panel as defined in Sec 5.

b : Length, in mm, of the shorter side of the plate panel as defined in Sec 5.

A_i : Area, in mm^2, of the *i*-th plate element of the buckling panel.

n : Number of plate elements in the buckling panel.

σ_{xi} : Actual stress, in N/mm^2, at the centroid of the *i*-th plate element in x direction, applied along the shorter edge of the buckling panel.

σ_{yi} : Actual stress, in N/mm^2, at the centroid of the *i*-th plate element in y direction, applied along the longer edge of the buckling panel.

ψ : Edge stress ratio as defined in Sec 5.

τ_i : Actual membrane shear stress, in N/mm^2, at the centroid of the *i*-th plate element of the buckling panel.

1 STRESS BASED METHOD

1.1 Introduction

1.1.1

This section provides a method to determine stress distribution along edges of the considered buckling panel by 2nd order polynomial curve, by linear distribution using least square method and by weighted average approach. This method is called Stress based Method.

The reference stress is the stress components at centre of plate element transferred into the local system of the considered buckling panel.

1.1.2 Definition

A regular panel is a plate panel of rectangular shape. An irregular panel is plate panel which is not regular, as detailed in Ch 8, Sec 4, [2.3.1].

1.2 Stress application

1.2.1 Regular panel

The reference stresses are to be taken as defined in [2.1] for a regular panel when the following conditions are satisfied:

- At least, one plate element centre is located in each third part of the long edge *a* of a regular panel and
- This element centre is located at a distance in the panel local x direction not less than *a*/4 to at least one of the element centres in the adjacent third part of the panel.

Otherwise, the reference stresses are to be taken as defined in [2.2] for an irregular panel.

1.2.2 Irregular panel

The reference stresses of an irregular panel are to be taken as defined in [2.2].

2 REFERENCE STRESSES

2.1 Regular Panel

2.1.1 Longitudinal stress

The longitudinal stress σ_x applied on the shorter edge of the buckling panel is to be calculated as follows:

- For plate buckling assessment, the distribution of σ_x(x) is assumed as 2nd order polynomial curve as:

$$\sigma_x(x) = C \cdot x^2 + D \cdot x + E$$

The best fitting curve $\sigma_x(x)$ is to be obtained by minimising the square error Π considering the area of each element as a weighting factor.

$$\Pi = \sum_{i=1}^{n} A_i[\sigma_{ix} - (Cx_i^2 + Dx_i + E)]^2$$

The unknown coefficients *C*, *D* and *E* must yield zero first derivatives, $\partial\Pi$ with respect to *C*,*D* and *E* respectively.

$$\begin{cases} \dfrac{\partial\Pi}{\partial C} = 2\displaystyle\sum_{i=1}^{n} A_i x_i^2[\sigma_{ix} - (Cx_i^2 + Dx_i + E)] = 0 \\ \dfrac{\partial\Pi}{\partial D} = 2\displaystyle\sum_{i=1}^{n} A_i x_i[\sigma_{ix} - (Cx_i^2 + Dx_i + E)] = 0 \\ \dfrac{\partial\Pi}{\partial E} = 2\displaystyle\sum_{i=1}^{n} A_i[\sigma_{ix} - (Cx_i^2 + Dx_i + E)] = 0 \end{cases}$$

The unknown coefficients *C*, *D* and *E* can be obtained by solving the 3 above equations.

$$\sigma_{x1} = \frac{1}{b}\int_0^b \sigma_x(x)dx = \frac{b^2}{3}C + \frac{b}{2}D + E$$

$$\sigma_{x2} = \frac{1}{b}\int_{a-b}^{a} \sigma_x(x)dx = \left(a^2 - ab + \frac{b^2}{3}\right)C + \left(a - \frac{b}{2}\right)D + E$$

If $-D/2C < b/2$ or $-D/2C > a-b/2$, σ_{x3} is to be ignored. Otherwise, σ_{x3} is taken as:

$$\sigma_{x3} = \frac{1}{b}\int_{xmin}^{xmax} \sigma_x(x)dx = \frac{b^2}{12}C - \frac{D^2}{4C} + E$$

where:

$$x_{min} = -\frac{b}{2} - \frac{D}{2C}$$

$$x_{max} = \frac{b}{2} - \frac{D}{2C}$$

The longitudinal stress is to be taken as:

$$\sigma_x = max(\sigma_{x1};\sigma_{x2};\sigma_{x3})$$

The edge stress ratio is to be taken as:

$$\psi_x = 1$$

- For stiffener buckling assessment, $\sigma_x(x)$ applied on the shorter edge of the attached plate is to be taken as:

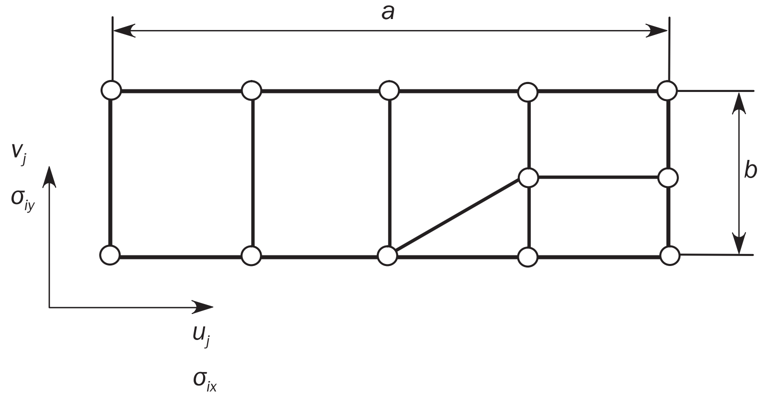
$$\sigma_x = \frac{\sum_{1}^{n} A_i \, \sigma_{xi}}{\sum_{1}^{n} A_i}$$

The edge stress ratio ψ_x for the stress σ_x is equal to 1.0.

2.1.2 Transverse stress

The transverse stress σ_y applied along the longer edges of the buckling panel is to be calculated by extrapolation of the transverse stresses of all elements up to the shorter edges of the considered buckling panel.

Figure 1 : Buckling panel



The distribution of $\sigma_y(x)$ is assumed as straight line. Therefore:

$$\sigma_y(x) = A + Bx$$

The best fitting curve $\sigma_y(x)$ is to be obtained by the least square method minimising the square error Π considering area of each element as a weighting factor.

$$\Pi = \sum_{i=1}^{n} A_i \, [\sigma_{iy} - (A + Bx_i)]^2$$

The unknown coefficients C and D must yield zero first partial derivatives, $\partial\Pi$ with respect to C and D, respectively.

$$\begin{cases} \dfrac{\partial\Pi}{\partial A} = 2\sum_{i=1}^{n} A_i \, [\sigma_{iy} - (A + Bx_i)] = 0 \\ \dfrac{\partial\Pi}{\partial B} = 2\sum_{i=1}^{n} A_i \, x_i \, [\sigma_{iy} - (A + Bx_i)] = 0 \end{cases}$$

The unknown coefficients A and B are obtained by solving the 2 above equations and are given as follow:

$$\begin{cases} A = \dfrac{\left(\sum_{i=1}^{n} A_i \, \sigma_{iy}\right)\left(\sum_{i=1}^{n} A_i \, x_i^2\right) - \left(\sum_{i=1}^{n} A_i \, x_i\right)\left(\sum_{i=1}^{n} A_i \, x_i \, \sigma_{iy}\right)}{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i \, x_i^2\right) - \left(\sum_{i=1}^{n} A_i \, x_i\right)^2} \\ B = \dfrac{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i \, x_i \, \sigma_{iy}\right) - \left(\sum_{i=1}^{n} A_i \, x_i\right)\left(\sum_{i=1}^{n} A_i \, \sigma_{iy}\right)}{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i \, x_i^2\right) - \left(\sum_{i=1}^{n} A_i \, x_i\right)^2} \end{cases}$$

$$\sigma_y = max \; (A, A + Ba)$$

$$\psi_y = \frac{min \; (A, A + Ba)}{max \; (A, A + Ba)} \quad \text{for } \sigma_y \geq 0$$

$$\psi_y = 1 \quad \text{for } \sigma_y < 0$$

2.1.3 Shear stress

The shear stress τ is to be calculated using a weighted average approach, and is to be taken as:

$$\tau = \frac{\sum_{1}^{n} A_i \, \tau_i}{\sum_{1}^{n} A_i}$$

2.2 Irregular panel

2.2.1 Reference stresses

The longitudinal, transverse and shear stresses are to be calculated using a weighted average approach. They are to be taken as:

$$\sigma_x = \frac{\sum_{1}^{n} A_i \, \sigma_{xi}}{\sum_{1}^{n} A_i}$$

$$\sigma_y = \frac{\sum_{1}^{n} A_i \, \sigma_{yi}}{\sum_{1}^{n} A_i}$$

$$\tau = \frac{\sum_{1}^{n} A_i \tau_i}{\sum_{1}^{n} A_i}$$

The edge stress ratios are to be taken as:

$$\psi_x = 1$$

$$\psi_y = 1$$

PART 1 CHAPTER 9

FATIGUE

Table of Contents

SECTION 6
Detail Design Standard

SECTION 1
GENERAL CONSIDERATIONS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

T_{DF} : Design fatigue life, in year, specified by the designer, but not to be taken less than 25 years.

1 RULE APPLICATION FOR FATIGUE REQUIREMENTS

1.1 Scope

1.1.1 General

This chapter provides requirements applicable to ships having rule length *L* between 150 m and 500 m to evaluate fatigue strength of the ship's structural details considering an operation time in North Atlantic environment equal to the design fatigue life, T_{DF}.

1.1.2 Assessed area

Fatigue assessment is performed for structural details located in the ship's cargo hold region in order to prevent the following types of fatigue failure:

- Fatigue cracks initiating from the toe of the weld and propagating into the plate.
- Fatigue cracks initiating from free edge of non-welded details.

1.1.3 Structural details to be assessed

The structural details required for fatigue assessment are given in Ch 9, Sec 2:

- Structural details to be checked are listed in:
    - Ch 9, Sec 2, [1] for simplified stress analysis according to Ch 9, Sec 4, or
    - Ch 9, Sec 2, [2] for finite element stress analysis according to Ch 9, Sec 5.
- Structural details to be checked by screening fatigue assessment are listed in Ch 9, Sec 2, Table 2.

Additional specific details may be requested to be checked on a case-by-case basis by the Society.

1.1.4 Detail design standard

Detail design standard given in Ch 9, Sec 6 provides welding requirement at critical structural details in order to prevent the following types of fatigue failure:

- Fatigue cracks initiating from the weld toe into the base material.
- Fatigue cracks initiating from the weld root and propagating into the plate section under the weld.
- Fatigue cracks initiating from the weld root and propagating through the weld throat.
- Fatigue cracks initiating from surface irregularity or notch at the free edge into the base material.

1.1.5 Material

The fatigue assessment is applicable for steel material with specified minimum yield stress less than or equal to 390 N/mm^2. For steel with specified minimum yield stress value higher than 390 N/mm^2 and for steels with improved fatigue performance, the S-N curves to be used are considered by the Society on a case-by-case basis.

1.1.6 Wave loads

Fatigue assessment is based on quasi-static wave loads.

1.1.7 Loads other than wave loads

Fatigue induced by low cycle loads such as cargo variations or impact loads such as sloshing in partially filled tanks which may induce fatigue damage is disregarded in this chapter.

2 DEFINITION

2.1 Hot spots

2.1.1

Hot spots are locations in the structure where fatigue cracks may initiate due to the combined effect of nominal structural stress fluctuation and stress raising effects due to the weld geometry or similar effects due to notch in the base material.

Hot spots may be located at:

- Weld toe.
- Weld root of partial penetration or fillet weld.
- Base material at free edge of plate.

2.2 Nominal stress

2.2.1

Nominal stress is the stress in a structural component taking into account macro-geometric effect but disregarding the stress concentration due to structural discontinuities and the presence of welds. Nominal stress is to be obtained either using coarse or fine mesh FE analysis, as required in Ch 9, Sec 5 or using analytical calculation based on beam theory, as required in Ch 9, Sec 4.

2.3 Hot spot stress

2.3.1

Hot spot stress is the stress at the weld toe taking into account the stress concentration due to structural discontinuities and presence of welded attachments but disregarding the non-linear stress peak caused by the notch at the weld toe. The hot spot stresses to be considered correspond to the two principal stresses on the surface plating at the weld toe. The first principal stress acts within ±45°, perpendicular to the weld and the second principal stress acts outside ±45°.

The hot spot stress is to be obtained by multiplying the nominal stress by a Stress Concentration Factor (SCF), according to Ch 9, Sec 4, [5] or directly by a very fine mesh FE analysis, according to Ch 9, Sec 5, [3] and Ch 9, Sec 5, [4].

2.4 Local stress at free edge

2.4.1

Local stress at free edge is the stress at the plate free edge derived using finite element analysis according to Ch 9, Sec 5, [3.2].

2.5 Fatigue stress

2.5.1

Fatigue stress is the stress relevant for fatigue assessment purpose, i.e.:

- Maximum of the two principal hot spot stress for weld toe with the mean stress effect and thickness effect corrections.
- Local stress at free edge with corrections due to the base material surface finishing, mean stress effect, thickness effect and material strength.

3 ASSUMPTIONS

3.1 General

3.1.1

The following assumptions are made in the fatigue assessment:

a) A linear cumulative damage model, i.e. Palmgren-Miner's Rule, given in Ch 9, Sec 3, [5], has been used in connection with the design S-N curves, given in Ch 9, Sec 3, [4].

b) Design fatigue life, T_{DF}, is taken not less than 25 years.

c) Rule quasi-static wave induced loads are based on North Atlantic wave environment. They are determined at 10^{-2} probability level of exceedance by the Equivalent Design Wave (EDW) concept.

d) Net thickness t_{n50} approach is used, according to [5].

e) Type of stress used for crack initiating at the weld toe is the hot spot stress. Type of stress used for crack initiating at free edge of non-welded details is local stress at free edge.

f) Fatigue stress range $\Delta\sigma_{FS}$ may be calculated by simplified stress analysis or by finite element stress analysis for details with more complex geometry.

g) Long term distribution of stress range of a structural detail is assumed to follow a two-parameter Weibull distribution. Weibull shape parameter ξ is equal to 1 and the fatigue stress range $\Delta\sigma_{FS}$ is given at the reference probability level of exceedance equal to 10^{-2}.

h) The acceptance criteria for fatigue checking are the total fatigue damage D to be less than 1 for the design fatigue life, as required in Ch 9, Sec 3, [2].

4 METHODOLOGY

4.1 Principles

4.1.1 General

Appropriate fatigue strength of structural details is ensured by use of:

- Detail design standards given in Ch 9, Sec 6, providing specific design requirements.
- Fatigue strength assessment by fatigue life calculation, based on three different methods for hot spot stress calculation: simplified stress analysis, very fine mesh finite element stress analysis and fatigue screening assessment.

4.2 Simplified stress analysis

4.2.1

Procedure based on simplified stress analysis, required in Ch 9, Sec 4, is used to determine the hot spot stress at weld toe of longitudinal stiffener end connections, given in Ch 9, Sec 2, [1.1].

Nominal stresses are calculated by using analytical method based on beam theory according to Ch 9, Sec 4, [3] and Ch 9, Sec 4, [4]. Hot spot stresses are obtained by multiplying nominal stresses by stress concentration factors (SCF) of the considered detail according to Ch 9, Sec 4, [5.2].

4.3 Finite element stress analysis

4.3.1

Procedure based on finite element stress analysis, required in Ch 9, Sec 5, is used to determine hot spot stress at weld toe of specified structural details, from very fine mesh models.

The hot spot stress is generally highly dependent on the finite element model used for representing the structure.

General procedure for the calculation of hot spot stress at weld toe for any welded details except for web stiffened cruciform joints is given in Ch 9, Sec 5, [3.1]. Procedure for the calculation of hot spot stress at the flange connections for web stiffened cruciform joints is given in Ch 9, Sec 5, [4]. Calculation of local stress for non-welded area is provided in Ch 9, Sec 5, [3.2].

A list of details for which the fatigue assessment is to be made through a compulsory very fine mesh finite element analysis or through the compliance with the design standard given in Ch 9, Sec 6 if a very fine mesh finite element analysis is omitted, is given respectively in Ch 9, Sec 2, Table 1 and Ch 9, Sec 2, Table 3.

4.4 Fatigue screening assessment

4.4.1

A fatigue screening procedure is used to assess the fatigue strength of specified structural details, given in Ch 9, Sec 2, [2.1.3]. The screening procedure is based on screening hot spot stress at weld toe of specified structural details determined by multiplying the stresses obtained from a local fine mesh finite element model, required in Ch 7, Sec 3, by stress magnification factor η of the considered detail, given in Ch 9, Sec 5, Table 2.

4.5 Fatigue design standards

4.5.1

Detail design standards given in Ch 9, Sec 6 are provided to ensure improved fatigue performance of critical structural details. Alternative detail design configurations may be accepted subject to demonstration of satisfactory fatigue performance.

5 CORROSION MODEL

5.1 Net thickness

5.1.1 General

The fatigue assessment should be performed based on net thicknesses according to Ch 3, Sec 2.

5.1.2 Stress correction

The hull girder stresses for simplified stress analysis and stresses calculated by FE analysis are to be corrected by multiplying the calculated stress by f_c, correction factor taken as:

$f_c = 0.95$

6 LOADING CONDITIONS

6.1 Description

6.1.1

Fatigue analyses are to be carried out for representative loading conditions according to the intended ship's operation as given in [6.2] and [6.3].

6.2 Loading conditions for oil tankers

6.2.1

The loading conditions to be considered for oil tankers and corresponding fraction of time for each loading condition, $\alpha_{(j)}$, are defined in Table 1. The standard loading conditions for fatigue assessment of oil tankers are provided in Ch 4, Sec 8, [5.1].

Table 1 : Fraction of time in each loading condition for oil tanker

Loading conditions	$\alpha_{(j)}$
Full Load condition (Homogeneous)	0.5
Normal ballast condition	0.5

6.3 Loading conditions for bulk carriers

6.3.1

The loading conditions to be considered for bulk carriers and corresponding fraction of time for each loading condition, $\alpha_{(j)}$, are defined respectively in Table 2 and Table 3 depending on the ship's type (BC-A, BC-B, BC-C). The standard loading conditions for fatigue assessment of bulk carriers are provided in Ch 4, Sec 8, [5.2].

7 LOAD CASES

7.1 Assumptions

7.1.1

The load cases to be considered for fatigue assessment are given in Ch 4, Sec 2, [3].

The design load scenario for fatigue assessment is defined in Ch 4, Sec 7, Table 3.

For each loading condition defined in [6], all fatigue load cases are to be considered to generate the combination of dynamic loads for fatigue assessment

7.1.2 Predominant load case

The predominant load case for each loading condition (j) is defined as load case where the fatigue stress range for the critical location is the maximum among all fatigue load cases.

Table 2 : Loading conditions for bulk carriers

Ship type	Full load condition		Ballast condition	
	Homogeneous	Alternate	Normal ballast	Heavy ballast
BC-A	X	X	X	X
BC-B	X	-	X	X
BC-C	X	-	X	X

Table 3 : Fraction of time for each loading condition of bulk carriers

Ship length	Loading conditions	$\alpha_{(j)}$	
		BC-A	BC-B, BC-C
L < 200 m	Homogeneous	0.60	0.70
	Alternate	0.10	-
	Normal ballast	0.15	0.15
	Heavy ballast	0.15	0.15
$L \geq$ 200 m	Homogeneous	0.25	0.50
	Alternate	0.25	-
	Normal ballast	0.20	0.20
	Heavy ballast	0.30	0.30

SECTION 2
STRUCTURAL DETAILS TO BE ASSESSED

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

EA : Empty cargo hold in alternate loading condition.

FA : Full cargo hold in alternate loading condition.

1 SIMPLIFIED STRESS ANALYSIS

1.1 Structural details to be assessed

1.1.1

Critical structural details to be checked over the full extent of the cargo region for fatigue assessment by simplified stress analysis according to Ch 9, Sec 1 are:

- End connections of longitudinal stiffeners to transverse bulkheads, including swash bulkheads,
- End connections of longitudinal stiffeners to floors and web frames.

2 FINITE ELEMENT ANALYSIS

2.1 Structural details to be assessed

2.1.1 General

Critical structural details to be checked for fatigue by finite element analysis according to Ch 9, Sec 5 are given in [2.1.2] to [2.1.4].

Table 4 to Table 18 give the list of hot spots for structural details.

2.1.2 Details to be checked by very fine mesh analysis

Critical structural details to be assessed for fatigue by very fine mesh analysis according to Ch 9, Sec 5, [1] to Ch 9, Sec 5, [4] are provided in Table 1, irrespective of their compliance with the design standard given in Ch 9, Sec 6.

2.1.3 Details to be checked by screening fatigue assessment

The structural details listed in Table 2 for which FE fine mesh models have been analysed according to yielding requirements given in Ch 7, Sec 3 are to be assessed using the screening fatigue procedure as given in Ch 9, Sec 5, [6].

2.1.4 Details in accordance with detail design standard

Table 3 gives critical structural details for which fatigue assessment by very fine mesh analysis can be omitted if their design is in accordance with detail design standard given in Ch 9, Sec 6.

Table 1 : Structural details to be assessed by very fine mesh analysis

No	Critical detail	Applicability	
		Oil tanker	Bulk carrier
1	Welded lower hopper knuckle connection (intersection of hopper sloping plate, inner bottom plate, longitudinal girder, floor and transverse web) at the most critical frame location. (1)	One cargo tank (4)	Ballast hold
2	Radiused lower hopper knuckle connection (intersection of knuckled inner bottom plate, longitudinal girder, floor and transverse web) at the most critical frame location. (1)	One cargo tank (4)	Ballast hold
3	Welded upper knuckle connection (intersection of hopper sloping plate, inner hull longitudinal bulkhead, transverse web and side stringer) where the angle between hopper plate and inner hull longitudinal bulkhead is less than 130 deg, at the most critical frame location. (1)	One cargo tank (4)	Ballast hold of double side bulk carrier
4	Connections of transverse bulkhead lower stools to the inner bottom plating in way of double bottom girders. (2) (3)	One cargo tank (4)	Ballast hold
5	Upper side frame bracket toe in case of flat bottom of top wing tank. (1)	N/A	FA hold (4), EA hold (4) and ballast hold of single skin bulk carrier
6	Deck plating and longitudinal hatch coaming end bracket toe.	N/A	Two aftermost holds, midship hold and two foremost holds

(1) The most critical frame position is generally, but not necessarily, located closest to the mid length of the hold. Where a swash bulkhead is fitted, this is generally located closest to the mid length between the swash bulkhead and the oil-tight bulkhead.
(2) Stool connections at each end of the hold are to be checked unless these are symmetrical about mid-hold.
(3) Position at the mid breadth location of the largest hold.
(4) Cargo hold located closest to the midship.

Table 2 : Structural details for screening fatigue assessment

No	Critical detail	Applicability	
		Oil tanker	Bulk carrier
1	Bracket toe of transverse web frame	Applicable (1)	N/A
2	Toe of horizontal stringer	Applicable (1)	N/A
3	Lower hopper knuckle connection in EA hold (2) and in FA hold (2) not assigned as a ballast hold	N/A	Applicable (1)
4	Connections of transverse bulkhead lower stool to inner bottom in EA hold (2) and in FA hold (2) where the ballast hold is not assigned to the ship	N/A	Applicable (1)

(1) For details assessed by fine mesh analysis according to Ch 7, Sec 3, [2.1] and Ch 7, Sec 3, [3.3.2].
(2) Cargo hold located closest to the midship

Table 3 : Structural details to be assessed by very fine mesh analysis if not designed in accordance with detail design standard

No	Critical detail	Corresponding detail design standard	Applicability	
			Oil tanker	Bulk carrier
1	Radiused upper hopper knuckle connection (intersection of knuckled inner side plate, side girder and transverse web) at the most critical frame location. (1)	Ch 9, Sec 6, [4]	One cargo tank (4)	Ballast hold of double side bulk carrier
2	Corrugated transverse bulkhead to lower stool or inner bottom plating connection. (2) (3)	Ch 9, Sec 6, [6] and Ch 9, Sec 6, [7]	One cargo tank (4)	Ballast hold
3	Corrugated transverse bulkhead to upper stool. (2) (3)	Ch 9, Sec 6, [6]	N/A	Ballast hold
4	Cruciform heel connections between side stringers in double side and transverse bulkhead horizontal stringers, for the stringer closest to the mid depth and for the uppermost one.	Ch 9, Sec 6, [5]	One cargo tank (4)	N/A
5	Lower side frame bracket toe at the most critical frame position. (1)	Ch 9, Sec 6, [8]	N/A	FA hold (4), EA hold (4) and ballast hold of single skin bulk carrier
6	Cut out for longitudinal stiffeners in web-frame without web stiffener connection.	Ch 9, Sec 6, [2.1]	One cargo tank (4)	FA hold (4), EA hold (4) and ballast hold
7	Scallops in way of block joints on strength deck close to mid hold (and down to 0.1D from deck corner).	Ch 9, Sec 6, [3]	One cargo tank (4)	FA hold (4), EA hold (4) and ballast hold

(1) The most critical frame position is generally, but not necessarily, located closest to the mid length of the hold. Where a swash bulkhead is fitted, this is generally located closest to the mid length between the swash bulkhead and the oil-tight bulkhead.
(2) Stool connections at each end of the hold are to be checked unless these are symmetrical about mid-hold.
(3) Position at the mid breadth location of the largest hold in the considered transverse section.
(4) Cargo hold located closest to the midship.

Table 4 : Hot spots for welded lower hopper knuckle connection

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Inner bottom plate, on cargo tank side Hot spot 2: Hopper sloping plate, on cargo tank side	Ch 9, Sec 5, [4.2]
Hot spot 3: Hopper web, outboard of side girder Hot spot 4: Double bottom floor, inboard the side girder Hot spot 5: Side girder	Ch 9, Sec 5, [4.3]
Hot spot 6: Scarfing bracket to the inner bottom plate	Ch 9, Sec 5, [3.1], type '*b*'

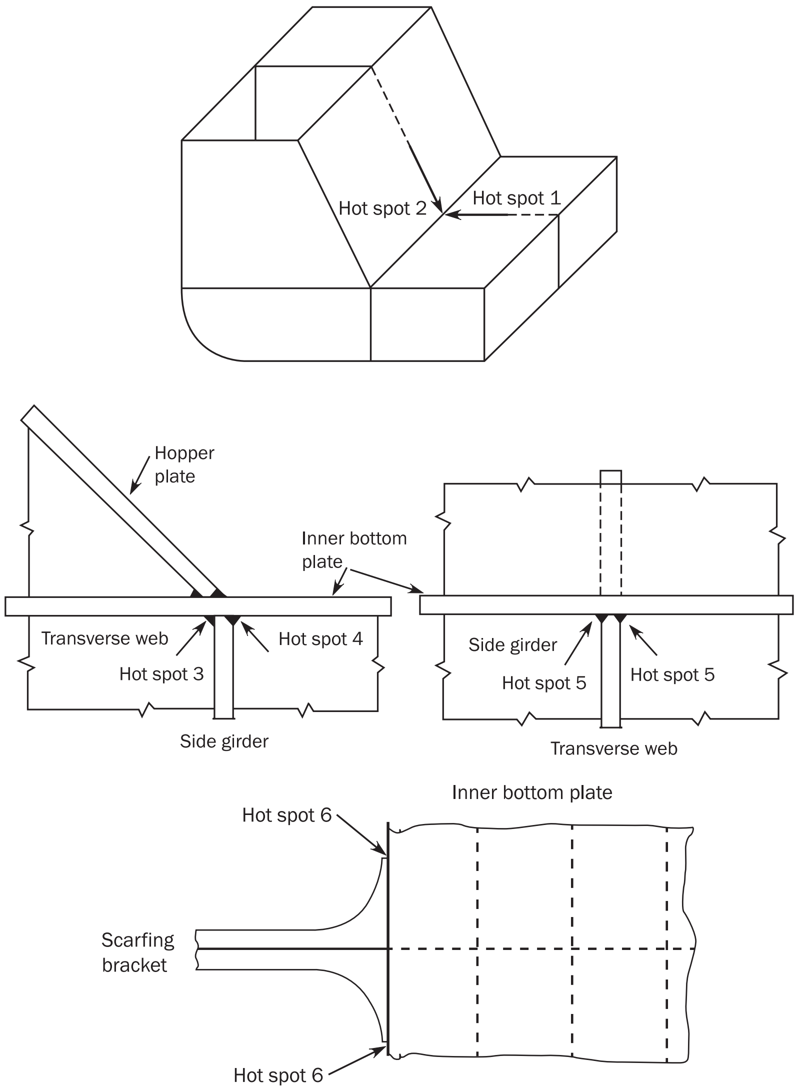


Table 5 : Hot spots for radiused lower hopper knuckle connection

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Inner bottom plate on ballast tank side, inboard of the side girder Hot spot 2: Radiused hopper sloping plate on ballast tank side outboard of the side girder Hot spot 3: Radiused hopper sloping plate on ballast tank side, outboard of the side girder, towards transverse web Hot spot 4: Hopper web, outboard of side girder Hot spot 5: Double bottom floor, inboard of the side girder Hot spot 6: Side girder	Ch 9, Sec 5, [3.3]

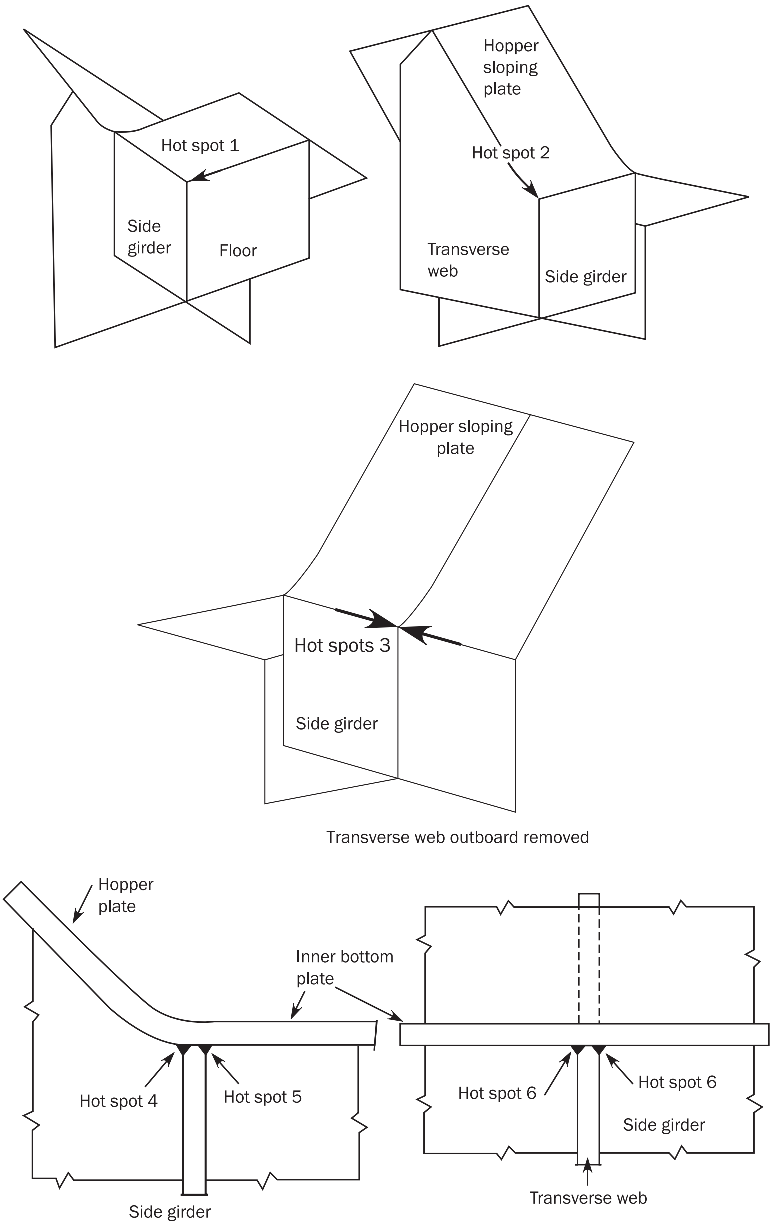


Table 6 : Hot spots for welded upper knuckle connection

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Side stringer on ballast tank side Hot spot 2: Hopper sloping plate, on ballast tank side	Ch 9, Sec 5, [4.2]
Hot spot 3: Transverse web, below stringer. Hot spot 4: Transverse side web, above stringer Hot spot 5: Inner hull longitudinal bulkhead on ballast tank side	Ch 9, Sec 5, [4.3]

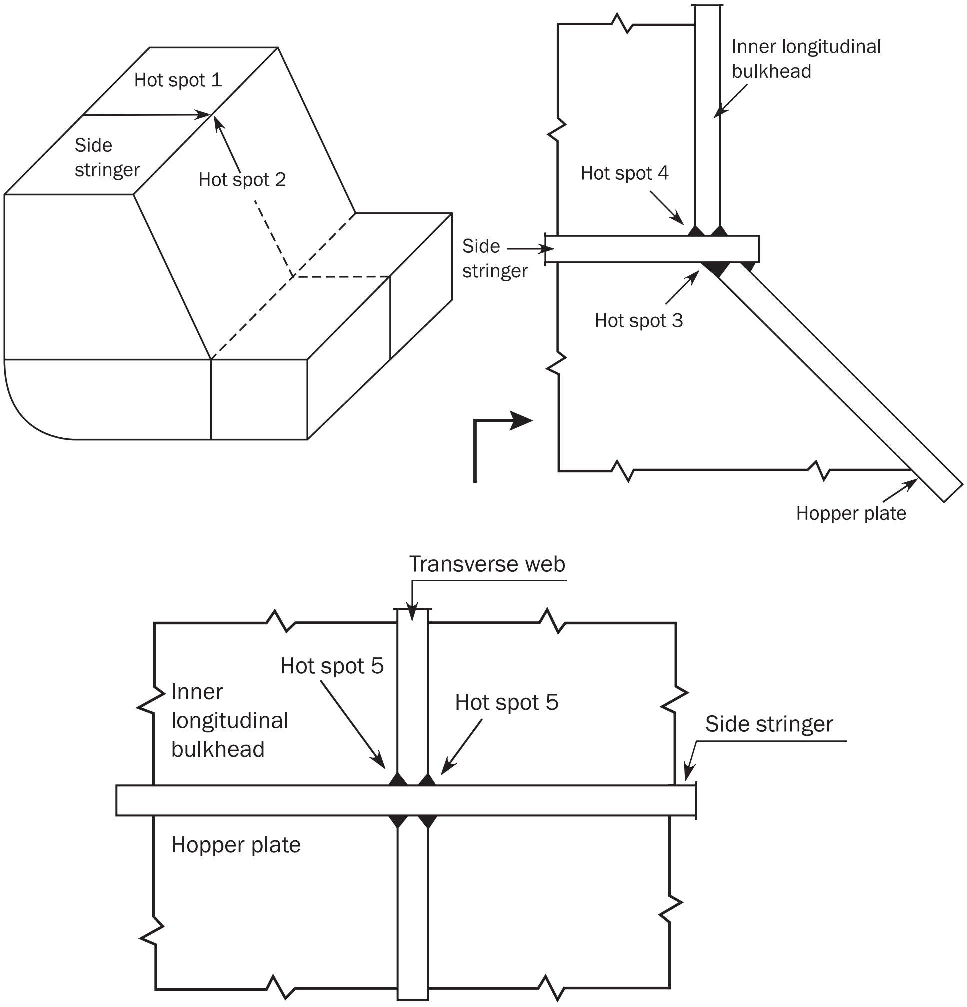


Table 7 : Hot spots for connections of transverse bulkhead lower stools to the inner bottom plating in way of double bottom girders

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Inner bottom plate, on cargo hold side Hot spot 2: Stool sloping plate, on cargo hold side	Ch 9, Sec 5, [4.2]
Hot spot 3: Longitudinal girder, under hold, to supporting floor in line with stool plate Hot spot 4: Longitudinal girder, under stool space to supporting floor in line with stool plate Hot spot 5: Double bottom supporting floor in line with stool plate	Ch 9, Sec 5, [4.3]

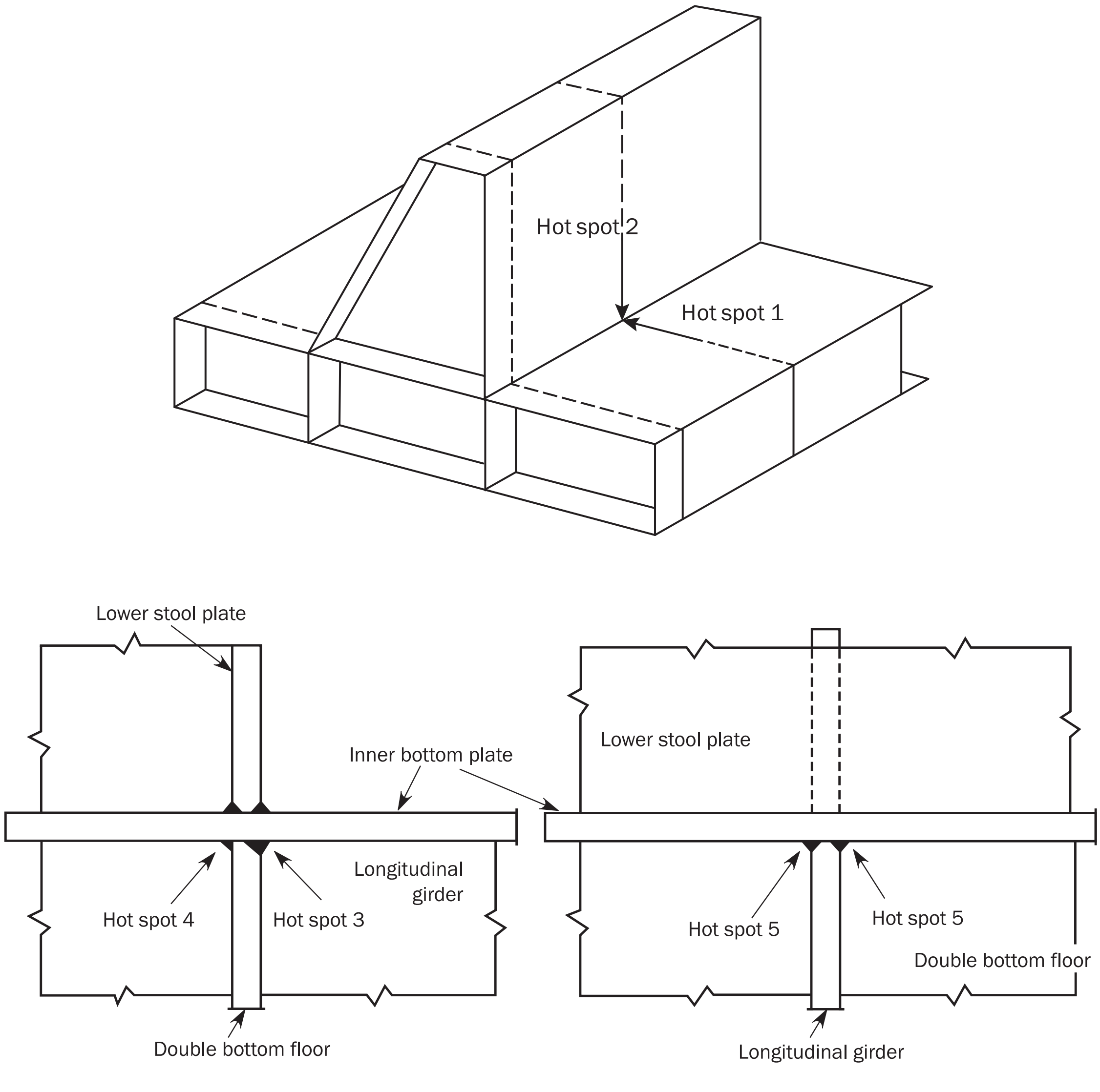


Table 8 : Hot spots for corrugated transverse bulkhead to lower stool connection

Hot spot location	Procedure for calculation of hot spot stress
Hot spots 1 and 3: Corrugation web above shedder plate Hot spot 4: Corrugation web below shedder plate Hot spot 5, 7 and 8: Corrugation flange Hot spot 6: Gusset plate Hot spot 9: Lower stool plate to stool top plate Hot spot 10: Corrugation corner to stool top plate Hot Spot 11: Gusset plate in way of corrugation corner	Ch 9, Sec 5, [3.1], type '*a*'
Hot spot 2: Corrugation web below shedder plate	Ch 9, Sec 5, [4.3]

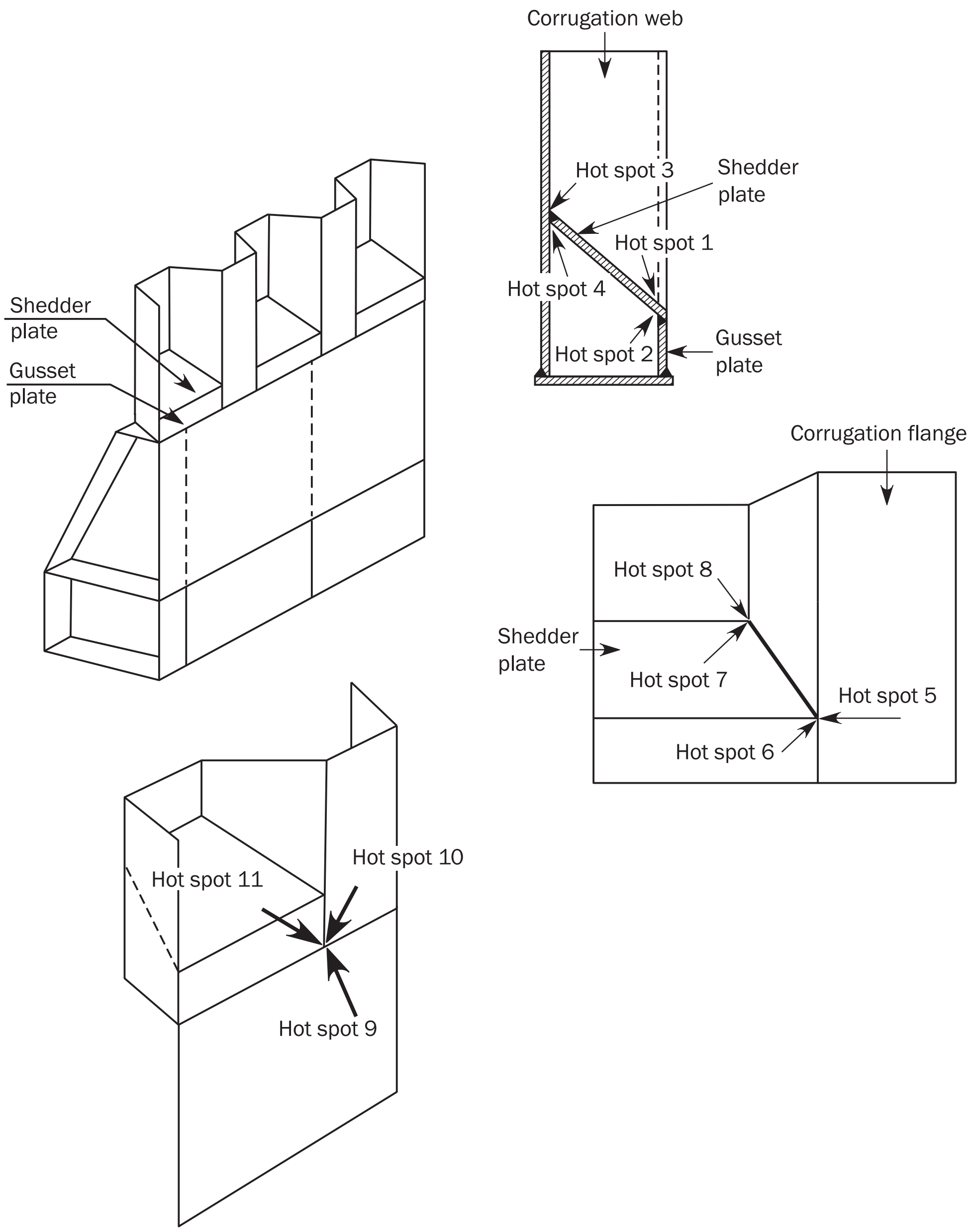


Table 9 : Hot spots for corrugated transverse bulkhead to lower stool - Intersecting shedder plates and single sided shedder plate

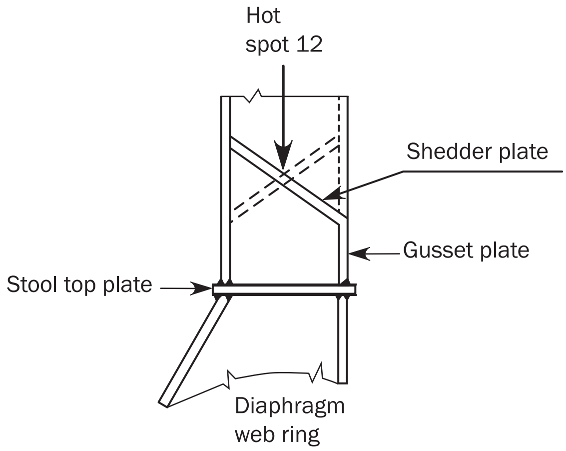
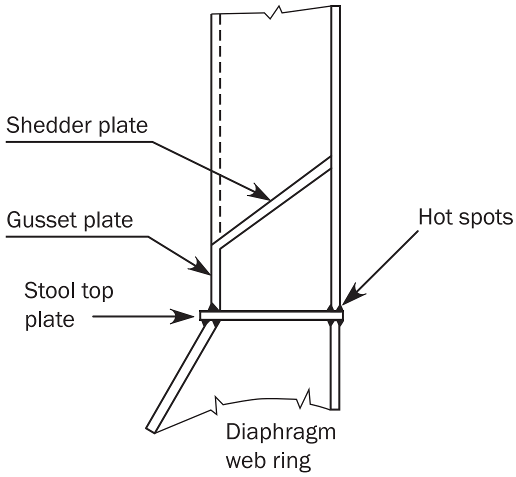
Hot spot location	Procedure for calculation of hot spot stress
Intersecting shedder plates	
Hot spot 12: Intersection of shedder plates	Ch 9, Sec 5, [3.1], type '*a*'
	
Single sided shedder plate	
Welded connection of web and flange of corrugation to lower stool top For details of hot spots see Table 10, hot spots 1-3 If supported brackets are fitted, see Table 10 for hot spots 4	Ch 9, Sec 5, [3.1], type '*a*'
	

Table 10 : Hot spots for corrugated transverse bulkhead to lower stool or inner bottom plating connection

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Inner bottom/lower stool top Hot spot 2: Corner of corrugation flange in way of inner bottom/lower stool top Hot spot 3: Corner of corrugation web in way of inner bottom/lower stool top Hot spot 4: Inner bottom/lower stool top in way of brackets supporting corrugation web	Ch 9, Sec 5, [3.1], type '*a*'
Hot spot 5: Edge of supporting brackets	Ch 9, Sec 5, [3.2].

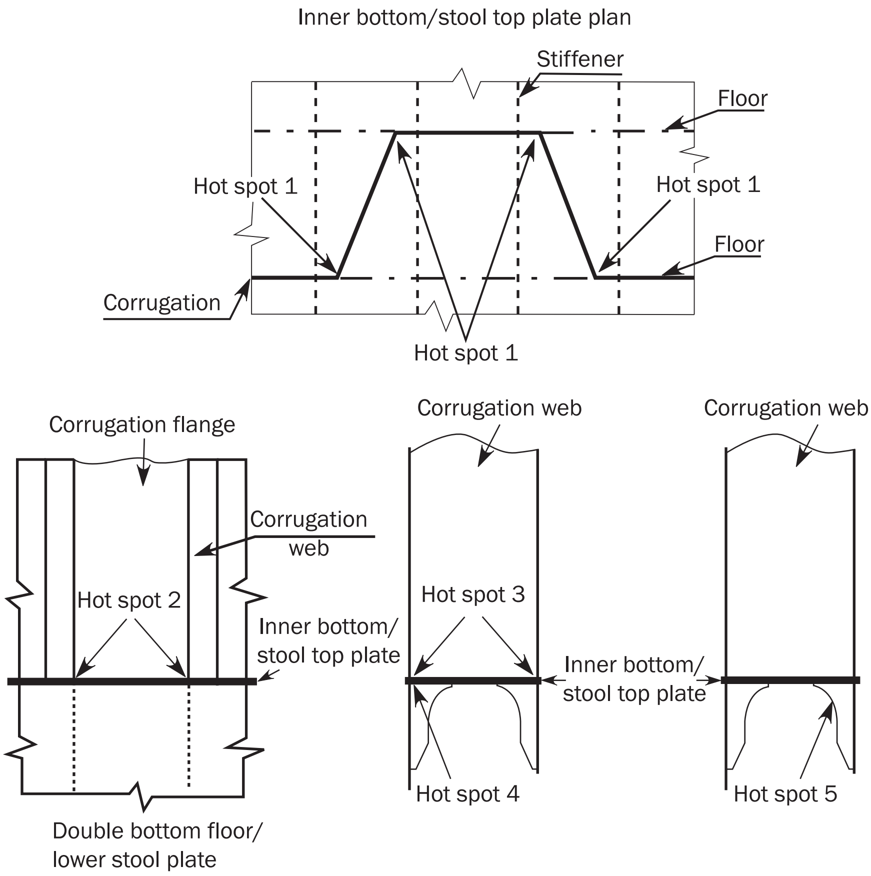


Table 11 : Hot spots for connections of corrugated longitudinal bulkhead to lower stool top

Hot spot location	Procedure for calculation of hot spot stress
See Table 9	Ch 9, Sec 5, [3.1], type '*a*'

Table 12 : Hot spots for connections of corrugated transverse bulkhead to upper stool bottom plate or to deck plate for tanker design without top stool

Hot spot location	Procedure for calculation of hot spot stress
See Table 8 and Table 9 Additional bending stresses in the deck stiffeners in way of corrugation flange induced by the bulkhead need to be considered	

Table 13 : Hot spots for connection between transverse bulkhead and inner hull longitudinal bulkhead in way of transverse bulkhead horizontal stringer and side stringer without backing bracket at stringer heel

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Inner hull longitudinal bulkhead plate on cargo tank side connection to plane side of transverse bulkhead (i.e. opposite side to stiffening) at heel of transverse bulkhead horizontal stringer Hot spot 2: Transverse bulkhead plate on plane side (i.e. opposite stiffening) at heel of transverse bulkhead horizontal stringer	Ch 9, Sec 5, [4.2]
Hot spot 3: Heel of transverse bulkhead horizontal stringer Hot spot 4: Side stringer in double side diagonally opposite horizontal stringer Hot spot 5: Side stringer in double side in line with horizontal stringer	Ch 9, Sec 5, [4.3]

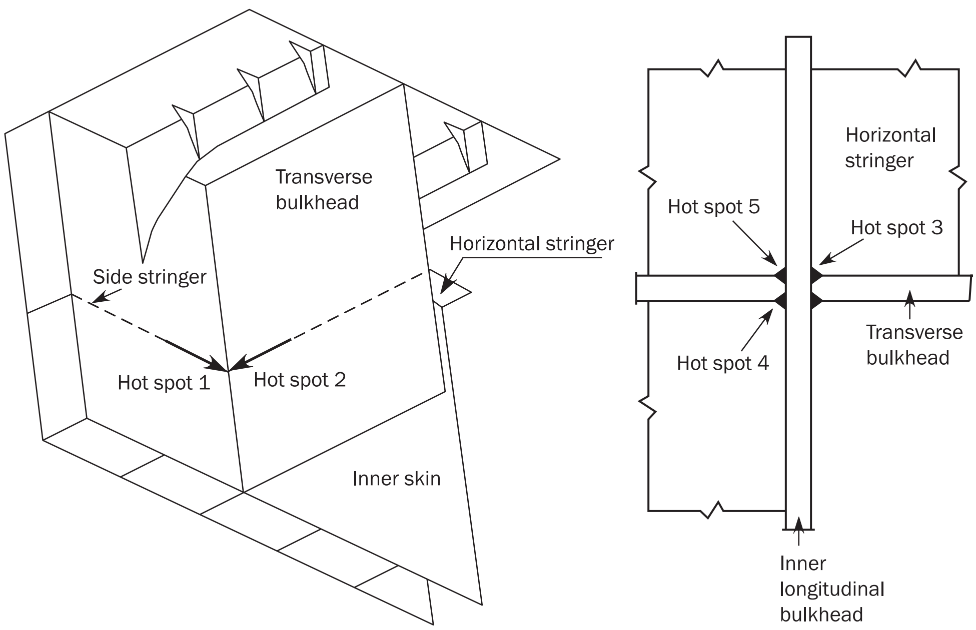


Table 14 : Hot spots for connection between transverse bulkhead and inner hull longitudinal bulkhead in way of transverse bulkhead horizontal stringer and side stringer, with backing bracket at stringer heel

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Bracket edge where a face plate is not fitted to the bracket Hot spot 4: Radius of bracket toe	Ch 9, Sec 5, [3.2]
Hot spot 2: Inner longitudinal bulkhead at bracket toe Hot spot 3: Transverse bulkhead at bracket toe Hot spot 6: Side stringer, in way of bracket toe Hot spot 7: Horizontal stringer in way of bracket toe	Ch 9, Sec 5, [3.1], type '*a*'
Hot spot 5: Where a face plate is fitted to the bracket, the weld connection of face plate to bracket in way of the face plate termination	Ch 9, Sec 5, [3.1], type '*b*'

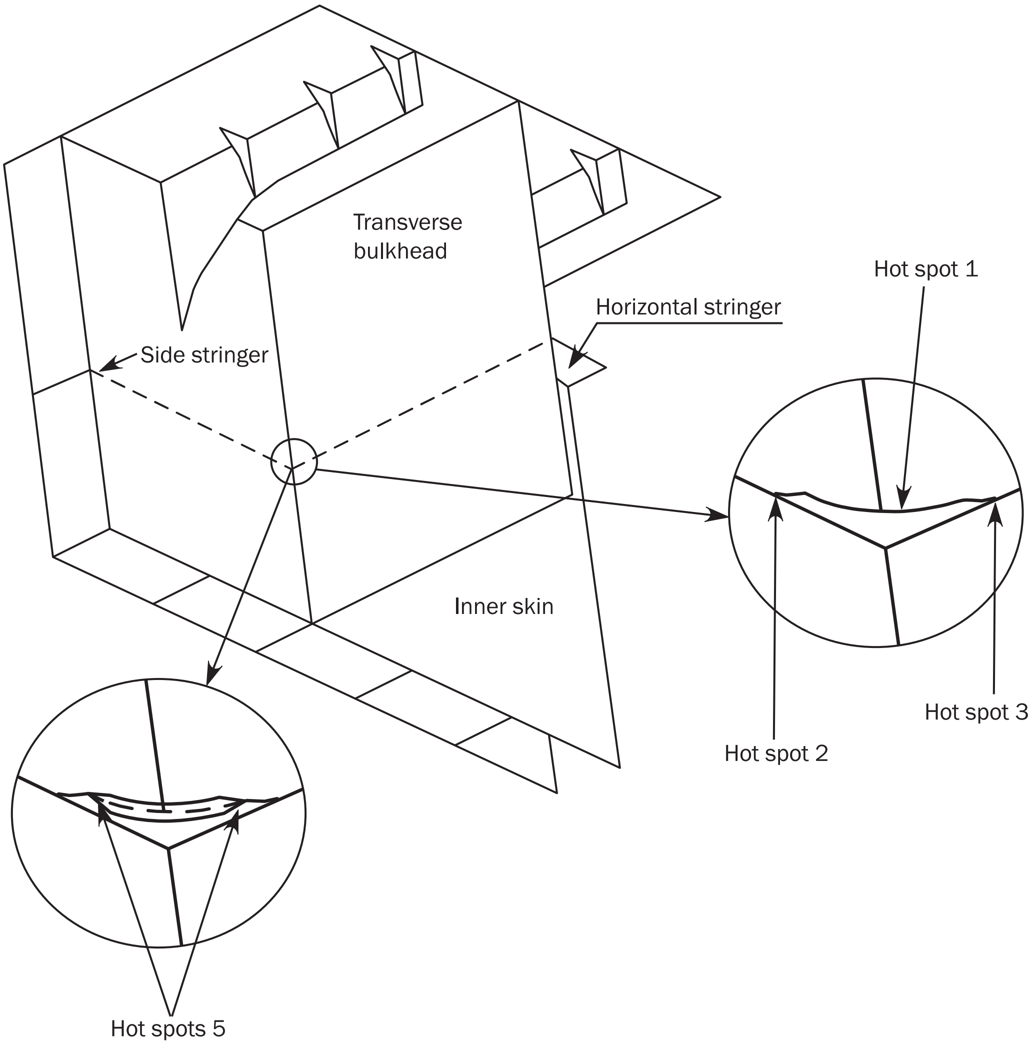


Table 15 : Hot spots for lower side frame bracket toe

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Hopper sloping plate in way of hold frame toe	Ch 9, Sec 5, [3.1], type '*a*'
Hot spot 2: Hold frame toe in way of face plate termination	Ch 9, Sec 5, [3.1], type '*b*'

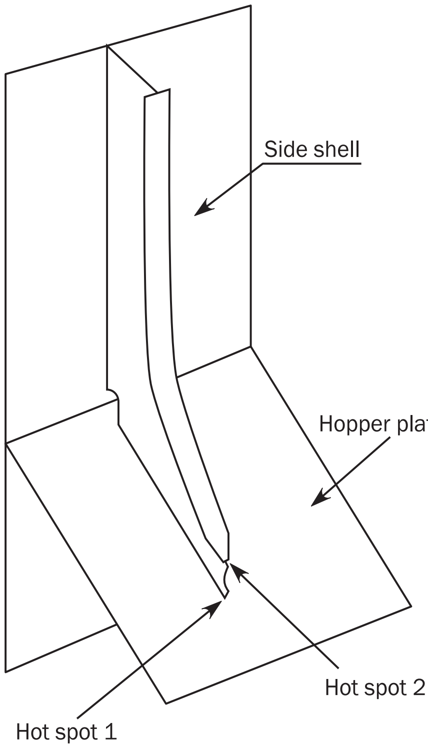


Table 16 : Hot spots for connection of longitudinal stiffener and transverse web including cut-outs and lug plates

Hot spot location	Procedure for calculation of hot spot stress
The critical hot spot has to be decided for each design in agreement with the Society. Typically the following three hot spot types are to be considered:	
Hot spot 1: Corners of the cut-out edge	Ch 9, Sec 5, [3.1].
Hot spot 2: Connection of transverse web/lug-plate to longitudinal stiffener web in way of slot Hot spot 3: Overlapping connection between transverse web and lug plate	Ch 9, Sec 5, [3.1], type '*b*'

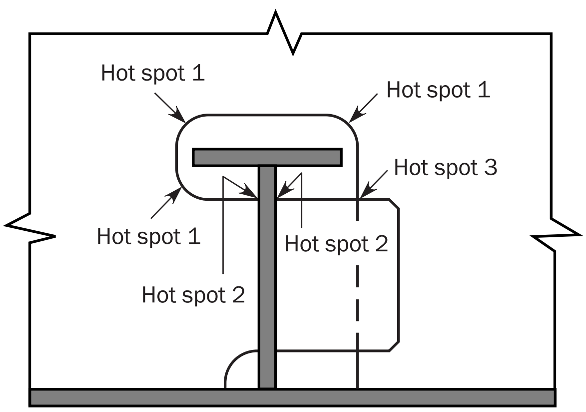


Table 17 : Hot spots for scallops in way of block connections joints at deck

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Butt weld in longitudinal stiffener web in way of scallop. Hot spot 2: Deck plate in way of scallop.	Ch 9, Sec 5, [3.1], type '*a*'

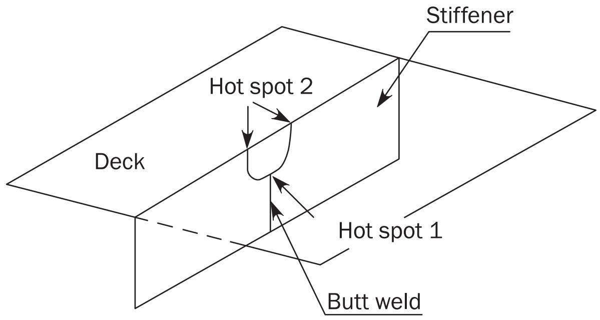
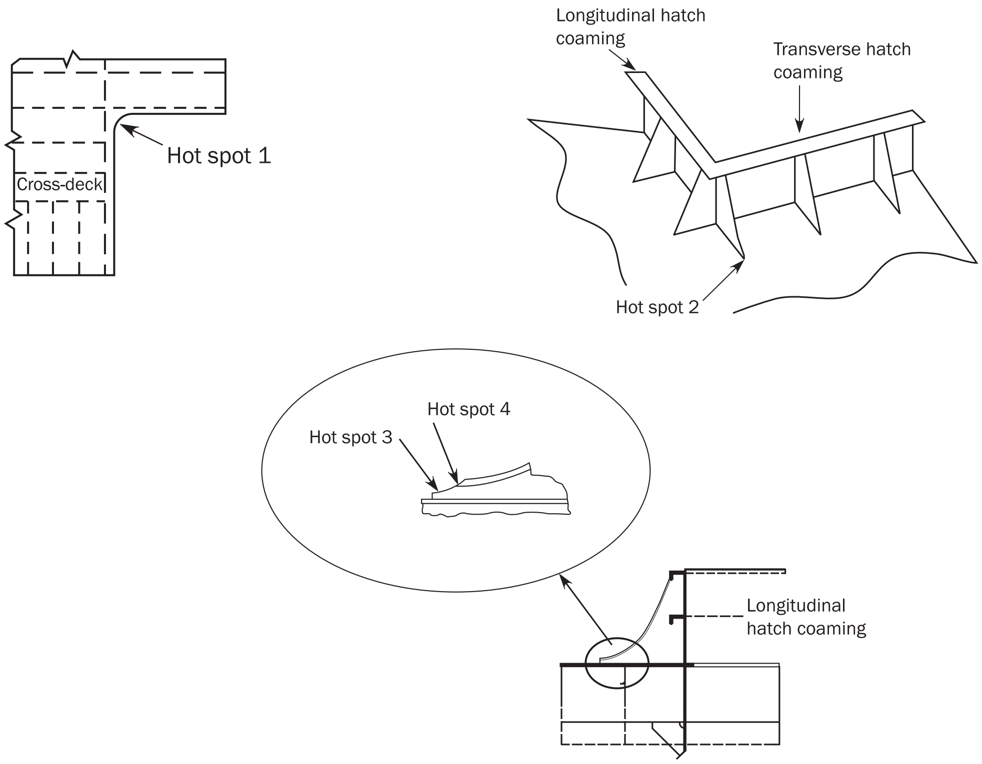


Table 18 : Hot spots for deck plating and longitudinal hatch coaming end bracket toe

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Hatch corner radiused edge Hot spot 3: Radius of hatch coaming bracket toe	Ch 9, Sec 5, [3.2]
Hot spot 2: Deck plating in way of hatch coaming bracket toe	Ch 9, Sec 5, [3.1], type '*a*'
Hot spot 4: Where a face plate is fitted to the bracket, the weld connection of face plate to bracket in way of the face plate termination	Ch 9, Sec 5, [3.1], type '*b*'



SECTION 3
FATIGUE EVALUATION

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

(i) : Suffix which denotes load case HSM, FSM, BSR-P, BSR-S, BSP-P, BSP-S, OST-P or OST-S specified in Ch 4, Sec 2, [3].

'*i1*' denotes load case: HSM-1, FSM-1, BSR-1P, BSR-1S, BSP-1P, BSP-1S, OST-1P or OST-1S.

'*i2*' denotes load case: HSM-2, FSM-2, BSR-2P, BSR-2S, BSP-2P, BSP-2S, OST-2P or OST-2S.

(j) : Suffix which denotes loading condition:

Full load or normal ballast for oil tankers as defined in Ch 9, Sec 1, [6.2].

Full load homogeneous, full load alternate, normal ballast or heavy ballast for bulk carriers as defined in Ch 9, Sec 1, [6.3].

T_C : Time in corrosive environment, in years, according to Table 5.

T_D : Design life, in years, to be taken as 25 years.

T_{DF} : Design fatigue life, in year, as defined in Ch 9, Sec 1.

T_F : Fatigue life, in year, calculated according to [5].

m : Inverse slope of the design S-N curve, as given in Table 2 for in-air environment and in Table 3 for corrosive environment.

The inverse slope for S-N curves in-air environment changes from m to m+2 at $N = 10^7$ cycles.

n_{LC} : Number of applicable loading conditions, as defined in Ch 9, Sec 1, [6.2] and Ch 9, Sec 1, [6.3].

f_c : Correction factor as defined in Ch 9, Sec 1, [5.1.2].

f_{thick} : Correction factor for plate thickness effect given in [3.3].

$f_{mean,\, i(j)}$: Correction factor for mean stress effect given in [3.2]

1 FATIGUE ANALYSIS METHODOLOGY

1.1 Cumulative damage

1.1.1

The fatigue assessment of the structure is based on the application of the Palmgren-Miner cumulative damage D taken as:

$$D = \sum_{i=1}^{n_{tot}} \frac{n_i}{N_i}$$

where:

n_i : Number of cycles at stress range $\Delta\sigma_i$.

N_i : Number of cycles to failure at stress range $\Delta\sigma_i$.

n_{tot} : Total number of stress range blocks.

i : Stress range block index.

1.1.2

As the long term stress range distribution of a structural detail in a ship can be described by a two-parameter Weibull distribution, as given in Ch 9, Sec 1, [3.1.1], fatigue damage can be obtained by means of a closed-form equation, as given in [5].

1.2 Fatigue strength assessment

1.2.1

Assessment of the fatigue strength of structural members according to [2] includes the following three steps:

a) Calculation of stress ranges, according to [3].

b) Selection of the design S-N curve, according to [4].

c) Calculation of the cumulative damage and the fatigue life calculation, according to [5].

2 ACCEPTANCE CRITERIA

2.1 Fatigue life and acceptance criteria

2.1.1

The calculated fatigue life, T_F, is to comply with the following formula:

$$T_F \geq T_{DF}$$

3 REFERENCE STRESSES FOR FATIGUE ASSESSMENT

3.1 Fatigue stress range

3.1.1

The fatigue stress range for each load case of each loading condition is defined in [3.1.2] for welded joints and in [3.1.3] for base material free edge.

The stress range of each loading condition *(j)* to be considered is the stress range obtained from the predominant load case, according to Ch 9, Sec 1, [7.1.2].

$$\Delta\sigma_{FS,\ (j)} = max_i\ (\Delta\sigma_{FS,\ i(j)})$$

where:

$\Delta\sigma_{FS,\ i(j)}$: Fatigue stress range, in N/mm², for load case *(i)* of loading condition *(j),* as defined in [3.1.2] for welded joints and in [3.1.3] for base material free edge.

3.1.2 Welded joints

For welded joints, the fatigue stress range $\Delta\sigma_{FS,i(j)}$, in N/mm², corrected for mean stress effect, thickness effect and warping effect, is taken as:

- For simplified stress analysis:

$$\Delta\sigma_{FS,\,i(j)} = f_{mean,\ i(j)} \cdot f_{thick} \cdot f_{warp} \cdot \Delta\sigma_{HS,\ i(j)}$$

- For FE analysis:
  - For web-stiffened cruciform joints:

    $$\Delta\sigma_{FS,\,i(j)} = max(\Delta\sigma_{FS1,\,i(j)},\,\Delta\sigma_{FS2,\,i(j)})$$

  - For other joints:

    $$\Delta\sigma_{FS,\,i(j)} = max_{(SideL,\,SideR)}[max(\Delta\sigma_{FS1,\,i(j)},\,\Delta\sigma_{FS2,\,i(j)})]$$

where:

$\Delta\sigma_{HS,i(j)}$: Hot spot stress range, in N/mm^2, due to dynamic loads in load case (*i*) of loading condition *(j)* given in Ch 9, Sec 4, [2.1.1].

$\Delta\sigma_{FS1,\,i(j)}$: Fatigue stress range, in N/mm^2,due to the principal hot spot stress range $\Delta\sigma_{HS1,\,i(j)}$

$$\Delta\sigma_{FS1,\,i(j)} = f_{mean1,\;i(j)} \cdot f_{thick} \cdot f_c \cdot \Delta\sigma_{HS1,\;i(j)}$$

$\Delta\sigma_{FS2,\,i(j)}$: Fatigue stress range, in N/mm^2,due to the principal hot spot stress range $\Delta\sigma_{HS2,\,i(j)}$

$$\Delta\sigma_{FS2,\,i(j)} = 0.9 \cdot f_{mean2,\;i(j)} \cdot f_{thick} \cdot f_c \cdot \Delta\sigma_{HS2,\;i(j)}$$

SideL, *SideR*: Left and right side respectively of the line A-A as shown in Ch 9, Sec 5, Figure 15 and Ch 9, Sec 5, Figure 16.

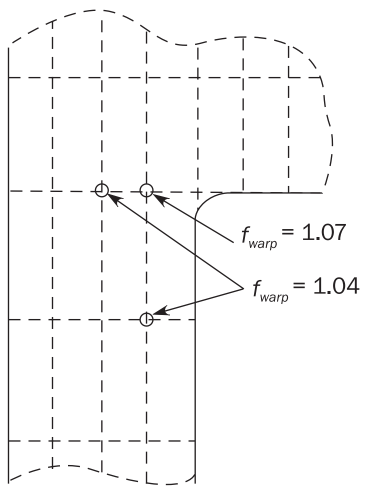
$f_{mean1,\,i(j)}$: Correction factor for mean stress effect given in [3.2].

$f_{mean2,\,i(j)}$: Correction factor for mean stress effect given in [3.2].

f_{warp} : Correction factor due to warping effect, taken as:

- f_{warp} = 1.07 for the deck longitudinal stiffener of bulk carrier, the closest to the longitudinal hatch coaming in way of the hatch corner as shown in Figure 1,
- f_{warp} = 1.04 for following deck longitudinal stiffeners of bulk carrier:
  - The closest stiffener to the longitudinal hatch coaming at one web frame away from the hatch corner, in way of the hatch opening as shown in Figure 1,
  - The second closest stiffener away from the longitudinal hatch coaming in way of the hatch corner as shown in Figure 1,
- f_{warp} = 1.0 for the other cases.

Figure 1 : Warping effect on deck longitudinal stiffeners of bulk carrier



$\Delta\sigma_{HS1,\,i(j)}$: Principal hot spot stress ranges, in N/mm^2, due to dynamic loads for load case (*i*) of loading condition *(j)* which acts within ±45° of the perpendicular to the weld toe, determined in Ch 9, Sec 5, [3.1.2], Ch 9, Sec 5, [3.3.2] and Ch 9, Sec 5, [4.2.3] for the two types of shell elements (4-node or 8-node).

$\Delta\sigma_{HS2,\ i(j)}$: Principal hot spot stress ranges, in N/mm², due to dynamic loads for load case (*i*) of loading condition *(j)* which acts outside ±45° of the perpendicular to the weld toe, determined in Ch 9, Sec 5, [3.1.2], Ch 9, Sec 5, [3.3.2] and Ch 9, Sec 5, [4.2.3] for the two types of shell elements (4-node or 8-node).

3.1.3 Base material free edge

For base material free edge, the fatigue stress range, $\Delta\sigma_{FS,i(j)}$ in N/mm², is taken as the local stress range at free edge, $\Delta\sigma_{BS,i(j)}$, as defined in Ch 9, Sec 1, [2.4] with correction factors:

$$\Delta\sigma_{FS,\ i(j)} = K_{sf} \cdot f_{material} \cdot f_{mean,\ i(j)} \cdot f_{thick} \cdot \Delta\sigma_{BS,\ i(j)}$$

where:

K_{sf} : Surface finishing factor for base material given in [4.2.3].

$f_{material}$: Correction factor for material strength, taken as:

$$f_{material} = \frac{1200}{965 + R_{eH}}$$

$\Delta\sigma_{BS,\ i(j)}$: Local stress range, in N/mm², due to dynamic loads in load case (*i*) of loading condition *(j)* taken as:

$$\Delta\sigma_{BS,\ i(j)} = |\sigma_{BS,\ i1(j)} - \sigma_{BS,\ i2(j)}|$$

$\sigma_{BS,\ i1(j)}$, $\sigma_{BS,\ i2(j)}$: Local stress, in N/mm², in load case '*i1*' and '*i2*' of loading condition *(j),* obtained by very fine mesh FE analysis specified in Ch 9, Sec 5.

3.2 Mean stress effect

3.2.1 Correction factor for mean stress effect

The mean stress correction factor to be considered for each principal hot spot stress range of welded joint, $\Delta\sigma_{HS,\ i(j)}$, or for local stress range at free edge, $\Delta\sigma_{BS,\ i(j)}$, is taken as:

a) For welded joint:

$$f_{mean,\ i(j)} = \begin{cases} min\left[1.0,\ 0.9 + 0.2\,\dfrac{\sigma_{mCor,\ i(j)}}{2\Delta\sigma_{HS,\ i(j)}}\right] & \text{for } \sigma_{mCor,\ i(j)} \geq 0 \\ max\left[0.3,\ 0.9 + 0.8\,\dfrac{\sigma_{mCor,\ i(j)}}{2\Delta\sigma_{HS,\ i(j)}}\right] & \text{for } \sigma_{mCor,\ i(j)} < 0 \end{cases}$$

b) For base material:

$$f_{mean,\ i(j)} = \begin{cases} min\left[1.0,\ 0.8 + 0.4\,\dfrac{\sigma_{mCor,\ i(j)}}{2\Delta\sigma_{BS,\ i(j)}}\right] & \text{for } \sigma_{mCor,\ i(j)} \geq 0 \\ max\left[0.3,\ 0.8 + \dfrac{\sigma_{mCor,\ i(j)}}{2\Delta\sigma_{BS,\ i(j)}}\right] & \text{for } \sigma_{mCor,\ i(j)} < 0 \end{cases}$$

where:

$$\sigma_{mCor,\ i(j)} = \begin{cases} \sigma_{mean,\ i(j)} & \text{for } \sigma_{max} \leq R_{eEq} \\ R_{eEq} - \sigma_{max} + \sigma_{mean,\ i(j)} & \text{for } \sigma_{max} > R_{eEq} \end{cases}$$

$$\sigma_{max} = \begin{cases} max_{i,\ (j)}(\Delta\sigma_{HS,\ i(j)} + \sigma_{mean,\ i(j)}) & \text{for welded joint} \\ max_{i,\ (j)}(\Delta\sigma_{BS,\ i(j)} + \sigma_{mean,\ i(j)}) & \text{for base material} \end{cases}$$

$$R_{eEq} = max(315;\ R_{eH})$$

$\sigma_{mean,\ i(j)}$: Fatigue mean stress, in N/mm², for base material or welded joint calculated according to [3.2.2].

3.2.2 Mean stress for base material free edge

The fatigue mean stress for base material free edge, $\sigma_{mean,i(j)}$, in N/mm^2, due to static and dynamic loads case '*i1*' and '*i2*' of loading condition *(j)* is calculated by the following formula based on local stress:

$$\sigma_{mean,\ i(j)} = \frac{\sigma_{BS,\ i1(j)} + \sigma_{BS,\ i2(j)}}{2}$$

3.2.3 Mean stress for simplified method

The fatigue mean stress to be considered for welded joint assessed by the simplified stress analysis is to be obtained from Ch 9, Sec 4, [2.2].

3.2.4 Mean stress for FE analysis

The fatigue mean stresses for welded joint due to static and dynamic loads, $\sigma_{mean,\ i(j),pX}$ and $\sigma_{mean,\ i(j),pY}$, in N/mm^2, for load cases '*i1*' and '*i2*' of loading condition (j) ,belonging to the two principal hot spot stress range directions, *pX* and *pY*, is calculated by the following formula based on hot spot stress components as defined in Ch 9, Sec 5, [3.1.2], Ch 9, Sec 5, [3.3.2] and Ch 9, Sec 5, [4.2.3]:

$$\sigma_{mean,\ i(j)pX} = \frac{(\sigma_{HS,\ i1(j)})_{xx} + (\sigma_{HS,\ i2(j)})_{xx} + (\sigma_{HS,\ i1(j)})_{yy} + (\sigma_{HS,\ i2(j)})_{yy}}{4} +$$
$$\left(\frac{(\sigma_{HS,\ i1(j)})_{xx} + (\sigma_{HS,\ i2(j)})_{xx} - (\sigma_{HS,\ i1(j)})_{yy} - (\sigma_{HS,\ i2(j)})_{yy}}{4}\right) \cdot \cos 2\theta + \left(\frac{(\sigma_{HS,\ i1(j)})_{xy} + (\sigma_{HS,\ i2(j)})_{xy}}{2}\right) \cdot \sin 2\theta$$

$$\sigma_{mean,\ i(j)pY} = \frac{(\sigma_{HS,\ i1(j)})_{xx} + (\sigma_{HS,\ i2(j)})_{xx} + (\sigma_{HS,\ i1(j)})_{yy} + (\sigma_{HS,\ i2(j)})_{yy}}{4} -$$
$$\frac{(\sigma_{HS,\ i1(j)})_{xx} + (\sigma_{HS,\ i2(j)})_{xx} - (\sigma_{HS,\ i1(j)})_{yy} - (\sigma_{HS,\ i2(j)})_{yy}}{4} \cdot \cos 2\theta - \left(\frac{(\sigma_{HS,\ i1(j)})_{xy} + (\sigma_{HS,\ i2(j)})_{xy}}{2}\right) \cdot \sin 2\theta$$

θ : Angle between the direction x of the element coordinate system and the principal direction *pX* of the principal hot spot stress range coordinate system (Ch 9, Sec 5, [3.1.2], Ch 9, Sec 5, [4.2.3]). The direction x of the element coordinate system is defined as the normal to the weld toe.

The one of the two mean stresses $\sigma_{mean,\ i(j),pX}$ and $\sigma_{mean,\ i(j),pY}$ which has a principal stress direction with an absolute value less than 45° is defined as $\sigma_{mean1,\ i(j)}$, belonging to $\Delta\sigma_{HS1,\ i(j)}$. The other mean stress is defined as $\sigma_{mean2,\ i(j)}$ belonging to $\Delta\sigma_{HS2,\ i(j)}$.

3.3 Thickness effect

3.3.1

Plate thickness primarily influences the fatigue strength of welded joints through the effect of geometry, and through-thickness stress distribution. The correction factor, f_{thick}, for plate thickness effect is taken as:

- For $t_{n50} \leq 22$ mm, $f_{thick} = 1.0$.
- For $t_{n50} > 22$ mm, $f_{thick} = (t_{n50}/22)^n$

where:

t_{n50} : Net thickness of the considered member in way of the hot spot for welded joints or base material free edge, in mm.

- For simplified stress analysis, the net thickness to be considered for stiffeners is as follows:
  - Flat bar and Bulb profile: no correction,
  - Angle bar and T-bar: flange net thickness.
- For FE analysis, the net thickness to be considered is the net thickness of the member where the crack is likely to initiate and propagate.

For 90° attachments, i.e. cruciform welded joints, transverse T-joints and plates with transverse attachment, the net thickness to be considered is to be taken as:

$$t_{n50} = min\left(\frac{d}{2}, t_{1n50}\right)$$

n : Thickness exponent provided in Table 1 and Table 4 respectively for welded and non-welded joints. n is to be selected according to the considered stress direction. For this selection, $\Delta\sigma_{HS1}$ and $\Delta\sigma_{HS2}$ are considered perpendicular and parallel to the weld respectively.

d : Toe distance, in mm, as shown in Figure 2, taken as:

$$d = t_{2n50} + 2\ell_{leg}$$

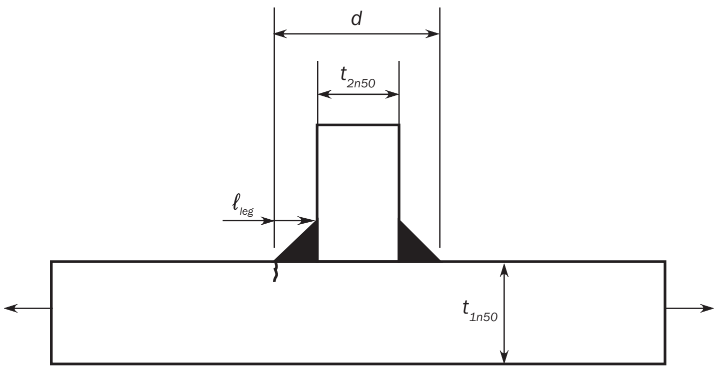
t_{1n50} : Net thickness, in mm, of the continuous plate as shown in Figure 2.

t_{2n50} : Net thickness, in mm, of the transverse attach plate where the hot spot is assessed, as shown in Figure 2.

ℓ_{leg} : Fillet weld leg length, in mm.

When post-weld treatment methods are applied to improve the fatigue life of considered welded joint, the thickness exponent is provided in [6].

Figure 2 : Toe distance for cruciform welded joints, transverse T-joints and plates with transverse attachment



4 S-N CURVES

4.1 Basic S-N curves

4.1.1 Capacity

The capacity of welded steel joints and steel base material with respect to fatigue strength is defined by S-N curves which provide the relationship between the stress range applied to the detail and the number of constant amplitude load cycles to failure.

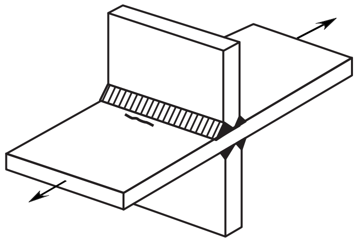
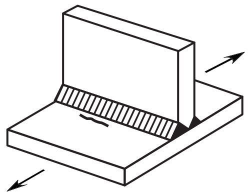
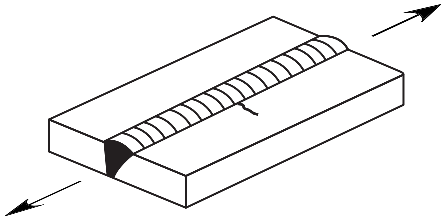
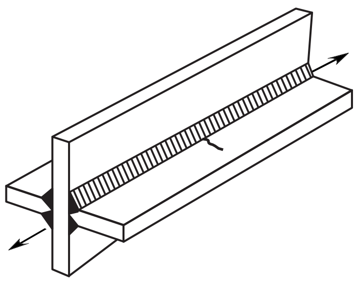
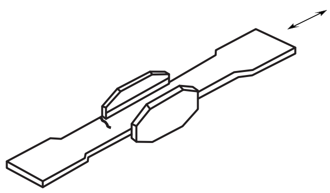
4.1.2 Design S-N curves

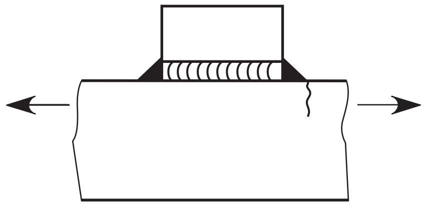
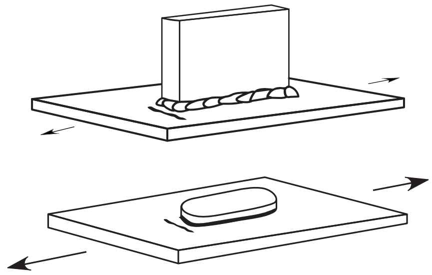
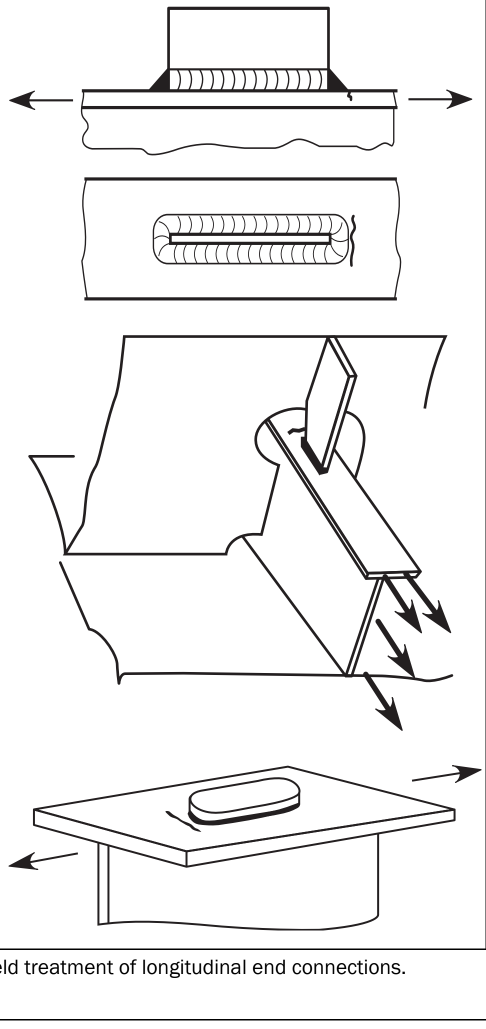
The fatigue assessment is based on use of S-N curves which are obtained from fatigue tests. The design S-N curves are established at two standard deviations below the mean S-N curves corresponding to 50% of probability of survival for relevant experimental data. Design S-N curves given in Table 2 and Table 3 correspond to a probability of survival of 97.7%.

4.1.3 S-N curve scope of application

The S-N curves are applicable to normal and high strength steels up to a specified minimum yield stress equal to 390 N/mm².

Table 1 : Welded joints: thickness exponents

No	Joint category description	Geometry	Condition	*n*
1	Cruciform joints, transverse T-joints, plates with transverse attachments		As-welded	0.25
			Weld toe treated by post-weld improvement method	0.2
2	Transverse butt welds		As-welded	0.2
			Ground flush or weld toe treated by post-weld improvement method	0.1
3	Longitudinal welds or attachments to plate edges		Any	0.1
		 	Weld toe treated by post-weld improvement method	0.1
(1)	No benefit applicable for post-weld treatment of longitudinal end connections.			

No	Joint category description	Geometry	Condition	*n*
4	Longitudinal attachments on the flat bar or bulb profile		Any	0
			Weld toe treated by post-weld improvement method (1)	0
5	Longitudinal attachments and doubling plates		As-welded	0.2
			Weld toe treated by post-weld improvement method	0.1
6	Longitudinal attachments and doubling plates supported longitudinally		As-welded	0.1
			Weld toe treated by post-weld improvement method (1)	0
(1)	No benefit applicable for post-weld treatment of longitudinal end connections.			

4.1.4 In-air environment

The basic design curves in-air environment shown in Figure 3 are represented by linear relationships between log ($\Delta\sigma$) and log (N) as follows:

$$\log(N) = \log(K_2) - m \cdot \log(\Delta\sigma)$$

where:

$\log(K_2) = \log(K_1) - 2\delta$.

K_1 : Constant related to mean S-N curve, as given in Table 2.

K_2 : Constant related to design S-N curve, as given in Table 2.

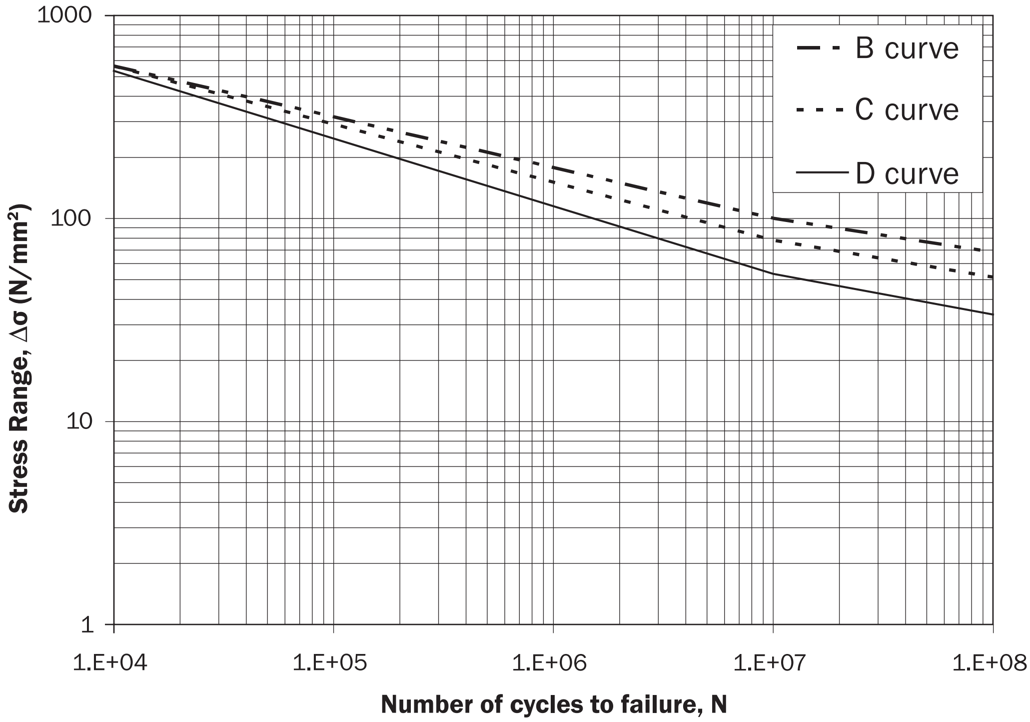
δ : Standard deviation of log (N), as given in Table 2.

$\Delta\sigma_q$: Stress range at $N = 10^7$ cycles related to design S-N curve, in N/mm², as given in Table 2.

Table 2 : Basic S-N curve data, in-air environment

Class	K_1		m	Standard deviation δ	K_2	Design stress range at 10^7 cycles	Design stress range at 2×10^6 cycles
	K_1	$\log_{10}K_1$		$\log_{10}\delta$	K_2	$\Delta\sigma_q$ N/mm²	N/mm²
B	2.343E15	15.3697	4.0	0.1821	1.01E15	100.2	149.9
C	1.082E14	14.0342	3.5	0.2041	4.23E13	78.2	123.9
D	3.988E12	12.6007	3.0	0.2095	1.52E12	53.4	91.3

Figure 3 : Basic design S-N curves, in-air environment



4.1.5 Corrosive environment

The basic design curves for corrosive environment shown in Figure 4 are represented by linear relationships between log($\Delta\sigma$) and log(N) as follows:

$$\log(N) = \log(K_2) - m \cdot \log(\Delta\sigma)$$

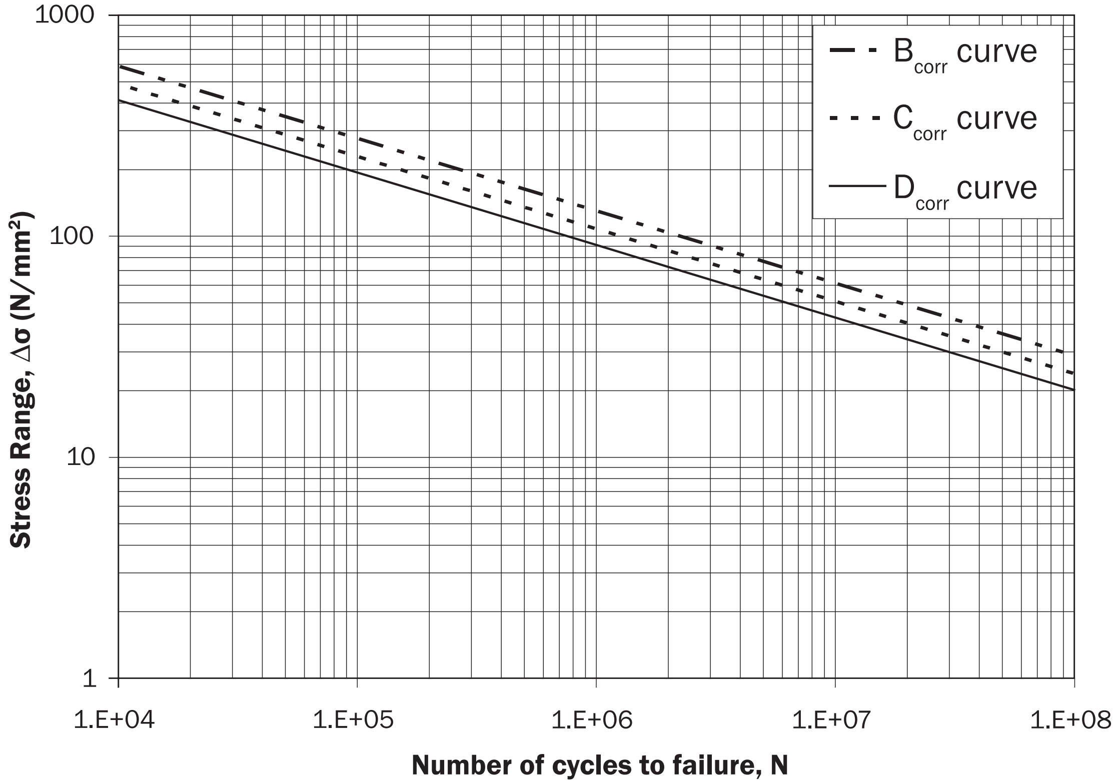
N : Predicted number of cycles to failure under stress range $\Delta\sigma$.

K_2 : Constant related to design S-N curve as given in Table 3.

Table 3 : Basic S-N curve data, corrosive environment

Class	K_2	m	Design stress range at 2×10^6 cycles, N/mm^2
B_{corr}	2.246E12	3.0	103.9
C_{corr}	1.267E12	3.0	85.9
D_{corr}	7.600E11	3.0	72.4

Figure 4 : Basic design S-N curves, corrosive environment



4.2 Selection of S-N curves

4.2.1 Welded joints

For fatigue assessment of welded joints exposed to in-air environment, S-N curve *D* as defined in Table 2 is to be used. For corrosive environment, S-N curve D_{corr} as defined in Table 3 is to be used.

4.2.2 Base material free edge

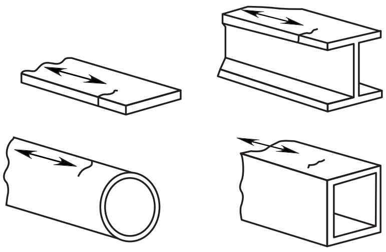
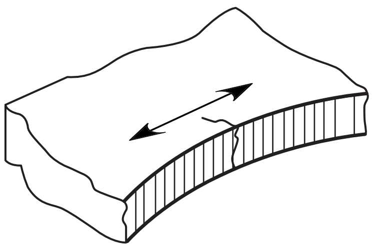
For fatigue assessment of base material at free edge exposed to in-air environment, S-N curves B or C as defined in Table 2 are to be used. For corrosive environment, S-N curves B_{corr} or C_{corr} as defined in Table 3 are to be used.

4.2.3 Surface finishing factor

The S-N curve *C* is applicable to most of non-welded locations taking into account the likelihood of some notching from corrosion, wear and tear in service with surface finishing factor as given in Table 4.

Higher surface finishing quality may be applied in using S-N curve *B* as given in Table 4, provided adequate protective measures are taken against wear, tear and corrosion.

Table 4 : Non-welded joints: thickness exponent and surface finishing factor

<table>
<tr><th colspan="2">Joint configuration, fatigue crack location and stress direction</th><th>Edge cutting process</th><th>Edge treatment</th><th>Surface finishing</th><th>n</th><th>K_{sf}</th><th>S-N curve</th></tr>
<tr><td>1</td><td>Rolled or extruded plates and sections as well as seamless pipes, no surface or rolling defects
</td><td>N/A</td><td>N/A</td><td>No surface nor roll defect</td><td>0</td><td>0.94</td><td>B</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">Cut edges
</td><td rowspan="2">Machine-cutting e.g. by a thermal process.
Sheared edge cutting.</td><td>Edges machined or ground smooth</td><td>Smooth surface free of cracks and notches</td><td>0.1</td><td>1.07</td><td>B</td></tr>
<tr><td>No edge treatment</td><td>Surface free of cracks and severe notches (inspection procedure)</td><td>0.1</td><td>1.0</td><td>C</td></tr>
<tr><td>Manually thermally cut e.g. by flame cutting</td><td>No edge treatment</td><td>Surface free of cracks and severe notches (inspection procedure)</td><td>0.1</td><td>1.24</td><td>C</td></tr>
<tr><td colspan="8">Note 1: Stress increase due to geometry of cut-outs to be considered.</td></tr>
</table>

5 FATIGUE DAMAGE CALCULATION

5.1 General

5.1.1

The design fatigue life is divided into a number of time periods due to different loading conditions and due to limitation of the corrosion protection.

It is assumed that the corrosion protection (i.e. coating system) is only effective for a limited number of years during which the structural details are protected, i.e. in-air environment. During the remaining part of the design life as specified in Table 5, the structural details are unprotected i.e. exposed to corrosive environment.

5.1.2

The elementary fatigue damage, given in [5.2], is the damage accumulated during a specific loading condition *(j)* associated with a specific environmental condition either protected condition, i.e. in-air environment, or unprotected condition, i.e. corrosive environment.

The combined fatigue damage, given in [5.3], is the combination of damage accumulated for a specific loading condition *(j)* for the in-air and corrosive environment time.

Total fatigue damage, given in [5.4], is the sum of the combined fatigue damages obtained for all loading conditions.

5.2 Elementary fatigue damage

5.2.1

The elementary fatigue damage for each fatigue loading condition *(j)* is to be calculated independently for both protected in-air environment and unprotected corrosive environment, based on the fatigue stress range obtained for the predominant load case as follows:

$$D_{E(j)} = \frac{\alpha_{(j)} \cdot N_D}{K_2} \frac{\Delta\sigma_{FS,\ (j)}^m}{(\ln N_R)^{m/\xi}} \cdot \mu_{(j)} \cdot \Gamma\left(1 + \frac{m}{\xi}\right)$$

where:

N_D : Total number of wave cycles experienced by ship during the design fatigue life, taken as:
$N_D = 31.557 \times 10^6 (f_0 T_D) / (4 \log L)$

f_0 : Factor taking into account time in seagoing operations excluding time in loading and unloading, repairs, etc.

$f_0 = 0.85$.

$\alpha_{(j)}$: Fraction of time in each loading condition given in Ch 9, Sec 1, Table 1 for oil tanker and in Ch 9, Sec 1, Table 3 for bulk carrier.

$\Delta\sigma_{FS,\ (j)}$: Fatigue stress range at the reference probability level of exceedance of 10^{-2}, in N/mm^2.

N_R : Number of cycles corresponding to the reference probability of exceedance of 10^{-2}.

$N_R = 100$.

ξ : Weibull shape parameter,

$\xi = 1$.

$\Gamma(x)$: Complete Gamma function.

K_2 : Constant of the design S-N curve, as given in Table 2 for in-air environment and in Table 3 for corrosive environment.

$\mu_{(j)}$: Coefficient taking into account the change of inverse slope of the S-N curve, m,

- For in-air environment:

$$\mu_{(j)} = 1 - \frac{\left\{\gamma\left(1 + \frac{m}{\xi}, \nu_{(j)}\right) - \nu_{(j)}^{-\Delta m/\xi} \cdot \gamma\left(1 + \left(\frac{m + \Delta m}{\xi}\right), \nu_{(j)}\right)\right\}}{\Gamma\left(1 + \frac{m}{\xi}\right)}$$

$$\nu_{(j)} = \left(\frac{\Delta\sigma_q}{\Delta\sigma_{FS,\ (j)}}\right)^{\xi} \ln N_R$$

- For corrosive environment:

$\mu_{(j)} = 1.0$

$\gamma(a,x)$: Incomplete Gamma function.

$\Delta\sigma_q$: Stress range, in N/mm^2, corresponding to the intersection of the two segments of design S-N curve at $N = 10^7$ cycles, as given in Table 2.

Δm : Change in inverse slope of S-N curve at $N=10^7$ cycles.
$\Delta m = 2$

5.3 Combined fatigue damage

5.3.1

The combined fatigue damage in protected in-air environment and unprotected corrosive environment for each loading condition *(j)* is to be calculated as follows:

$$D_{(j)} = D_{E,\ air(j)} \cdot \frac{T_D - T_C}{T_D} + D_{E,\ corr(j)} \cdot \frac{T_C}{T_D}$$

where:

$D_{E,air(j)}$: The elementary fatigue damage for in-air environment for loading condition *(j)* given in [5.2.1].

$D_{E,corr(j)}$: The elementary fatigue damage for corrosive environment for loading condition *(j)* as calculated in [5.2.1].

Table 5 : Time in corrosive environment, T_C

Location of weld joint or structural detail	Time in corrosive environment T_C, in years
Water ballast tank	5
Oil cargo tank	
Lower part (1) of bulk cargo hold and water ballast cargo hold	
Bulk cargo hold and water ballast cargo hold except lower part (1)	2
Void space Other areas	
(1) Lower part means cargo hold part below a horizontal level located at a distance of 300 mm below the frame end bracket for holds of single side skin construction or 300 mm below the hopper tank upper end for holds of double side skin construction (see Pt 2, Ch 1, Sec 2, Figure 1).	

5.4 Total fatigue damage

5.4.1

The total fatigue damage for all applicable loading conditions is calculated as follows:

$$D = \sum_{j=1}^{n_{LC}} D_{(j)}$$

where:

$D_{(j)}$: Combined fatigue damage for each applicable loading condition, as given in [5.3].

5.5 Fatigue life calculation

5.5.1

The fatigue life, T_F, is taken as:

$$T_F = \frac{T_D}{D_{air}} \qquad \text{if } \frac{T_D}{D_{air}} \leq (T_D - T_C)$$

$$T_F = T_D - T_C + \left(\frac{T_D}{D_{air}} - T_D + T_C \right) \frac{D_{air}}{D_{corr}} \text{ otherwise.}$$

where:

D_{air} : Total fatigue damage for all loading conditions in-air environment taken as:

$$D_{air} = \sum_{j=1}^{n_{LC}} D_{E,\ air(j)}$$

D_{corr} : Total fatigue damage for all loading conditions in corrosive environment taken as:

$$D_{corr} = \sum_{j=1}^{n_{LC}} D_{E,\ corr(j)}$$

6 WELD IMPROVEMENT METHODS

6.1 General

6.1.1

Post-weld fatigue strength improvement methods are to be considered as a supplementary means of achieving the required fatigue life, and subjected to quality control procedures. The benefit from post-weld treatment can only be applied for corrosion free condition and may only be considered provided that a protective coating is applied after the post-weld treatment and maintained during the design life time.

6.1.2 Limitation of the benefit of post-weld treatment

For structural details where the benefit of post-weld treatment is applicable, the calculated fatigue life at the design stage for the considered structural detail excluding the post-weld treatment effects, is not to be less than T_{DF} / 1.47.

However, for structural details inside a bulk cargo hold the calculated fatigue life at design stage excluding post-weld treatment effects is not to be less than 25 years.

Note 1: When T_{DF} is taken equal to 25 years, the calculated fatigue life at the design stage for the considered structural detail excluding the post-weld treatment effects, is not to be less than 17 years.

6.1.3 Post-weld treatment at fabrication stage

There is one basic post-weld treatment method considered in these Rules to improve fatigue strength at the fabrication stage, i.e. weld geometry control and defect removal method by burr grinding.

6.1.4 Weld toe

The improvement method is applied to the weld toe. Thus, it is intended to increase the fatigue life of the weld from the viewpoint of a potential fatigue failure arising at the weld toe. The possibility of failure initiation at other locations is always to be considered. If the failure is shifted from the weld toe to the root by applying post-weld treatment, there may be no significant improvement in the overall fatigue performance of the joint. Improvements of the weld root cannot be expected from treatment applied to weld toe.

A brief description of the method and the degree of improvement which can be achieved is given in [6.2].

6.1.5 Weld type for post-weld treatment

When weld improvements are planned, full or partial penetration welds with a minimum root face according to Ch 12, Sec 3, [2.4] are to be used to mitigate or to eliminate the possibility of cracking at the weld root.

6.2 Weld toe burr grinding

6.2.1

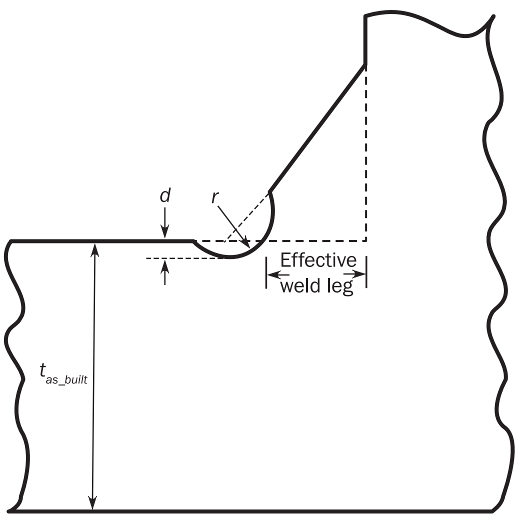
The weld may be machined using a burr grinding tool to produce a favourable shape to reduce stress concentrations and remove defects at the weld toe, see Figure 5. In order to eliminate defects, such as intrusions, undercuts and cold laps, the material in way of the weld toe is to be removed. The total depth of the burr grinding is not to be greater than the lesser of 2 mm and of 7% the local gross thickness of the machined plate. Any undercut not complying with this requirement is to be repaired by an approved method.

6.2.2

To avoid introducing a detrimental notch effect due to small radius grooves, the burr diameter is to be scaled to the plate thickness at the weld toe being ground. The diameter is to be in the 10 to 25 mm range for application to welded joints with plate thickness from 10 to 50 mm. The resulting root radius of the groove is to be no less than 0.25 t_{as_built}.The weld throat thickness and leg length after burr grinding must comply with the rule requirements or any increased weld sizes as indicated on the approved drawings.

The inspection procedure is to include a check of the weld toe radius, the depth of burr grinding, and confirmation that the weld toe undercut has been removed completely.

Figure 5 : Details of ground weld toe geometry



6.3 Fatigue improvement factor

6.3.1

The benefit of burr grinding corresponds to an increase in fatigue strength by a factor of 1.3 (i.e. a reduction of the effective stress range by 1.3), reducing the damage in air to D_{air}/ 2.2,

where:

D_{air} : Fatigue damage in air as given in Ch 9, Sec 3, [5.3.1].

6.4 Applicability

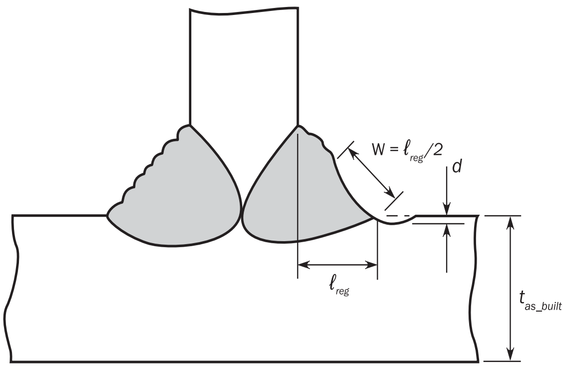
6.4.1

The application of post-weld improvement and fatigue improvement factor provided in this section is subject to following limitations:

- The weld type complies with [6.1.5].

- The weld improvement is effective in improving the fatigue strength of structural details under high cycle fatigue conditions therefore the fatigue improvements factors do not apply to low-cycle fatigue conditions, i.e. when $N \leq 5\times10^4$, where N is the number of life cycles to failure.
- Unless otherwise specifically stated, the fatigue improvement factor is to be used for welds, joining steel plates which are between 6 and 50 mm thick.
- This benefit can only be achieved in a corrosion free condition and may only be considered provided that a suitable protective coating is applied after the post-weld treatment and maintained during the design life time.
- Fatigue improvement factor is to be applied to as-welded transverse butt welds, as-welded T-joint and cruciform welds and as-welded longitudinal attachment welds excluding longitudinal end connections.
- In way of areas prone to mechanical damage, fatigue improvement may only be granted if these are adequately protected.
- Treatment of inter-bead toes is required for large multi-pass welds as shown in Figure 6.
- The builder is to provide the list of details and their locations on the ship for which the post-weld treatment has been applied.

Figure 6 : Extent of weld toe burr grinding to remove inter-bead toes on weld face



ℓ_{leg} : Weld leg length.
w : Width of groove.
d : Depth of grinding to be 0.5 mm $\leq d \leq$ 1 mm.

7 WORKMANSHIP

7.1 Application

7.1.1

In general, the fatigue performance of structural details can be improved by adopting enhanced workmanship standards, which include building alignment and weld control.

7.2 Workmanship control for construction details

7.2.1 Building alignment and tolerance control

Building alignment exceeding construction tolerance could introduce additional stress concentration for structural details, reducing the fatigue performance. The builder is responsible to comply with the construction requirements given in Ch 12, Sec 1.

7.2.2 Weld profile control

Poor weld geometry could introduce additional stress concentration; therefore special attention should be given to achieving a favourable geometry and smooth transition at the weld toe. Weld profile control, i.e. enhanced workmanship may be required by the Society in way of critical weld toe locations.

The weld notch stress concentration is a direct function of the weld flank angle and the weld toe radius.

The validity of the aforementioned S-N curves is based on a weld flank angle with a maximum mean value of 50 deg and on a weld toe radius with a minimum mean value of 0.5 mm. Welding details may be requested to be submitted for approval for some critical areas considering the calculated fatigue life.

7.2.3 Post-weld treatment methods

Post-weld treatment methods may be used to improve fatigue resistance of structural detail, as specified in [6].

At the design stage, the calculated fatigue life should not generally take into account any benefit that may be derived from such treatment. This benefit should only be considered in exceptional cases when the design fatigue life can not reasonably be achieved by adopting alternative design measures such as improvement of the shape of the cut-outs, soft brackets toes, local increase in thickness or other changes in geometry of the structural detail. This is to be considered on a case-by-case basis by the Society.

7.2.4 Detail design standard

Requirements for improved design of structural details are provided in Ch 9, Sec 6. The detail design standard also includes workmanship and welding requirements.

SECTION 4
SIMPLIFIED STRESS ANALYSIS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

(i) : Suffix which denotes dynamic load case HSM, FSM, BSR-P, BSR-S, BSP-P, BSP-S, OST-P or OST-S specified in Ch 4, Sec 2, [3.1].

'*i1*' denotes dynamic load case HSM-1, FSM-1, BSR-1P, BSR-1S, BSP-1P, BSP-1S, OST-1P or OST-1S

'*i2*' denotes dynamic load case HSM-2, FSM-2, BSR-2P, BSR-2S, BSP-2P, BSP-2S, OST-2P or OST-2S.

(j) : Suffix which denotes loading condition:

'Full load' or 'Normal ballast' for oil tankers, as defined in Ch 9, Sec 1, [6.2].

'Full load homogeneous', 'Full load alternate', 'Normal ballast' or 'Heavy ballast' for bulk carriers, as defined in Ch 9, Sec 1, [6.3].

ℓ_{bdg} : Effective bending span of stiffener, in m, as defined in Ch 3, Sec 7.

I_{y-n50} : Net vertical hull girder moment of inertia, at the longitudinal position being considered, in m^4.

I_{z-n50} : Net horizontal hull girder moment of inertia, at the longitudinal position being considered, in m^4.

y : Transverse coordinate of the load calculation point under consideration, in m.

z : Vertical coordinate of the load calculation point under consideration, in m.

z_n : Distance from the baseline to the horizontal neutral axis, in m.

f_c : Correction factor as defined in Ch 9, Sec 1, [5.1.2].

f_{NA} : Correction factor taken as:

- For bulk carrier:
  - $f_{NA} = 1.0$ for $0 < z \leq D/2$
  - $f_{NA} = 0.95$ for $z = D$
  - f_{NA} : linear interpolation for other values of z
- For oil tanker: $f_{NA} = 1.0$

K_a : Geometrical stress concentration factor for stress due to axial load given in [5.2].

K_b : Geometrical stress concentration factor for stress due to lateral pressure given in [5.2].

K_n : Stress concentration factor due to unsymmetrical stiffener geometry, as defined in [5.1].

1 GENERAL

1.1 Application

1.1.1

This section defines the procedure for a simplified stress assessment which is to be used to evaluate the fatigue strength of the longitudinal stiffener end connections.

1.1.2

The hot spot stress ranges and hot spot mean stresses in way of each end connection of longitudinal stiffener, as shown in Figure 2 are to be evaluated at the flange of the longitudinal stiffener in the following locations:

a) Transverse webs or floors other than those located
   - At transverse bulkhead including swash bulkhead of cargo hold or
   - In way of stool,

   such that additional hot spot stress due to the relative displacement is not to be considered.

b) Transverse webs or floors located
   - At transverse bulkhead including swash bulkhead of cargo hold or
   - In way of stool,

   such that additional hot spot stress due to the relative displacement are to be considered.

Stress concentration factors due to unsymmetrical stiffener geometry according [5.1] and due to the stiffener end connection geometry at point ‘A’ and ‘B’ according to [5.2] are to be applied.

1.2 Assumptions

1.2.1

The following assumptions are made in the fatigue assessment for longitudinal stiffener end connections:

a) The hot spot stress is based on:
   - Nominal stresses.
   - Stress concentration factors given in [5].
   - Loading conditions specified in Ch 9, Sec 1, [6].

b) The longitudinal stiffener end connection types are described in [5.2].

1.2.2

The end connections given in [5.2] are based on typical joint geometry under axial and lateral loadings. When a structural detail is different from those shown in Table 4, a finite element analysis is to be used to demonstrate the adequacy of the detail in terms of fatigue strength, according to [5.3].

2 HOT SPOT STRESS

2.1 Hot spot stress range

2.1.1

The hot spot stress range, in N/mm², due to dynamic loads for load case (*i*) of loading condition (*j*) is obtained from the following formula:

$$\Delta\sigma_{HS,\ i(j)} = \left|(\sigma_{GD,\ i1(j)} + \sigma_{LD,\ i1(j)} + \sigma_{dD,\ i1(j)}) - (\sigma_{GD,\ i2(j)} + \sigma_{LD,\ i2(j)} + \sigma_{dD,\ i2(j)})\right|$$

where:

$\sigma_{GD,i1(j)}$, $\sigma_{GD,i2(j)}$: Stresses due to global hull girder wave bending moments, in N/mm², as defined in [3.1.1].

$\sigma_{LD,i1(j)}$, $\sigma_{LD,i2(j)}$: Stresses due to local dynamic pressure, in N/mm², as defined in [4.1.1].

$\sigma_{dD,i1(j)}$, $\sigma_{dD,i2(j)}$: Stresses due to relative displacement in wave, in N/mm², as defined in [4.2.4] and [4.2.5].

2.2 Hot spot mean stress

2.2.1

The hot spot mean stress, in N/mm^2, due to static and dynamic loads for load case (i) of loading condition (j) is obtained from the following formula:

$$\sigma_{mean,\ i(j)} = \sigma_{GS,\ (j)} + \sigma_{LS,\ (j)} + \sigma_{dS,\ (j)} + \sigma_{mLD,\ i(j)} + \sigma_{mGD,\ i(j)}$$

where for the load case (i) of loading condition (j):

$\sigma_{GS,\ (j)}$: Stress due to still water hull girder bending moment, in N/mm², as defined in [3.2.1].

$\sigma_{LS,\ (j)}$: Stress due to local static pressure, in N/mm², as defined in [4.1.2].

$\sigma_{dS,\ (j)}$: Stress due to relative displacement in still water, in N/mm², as defined in [4.2.7].

$\sigma_{mLD,\ i(j)}$: Mean stress due to local dynamic pressure, in N/mm², as defined as:

$$\sigma_{mLD,\ i(j)} = \frac{\sigma_{LD,\ i1(j)} + \sigma_{LD,\ i2(j)}}{2}$$

$\sigma_{LD,i1(j)}$, $\sigma_{LD,i2(j)}$: Stress due to local dynamic pressure, in N/mm², as defined in [4.1.1].

$\sigma_{mGD,\ i(j)}$: Mean stress due to global wave bending moment, in N/mm², as defined as:

$$\sigma_{mGD,\ i(j)} = \frac{\sigma_{GD,\ i1(j)} + \sigma_{GD,\ i2(j)}}{2}$$

$\sigma_{GD,i1(j)}$, $\sigma_{GD,i2(j)}$: Stress due to global wave bending moment, in N/mm², as defined in [3.1.1].

3 HULL GIRDER STRESS

3.1 Stress due to hull girder wave bending moments

3.1.1

The hull girder hot spot stress, in N/mm^2, for load cases $i1$ and $i2$ of loading condition (j) is obtained from the following formula:

$$\sigma_{GD,\ ik(j)} = f_c \cdot K_a \left(\frac{M_{wv-LC,\ ik}}{I_{y-n50}} (z - z_n) \cdot f_{NA} - \frac{M_{wh-LC,\ ik}}{I_{z-n50}} y \right) 10^{-3}$$

where:

$M_{wv\text{-}LC,\ ik}$: Vertical wave bending moment, in kNm, of the considered dynamic load case, as defined in Ch 4, Sec 4, at the hull girder load calculation point of the considered longitudinal position for the loading condition (j) for ik being equal to $i1$ and $i2$.

$M_{wh\text{-}LC,\ ik}$: Horizontal wave bending moment, in kNm, of the considered dynamic load case, as defined in Ch 4, Sec 4, at the hull girder load calculation point of the considered longitudinal position for the loading condition (j) for ik being equal to $i1$ and $i2$.

3.2 Stress due to still water hull girder bending moment

3.2.1

The hull girder hot spot stress due to still water bending moment, in N/mm^2, in loading condition (j) is obtained from the following formula:

$$\sigma_{GS,\ (j)} = \frac{f_c \cdot f_{NA} \cdot K_a \cdot \beta_{(j)} \cdot M_{sw} \cdot (z - z_n)}{I_{y-n50}} 10^{-3}$$

where:

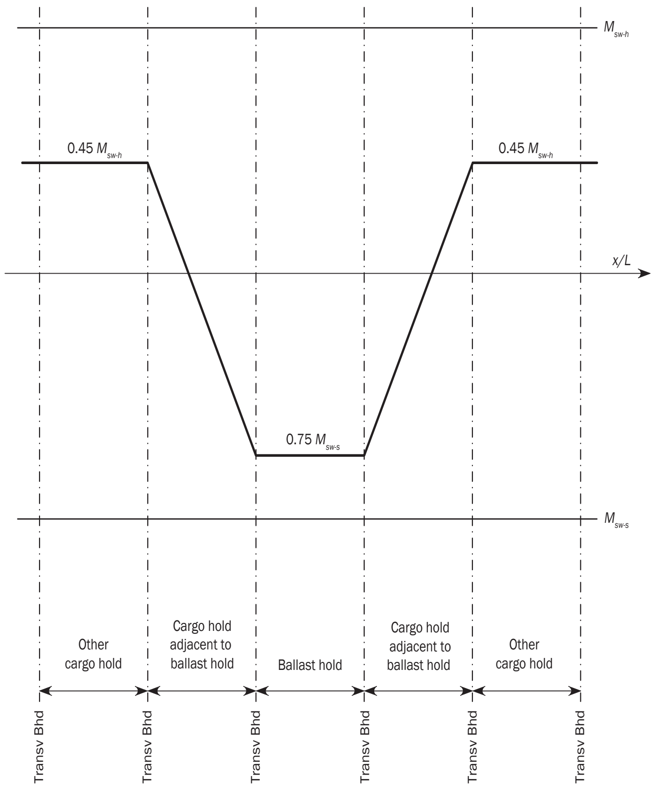
M_{sw} : Permissible still water vertical bending moment, in kNm, as defined in Ch 4, Sec 4 at the hull girder load calculation point of the considered longitudinal position.

$\beta_{(j)}$: Fraction of permissible still water vertical bending moment, as defined in Table 1.

Table 1 : Fraction of permissible still water vertical bending moments, $\beta_{(j)}$

Ship type	Loading conditions	Longitudinal position on the considered section	$\beta_{(j)}$
Oil tankers	Homogeneous	N/A	0.60 in sagging condition
	Normal ballast		0.80 in hogging condition
Bulk carriers	Homogeneous		0.40 in sagging condition
	Alternate		0.75 in hogging condition
	Normal ballast		0.80 in hogging condition
	Heavy ballast (See Figure 1)	Ballast hold	0.75 in sagging condition
		Cargo holds adjacent to ballast hold	Linear interpolation between 0.75 in sagging condition and 0.45 in hogging condition
		Other cargo holds	0.45 in hogging condition

Figure 1 : Distribution of still water bending moment for fatigue assessment in way of ballast hold



4 LOCAL STIFFENER STRESS

4.1 Stress due to stiffener bending

4.1.1 Stress due to dynamic pressure

The hot spot stress, in N/mm^2, due to local dynamic pressure in load case *i1* and *i2* for loading condition (*j*) is obtained from the following formula:

$$\sigma_{LD,\ ik(j)} = \frac{K_b\ K_n\ s\ \ell_{bdg}^2\ (\eta_W\ f_{NL}\ P_{W,\ ik(j)} + \eta_{ld}\ P_{ld,\ ik(j)} + \eta_{bd}\ P_{bd,\ ik(j)})\left(1 - \dfrac{6x_e}{\ell_{bdg}} + \dfrac{6{x_e}^2}{\ell_{bdg}^2}\right)}{12\ Z_{eff-n50}}$$

where:

$P_{W,\ ik(j)}$: Dynamic wave pressure, at the mid span, in kN/m^2, specified in Ch 4, Sec 5, [1.4], in load case *i1* and *i2* for loading condition (*j*).

$P_{ld,\ ik(j)}$: Dynamic liquid tank pressure, at the mid span, in kN/m^2, as specified in Ch 4, Sec 6, [1.1.1], in load case *i1* and *i2* for loading condition (*j*).

Pressure acting on both sides of the stiffener, i.e. applied on the attached plate on stiffener side or on opposite side to the stiffener, could be simultaneously considered if relevant in the loading condition.

$P_{bd,\ ik(j)}$: Dynamic dry bulk cargo pressure at the mid span, in kN/m^2, as specified in Ch 4, Sec 6, [2.4.1], in load case *i1* and *i2* for loading condition (*j*).

η_W, η_{ld}, η_{bd}: Pressure normal coefficients, taken as:

η = 1 when the considered pressure is applied on the stiffener side,

η = -1 otherwise.

f_{NL} : Correction factor for the non-linearity of the wave pressure taken as:

$f_{NL} = 1$ for $z > T_{LC} + 2h_w$

$f_{NL} = 2.5\,\dfrac{z - T_{LC}}{h_w} - 4$ for $T_{LC} + 1.8h_w < z \le T_{LC} + 2h_w$

$f_{NL} = 0.5\,\dfrac{z - T_{LC}}{h_w} - 0.4$ for $T_{LC} + 1.6h_w < z \le T_{LC} + 1.8h_w$

$f_{NL} = 0.4$ for $T_{LC} + 1.2h_w < z \le T_{LC} + 1.6h_w$

$f_{NL} = 0.7 - 0.25\,\dfrac{z - T_{LC}}{h_w}$ for $T_{LC} + 0.6h_w < z \le T_{LC} + 1.2h_w$

$f_{NL} = 1 - 0.75\,\dfrac{z - T_{LC}}{h_w}$ for $T_{LC} - 0.2h_w < z \le T_{LC} + 0.6h_w$

$f_{NL} = 0.1875\,\dfrac{z - T_{LC}}{h_w} + 1.1875$ for $T_{LC} - h_w < z \le T_{LC} - 0.2h_w$

$f_{NL} = 1$ for $z \le T_{LC} - h_w$

h_w : Water head equivalent to the pressure at waterline, in m, as defined in Ch 4, Sec 5.

x_e : Distance, in m, to the hot spot from the closest end of the span ℓ_{bdg}, as defined in Figure 2.

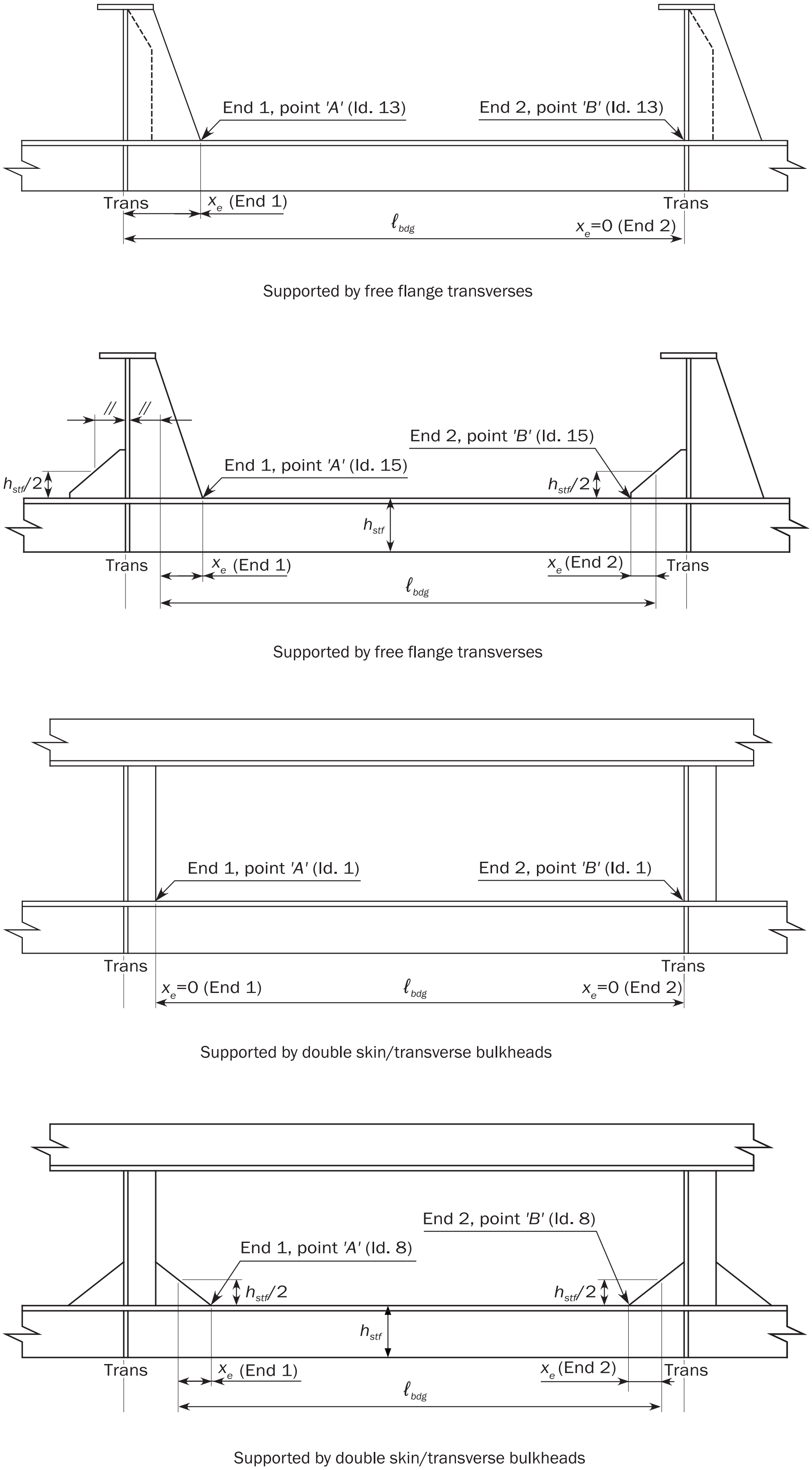
$Z_{eff-n50}$: Net section modulus, in cm^3, of the considered stiffener calculated considering an effective breadth b_{eff} of attached plating.

b_{eff} : Effective breadth, in mm, of attached plating specified at the ends of the span and in way of end brackets and supports, taken as:

$$b_{eff} = s \cdot min\left(\frac{1.04}{1 + \dfrac{3}{\left(\dfrac{\ell_{bdg}}{s}\left(1 - \dfrac{1}{\sqrt{3}}\right) \cdot 10^3\right)^{1.35}}};1.0\right) \quad \text{for} \quad \frac{\ell_{bdg}}{s}\left(1 - \frac{1}{\sqrt{3}}\right)\times 10^3 \ge 1$$

$$b_{eff} = 0.26\ell_{bdg}\left(1 - \frac{1}{\sqrt{3}}\right)\times 10^3 \quad \text{for} \quad \frac{\ell_{bdg}}{s}\left(1 - \frac{1}{\sqrt{3}}\right)\times 10^3 < 1$$

Figure 2 : Definition of effective span and x_e for hot spot



4.1.2 Stress due to static pressure

The hot spot stress due to local static pressure, in N/mm^2, for loading condition (j) is obtained from the following formula:

$$\sigma_{LS,(j)} = \frac{K_b\, K_n\, s\, \ell_{bdg}^2\, (\eta_S\, P_{S,\ (j)} + \eta_{ls}\, P_{ls,\ (j)} + \eta_{bs}\, P_{bs,\ (j)}) \left(1 - \frac{6x_e}{\ell_{bdg}} + \frac{6{x_e}^2}{\ell_{bdg}^2}\right)}{12\, Z_{eff-n50}}$$

where:

$P_{S,(j)}$: Static external pressure, in kN/m^2, in loading condition (j) specified in Ch 4, Sec 5, [1.2].

$P_{ls,(j)}$: Static liquid tank pressure, in kN/m^2, in loading condition (j) specified in Ch 4, Sec 6, [1.1.1].

Pressure acting on both sides could be simultaneously considered if relevant in the loading condition.

$P_{bs,(j)}$: Static dry bulk cargo pressure, in kN/m^2, in loading condition (j) specified in Ch 4, Sec 6, [2.4.1].

η_S, η_{ls}, η_{bs}:Pressure normal coefficients, taken as:

η = 1 when the considered pressure is applied on the stiffener side,

η = -1 otherwise.

4.2 Stress due to relative displacement

4.2.1 General

For longitudinal stiffener end connections fitted on transverse web or floor located

- At transverse bulkhead including swash bulkhead of cargo hold or
- In way of stool,

the additional hot spot stress due to the relative displacement is to be considered.

4.2.2 Relative displacement definition

The relative displacement is defined as follows.

- For longitudinals penetrating floors in way of stool the relative displacement is defined as the displacement of the longitudinal measured at the first floor forward (*Fwd*) or afterward (*Aft*) relative to the displacement of the longitudinal at the floor in way of stool.
- For other longitudinals, the relative displacement is defined as the displacement of the longitudinal measured at the first transverse web frame (or floor) forward (*Fwd*) or afterward (*Aft*) relative to the displacement of the longitudinal at the transverse bulkhead including swash bulkhead.

4.2.3 Sign convention

Where the stress at the hot spot location, i.e. at the flange of longitudinal, due to relative displacement is in tension, the sign of the relative displacement is positive.

4.2.4 Oil tankers

The additional hot spot stress due to relative displacement for load case *i1* and *i2* of loading condition (j) for an oil tanker is to be accounted for either using finite element method as described in [4.2.6] or by applying a stress factor on the local dynamic stress component as described in the following:

$$\sigma_{dD,\ ik(j)} = (K_d - 1) \cdot |\sigma_{LD,\ ik(j)}|$$

where:

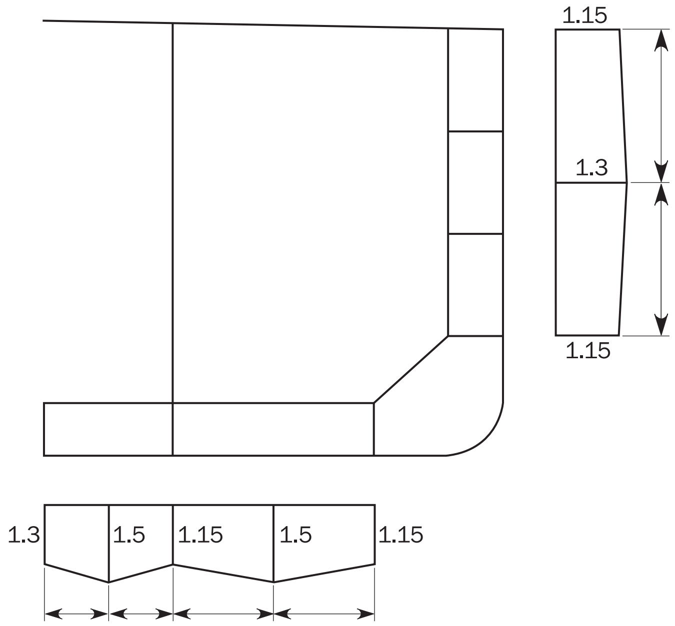
$\sigma_{LD,\,ik(j)}$: Local dynamic stress defined in [4.1.1].

K_d : Bending stress factor for longitudinal stiffeners caused by relative displacement between supports, shown on Figure 3, as given in Table 2.

Table 2 : Bending stress factor of longitudinals due to relative displacement between transverse bulkhead (including swash bulkhead) and adjacent web frames (floors)

Location		K_d factor Full load condition	K_d factor Ballast condition
Bottom longitudinal	Mid position between longitudinal bulkhead, bottom girders or buttress structure	1.50	
	At longitudinal bulkhead, bottom girders (except centre line girder) or buttress structure	1.15	
	At centre line girder	1.30	
	Intermediate position between above bottom positions	Linear interpolation	
Side longitudinals	Mid position between lowest side stringer and deck at side	1.30	1.15
	Lowest side stringer and deck at side	1.15	1.15
	Intermediate positions	Linear interpolation	1.15
Other longitudinals		1.15	

Figure 3 : K_d factor in full load condition for oil tanker with two longitudinal bulkheads



4.2.5 Bulk carriers

The additional hot spot stress due to relative displacement for load case *i1* and *i2* of loading condition (*j*) for a bulk carrier is to be calculated using finite element method as described in [4.2.6].

4.2.6 Stress due to relative displacement derived using FE method

The following procedure is based on a cargo hold model complying with Ch 7, Sec 2, [2] to calculate the stress due to relative displacements. The stress due to relative displacements, in N/mm², for load case *i1* and *i2* of loading condition (*j*) for both locations "*a*" and "*f*" is to be calculated directly using the following expression:

$$\sigma_{dD,\ ik(j)} = \begin{cases} K_b\ \sigma_{dFwd-a,\ ik(j)} + K_b\ \sigma_{dAft-a,\ ik(j)} & for\ location\ "a" \\ K_b\ \sigma_{dFwd-f,\ ik(j)} + K_b\ \sigma_{dAft-f,\ ik(j)} & for\ location\ "f" \end{cases} \qquad (k = 1, 2)$$

where:

a, f : Suffix which denotes the location as indicated in Figure 4.

Aft, *Fwd*: Suffix which denotes the direction, afterward (*Aft*) or forward (*Fwd*), from the transverse bulkhead. as shown in Figure 4.

K_b : Stress concentration factor due to bending for the location '*a*' or '*f*' which may correspond to points '*A*' or '*B*' as defined in Table 4.

$\sigma_{dFwd-a,ik(j)}$, $\sigma_{dAft-a,ik(j)}$, $\sigma_{dFwd-f,ik(j)}$, $\sigma_{dAft-f,ik(j)}$: Additional stress at location '*a*' and '*f*', in N/mm², due to the relative displacement between the transverse bulkhead including swash bulkhead or floors in way of stool and the forward (*Fwd*) and afterward (*Aft*) transverse web or floor respectively for load case *i1* and *i2* of loading condition (*j*), taken as:

$$\sigma_{dFwd-a,\ ik(j)} = \frac{3.9\delta_{Fwd,\ ik(j)}\ EI_{Aft-n50}\ I_{Fwd-n50}}{Z_{Aft-n50}\ \ell_{Fwd}\ (\ell_{Aft}\ I_{Fwd-n50} + \ell_{Fwd}\ I_{Aft-n50})}\left(1 - 1.15\ \frac{|x_{eAft}|}{\ell_{Aft}}\right) 10^{-5}$$

$$\sigma_{dAft-a,\ ik(j)} = \left[\frac{3.9\delta_{Aft,\ ik(j)}\ EI_{Aft-n50}\ I_{Fwd-n50}}{Z_{Aft-n50}\ \ell_{Aft}\ (\ell_{Aft}\ I_{Fwd-n50} + \ell_{Fwd}\ I_{Aft-n50})}\left(1 - 1.15\ \frac{|x_{eAft}|}{\ell_{Aft}}\right) - \frac{0.9\delta_{Aft,\ ik(j)}\ EI_{Aft-n50}\ |x_{eAft}|}{Z_{Aft-n50}\ \ell_{Aft}^{\ 3}}\right] 10^{-5}$$

$$\sigma_{dFwd-f,\ ik(j)} = \left[\frac{3.9\delta_{Fwd,\ ik(j)}\ EI_{Aft-n50}\ I_{Fwd-n50}}{Z_{Fwd-n50}\ \ell_{Fwd}\ (\ell_{Aft}\ I_{Fwd} + \ell_{Fwd}\ I_{Aft-n50})}\left(1 - 1.15\ \frac{|x_{eFwd}|}{\ell_{Fwd}}\right) - \frac{0.9\delta_{Fwd,\ ik(j)}\ EI_{Fwd-n50}\ |x_{eFwd}|}{Z_{Fwd-n50}\ \ell_{Fwd}^{\ 3}}\right] 10^{-5}$$

$$\sigma_{dAft-f,\ ik(j)} = \frac{3.9\delta_{Aft,\ ik(j)}\ EI_{Aft-n50}\ I_{Fwd-n50}}{Z_{Fwd-n50}\ \ell_{Aft}\ (\ell_{Aft}\ I_{Fwd-n50} + \ell_{Fwd}\ I_{Aft-n50})}\left(1 - 1.15\ \frac{|x_{eFwd}|}{\ell_{Fwd}}\right) 10^{-5}$$

$I_{Fwd-n50}$, $I_{Aft-n50}$: Net moment of inertia, in cm⁴, of forward (*Fwd*) and afterward (*Aft*) longitudinal.

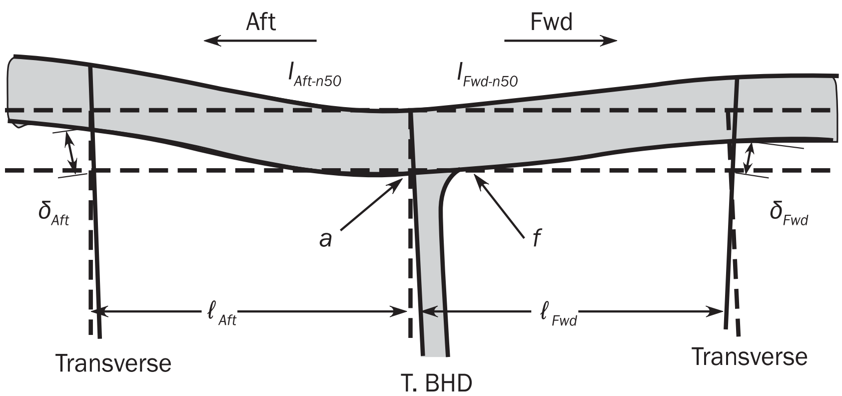
$Z_{Fwd-n50}$, $Z_{Aft-n50}$: Net section modulus of forward (*Fwd*) and afterward (*Aft*) stiffener, in cm³.

ℓ_{Fwd}, ℓ_{Aft} : Span, in m, of forward (*Fwd*) and afterward (*Aft*) longitudinal, as shown in Figure 4.

x_{eFwd}, x_{eAft}: Distance, in m, as shown in Figure 2, to the hot spot in location '*a*' or '*f*' from the closest end of ℓ_{Fwd} and ℓ_{Aft} respectively.

$\delta_{Fwd,ik(j)}$, $\delta_{Aft,ik(j)}$: Relative displacement in the direction perpendicular to the attached plate, in mm, between the transverse bulkhead (including swash bulkhead or floor in way of stools) and the forward (*Fwd*) or afterward (*Aft*) transverse web (or floor) as shown in Figure 4.

Figure 4 : Definition of the relative displacement (example of the side longitudinal)



4.2.7 Stress due to relative displacement in still water

The additional hot spot stress, in N/mm², in still water, due to the relative displacement in the direction perpendicular to the attached plate between the transverse bulkhead including swash bulkhead or floor in way of stools and the adjacent transverse web or floor is to be obtained according to procedures of [4.2.4] and [4.2.5] for oil tankers and bulk carriers respectively, replacing dynamic local stress σ_{LD} and dynamic pressure with static local stress σ_{LS} and static pressure.

5 STRESS CONCENTRATION FACTORS

5.1 Unsymmetrical stiffener

5.1.1

The stress concentration factor K_n for unsymmetrical flange of built-up and rolled angle stiffeners under lateral load, calculated at the web's mid-thickness position, as shown in Figure 5, is to be taken as:

$$K_n = \frac{1 + \lambda\ \beta^2}{1 + \lambda\ \beta^2\ \psi_z}$$

where:

$$\lambda = \frac{3\left(1 + \dfrac{\eta}{280}\right)}{1 + \dfrac{\eta}{40}}$$

$$\eta = \frac{\ell_{bdg}{}^4 10^{12}}{b_{f-n50}{}^3 \cdot t_{f-n50} \cdot h_{stf-n50}{}^2 \left(\dfrac{4 \cdot h_{stf-n50}}{t_{w-n50}{}^3} + \dfrac{s}{t_{p-n50}{}^3}\right)}$$

$$\beta = 1 - \frac{2 b_{g-n50}}{b_{f-n50}}$$ for built-up profiles.

$$\beta = 1 - \frac{t_{w-n50}}{b_{f-n50}}$$ for rolled angle profiles.

$b_{g\text{-}n50}$: Eccentricity of the stiffener equal to the distance from flange's edge to web's centreline, in mm, as shown in Figure 6.

$b_{f\text{-}n50}$: Net breadth of flange, in mm, as shown in Figure 6.

$t_{f\text{-}n50}$: Net flange thickness, in mm, as shown in Figure 6.

$h_{stf\text{-}n50}$: Net stiffener height, including face plate, in mm, as shown in Figure 6.

$t_{w\text{-}n50}$: Net web thickness, in mm, as shown in Figure 6.

$h_{w\text{-}n50}$: Net web's height stiffener, in mm, as shown in Figure 6.

$t_{p\text{-}n50}$: Net thickness of attached plating, in mm, as shown in Figure 6.

ψ_z : Coefficient given as:

$$\psi_z = \frac{h_{w-n50}^2\ t_{w-n50}}{4\ Z_{n50}} 10^{-3}$$

Z_{n50} : Net section modulus, in cm^3, of stiffener with an attached plating breadth equal to the stiffener spacing.

Figure 5 : Bending stress in stiffener with symmetrical and unsymmetrical flange

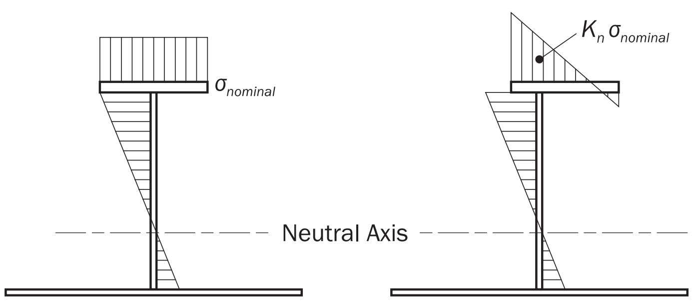
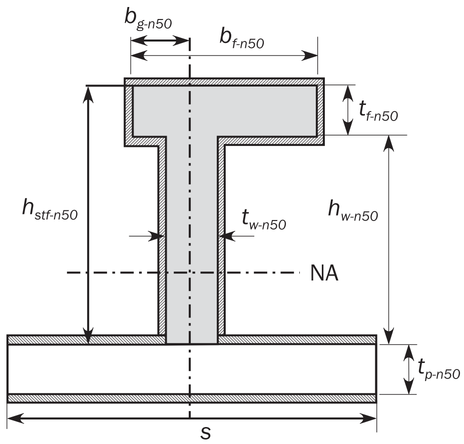


Figure 6 : Stiffener - net scantling



5.1.2 Bulb profiles

For bulb profiles K_n factor is to be calculated using the equivalent built-up profile as shown in Figure 7. The flange of the equivalent built-up profile is to have the same properties as the bulb flange, i.e. same cross sectional area and moment of inertia about the vertical axis and neutral axis position.

For HP bulb profiles, examples of the equivalent built up profile dimensions are listed in Table 3.

Figure 7 : Bulb profile and equivalent built-up profile

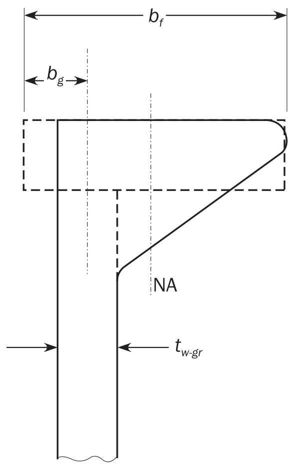


Table 3 : HP equivalent built-up profile dimensions

HP-bulb		Equivalent built-up flange in gross thickness		
Height (mm)	Gross web thickness, $t_{w\text{-}gr}$ (mm)	b_f (mm)	$t_{f\text{-}gr}$ (mm)	b_g (mm)
200	9 – 13	$t_{w\text{-}gr}$ + 24.5	22.9	($t_{w\text{-}gr}$ + 0.9)/2
220	9 – 13	$t_{w\text{-}gr}$ + 27.6	25.4	($t_{w\text{-}gr}$ + 1.0)/2
240	10 – 14	$t_{w\text{-}gr}$ + 30.3	28.0	($t_{w\text{-}gr}$ + 1.1)/2
260	10 – 14	$t_{w\text{-}gr}$ + 33.0	30.6	($t_{w\text{-}gr}$ + 1.3)/2
280	10 – 14	$t_{w\text{-}gr}$ + 35.4	33.3	($t_{w\text{-}gr}$ + 1.4)/2
300	11 – 16	$t_{w\text{-}gr}$ + 38.4	35.9	($t_{w\text{-}gr}$ + 1.5)/2
320	11 – 16	$t_{w\text{-}gr}$ + 41.0	38.5	($t_{w\text{-}gr}$ + 1.6)/2
340	12 – 17	$t_{w\text{-}gr}$ + 43.3	41.3	($t_{w\text{-}gr}$ + 1.7)/2
370	13 – 19	$t_{w\text{-}gr}$ + 47.5	45.2	($t_{w\text{-}gr}$ + 1.9)/2
400	14 – 19	$t_{w\text{-}gr}$ + 51.7	49.1	($t_{w\text{-}gr}$ + 2.1)/2
430	15 – 21	$t_{w\text{-}gr}$ + 55.8	53.1	($t_{w\text{-}gr}$ + 2.3)/2

5.2 Longitudinal stiffener end connections

5.2.1

The stress concentration factors K_a and K_b are given in Table 4 for end connection of stiffeners subjected to axial and lateral loads. The values given in Table 4 for soft toe are valid provided the toe geometry complies with the requirements given in [5.2.5]. The stress concentration factor K_b given for lateral loads are to be used also for stress due to relative displacements.

5.2.2 Other connection types

When connection types other than those given in Table 4 are proposed, the fatigue strength for the proposed connection type is to be assessed either by performing a very fine mesh FE analysis as described in Ch 9, Sec 5 to obtain directly the hot spot stress, or by calculating the stress concentration factor using FE analysis according to [5.3].

5.2.3 Overlapped connection

Overlapped connection types for longitudinal stiffeners, i.e. attachments welded to the web of the longitudinals, are not to be used in the cargo hold region.

5.2.4 End stiffener without connection to web stiffener

Where the web stiffener is omitted or not connected to the longitudinal flange in way of:

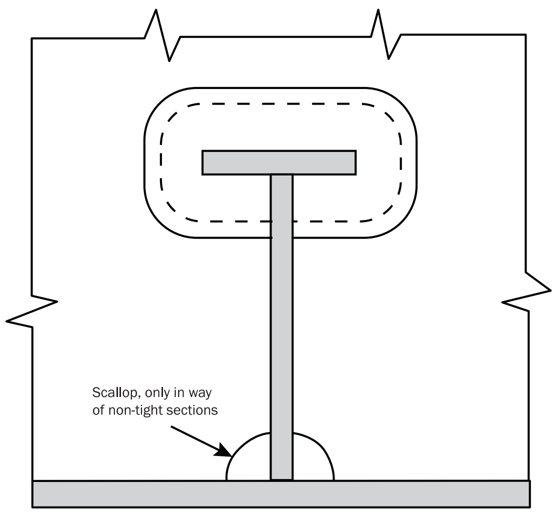
- Side shell below 1.1 T_{sc}.
- Bottom.
- Inner hull longitudinal bulkhead below 1.1 T_{sc}.
- Hopper.
- Topside tank sloping plating below 1.1 T_{sc}.
- Inner bottom.

the following is required:

- A complete collar as defined in Figure 8 (i.e. connection type ID 31 of Table 4), or,
- A detail design for cut-outs as described in Ch 9, Sec 6, [2.1].

Equivalence to cut-outs given in Ch 9, Sec 6, [2.1] may be accepted provided it is assessed for fatigue by using comparative FE analysis which is based on hot spot stress around the cut-out in the web plate of the primary supporting member inclusive of the collar, as given in Ch 9, Sec 6, [2.2].

Figure 8 : Complete collar



5.2.5 Soft toe of web stiffener and backing bracket

The toe geometry end connection of web stiffener and backing bracket is to comply with the following:

$\theta \leq 20$

$h_{toe} \leq \max(t_{bkt\text{-}gr}; 15)$

where:

θ : Angle of the toe, in deg, as shown in Figure 9.

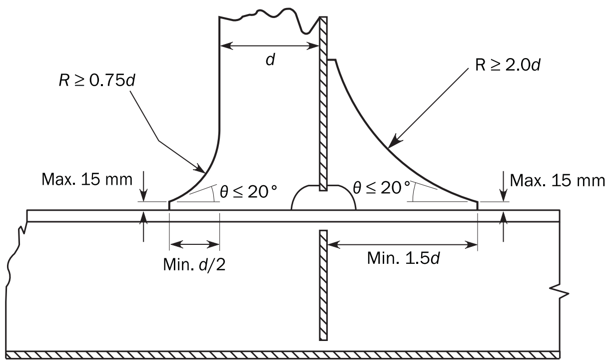
h_{toe} : Height of the toe, in mm, as shown in Figure 9.

$t_{bkt\text{-}gr}$: Gross thickness of the bracket, in mm.

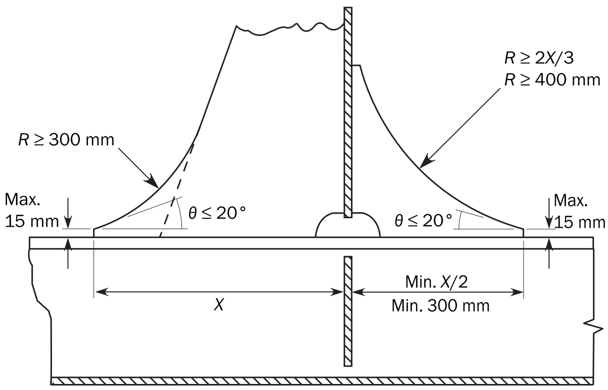
5.2.6 Recommended detail designs

Recommended detail designs for longitudinal end connections with soft toes and backing brackets are given in Figure 9.

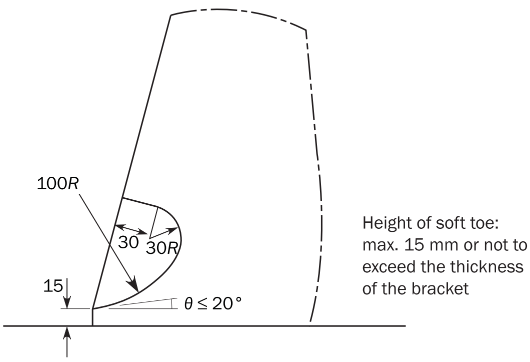
Figure 9 : Detail design for soft toes and backing brackets



Recommended design of soft toes and backing bracket of pillar stiffeners

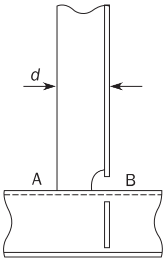
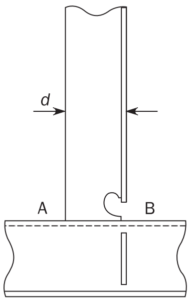
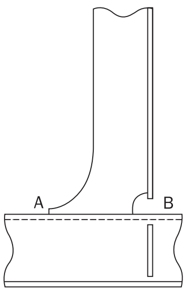
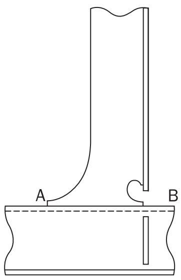
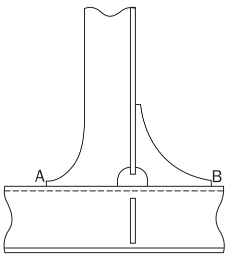


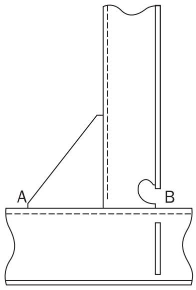
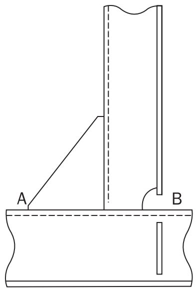
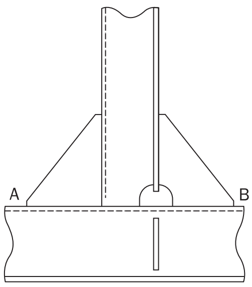
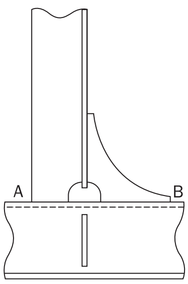
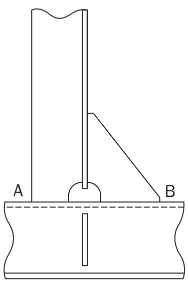
Recommended design of soft toes and backing bracket of tripping brackets

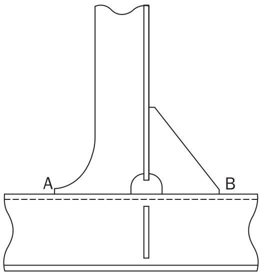
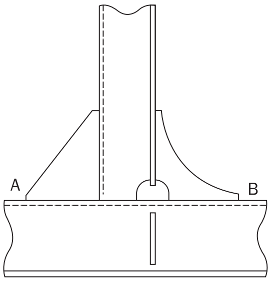
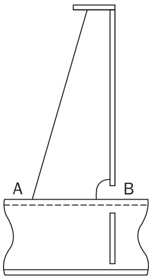
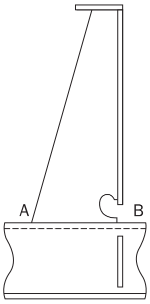
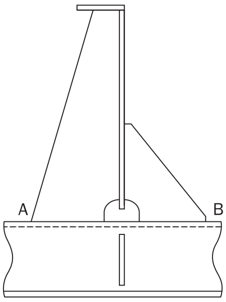


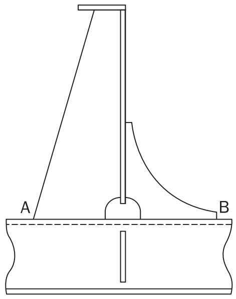
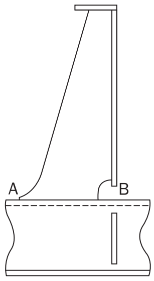
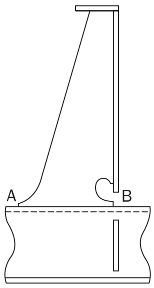
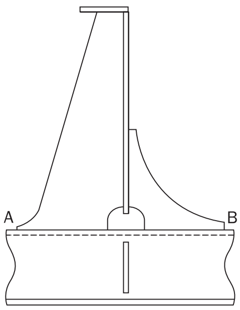
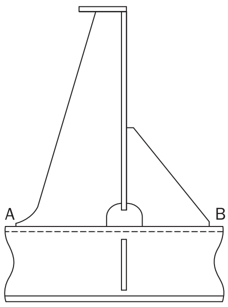
Recommended alternative design of soft toes of tripping brackets

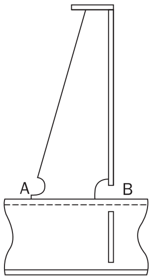
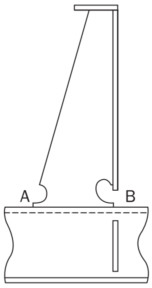
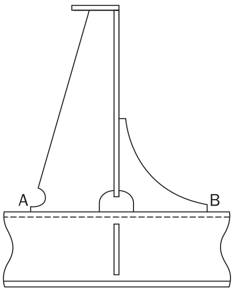
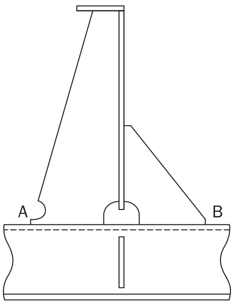
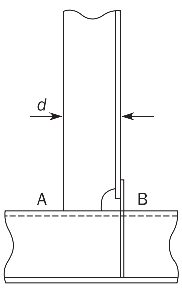
Table 4 : Stress concentration factors

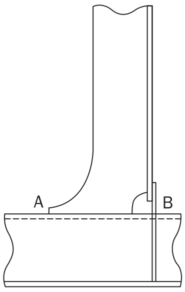
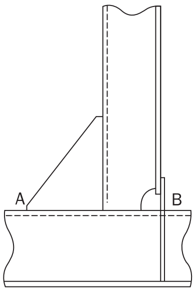
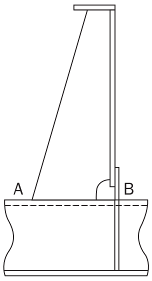
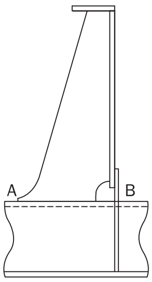
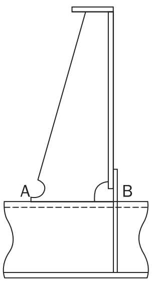
ID	Connection type (2) (3)	Point ‘*A*’		Point ‘*B*’	
		K_a	K_b	K_a	K_b
1 (1)		1.28 for $d \leq 150$ 1.36 for $150 < d \leq 250$ 1.45 for $d > 250$	1.40 for $d \leq 150$ 1.50 for $150 < d \leq 250$ 1.60 for $d > 250$	1.28 for $d \leq 150$ 1.36 for $150 < d \leq 250$ 1.45 for $d > 250$	1.60
2 (1)		1.28 for $d \leq 150$ 1.36 for $150 < d \leq 250$ 1.45 for $d > 250$	1.40 for $d \leq 150$ 1.50 for $150 < d \leq 250$ 1.60 for $d > 250$	1.14 for $d \leq 150$ 1.24 for $150 < d \leq 250$ 1.34 for $d > 250$	1.27
3		1.28	1.34	1.52	1.67
4		1.28	1.34	1.34	1.34
5		1.28	1.34	1.28	1.34

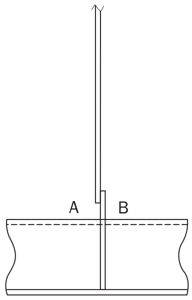
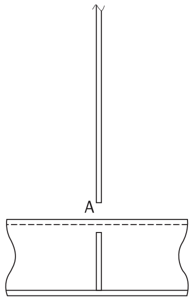
ID	Connection type (2) (3)	Point ‘*A*’		Point ‘*B*’	
		K_a	K_b	K_a	K_b
6		1.52	1.67	1.34	1.34
7		1.52	1.67	1.52	1.67
8		1.52	1.67	1.52	1.67
9		1.52	1.67	1.28	1.34
10		1.52	1.67	1.52	1.67

ID	Connection type [(2)(3)]	Point 'A'		Point 'B'	
		K_a	K_b	K_a	K_b
11		1.28	1.34	1.52	1.67
12		1.52	1.67	1.28	1.34
13		1.52	1.67	1.52	1.67
14		1.52	1.67	1.34	1.34
15		1.52	1.67	1.52	1.67

ID	Connection type [(2)(3)]	Point 'A'		Point 'B'	
		K_a	K_b	K_a	K_b
16		1.52	1.67	1.28	1.34
17		1.34	1.34	1.52	1.67
18		1.34	1.34	1.34	1.34
19		1.34	1.34	1.28	1.34
20		1.34	1.34	1.52	1.67

ID	Connection type [(2) (3)]	Point 'A'		Point 'B'	
		K_a	K_b	K_a	K_b
21		1.34	1.34	1.52	1.67
22		1.34	1.34	1.34	1.34
23		1.34	1.34	1.28	1.34
24		1.34	1.34	1.52	1.67
25 (1)		1.28 for $d \le 150$ 1.36 for $150 < d \le 250$ 1.45 for $d > 250$	1.40 for $d \le 150$ 1.50 for $150 < d \le 250$ 1.60 for $d > 250$	1.14 for $d \le 150$ 1.24 for $150 < d \le 250$ 1.34 for $d > 250$	1.25 for $d \le 150$ 1.36 for $150 < d \le 250$ 1.47 for $d > 250$

ID	Connection type [(2) (3)]	Point 'A'		Point 'B'	
		K_a	K_b	K_a	K_b
26		1.28	1.34	1.34	1.47
27		1.52	1.67	1.34	1.47
28		1.52	1.67	1.34	1.47
29		1.34	1.34	1.34	1.47
30		1.34	1.34	1.34	1.47

ID	Connection type (2) (3)	Point 'A'		Point 'B'	
		K_a	K_b	K_a	K_b
31 (4)		1.34	1.47	1.34	1.47
32 (4) (5) (6)		1.34	1.14	N/A	N/A

(1) The attachment length *d*, in mm, is defined as the length of the welded attachment on the longitudinal stiffener flange without deduction of scallop.

(2) Where the longitudinal stiffener is a flat bar and there is a web stiffener/bracket welded to the flat bar stiffener, the stress concentration factor listed in the table is to be multiplied by a factor of 1.12. This also applies to unsymmetrical profiles where there is less than 8 mm clearance between the edge of the stiffener flange and the attachment, e.g. bulb or angle profiles where the clearance of 8 mm cannot be achieved.

(3) Designs with overlapped connection / attachments, see [5.2.3].

(4) ID. 31 and 32 refer to details where web stiffeners are omitted or not connected to the longitudinal stiffener flange. See [5.2.4]

(5) For connection type ID. 32 with no collar and/or web plate welded to the flange, the stress concentration factors provided in this table are to be used irrespective of slot configuration.

(6) The fatigue assessment point 'A' is located at the connection between the stiffener web and the transverse web frame or lug plate.

5.3 Alternative design

5.3.1

Upon agreement by the Society, the geometrical stress concentration factors for alternative designs are to be calculated by a very fine mesh FE analysis according to the requirements given in Ch 9, Sec 5. Additional requirements for derivation of geometrical stress concentration factors for stiffener end connections using very fine mesh FE analysis are given below:

a) FE model extent: the FE model, as shown in Figure 10, is to cover at least four web frame spacings in the longitudinal stiffener direction with the detail to be considered located at the middle frame. The same type of end connection is to be modelled at all the web frames. In the transverse direction, the model may be limited to one stiffener spacing.

b) Load application: in general, two loading cases are to be considered:

- Axial loading by enforced displacement applied to the model ends and
- Lateral loading by unit pressure load applied to the shell plating.

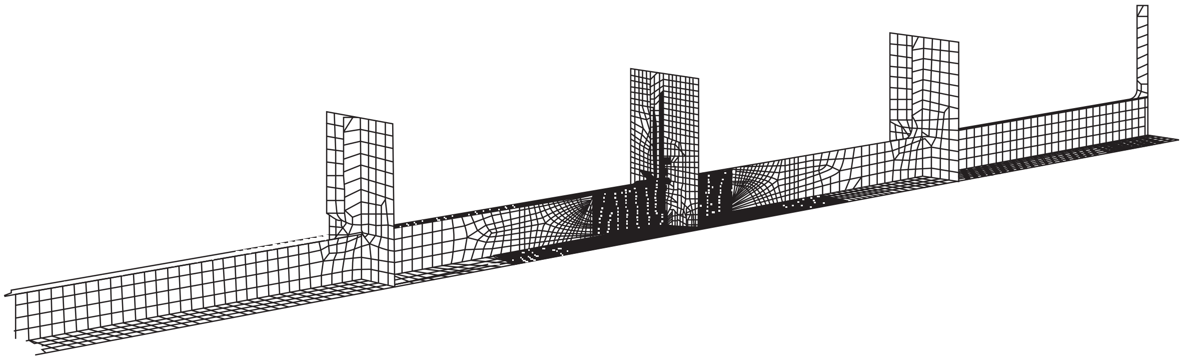
c) Boundary conditions:

- Symmetry conditions are applied along the longitudinal cut of the plate flange, along transverse and vertical cuts on web frames and on top of the web stiffener.

- For lateral pressure loading: the model is to be fixed in all degrees of freedom at both forward and aft ends.
- For axial loading: the model is to be fixed for displacement in the longitudinal direction at the aft end of the model while enforced axial displacement is applied at the forward end, or vice versa.

d) FE mesh density: At the location of the hot spots under consideration, the element size is to be in the order of the thickness of the stiffener flange. In the remaining part of the model, the element size is to be in the order of $s/10$, where s is the stiffener spacing.

Figure 10 : Fine mesh finite element model for derivation of geometrical stress concentration factor



For the 2 loading cases specified above, the stress concentration factors are determined as follows:

- For the axial loading case:

$$K_a = \frac{\sigma_{HSAx}}{\sigma_{NomAx}}$$

- For the bending loading case:

$$K_b = \frac{\sigma_{HSBd}}{\sigma_{NomBd}}$$

σ_{HSAx} : Hot spot stress, in N/mm^2, determined at the stiffener flange for the axial load.

σ_{NomAx} : Nominal axial stress, in N/mm^2, calculated at the stiffener flange according to [3.1] for the axial load applied for the FE calculation.

σ_{HSBd} : Hot spot stress, in N/mm^2, determined at the stiffener flange for the unit pressure load.

σ_{NomBd} : Nominal bending stress, in N/mm^2, calculated at the stiffener flange according to [4.1] in way of the hot spot for the unit pressure load applied for the FE calculation.

The derivation of geometrical stress concentration factors for alternative designs is to be documented and provided to the Society.

SECTION 5
FINITE ELEMENT STRESS ANALYSIS

1 GENERAL

1.1 Applicability

1.1.1

This section applies to fatigue assessment by finite element stress analysis. The methods are based on the hot spot stress approach and requirements are given for both welded and non-welded hot spots. The hot spot stress takes into account structural discontinuities due to the structural detail of the welded joint, but not taking into account the notch effect at the weld toe.

1.1.2

The hot spot stress is generally highly dependent on the finite element model used for representation of the structure and the procedure used to calculate the hot spot stress. No other methods than those described in this Section is to be adopted for calculation of FE based hot spot stress.

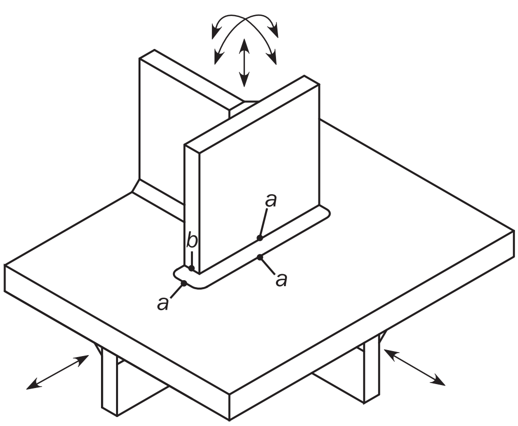
1.1.3

Two types of hot spots, denoted '*a*' and '*b*' are described in Table 1. These are defined according to their location on the plate and their orientation to the weld toe as illustrated in Figure 1.

Table 1 : Types of hot spots

Type	Description
a	Hot spot at the weld toe on plate surface
b	Hot spot at the weld toe around the plate edge

Figure 1 : Types of hot spots



1.1.4

The method for calculation of hot spot stress at weld toe for any welded details is given in [3.1] except for web-stiffened cruciform joints. The method for calculation of local stress for non-welded area is given in [3.2].

1.1.5

The method for calculation of hot spot stress at web-stiffened cruciform joints such as hopper knuckle connection, transverse bulkhead lower stool to inner bottom connection and horizontal stringer heel is given in [4].

1.1.6

Attention is to be given to limitations of the hot spot stress methodology for simple connections given in [5].

2 FE MODELLING

2.1 General

2.1.1

Evaluation of hot spot stresses for fatigue assessment requires the use of very fine finite element meshes in way of areas of high stress concentration. These very fine mesh zones may be incorporated into the global model as shown in Figure 2. The coarse mesh model of the cargo holds is to be made according to Ch 7, Sec 2, [2.4]. Alternatively, this very fine mesh analysis can be carried out by means of separate local finite element models with very fine mesh zones in conjunction with the boundary conditions obtained from a global model of the cargo holds. Typical local finite element models of a hopper knuckle with very fine mesh are shown in Figure 3, Figure 4, and Figure 5.

2.1.2 Corrosion model

The very fine mesh finite element models used for fatigue assessment are to be made using net thickness, t_{n50}, in accordance with Ch 9, Sec 1, [5.1].

2.1.3 Separate local FE model

Where a separate local finite element model is used, the extent of the local model is to be such that the calculated stresses are not significantly affected by the imposed boundary conditions and application of loads. The boundary of the fine mesh model is to be taken at adjacent primary supporting members such as girders, stringers and floors in the cargo hold model as far as practicable. Transverse web frames, stringer plates and girders at the boundaries of the local model need not be represented in the local model.

2.1.4

The evaluation of hot spot stress for '*a*' type hot spot is to be based on shell element of mesh size $t_{n50} \times t_{n50}$, where t_{n50} is the net thickness of the plate in way of the considered hot spot. The evaluation of hot spot stress for a '*b*' type hot spot is to be based on shell element of mesh size 10×10 mm. The aforementioned mesh size is to be maintained within the very fine mesh zone, extending over at least 10 elements in all directions from the fatigue hot spot position. The transition of element size between the coarser mesh and the very fine mesh zone is to be done gradually and an acceptable mesh quality is to be maintained. This transition mesh is to be such that a uniform mesh with regular shape gradually transitions from smaller elements to larger ones. An example of the mesh transition in way of the side frame bracket toe is shown in Figure 6.

2.1.5

Four-node shell elements with adequate bending and membrane properties are to be used inside the very fine mesh zone. The four node element is to have a complete linear field of in-plane stresses and hence pure in-plane bending of the element can be exactly represented. In case of steep stress gradients, 8 node thin shell elements are to be used if deemed practical. The shell elements are to represent the mid plane of the plating. For practical purposes, adjoining plates of different thickness may be assumed to be median line aligned, i.e. no staggering in way of thickness change is required. The geometry of the weld and construction misalignment is not required to be modelled.

2.1.6

All structure in close proximity to the very fine mesh zones is to be modelled explicitly with shell elements. Triangular elements are to be avoided where possible. Use of extreme aspect ratio (e.g. aspect ratio greater than 3) and distorted elements (e.g. element's corner angle less than 60 deg or greater than 120 deg) are to be avoided.

2.1.7

Where stresses are to be evaluated on a free edge, such as cut-outs for stiffener connections at web frames, edge of plating and hatch corners, beam elements having the same depth as the adjoining plate thickness and negligible width is to be used to obtain the required local edge stress values.

2.2 Hopper knuckle welded connection

2.2.1

In addition to the general requirements in [2.1], the modelling requirements in this sub-article are applicable to the modelling of bilge hopper lower-knuckle and upper-knuckle welded connections.

2.2.2

Where a separate local finite element model is used, the minimum extent of the local model is to be according to the following:

a) Longitudinally, the model is to cover two web frame spaces (i.e. one web frame space extending either side of the transverse web frame of interest). Transverse web frames at the end of the local model need not be represented in the local model.

b) Vertically, the model is to extend from the baseline to the lower stringer in the double side water ballast tank for tankers and double skin bulk carriers. For single skin bulk carriers, the model is to extend from the baseline to the top of the hopper ballast tank. Where a fatigue assessment is also carried out for the upper knuckle connection, the model is to be extended to four longitudinal spaces above the lower stringer in the double side ballast tank.

c) Transversely, for the hopper lower knuckle, the model is to extend from the ship side to 4 longitudinal spaces inboard of the double bottom side girder. For the upper hopper knuckle, the model is to extend from the ship side to the double bottom side girder.

2.2.3

Any scarfing brackets on the web frame adjoining the inner bottom plating, the first longitudinal stiffeners away from the knuckle hot spot as well as any carlings and brackets offset from the main frames are to be modelled explicitly using shell elements. Longitudinal stiffeners further away from the knuckle may be modelled by beam elements. The inner bottom plate 'overhang' outboard of the girder is to be modelled using shell elements up to the extent of the scarfing bracket. Away from the scarfing bracket in longitudinal direction, the inner bottom plate 'overhang' may be modelled using line elements of equivalent the area. Any perforations, such as cut-outs for cabling, pipes and access that are within one stiffener space from the knuckle point are to be modelled explicitly.

2.2.4

Figure 3, Figure 4 and Figure 5 show typical local finite element models of the hopper knuckle connection and close-up views of the $t_{n50} \times t_{n50}$ mesh zone.

2.3 Horizontal stringer heel connection

2.3.1

In addition to the general requirements in [2.1], the modelling requirements in this sub-article are applicable to the modelling of horizontal stringer heel connections.

2.3.2

Where a separate local finite element model is used, the minimum extent of the local model is to be according to the following:

a) Longitudinally, the model is to cover one web frame space away from the stringer heel to at least one web frame space ahead of the stringer toe. Transverse web frames at the end of the local model need not be represented in the local model.

b) Vertically, the model is to extend at least to the next stringer level above and below the concerned stringer heel location.

c) Transversely, the model is to extend from the ship side to a half of the tank width in case of a stringer heel located at the inner hull longitudinal bulkhead. In case of stringer heel located at other longitudinal bulkheads the model is to extend transversely up to half the tank width on either side of the concerned stringer heel.

2.3.3

Shell elements are to be used for modelling the stringer heel connection and adjacent stiffeners. The first longitudinal and vertical stiffeners away from the heel hot spot are to be modelled explicitly using shell elements. Longitudinal and vertical stiffeners further away from the hot spot may be modelled by beam elements. Figure 7 shows a typical finite element model of the stringer heel connection with the very fine mesh zone having $t_{n50} \times t_{n50}$ mesh size.

2.4 Lower stool – inner bottom connection

2.4.1

In addition to [2.1], the modelling requirements in this sub-article are applicable to the assessment of the connection between lower stool plate and inner bottom plate.

2.4.2

The minimum extent of the local model is as follows:

a) Vertically, from the bottom shell to a level at least 2 m above the inner bottom or up to the connection of the corrugation to the upper shelf plate of the lower stool, whichever is greater.

b) The local model is to be extended transversely to the nearest diaphragm web in the lower stool on each side of the fine mesh zone (i.e. to the adjacent double bottom girder). The end diaphragms need not be modelled.

c) Longitudinally, the model is to cover one floor space aft of the aft lower stool – inner bottom connection and one floor space forward of the forward lower stool – inner bottom connection.

2.4.3

Diaphragm webs, brackets inside the lower stool and stiffeners on the stool plates are to be modelled at their actual positions within the extent of the local model. Shell elements are to be used for modelling of diaphragms and brackets. The first vertical or horizontal stiffeners on the lower stool plate and the first longitudinal stiffeners on the inner bottom are to be represented by shell elements, other stiffeners may be represented by beam elements. Figure 8 shows a typical finite element model of the lower stool - inner bottom connection with very fine mesh zone having $t_{n50} \times t_{n50}$ mesh size.

2.5 Lower stool – corrugated bulkhead connection

2.5.1

In addition to [2.1], the modelling requirements in this sub-article are applicable to the assessment of the connection between lower stool plate and corrugated bulkhead.

2.5.2

The minimum extent of the local model is as follows:

a) Vertically, from the bottom of the lower stool to a level at least 2 m above the upper shelf plate of the lower stool.

b) The local model is to be extended transversely to the nearest diaphragm web in the lower stool on each side of the fine mesh zone (i.e. to the adjacent double bottom girder). The end diaphragms need not be modelled.

c) Longitudinally, the model is to cover one floor space aft of the aft lower stool – inner bottom connection and one floor space forward of the forward lower stool – inner bottom connection.

2.5.3

Diaphragm webs, brackets inside the lower stool and stiffeners on the stool plates are to be modelled at their actual positions within the extent of the local model. Shell elements are to be used for modelling of diaphragms, and bracket. The first vertical or horizontal stiffeners on the lower stool plate are to be represented by shell elements, other stiffeners may be represented by beam elements. Figure 9 shows a typical finite element model of the lower stool - corrugated bulkhead connection with very fine mesh zone having $t_{n50} \times t_{n50}$ mesh size.

2.6 Side frame bracket to hopper sloping plate connections

2.6.1

In addition to the general requirements in [2.1], the modelling requirements in this sub-article are applicable to the modelling of a side frame to hopper sloping plate bracket connections.

2.6.2

Shell elements are to be used for modelling the side frame bracket, hopper tank sloping plate and adjacent stiffeners. Figure 10 shows a typical finite element model of the side frame bracket to hopper sloping plate connection with the very fine mesh zone having $t_{n50} \times t_{n50}$ mesh size.

2.6.3

Where a separate local finite element model is used, the minimum extent of the local model is to be according to the following:

a) Longitudinally, the model is to cover two web frame spaces (i.e. one web frame space extending either side of the bracket connection of interest). Transverse web frames at the end of the local model need not be represented in the local model.

b) Vertically, the model is to extend from the baseline to the bottom of the topside tank sloping plate.

c) Transversely, the model is to extend from the ship side to the adjacent double bottom side girder.

2.7 Side frame bracket to the upper sloping / flat bottom wing tank connections

2.7.1

In addition to the general requirements in [2.1], the modelling requirements in this sub-article are applicable to the modelling of a side frame bracket to upper sloping/flat bottom wing tank connections.

2.7.2

Shell elements are to be used for modelling the side frame bracket, upper sloping or flat bottom plate and adjacent stiffeners. Figure 11 shows a typical finite element model of the side frame bracket to upper sloping wing tank with the very fine mesh zone having $t_{n50} \times t_{n50}$ mesh size.

2.7.3

Where a separate local finite element model is used, the minimum extent of the local model is to be according to the following:

a) Longitudinally, the model is to cover two web frame spaces (i.e. one web frame space extending either side of the bracket connection of interest). Transverse web frames at the end of the local model need not be represented in the local model.

b) Vertically, the model is to extend from the deck level to the top of the hopper sloping plate.

c) Transversely, the model is to extend from the ship side to the end of upper sloping/flat bottom wing tank.

2.8 Hatch corners and hatch coaming end bracket

2.8.1

In addition to the general requirements in [2.1], the modelling requirements in this sub-article are applicable to the modelling of hatch corners/hatch coaming end bracket. The selection of hatch corners / hatch coaming end bracket for fatigue analysis is to be determined based on the level of stresses obtained from the cargo hold FE analysis.

2.8.2

Where separate local finite element models are used, the model extents are to be according to the following:

a) Transversely, over the half-breadth of the ship,

b) Longitudinally, from the midpoint of the cargo hold in which the concerned hatch corners/hatch coaming end bracket is located to the adjacent cargo hold up to and including the full width of the cross deck nearest to the concerned hatch corners/hatch coaming end bracket.

c) Vertically, from the top plate of coaming to the intersection of the topside tank sloping plate with the side or inner side shell.

2.8.3

The primary supporting members and coaming stays are to be represented by shell finite elements having both membrane and bending properties. Figure 12 shows a typical FE model of the toe connection of a longitudinal hatch coaming end bracket to the deck plating with the very fine mesh zone having $t_{n50} \times t_{n50}$ mesh size.

2.8.4

The level of FE mesh refinement is to be such as to enable stress concentrations arising from the hatch corner geometry to be captured in the hot spot stress. The plate edge of hatch opening corners at the level of upper deck and cross deck structure is to be assessed. The free edge of hatch coaming end bracket and bracket toe welded connection to the deck plating are also to be assessed. Beam elements having the same depth as the adjoining plate thickness and negligible width are to be used at a plate edge of hatch opening corners or free edge of the hatch coaming end bracket to obtain the required local edge stress values as outlined in [2.1.7].

2.8.5

The local structural geometry, particularly in the areas of concern, is to be represented. The hatch corner area is to be meshed using elements with a sufficiently small size to capture the local stress on the edge. In general, a minimum of 15 elements in a 90 degree arc are to be used to describe the curvature of the hatchway radius plating for a rounded corner (see Figure 13). For an elliptical or parabolic corner, a minimum of 15 elements are to be used from the inboard radius end to a point on the edge located at half the longitudinal distance of the semi- major axis. A total of 20 elements are to be used at the elliptical edge of the hatch corner (see Figure 14). However, the element edge dimensions along the free edge of the radius need not be less than the thickness of the plating being represented and also should not be greater than 5 times the thickness of the plating being represented. Except where necessary from practical meshing

considerations, this level of idealisation is to be maintained over the bracket plating and is to extend into the stringer plating, deck plating and coaming. Mesh transitions should not be arranged close to bracket toes.

2.9 Boundary conditions

2.9.1 Cargo hold model

The boundary conditions to be applied to the ends of the cargo hold model are to be in accordance with Ch 7, Sec 2, [2.5].

2.9.2 Separate local finite element model

Where a separate local finite element model is used for evaluating the hot spot stress range, the boundary conditions and application of loads are to be in accordance with Ch 7, Sec 3, [4.2].

Figure 2 : Very fine mesh areas incorporated directly into the cargo hold model

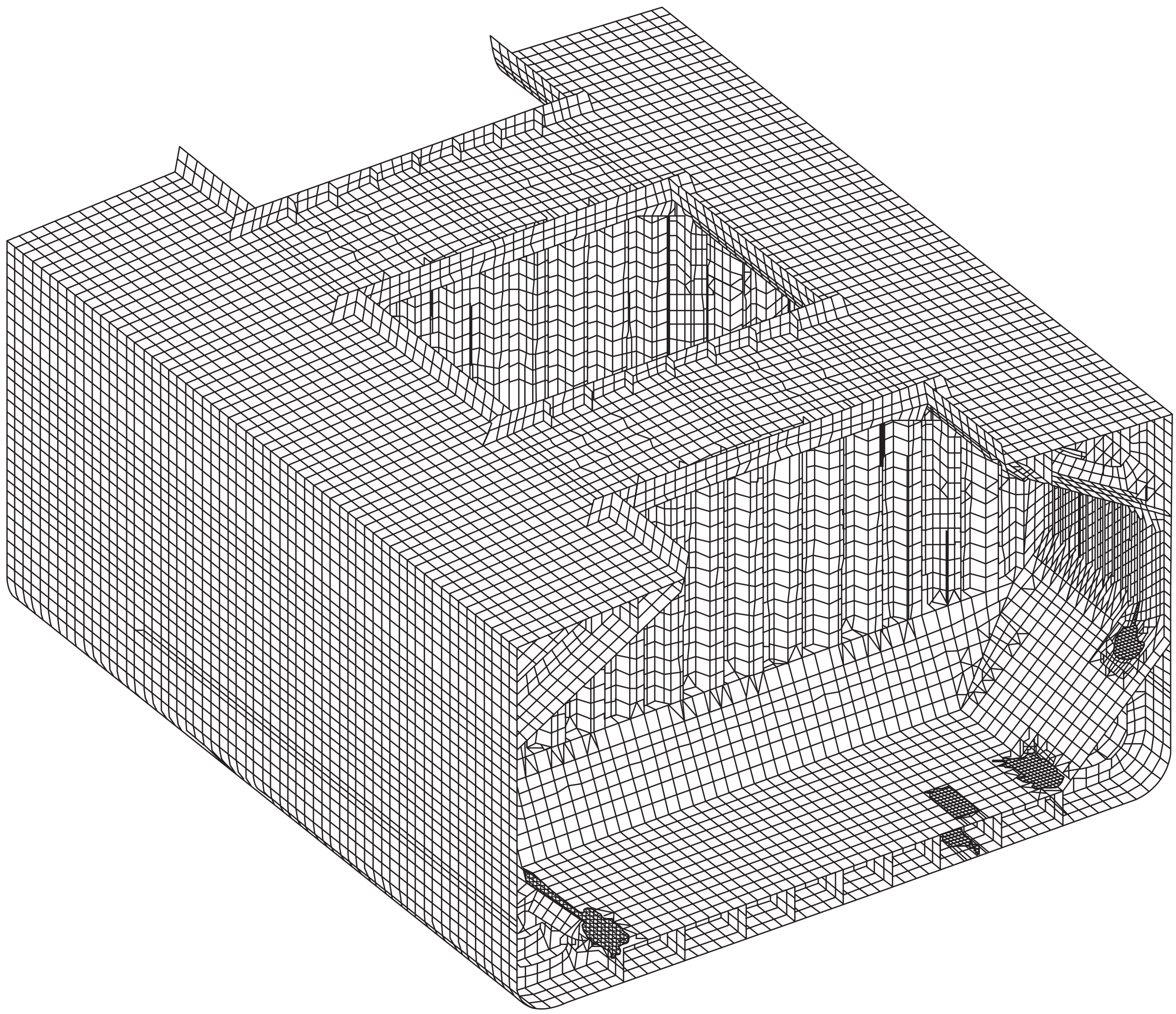


Figure 3 : Local very fine mesh model ($t_{n50} \times t_{n50}$) of hopper knuckle connection between inner bottom and hopper plate

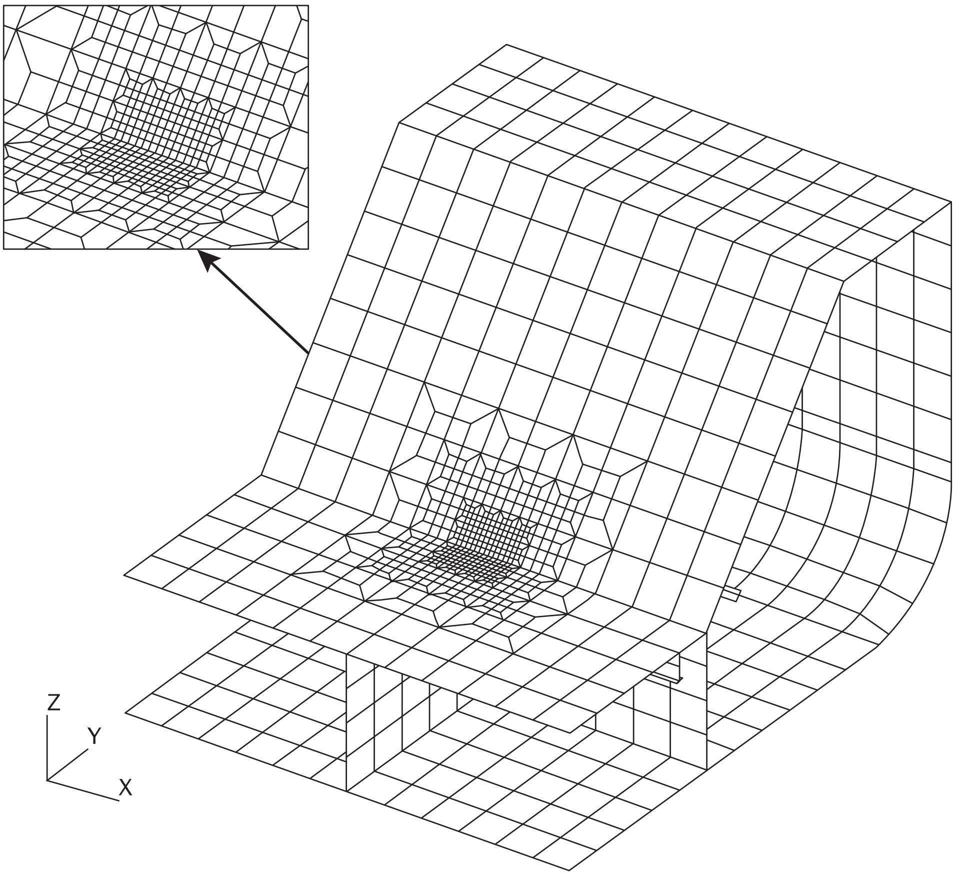


Figure 4 : Local very fine mesh model ($t_{n50} \times t_{n50}$) of hopper knuckle connection between inner bottom, hopper plate, web frame, girder and bracket

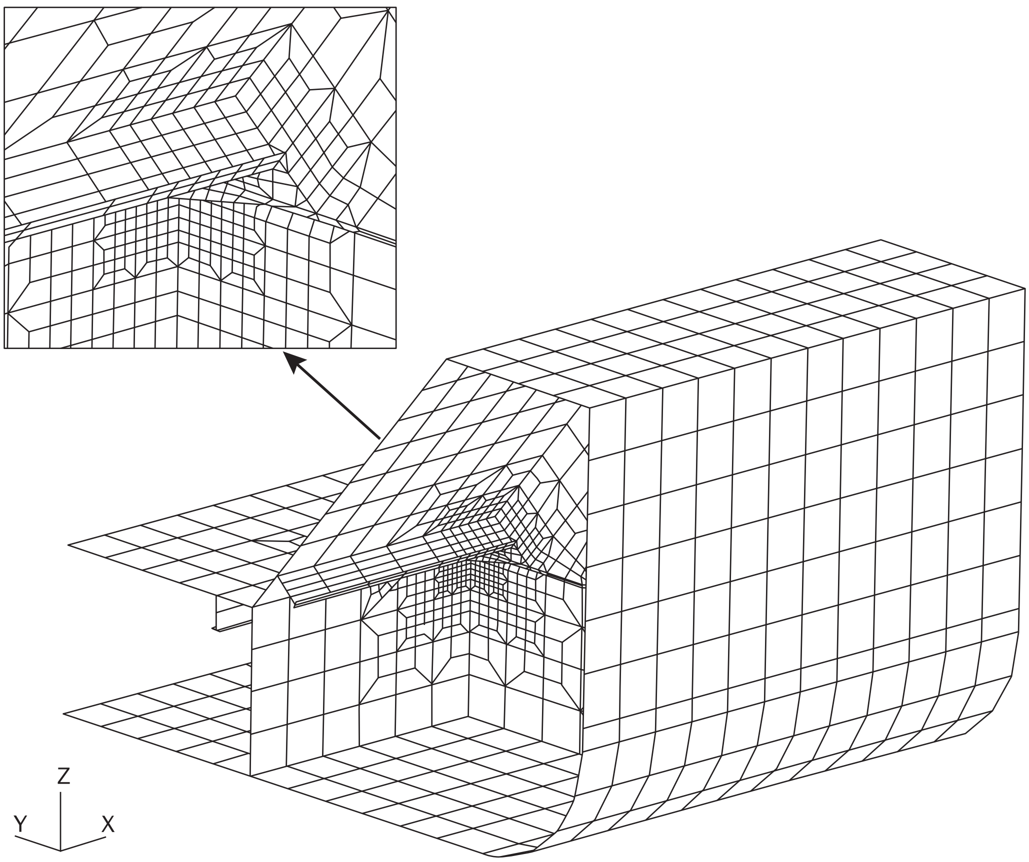


Figure 5 : Local very fine mesh model ($t_{n50} \times t_{n50}$) of upper hopper knuckle connection between inner side shell and hopper plate

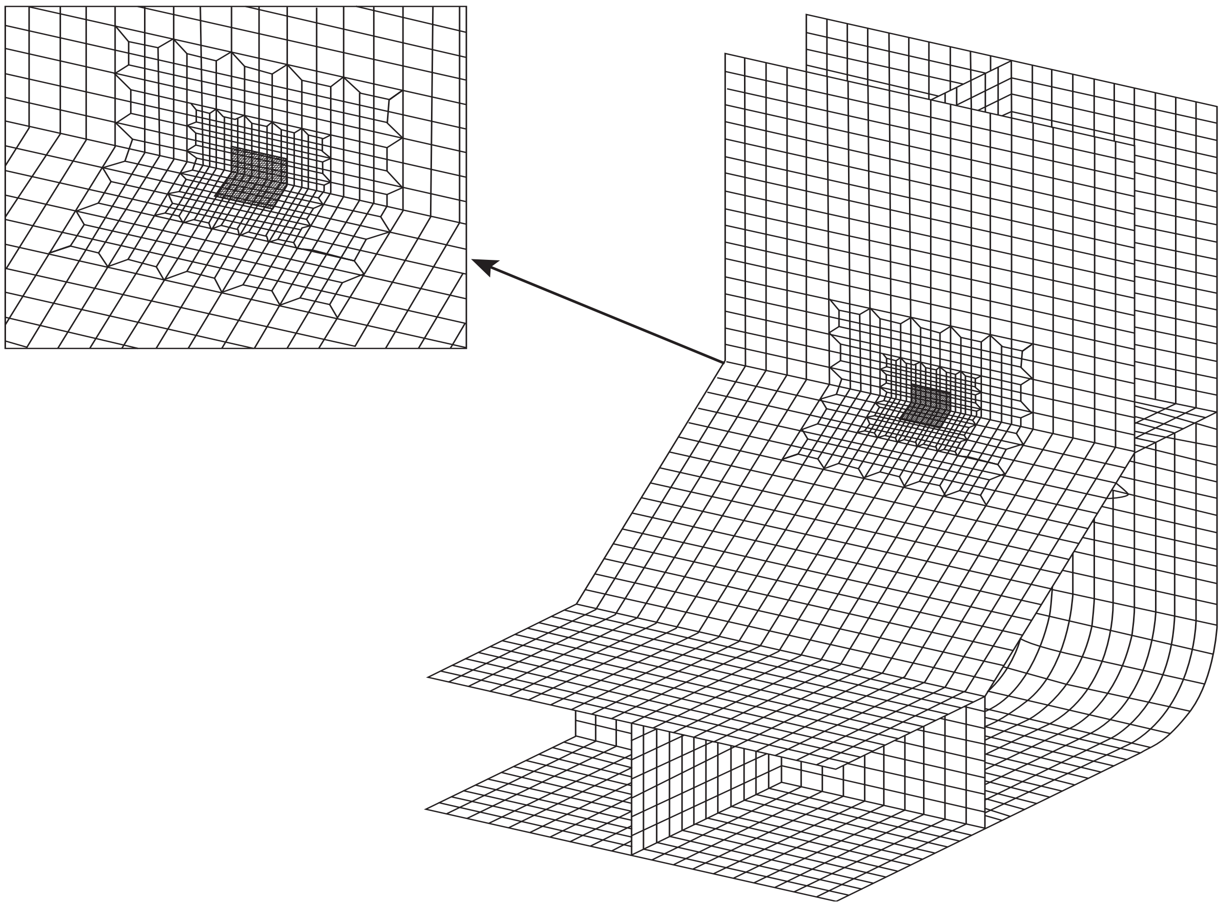


Figure 6 : Transition area between coarse and very fine mesh

Figure 7 : Finite element model of stringer heel connection

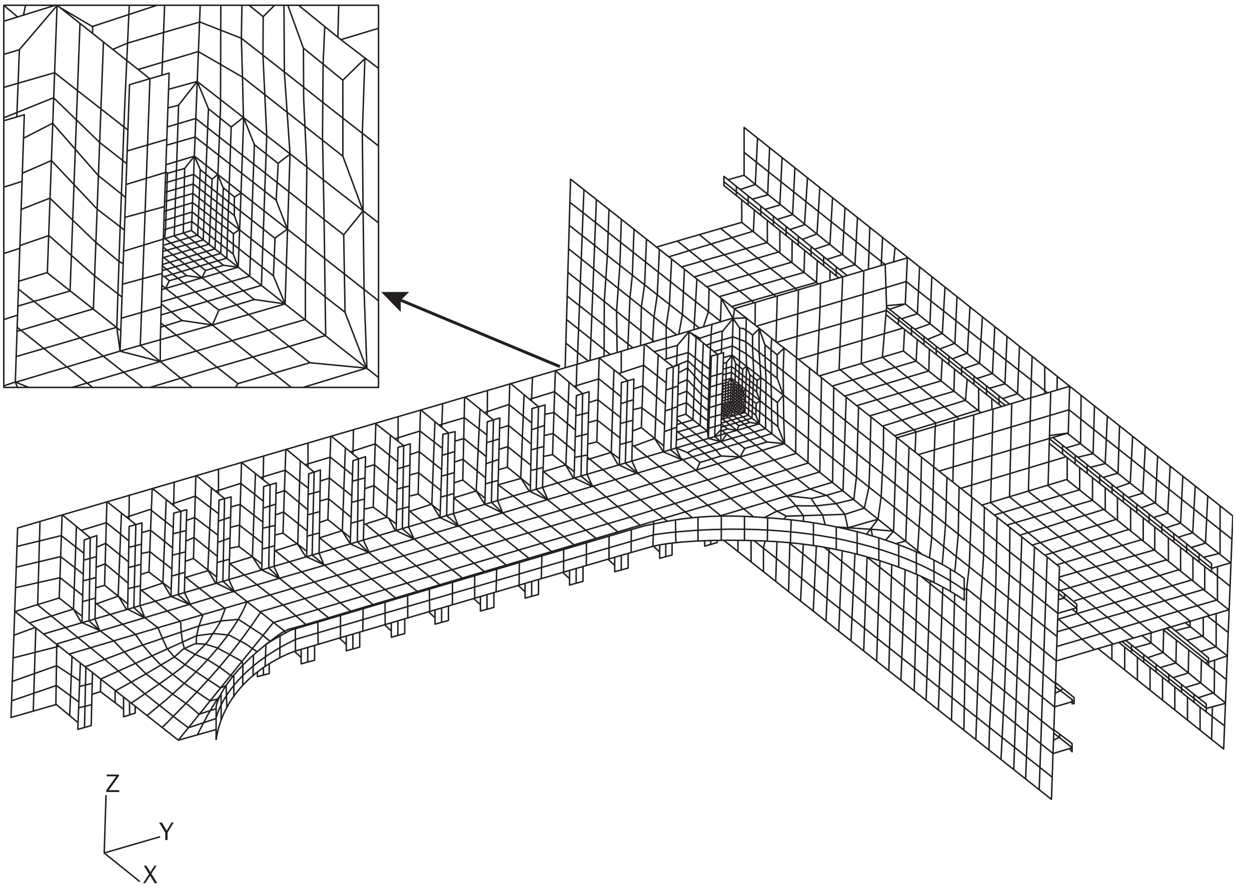


Figure 8 : Local FE model of lower stool connection between inner bottom and lower stool plate, $t_{n50} \times t_{n50}$ mesh

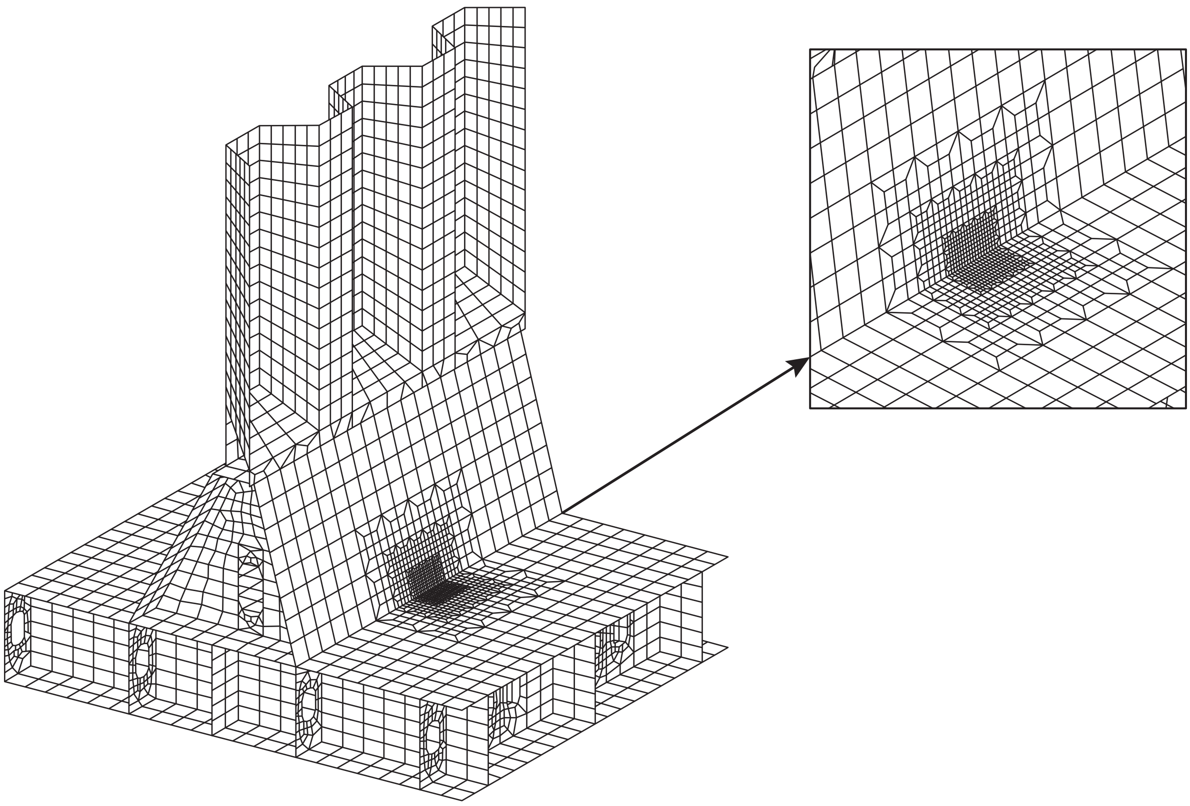


Figure 9 : Local finite element model of lower stool - corrugated bulkhead connection between corrugated bulkhead and lower stool plate, t_{n50} × t_{n50} mesh

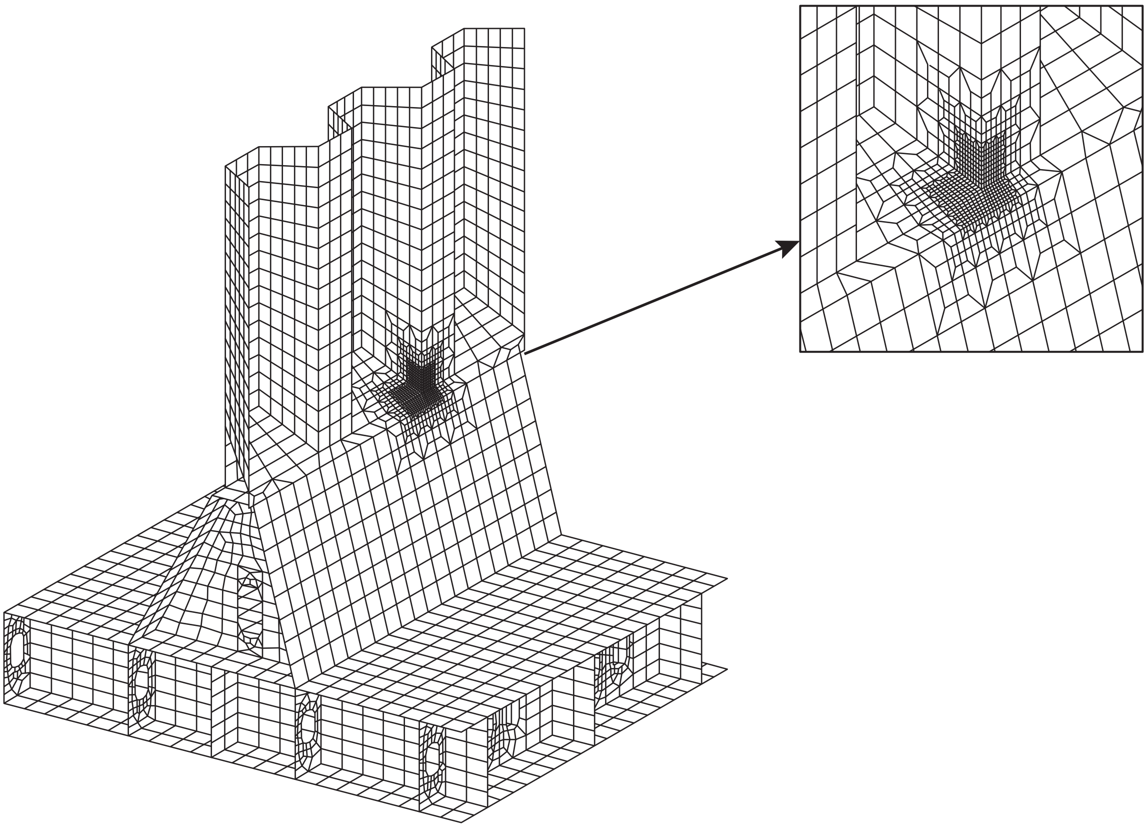


Figure 10 : Local finite element model of side frame bracket, t_{n50} × t_{n50} mesh

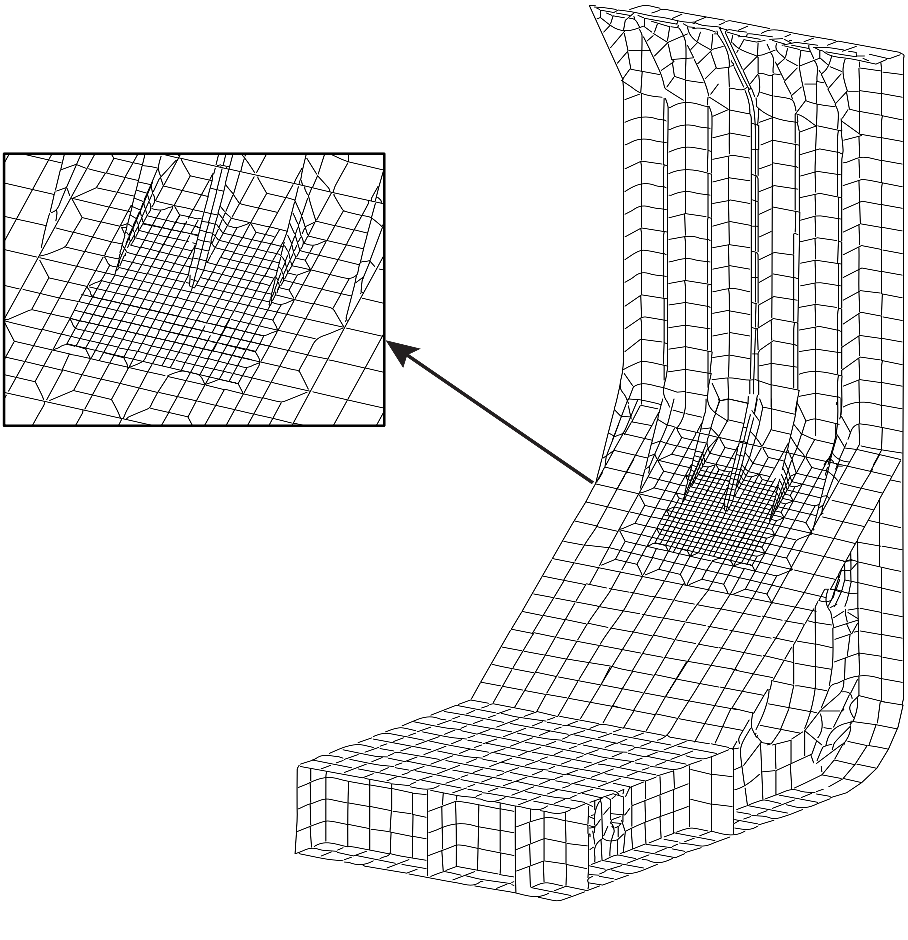


Figure 11 : Local FE model of upper side frame bracket, $t_{n50} \times t_{n50}$ mesh

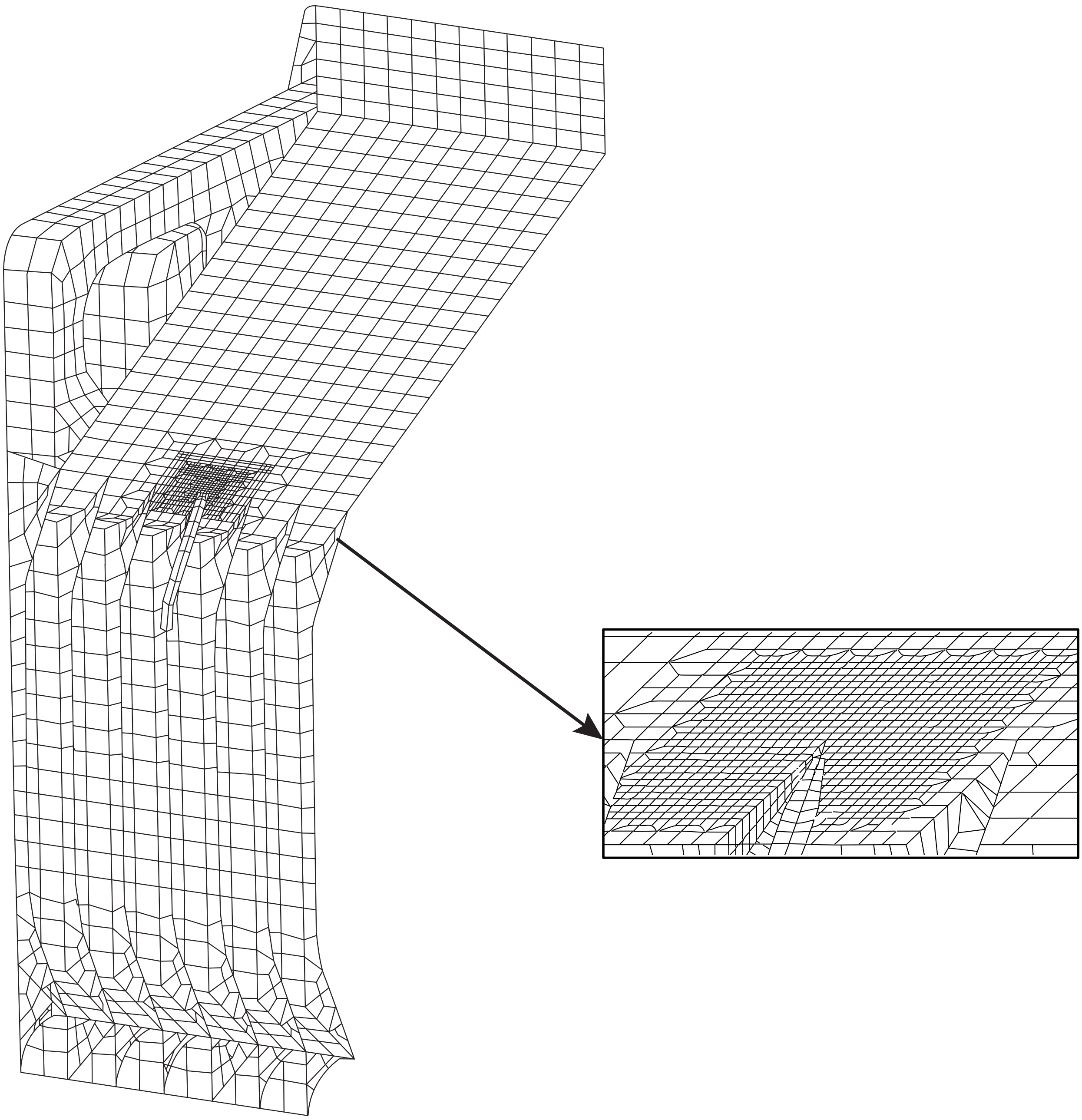


Figure 12 : Local FE model of longitudinal hatch coaming end bracket to the deck plating with very fine mesh zone, $t_{n50} \times t_{n50}$ mesh

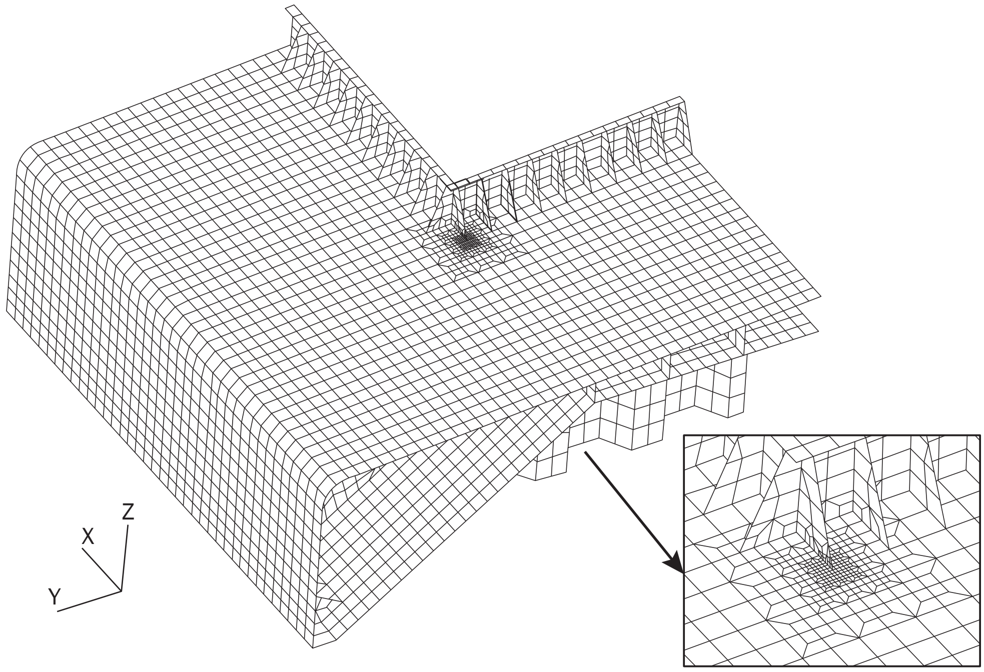


Figure 13 : Mesh density for rounded hatch corner

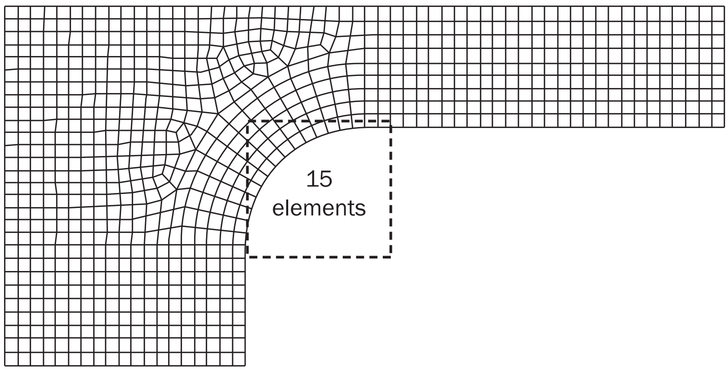
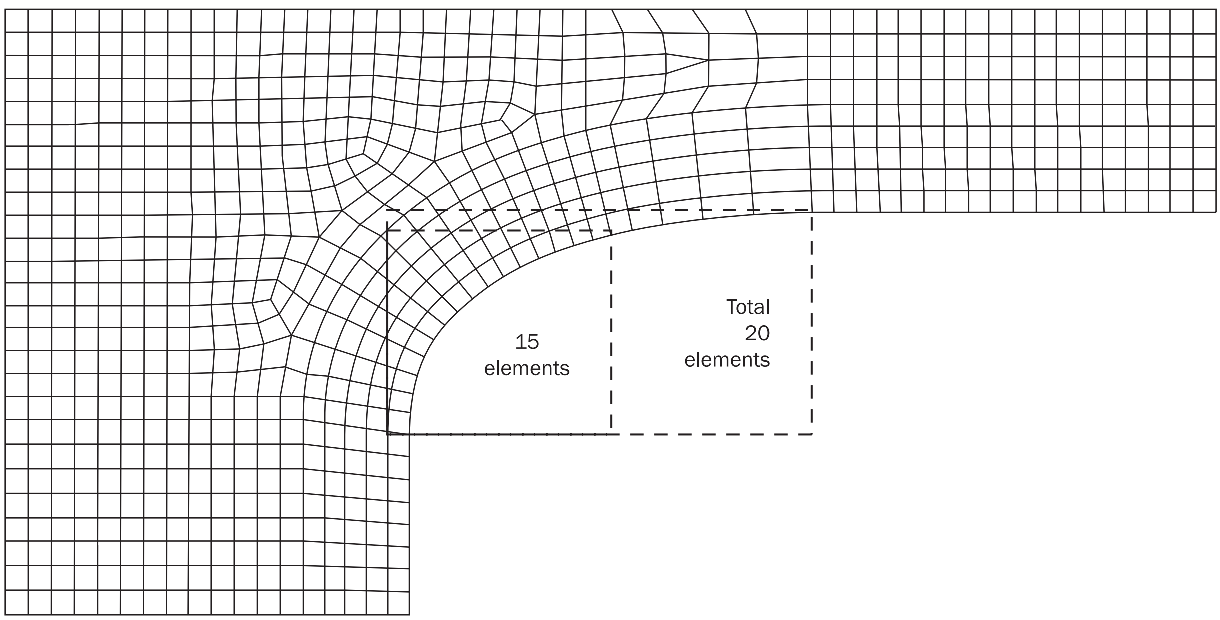


Figure 14 : Mesh density for elliptical hatch corner



3 HOT SPOT STRESS FOR DETAILS DIFFERENT FROM WEB-STIFFENED CRUCIFORM JOINTS

3.1 Welded details

3.1.1

For hot spot type 'a', the structural hot spot stress, σ_{HS}, is calculated from a finite element analysis with $t_{n50} \times t_{n50}$ mesh density and is obtained by the following formula:

$$\sigma_{HS} = 1.12 \cdot \sigma$$

where:

σ : Surface principal stress, in N/mm^2, read out at a distance $t_{n50}/2$ away from the intersection line.

t_{n50} : Plate net thickness, in mm, in way of the weld toe.

At structural details where the hot spot type 'a' is classified as a web-stiffened cruciform joint, the stress read out procedure of [4.2] is to be applied.

For hot spot type 'b', the stress distribution is not dependent on the plate thickness; the structural hot spot stress, σ_{HS}, is derived from a finite element analysis with mesh density 10×10 mm and is obtained by the following formula:

$$\sigma_{HS} = 1.12 \cdot \sigma$$

where:

σ : Surface principal stress, in N/mm^2, read out at an absolute distance from the intersection line of 5 mm.

3.1.2 Stress read out methods

Depending on the element type, one of the following stress read out method is to be used:

- With 4-node shell element:

  Element surface stress components at the centre points are linearly extrapolated to the line A-A as shown in Figure 15 to determine the stress components for load case '*i1*' and '*i2*' at the stress read out point located at a distance $t_{n50}/2$ from the intersection line for type 'a' hot spot. Two principal hot spot stress ranges are determined at the stress read out point from the stress components tensor differences (between load case '*i1*' and '*i2*') calculated from each side (side L, side R) of line A-A. The angle θ between the direction x of the element co-ordinate system and the principal direction *pX* of the principal hot spot stress range co-ordinate system has to be determined.

- With 8-node shell element:

  With a $t_{n50} \times t_{n50}$ element mesh using 8-node element type, the element mid-side node is located on the line A-A at a distance $t_{n50}/2$ for type 'a' hot spots. This node coincides with the stress read out point. The element surface stress components for load case '*i1*' and '*i2*' can be used directly without extrapolation within each adjacent element located on each side (side L, side R) of the line A-A as illustrated in Figure 16. Two principal hot spot stress ranges are determined at the stress read out point from the stress components tensor difference (between load case '*i1*' and '*i2*') calculated from each side of line A-A. The angle θ between the direction x of the element coordinate system and the principal direction *pX* of the principal hot spot stress range coordinate system has to be determined.

For fatigue assessment of type 'b' hot spots, a beam element is to be used to obtain the fatigue stress range. The stress range is to be based on axial and bending stress in the beam element. The beam element is to have the same depth as the connecting plate thickness while the in-plane width is negligible.

Figure 15 : Determination of stress read out points and hot spot stress for 4-node element

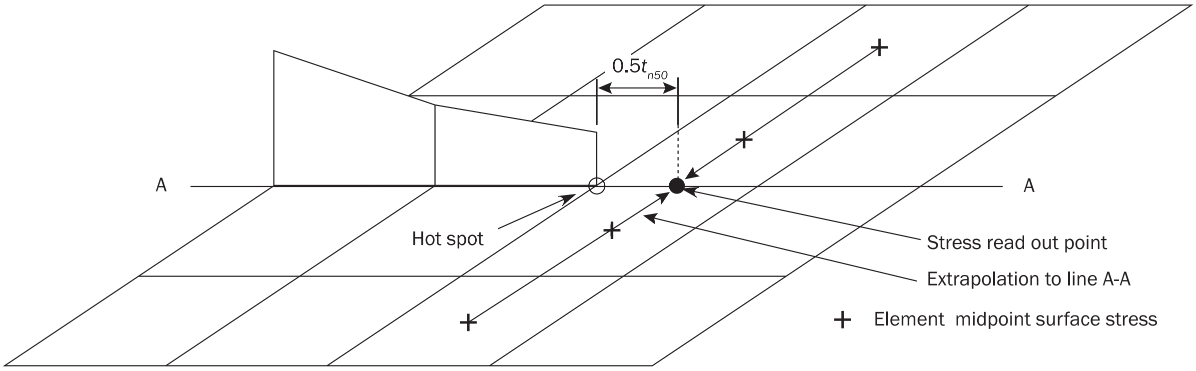
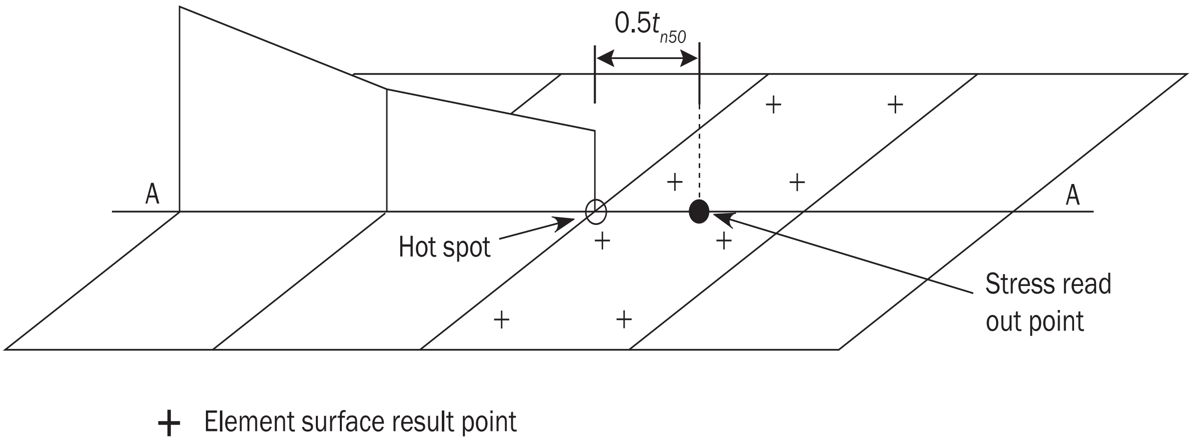


Figure 16 : Determination of stress read out points and hot spot stress for 8-node element



3.1.3

The above read out procedure is based on element surface stresses. Generally, in FE software the element stresses are calculated at the Gaussian integration points located inside the element. Depending on the element type implemented in the FE software, it may be necessary to perform several interpolations in order to determine the actual stress at the considered stress read out point at the surface of the element mid-point or element edge.

3.2 Base material

3.2.1

For fatigue assessment at a free plate edge, a beam element is to be used to obtain the fatigue stress range. The beam element is to have the same depth as the connecting plate thickness while the in-plane width should be negligible.

3.3 Bent hopper knuckle

3.3.1

The hot spot stress at the inner bottom/hopper sloping plate in transverse and longitudinal directions (i.e. hot spots 1, 2 and 3 defined in Ch 9, Sec 2, Table 5) of a bent hopper knuckle is to be taken as the surface principal stress read out from a point shifted away from the intersection line between the considered member and abutting member by the weld leg length.

The hot spot stress, in N/mm^2, is obtained by the following formula:

$$\sigma_{HS} = \sigma_{shift}$$

where:

σ_{shift} : Surface principal stress, in N/mm², at the shifted read out position as defined in [4.2.1] and taken as:

$$\sigma_{shift} = \sigma_{membrane}(x_{shift}) + \sigma_{bending}(x_{shift})$$

$\sigma_{bending}(x_{shift})$: Bending stress, in N/mm², at x_{shift} position.

$\sigma_{membrane}(x_{shift})$: Membrane stress at x_{shift} position, in N/mm².

3.3.2

The procedure for calculation of hot spot stress at flange such as inner bottom /hopper sloping plate is the same that for web-stiffened cruciform joints as described in [4.2.1]. The procedure that applies for hot spots on the ballast tank side of the inner bottom/hopper plate in way of a bent hopper knuckle is in principal the same as that applied on the cargo tank side of the inner bottom plate for welded knuckle in Figure 18 and Figure 19. The intersection line is taken at the mid-thickness of the joint assuming median alignment. The plate angle correction factor and the reduction of bending stress as applied for a web-stiffened cruciform joint in [4.2.2] are not to be applied for the bent hopper knuckle type.

3.3.3

The stress at hot spots located in way of the web such as transverse web and side girder (i.e. hot spots 4, 5 and 6 defined in Ch 9, Sec 2, Table 5) at a bent hopper knuckle type is to be derived as described for web-stiffened cruciform joints in [4.3.1].

4 HOT SPOT STRESS FOR WEB-STIFFENED CRUCIFORM JOINT

4.1 Applicability

4.1.1

Among the structural details to be assessed listed in Ch 9, Sec 2, Table 3 the following structural details are considered as a web-stiffened cruciform joint:

a) Welded hopper knuckle connection, shown in Figure 17.

b) Heel of horizontal stringer, shown in Figure 17.

c) Lower stool – inner bottom connection.

Two kinds of hot spots relative to the web-stiffened cruciform joints are to be assessed:

- Hot spots at the flange of web-stiffened cruciform joint,
- Hot spots in way of the web of web-stiffened cruciform joint.

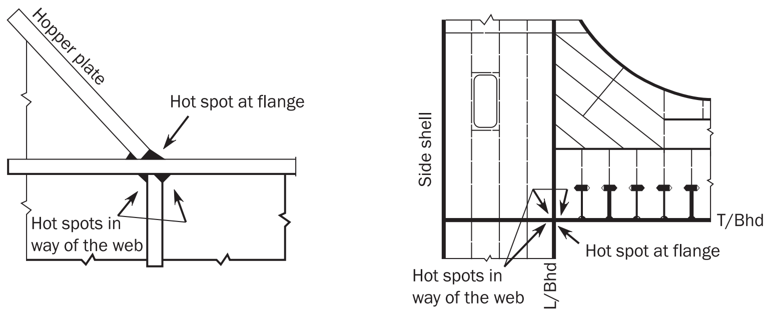
4.1.2

The procedure for calculating hot spot stress at flange of web-stiffened cruciform joint is given in [4.2].

4.1.3

The procedure for calculating hot spot stress in way of the web of the web-stiffened cruciform joint is given in [4.3].

Figure 17 : Web-stiffened cruciform joints



4.2 Calculation of hot spot stress at the flange

4.2.1

For hot spot at the flange of web-stiffened cruciform joints, the surface principal stress is to be read out from a point shifted away from the intersection line between the considered member and abutting member to the position of the actual weld toe and multiplied by 1.12. The intersection line is taken at the mid-thickness of the cruciform joint assuming a median alignment.

The hot spot stress, in N/mm^2, is to be obtained as:

$\sigma_{HS} = 1.12\ \sigma_{shift}$

where:

σ_{shift} : Surface principal stress, in N/mm^2, at shifted stress read out position.

The stress read out point shifted away from the intersection line is obtained as:

$$x_{shift} = \frac{t_{1-n50}}{2} + x_{wt}$$

where:

$t_{1\text{-}n50}$: Net plate thickness of the plate number 1, in mm, as shown in Figure 18

x_{wt} : Extended fillet weld leg length, in mm, as defined in Figure 18, not taken larger than $t_{1\text{-}n50}/2$.

4.2.2

The stress at the shifted position is derived according to the following formula and illustrated in Figure 19:

$$\sigma_{shift} = [\sigma_{membrane}(x_{shift}) + 0.60 \cdot \sigma_{bending}(x_{shift})] \cdot \beta$$

where:

$\sigma_{bending}(x_{shift})$:Bending stress, in N/mm^2, at the shifted position taken as:

$$\sigma_{bending}(x_{shift}) = \sigma_{surface}(x_{shift}) - \sigma_{membrane}(x_{shift})$$

$\sigma_{surface}(x_{shift})$: Total surface stress at x_{shift} position (including membrane stress and bending stress), in N/mm^2.

$\sigma_{membrane}(x_{shift})$: Membrane stress at x_{shift} position, in N/mm^2.

β : Plate angle hot spot stress correction factor, taken as:

- For $\alpha = 135°$:

$$\beta = 0.96 - 0.13\frac{x_{wt}}{t_{1-n50}} + 0.20\left(\frac{x_{wt}}{t_{1-n50}}\right)^2$$

- For $\alpha = 120°$:

$$\beta = 0.97 - 0.14\frac{x_{wt}}{t_{1-n50}} + 0.32\left(\frac{x_{wt}}{t_{1-n50}}\right)^2$$

- For $\alpha = 90°$:

$$\beta = 0.96 + 0.031 \frac{x_{wt}}{t_{1-n50}} + 0.24 \left(\frac{x_{wt}}{t_{1-n50}}\right)^2$$

α : Angle, in deg, between the plates forming a web-stiffened cruciform joint as shown in Figure 19.

Correction factors for connections with plate angles intermediate to those given should be derived based on a linear interpolation of the above values. The calculated hot spot stress is to be used in conjunction with the hot spot S-N curve for weld toe connections according to Ch 9, Sec 3, [4.2].

Figure 18 : Geometrical parameters of web-stiffened cruciform connections

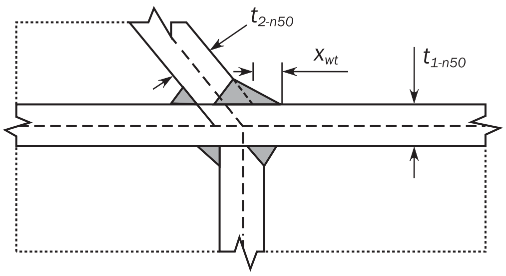


Figure 19 : Procedure for calculation of hot spot stress at web-stiffened cruciform connections

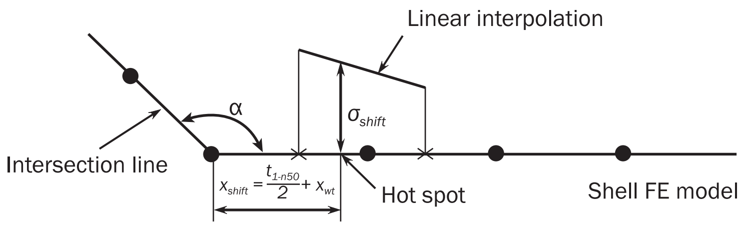
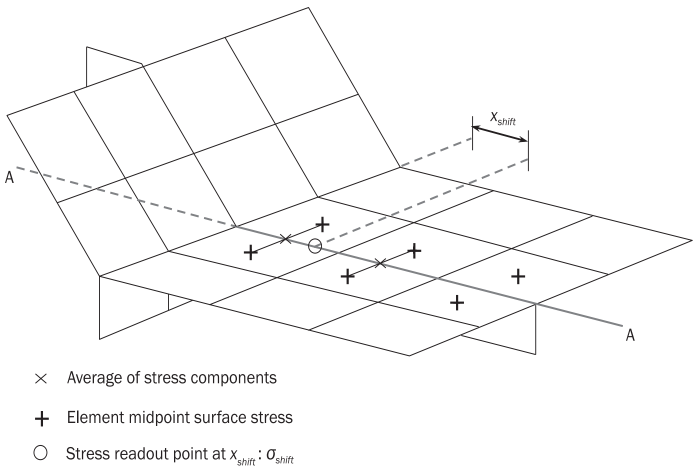


Figure 20 : Determination of stress read out points for web-stiffened cruciform connections



4.2.3

Surface principal stresses at the centre point of the two first elements on left and right side of the line A-A are averaged and taken as the surface principal stresses in way of the web position (line A-A). The surface principal stresses for load case '*i1*' and '*i2*' are linearly interpolated along the line A-A in order to determine hot spot principal stresses at the stress read out point located at the x_{shift} position as shown in Figure 20. The two principal hot spot stress ranges are determined at the stress read out point between load case '*i1*' and '*i2*'.

4.3 Calculation of hot spot stress in the web

4.3.1

Hot spots located in way of the web as indicated in Figure 21 are to be checked with the hot spot stress defined from the maximum principal surface stress at the intersection offset by the distance x_{shift} from the vertical and horizontal element intersection lines as illustrated in Figure 21. The intersection line is taken at the mid thickness of the cruciform joint assuming a median alignment. The hot spot stress, in N/mm^2, is to be obtained as:

$\sigma_{HS} = \sigma_{shift}$

where:

σ_{shift} : Maximum principal surface stress, in N/mm^2, at the intersection offset by the distance x_{shift}.

The stress read out point at the intersection offset is obtained as:

$$x_{shift} = \frac{t_{3-n50}}{2} + x_{wt}$$

where:

$t_{3\text{-}n50}$: Net plate thickness of the web, in mm, as shown in Figure 21

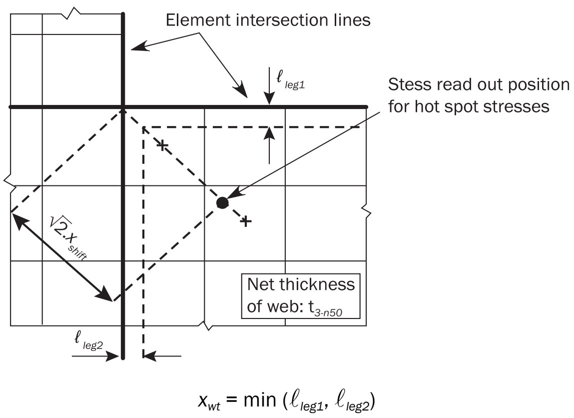
x_{wt} : Extended fillet weld leg length, in mm, , taken as:

$x_{wt} = \min(\ell_{leg1}, \ell_{leg2})$

ℓ_{leg1}, ℓ_{leg2}: Leg length, in mm, of the vertical and horizontal weld lines as shown in Figure 21.

.

Figure 21 : Hot spots in way of web



5 LIMITATIONS OF HOT SPOT STRESS APPROACH

5.1 Scope of application of hot spot stress approach

5.1.1

The hot spot stress approach given in Ch 9, Sec 1, [2.3.1] is not applicable for simple cruciform joints and simple T-joints when the stress flow in direction I as shown in Figure 22 is considered. For stresses in the direction normal to the weld at hot spot location "c" (direction I) there is no stress flow into the transverse plating as it is represented only by one plane in the shell model. However, it attracts stresses for in-plane direction (direction II) at hot spot location "*a*".

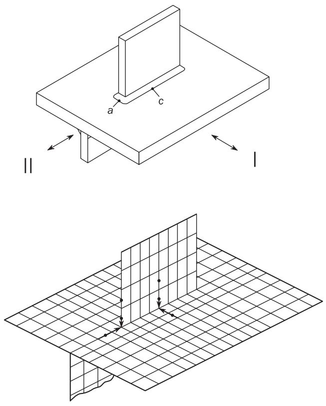
In situations where a bracket is fitted behind the transverse plate as shown in Figure 1, acting with stiffness in the direction normal to the transverse plate, stresses flow also into the transverse plate and the hot spot methodology is considered applicable.

5.1.2

The hot spot stress at position '*c*' for simple cruciform joints and simple T-joints is to be determined by the stress read out procedure given in [3.1] multiplied by a geometrical stress concentration factor of 1.3 and is taken as:

$$\sigma_{HS} = 1.3 \cdot 1.12\sigma$$

Figure 22 : Illustration of check points in way of a welded attachment under orthogonal applied in plane loads



6 SCREENING FATIGUE ASSESSMENT

6.1 Screening procedure

6.1.1 Assumptions

The screening fatigue procedure is based on:

- Screening hot spot stress obtained by multiplying the stresses calculated from fine mesh analysis according to Ch 7, Sec 3 by the stress magnification factor of the considered structural detail.
- Mean stress effect and thickness effect are used according to Ch 9, Sec 3, [3.2] and Ch 9, Sec 3, [3.3].

6.1.2 Procedure

The screening fatigue procedure includes the following three phases:

a) Phase 1: Calculation of fatigue stress.

   - Stresses are calculated at the stress read out point from the fine mesh element analysis with elements size of 50 × 50 mm, according to Ch 7, Sec 3 for all fatigue load cases defined in Ch 9, Sec 1, [7], for all loading conditions. Stresses to be used are element average membrane components stress defined in [6.2.3].
   - Hot- spot surface stress components are calculated for each load case '*i1*' and '*i2*' from the stresses multiplied by the stress magnification factor η, taken as:
     - $\sigma_{HS,\, i1(j)} = \eta\ \sigma_{S,\, i1(j)}$
     - $\sigma_{HS,\, i2(j)} = \eta\ \sigma_{S,\, i2(j)}$
   - Hot spot principal surface stress ranges are the difference of hot spot stress components obtained for each load case '*i1*' and '*i2*'.
   - Fatigue stress ranges for welded joints are determined from hot spot principal surface stress ranges with correction factor for mean stress and thickness effect.

   where:

   $\sigma_{S,\, i1(j)}$: Stress calculated from the fine mesh analysis in load case '*i1*' of loading condition (*j*) defined in [6.2].

   $\sigma_{S,\, i2(j)}$: Stress calculated from the fine mesh analysis in load case '*i2*' of loading condition (*j*) defined in [6.2].

η : Stress magnification factor given in Table 2.

b) Phase 2: Selection of S-N curve.

The S-N curve D defined in Ch 9, Sec 3, [4] is to be used with the fatigue stress range of weld toe in screening fatigue procedure.

c) Phase 3: Calculation of fatigue damage and fatigue life according to [6.1.3].

Table 2 : Stress magnification factor

Ship type	Structural details category	Stress magnification factor, η
Oil tanker	Toe of stringer	2.45
	Bracket toe of transverse web frame	1.65
Bulk carrier	Lower hopper knuckle	2.10 for FA (1) 2.00 for EA (1)
	Lower stool – inner bottom (for knuckle angle = 90 deg)	1.66
	Lower stool – inner bottom (for knuckle angle > 90 deg)	1.45 for FA (1) 1.75 for EA (1)
(1) FA and EA mean full and empty cargo hold in alternate loading condition respectively.		

6.1.3 Screening fatigue criteria

The total fatigue damage and the fatigue life of screened details are to comply with the criteria given in Ch 9, Sec 3, [2].

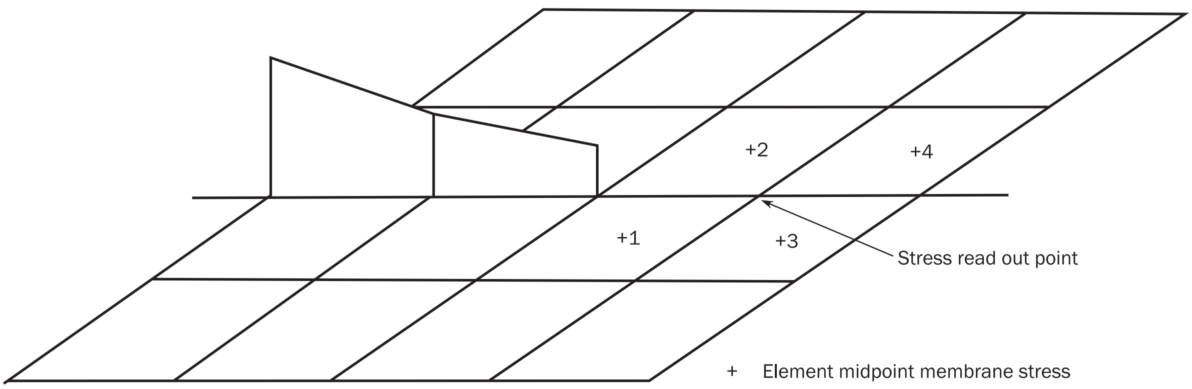
Structural details that do not comply with the acceptance criteria are to be checked with respect to fatigue strength using a very fine mesh finite element analysis as described in Ch 9, Sec 5.

6.2 Stress read out procedure

6.2.1 Bracket toe

For bracket toe, the stress read out point is located at a 50 mm distance away from the bracket toe as shown in Figure 23.

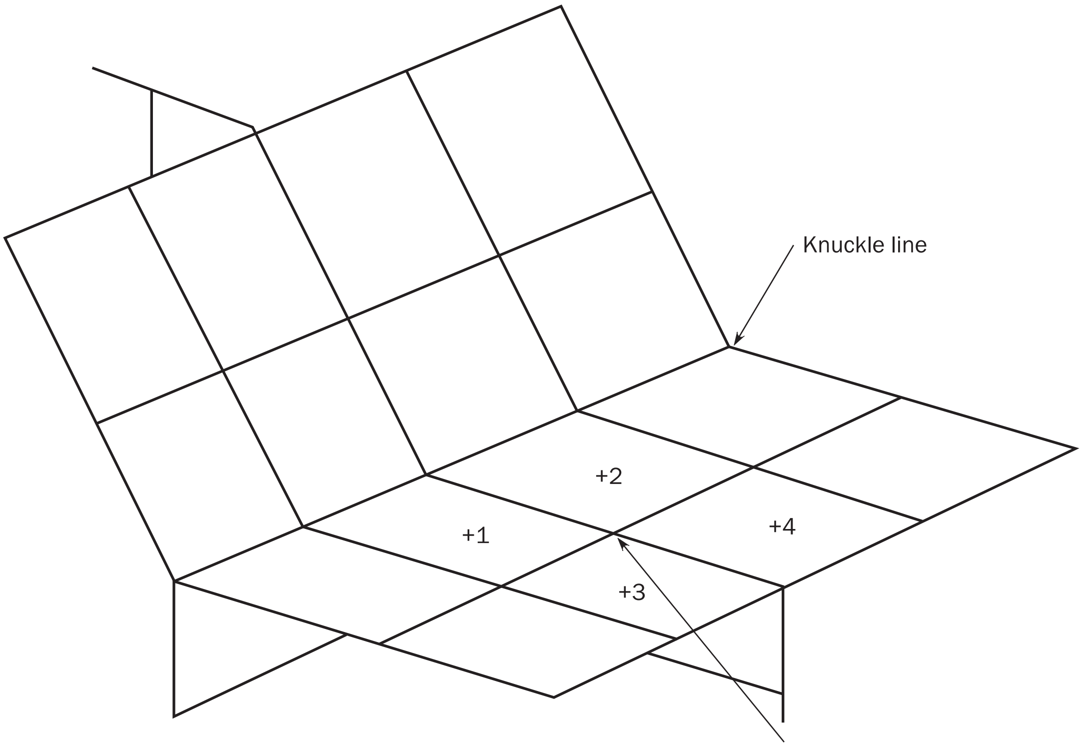
Figure 23 : Stress read out point at bracket toe



6.2.2 Knuckle detail

For the lower hopper knuckle and for the connection between transverse bulkhead lower stool and inner bottom, the stress read out point is located at a 50 mm distance away from the knuckle line (i.e. model intersection line) as shown in Figure 24.

Figure 24 : Stress read out point of knuckle detail

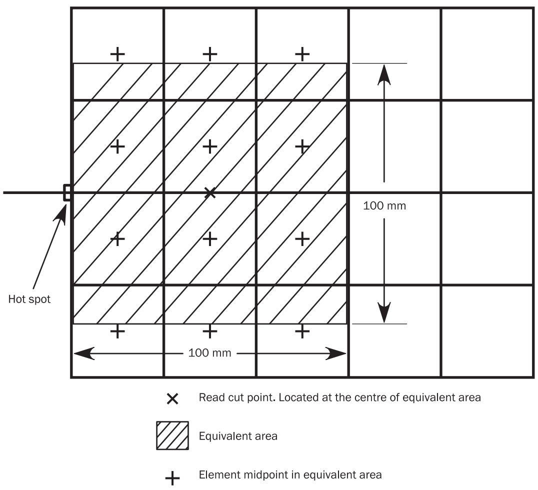


6.2.3 Read out point stress

The average of membrane stress components at the centre of four elements, modelled with elements size of 50 × 50 mm connected to the stress read out point (or node) can be used as read out point stress.

When the element size is less than 50 x 50 mm, the stress of read out point can be derived using elements in an equivalent area as shown in Figure 25.

Figure 25 : Equivalent area for element size less than 50 × 50 mm



SECTION 6
DETAIL DESIGN STANDARD

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

1 GENERAL

1.1 Purpose

1.1.1

Design standard provides fatigue resistant detail design at an early stage in the structural design process by giving consideration to the following aspects:

- Application of fatigue design principles.
- Construction tolerances and other practical considerations.
- In-service experience and fatigue performance.

1.1.2

The design standard is to be applied to the design of ship structural details in following steps:

- Highlighting potential critical areas within the ship structure.
- Identification of the fatigue hot spot locations for each of the critical structural details.
- Provision of a set of alternative improved configurations from which a suitable solution can be selected.
- Requirements on geometrical configurations, scantlings, welding requirements and construction tolerances.
- Post fabrication method of improving fatigue life, such as weld toe grinding.

1.2 Application

1.2.1

The structural details described in this section are to be designed according to the given design standard but alternative detail design configurations may be accepted subject to demonstration of satisfactory fatigue performance.

For the details given in Ch 9, Sec 2, Table 3, the fatigue assessment by very fine mesh finite element analysis may be omitted if the detail is designed in accordance with the design standard given in this section.

2 STIFFENER-FRAME CONNECTIONS

2.1 Design standard A

2.1.1

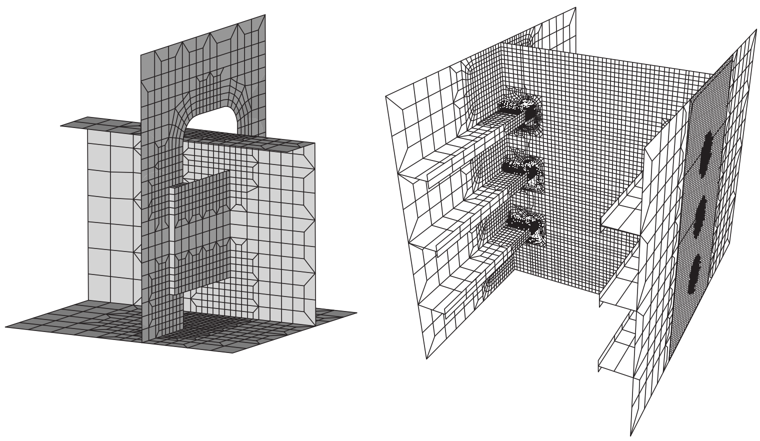
Designs for cut outs in cases where web stiffeners are omitted or not connected to the longitudinals are required to adopt tight collar or the improved design standard "*A*" as shown in Table 1 or equivalent, for the following members:

- Side shell below $1.1T_{sc}$.
- Bottom.
- Inner hull longitudinal bulkhead below $1.1T_{sc}$.
- Topside tank sloping plating below $1.1T_{sc}$.
- Hopper.
- Inner bottom.

2.1.2

Designs that are different from those shown in Table 1 are acceptable subject to demonstration of satisfactory fatigue performance, e.g. by using comparative finite element analysis. The comparative FE analysis is to be performed following the modelling guidance given in Figure 1.

Figure 1 : Finite element model for verification of equivalent design



2.2 Equivalent design of stiffener-frame connections

2.2.1

If the required designs for stiffener-frame connections in [2.1] are not followed, the alternative design is to be verified to have equivalent fatigue strength to the design standard "A" or to be verified to have satisfactory fatigue performance. The alternative design is to be verified according to the procedure given in [2.2.2] to [2.2.5] and documentation of results is to be submitted to the Society.

2.2.2

The procedure of [2.2.3] and [2.2.4] is provided to verify the alternative design to have equivalent fatigue strength with respect to any position in the transverse ring, i.e. double bottom and double side. The hot spot stress of the alternative design and that of the required design is to be compared to the critical hot spots in way of the cut-out. The critical hot spots depend on the detail design and are to be selected in agreement with the Society. The hot spot stress is to be derived according to Ch 9, Sec 5, [3.1] and Ch 9, Sec 5, [3.2]. It is to be

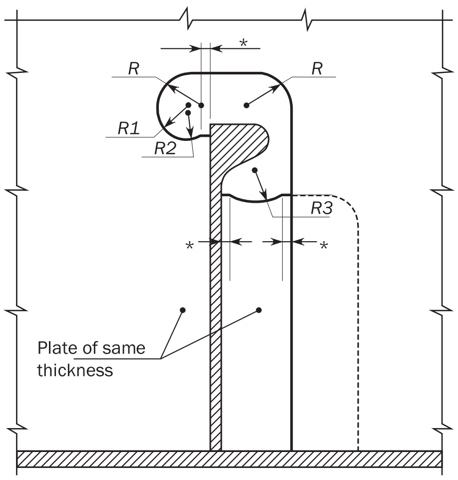
noted that welded hot spots at the free edge are classified as hot spot type “*b*”. Example of typical hot spots for checking is shown in Ch 9, Sec 2, [2].

Table 1 : Design standard A – stiffener-frame connection

Cut outs for longitudinals in transverse webs where web stiffeners are omitted or not connected to the longitudinal flange

Design standard *A*

1



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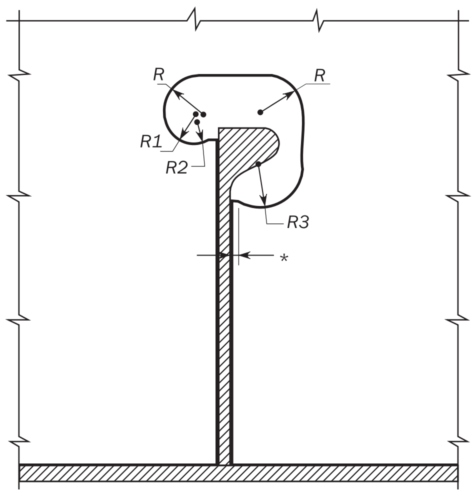

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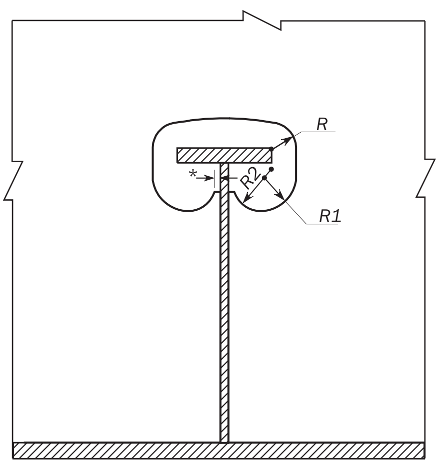

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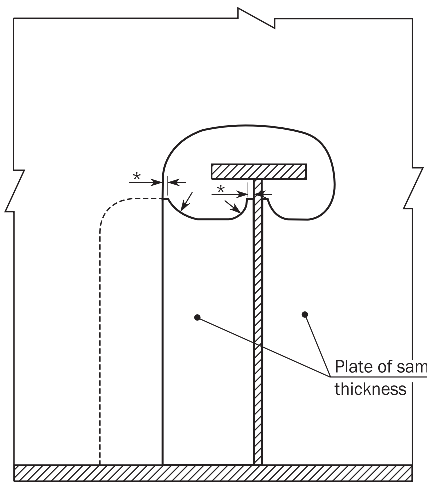


Note 1: Soft toes marked ‘*’ are to be dimensioned to suit the weld leg length such that smooth transition from the weld to the curved part can be achieved. Maximum 15 mm or thickness of transverse web/collar plates/lug plates whichever is the greater.

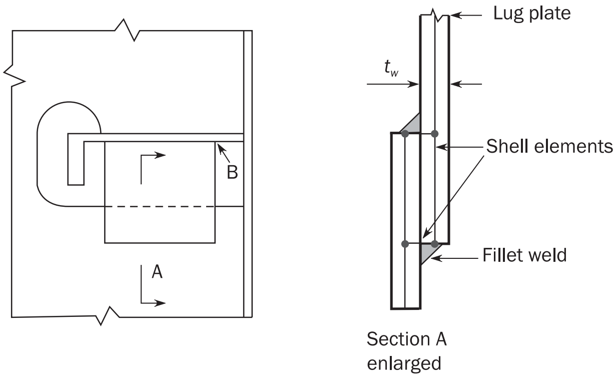
Note 2: Configurations 1 and 4 indicate acceptable lapped lug plate connections.

Critical location	Locations around cut-out with high stress concentration and locations in way of weld terminations.
Detail design standard	Improved slot shape to avoid high stress concentrations in transverse webs due to shear loads and local pressure loads transmitted via welded joints.
Building tolerances	Ensure alignment of all connecting members and accurate dimensional control of cut-outs according to IACS Recommendation No. 47.
Welding requirements	A wraparound weld, free of undercut or notches, around the transverse web connection to longitudinal stiffener web.

2.2.3

The very fine mesh finite element models are made to analyse the behaviour in way of double side or double bottom. The models should have an extent of 3 stiffeners in cross section, i.e. 4 stiffener spacings, and the longitudinal extent is to be one half frame spacing in both forward and aft direction. A typical model is shown in Figure 1. No cut-outs for access openings are to be included in the models. Connection between the lug or the web-frame to the longitudinal stiffener web, connections of the lug to the web-frame and free edges on lugs and cut-outs in web-frame are to be modelled with elements of net plate thickness size (t_{n50} × t_{n50}). The mesh with net plate thickness size should extend at least five elements in all directions. Outside this area, the mesh size may gradually be increased in accordance with the requirements in Ch 9, Sec 5, [2]. The eccentricity of the lapped lug plates is to be included in the model. Transverse web and lug plates are to be connected by eccentricity elements (transverse plate elements). The height of eccentricity element is to be the distance between mid-layers of transverse web and lug plates having a thickness equal to 2 times the net thickness of web-frame plate $t_{w\text{-}n50}$. Eccentricity elements representing fillet welds are shown in Figure 2.

Figure 2 : Modelling of eccentric lug plate by shell elements



2.2.4

Three load cases are to be applied to the models of the design standard and alternative designs:

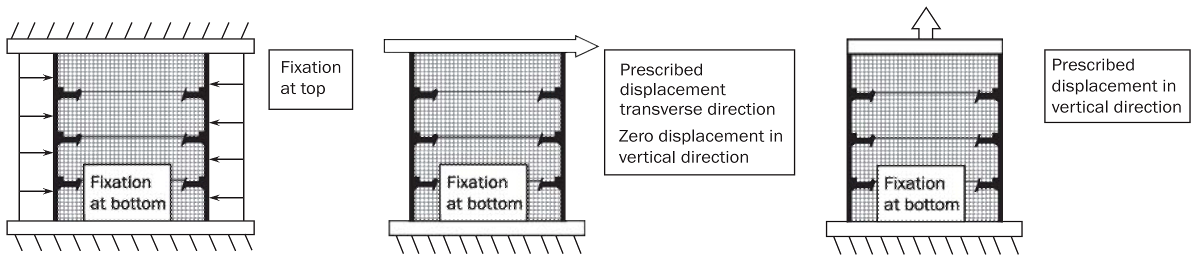
- External pressure of unit value, fixed boundary conditions at top and bottom of model.
- Shear stress by prescribed unit displacement at the model top and fixed boundary conditions at the model bottom.
- Axial load by prescribed unit displacement at the model top and fixed boundary conditions at the model bottom.

The forward and aft part of the model should have symmetry condition describing the behaviour in a double hull structure. Load application and boundary conditions are provided in Figure 3.

2.2.5

The alternative design may also be verified to have satisfactory fatigue performance using sub-modelling technique where a very fine mesh model of the alternative design located at the actual position of the stiffener-frame connection is analysed. The alternative design is considered acceptable if the fatigue acceptance criterion of Ch 9, Sec 1 is achieved. The fatigue acceptance criterion is checked by applying the methodology described in Ch 9, Sec 1, Ch 9, Sec 3 and Ch 9, Sec 5. The alternative design is considered acceptable only for the particular position where it is analysed.

Figure 3 : Load application and boundary conditions – FE model for verification of alternative design



3 SCALLOPS IN WAY OF BLOCK JOINTS

3.1 Design standard B

3.1.1

Scallops in way of block joints in the cargo tank/hold region, located on the stiffeners fitted on strength deck, and side above 0.9 *D* from the baseline, are required to be designed according to the design standard B as shown in Table 2.

4 HOPPER KNUCKLE CONNECTION

4.1 Design standard C to H

4.1.1

The welded knuckle between hopper plating and inner bottom plating for double-hull oil tankers is to be designed according to the design standard C in Table 3. The design standard D in Table 4 may be used as an alternative to increase fatigue strength at the hopper connection.

4.1.2

The welded knuckle between hopper plating and inner bottom plating for bulk carriers is to be designed according to the design standard E in Table 5.

4.1.3

The radiused knuckle between hopper plating and inner bottom plating is to be designed according to the design standard F in Table 6 for double hull oil tankers.

Alternative structural arrangements may be accepted based on verification in accordance with Ch 9, Sec 5, [3.3].

4.1.4

The radiused knuckle between hopper plating and inner bottom plating for bulk carriers is to be designed according to the design standard G in Table 7.

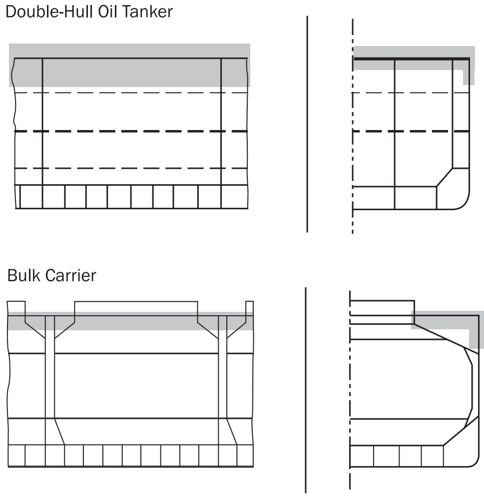
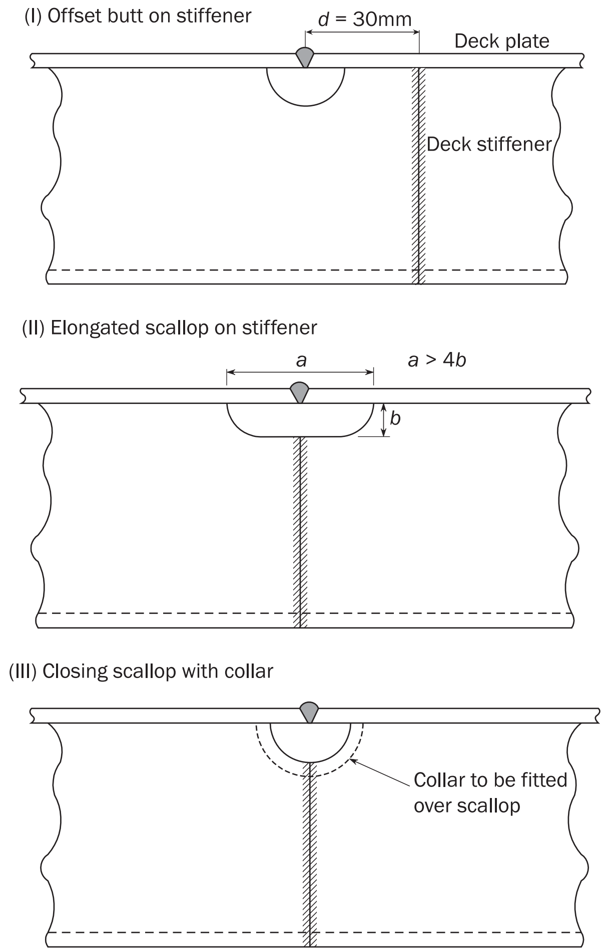
4.1.5

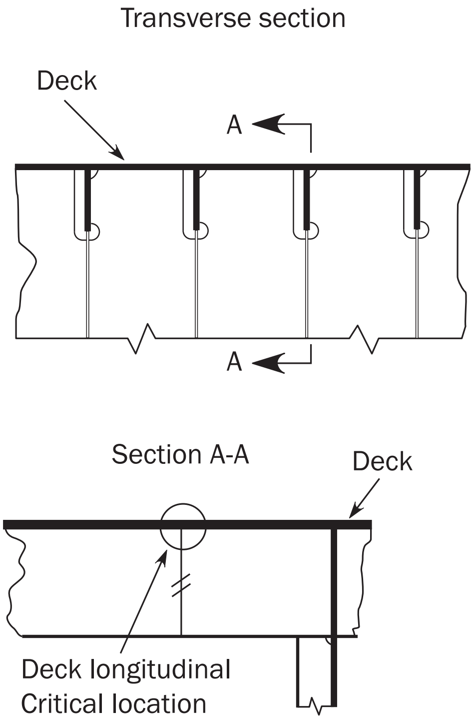
The radiused knuckle between hopper plating and inner side plating for oil tankers and double side bulk carriers is to be designed according to the design standard H in Table 8.

4.1.6

In general, the prescribed minimum requirements for welding, weld dressing and building tolerances as given in Table 3 to Table 8 are to be followed. Alternative positioning and/or dispensation of some support structure, such as transverse and longitudinal brackets may be accepted subject to demonstration of acceptable fatigue lives. Inserts and/or weld dressing additional to those prescribed may be required as a consequence of hot spot fatigue analysis.

Table 2 : Design standard B – scallops in way of block joints

<table>
<tr><th colspan="2">Welding of deck stiffeners in way of block joints</th></tr>
<tr><th>Critical areas</th><th>Design standard B</th></tr>
<tr><td>
</td>
<td rowspan="3">

Note 1: Alternative scallop geometry to that shown in option II may be accepted subject to demonstration of satisfactory fatigue life based on hull girder loads taking into account additional stress concentration factor in way of weld</td></tr>
<tr><th>Critical locations</th></tr>
<tr><td>
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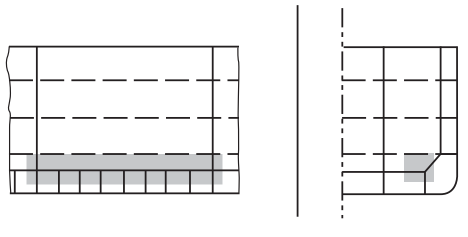
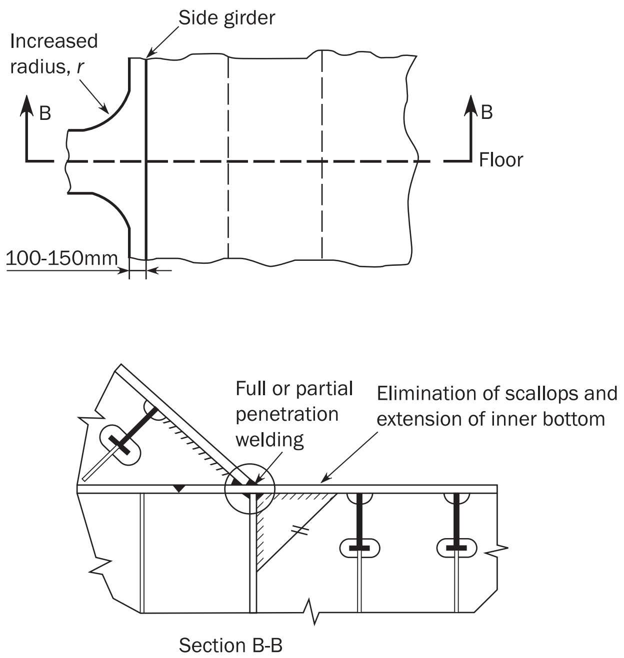
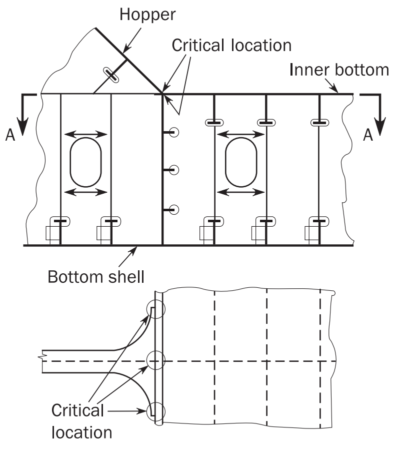
</table>

Critical location	Welding of deck stiffeners in way of block joints in cargo tank region, the strength deck and side above 0.9 *D* from the baseline.
Detail design standard	All scallops are to be fitted according to detail design standard B.
Building tolerances	Ensure alignment of all structural members according to IACS Recommendation No. 47.
Welding requirements	Full penetration butt weld, free of undercut or notches, around the web and flange of the longitudinal stiffener at block joints, particularly in way of the weld termination at the scallop for option II.

Table 3 : Design standard C – hopper knuckle connection detail, welded, without bracket, double hull oil tanker

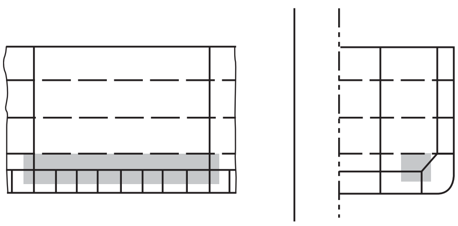
<table>
<tr><th colspan="2">Connections of floors in double bottom tanks to hopper tanks
Hopper corner connections employing welded inner bottom and hopper sloping plating</th></tr>
<tr><th>Critical areas</th><th>Design standard C</th></tr>
<tr><td></td><td rowspan="3">
</td></tr>
<tr><th>Critical locations</th></tr>
<tr><td>
</td></tr>
</table>

Minimum requirement	As a minimum, detail design standard C or D is to be fitted. The ground surface is to be protected by a stripe coat of suitable paint composition, where the lower hopper knuckle region of cargo tanks is not coated.
Critical location	Hopper sloping plating connections to inner bottom plating in way of floors. Floor connections to inner bottom plating and side girder in way of hopper corners.
Detail design standard	Elimination of scallops in way of hopper corners, extension of inner bottom plating to reduce level of resultant stresses arising from cyclic external hydrodynamic pressure, cargo inertia pressure and hull girder loads. Scarfing bracket thickness is to be close to that of the inner bottom in way of the knuckle.
Building tolerances	Median line of hopper sloping plate is to be in line with the median line of the girder with an allowable tolerance of $t_{as\text{-}built}/3$ or 5 mm, whichever is less, where $t_{as\text{-}built}$ is the as-built side girder thickness. The allowable tolerance is to be measured parallel to the inner bottom.
Welding requirements	Full or partial penetration welding is to be applied to hopper sloping plating and inner bottom plating connection. Partial penetration welding is to be applied to connections of side girder to inner bottom plating, to connections of floors to inner bottom plating and to side girder, to connections of hopper transverse webs to sloping plating, to inner bottom and to side girder in way of the hopper knuckle. Definition of full and partial penetration welding and their required extent are given in Ch 12, Sec 3 Weld between hopper plating and inner bottom plating to be enlarged and ground smooth. Visible undercuts are to be removed, see Ch 9, Sec 3, [6]. Weld enlargement and grinding are applicable to minimum 200 mm on each side of the floor.

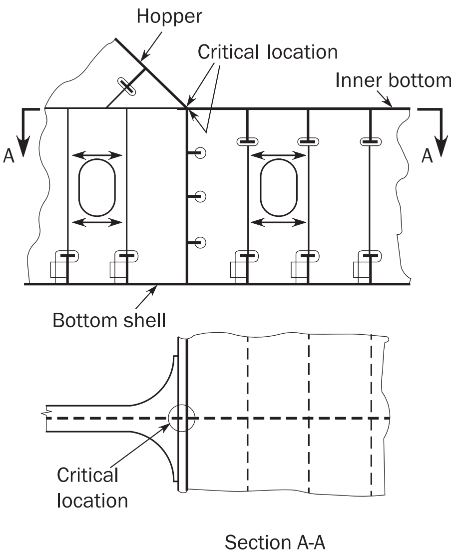
Table 4 : Design standard D – hopper knuckle connection detail, welded, with bracket, double hull oil tanker

Connections of floors in double bottom tanks to hopper tanks
Hopper corner connections employing welded inner bottom and hopper sloping plating

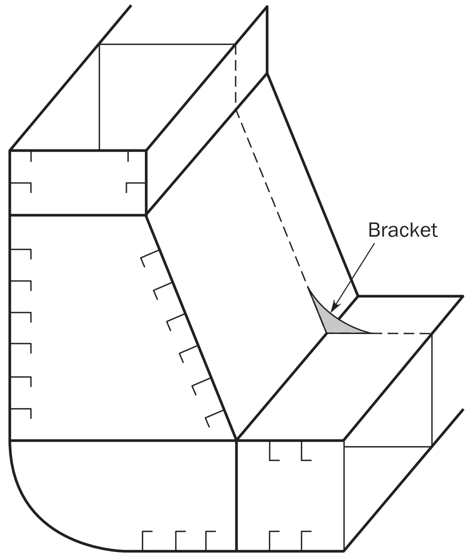
Critical areas



Critical locations



Design standard D



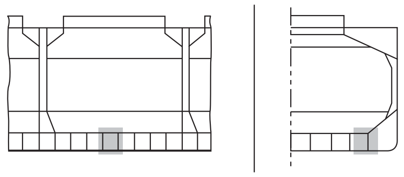
Note 1: Bracket to be fitted inside cargo tank.
Note 2: Bracket to extend approximately to the first longitudinal.
Note 3: The bracket toes are to have a soft nose design.
Note 4: Bracket material to be same as that of inner bottom.
Note 5: Slenderness of bracket to be in accordance with Ch 8, Sec 2, [5.2].

Minimum requirement	As a minimum, detail design standard C or D is to be applied.
Critical location	Hopper sloping plating connections to inner bottom plating in way of floors. Floor connections to inner bottom plating and side girder in way of hopper corners. The bracket connection to inner bottom and hopper sloping plate.
Detail design standard	Elimination of scallops in way of hopper corners, extension of inner bottom plating to reduce level of resultant stresses arising from cyclic external hydrodynamic pressure, cargo inertia pressure and hull girder loads. Scarfing bracket thickness similar to that of the inner bottom in way of the knuckle.
Building tolerances	Median line of hopper sloping plate is to be in line with the median line of girder with an allowable tolerance of $t_{as\text{-}built}$ /3 or 5 mm, whichever is less, where $t_{as\text{-}built}$ is the as-built side girder thickness.
Welding requirements	Partial penetration welding is to be applied to hopper sloping plating and inner bottom plating connection, to connections of side girder to inner bottom plating, to connections of floors to inner bottom plating and to side girder, to connections of hopper transverse webs to sloping plating, to inner bottom and to side girder in way of the hopper knuckle. Partial penetration welding is to be applied to the bracket connections to inner bottom and hopper sloping plate, full penetration welding is to be applied at bracket toes. Definition of full and partial penetration welding and their required extent are given in Ch 12, Sec 3.

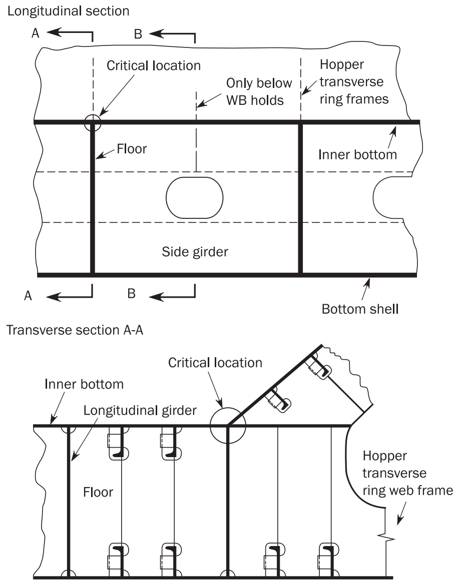
Table 5 : Design standard E – hopper knuckle connection detail, welded, bulk carrier

Connections of floors in double bottom tanks to hopper tanks Welded knuckle connection of hopper tank sloping plating to inner bottom plating	
Critical areas	**Design standard E**

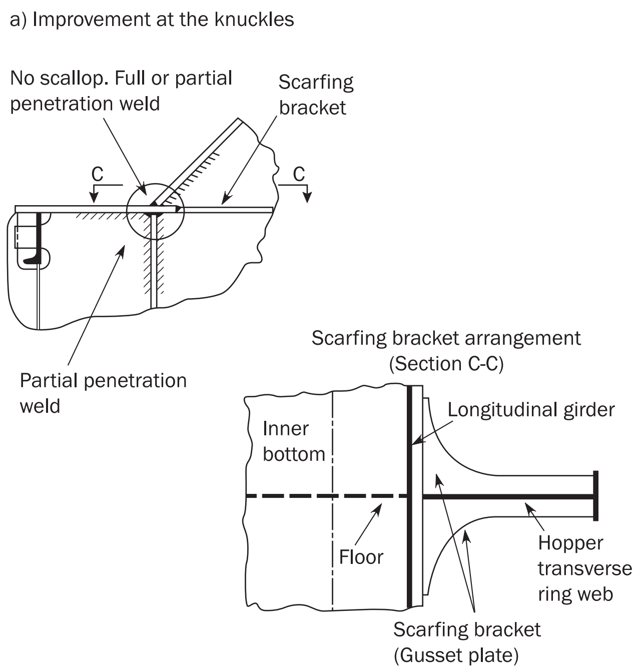
Critical areas



Critical locations

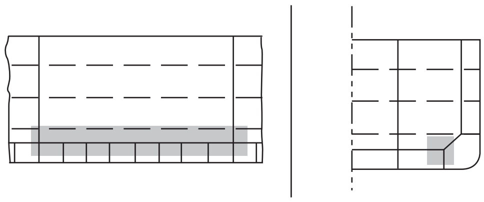
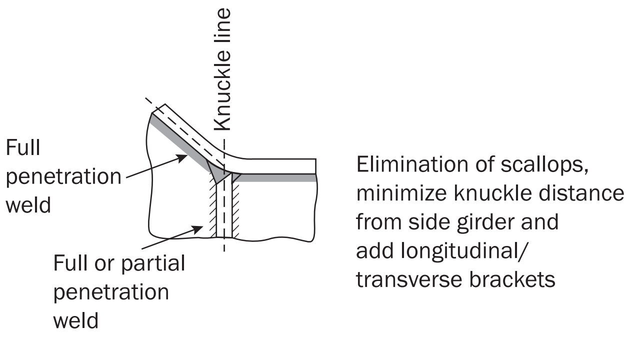


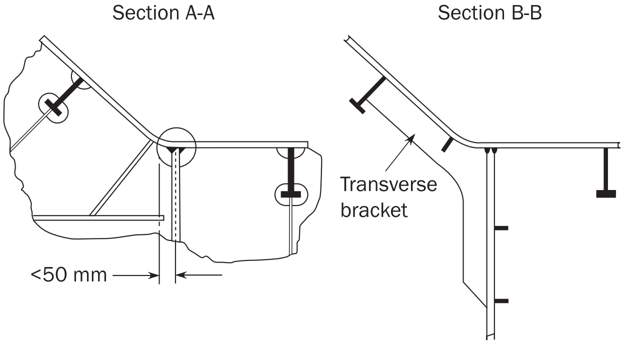
Design standard E

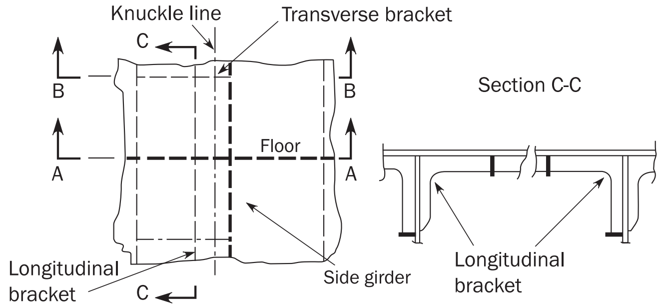


Minimum requirement	As a minimum, detail design standard E is to be fitted. Ballast holds: No scallops or close scallops with collars; scarfing bracket; intermediate bracket if floor spacing greater than 2.5 m. Dry holds: No scallop or close scallops with collars and scarfing bracket.
Critical location	Hopper sloping plating connections to inner bottom plating in way of the floors. Floor connections to inner bottom plating and side girder in way of the hopper knuckle.
Detail design standard	Elimination of scallops in way of hopper knuckle, extension of inner bottom plating to reduce level of resultant stresses arising from cyclic external hydrodynamic pressure, cargo inertia pressure and hull girder loads. Scarfing bracket net thickness is to be minimum 80% of that of the inner bottom in way of knuckle and steel material to be of the same yield strength.
Building tolerances	Median line of hopper sloping plate is to be in line with the median line of girder with an allowable tolerance of $t_{as\text{-}built}/3$ or 5 mm, whichever is less, where $t_{as\text{-}built}$ is the as-built side girder thickness.
Welding requirements	Full or partial penetration welding is to be applied to hopper sloping plating and inner bottom plating connection for the length of the cargo hold. Partial penetration welding is to be applied to connections of side girder to inner bottom plating, to connections of floors to inner bottom plating and to side girder, to connections of hopper transverse webs to sloping plating, to inner bottom and to side girder in way of the hopper knuckle. Weld between hopper plating and inner bottom plating is to be enlarged and ground smooth. Visible undercuts are to be removed. Weld enlargement and grinding are applicable to minimum 200 mm on each side of the floor. Definition of full and partial penetration welding and their required extent are given in Ch 12, Sec 3.

Table 6 : Design standard F – hopper knuckle connection detail, radiused type, for double hull oil tanker

<table>
<tr><td colspan="2">Connections of floors in double bottom tanks to hopper tanks
Hopper corner connections employing radiused knuckle between inner bottom and hopper sloping plating</td></tr>
<tr><td>Critical areas</td><td>Design standard F</td></tr>
<tr><td></td><td rowspan="3">




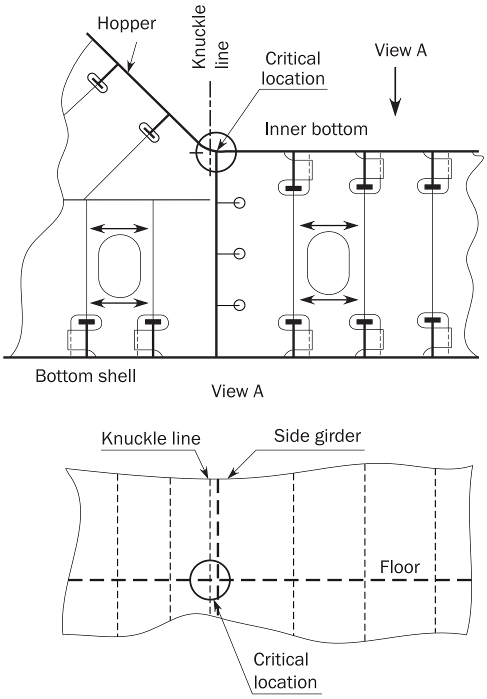


Note 1: Distance from side girder to centre of knuckle is to be as small as practicable, but is not to exceed 50 mm.

Note 2: The knuckle radius is not to be less than 4.5 $t_{as\text{-}built}$ or 100 mm, whichever is the greater, where $t_{as\text{-}built}$ is the as-built thickness of the knuckle part.

Note 3: Additional transverse brackets offset at a suitable distance on either side of transverse floor/hopper connection.

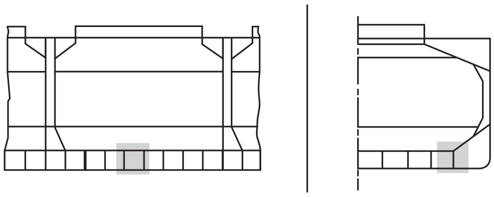
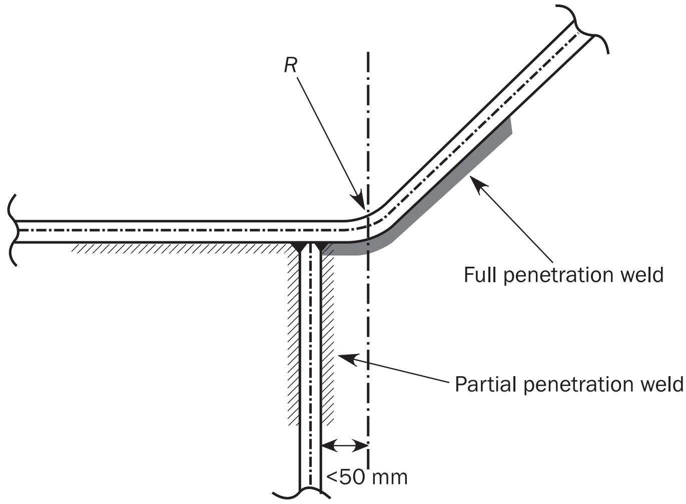
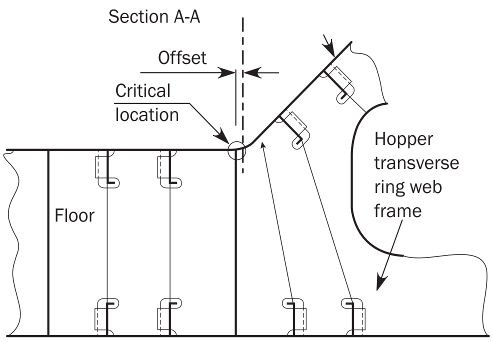
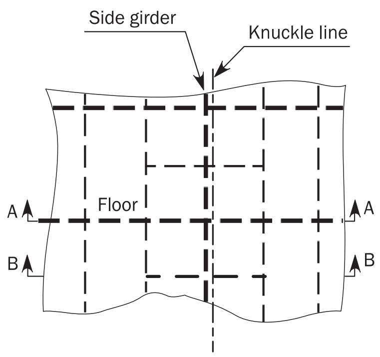
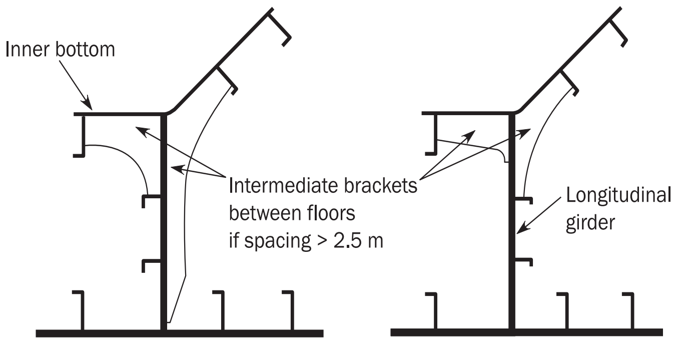
Note 4: Additional longitudinal bracket on the side of sloping plate.

Note 5: Longitudinal and/or transverse brackets may be omitted if it can be demonstrated that the girder provides sufficient support at the knuckle line, i.e. that fatigue requirements according to Ch 9, Sec 5 and local strength analysis requirements according to Ch 7, Sec 3 are fulfilled.
</td></tr>
<tr><td>Critical locations</td></tr>
<tr><td>

</td></tr>
<tr><td>Critical location</td><td>Floor and hopper transverse web connections to inner bottom plating and hopper sloping plate, respectively and to side girder in way of hopper knuckle. Side girder connections to inner bottom plating in way of floors.</td></tr>
</table>

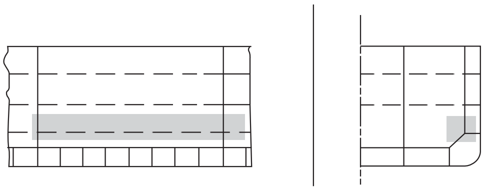
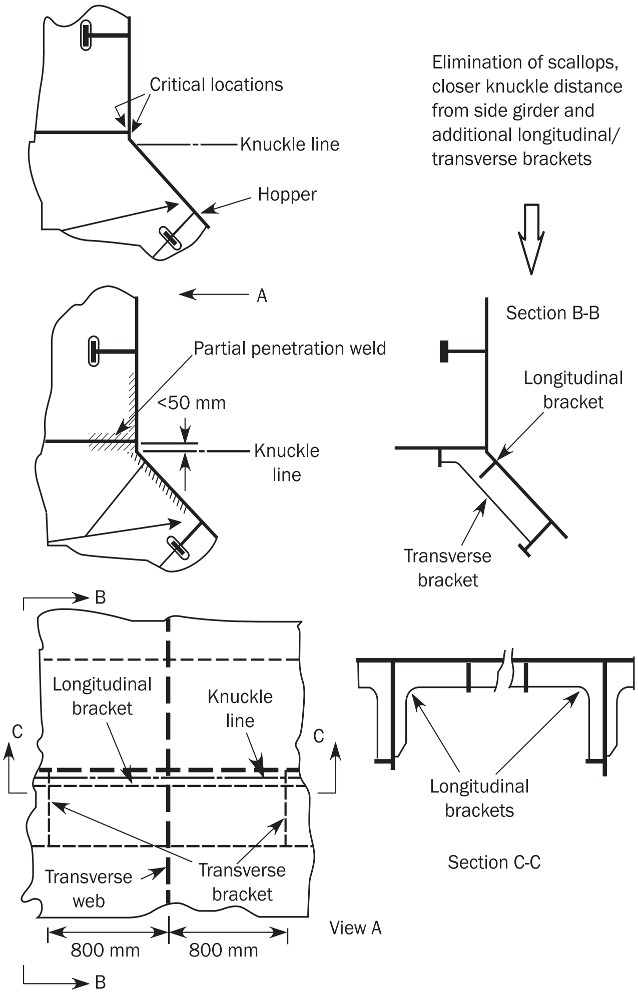
Connections of floors in double bottom tanks to hopper tanks Hopper corner connections employing radiused knuckle between inner bottom and hopper sloping plating	
Detail design standard	Elimination of scallops in way of hopper/girder connection and additional transverse and longitudinal brackets to reduce peak and range of resultant stresses arising from cyclic external hydrodynamic pressure, cargo inertia pressure, and hull girder global loading, and provide additional support to sloping plate.
Building tolerances	The nominal distance between the centres of thickness of the two abutting members (e.g. floor and hopper web plate) is not to exceed 1/3 of the as-built thickness of the side girder.
Welding requirements	Full penetration welding is to be applied to connections of floors to hopper/inner bottom plating in way of radiused hopper knuckle. Partial penetration welding is to be applied to connections of floors/hopper transverse webs to the side girder in way of hopper corner, and to connections of side girder to hopper/inner bottom plating. Definition of full and partial penetration welding and their required extent are given in Ch 12, Sec 3. In order to improve the fatigue strength, weld enlargement and grinding are applicable to full and partial penetration welds with a minimum distance of 300 mm from the intersection point between the radiused knuckle, the floor and the side girder.

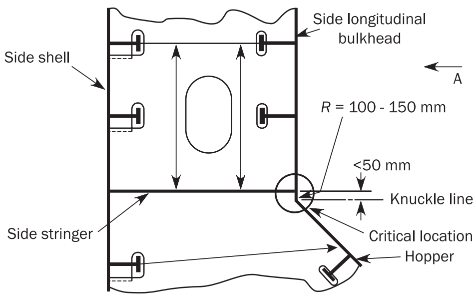
Table 7 : Design standard G – hopper knuckle connection detail, radiused type, bulk carrier

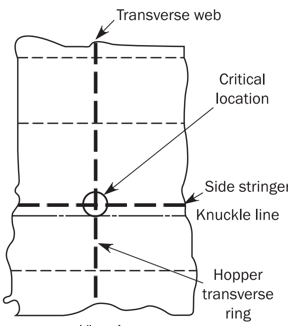
Connections of floors in double bottom tanks to hopper tanks Hopper corner connections employing radiused knuckle between inner bottom and hopper sloping plating	
Critical areas	**Design standard G**
	
Critical locations	Intermediate bracket arrangement (Section B-B). Two intermediate brackets at both sides of floor/transverse web.
 	 Note 1: Distance from side girder to centre of knuckle is to be as small as practicable, but is not to exceed 50 mm. Note 2: The knuckle radius is not to be less than 4.5 $t_{as\text{-}built}$ or 100 mm, whichever is the greater, in cases where $t_{as\text{-}built}$ is the as-built thickness of the knuckle part. Note 3: Additional transverse brackets on both side of transverse floor/hopper connection. Note 4: Transverse brackets may be omitted if it can be demonstrated that the girder provides sufficient support at the knuckle line, i.e. that fatigue requirements according to Ch 9, Sec 5 and local strength analysis requirements according to Ch 7, Sec 3 are fulfilled.
Critical location	Side girder connections to inner bottom plating in way of floors. Floor and hopper transverse web connections to inner bottom plating and hopper sloping plate, respectively, and to side girder in way of hopper corners.
Detail design standard	Elimination of scallops in way of hopper/girder connection. Ballast holds: Intermediate brackets fitted at approximately 0.5 floor space from floor/hopper web. Dry holds: Intermediate brackets fitted at 0.5 floor space from floor/hopper web if floor spacing is equal to or greater than 2.5 m.

Connections of floors in double bottom tanks to hopper tanks Hopper corner connections employing radiused knuckle between inner bottom and hopper sloping plating	
Building tolerances	The nominal distance between the centres of thickness of the two abutting members (e.g. floor and hopper web plate and additional supporting brackets) should not exceed 1/3 of the as-built thickness of the side girder.
Welding requirements	Full penetration welding is to be applied to connections of floors to hopper /inner bottom plating in way of radiused hopper knuckle. Partial penetration welding is to be applied to connections of floors/hopper transverse webs to side girder in way of hopper corners, to connections of side girder to hopper /inner bottom plating. Definition of full and partial penetration welding and their required extent are given in Ch 12, Sec 3.

Table 8 : Design standard H – upper hopper knuckle connection detail, radiused type, oil tankers and double side bulk carrier

<table>
<tr><th colspan="2">Connections of transverse webs in double side tanks to hopper tanks
Hopper corner connections employing radiused knuckle between side longitudinal bulkhead and hopper sloping plating</th></tr>
<tr><th>Critical areas</th><th>Design standard H</th></tr>
<tr><td></td><td rowspan="3">

Note 1: Distance from side stringer to centre of knuckle is to be as small as practicable, but is not to exceed 50 mm.
Note 2: The knuckle radius is not to be less than 4.5 $t_{as\text{-}built}$ or 100 mm, whichever is the greater, where $t_{as\text{-}built}$ is the as-built thickness of the knuckle part.
Note 3: Additional transverse brackets offset at a suitable distance on either side of transverse floor/hopper connection.
Note 4: Additional longitudinal bracket on the side of sloping plate.
Note 5: Longitudinal and/or transverse brackets may be omitted if it can be demonstrated that the girder provides sufficient support at the knuckle line, i.e. that fatigue requirements according to Ch 9, Sec 5 and local strength analysis requirements according to Ch 7, Sec 3 are fulfilled.</td></tr>
<tr><th>Critical locations</th></tr>
<tr><td>



View A</td></tr>
</table>

Critical location	Side stringer connections to side longitudinal bulkhead in way of transverse webs. Double side tank transverse web and hopper transverse web connections to side longitudinal bulkhead and to side stringers in way of hopper corners.
Detail design standard	Elimination of scallops in way of hopper corners, closer knuckle distance from side stringers. Additional longitudinal/transverse brackets to reduce peak and range of resultant stresses arising from cyclic external hydrodynamic pressure and cargo inertia pressure.

Connections of transverse webs in double side tanks to hopper tanks Hopper corner connections employing radiused knuckle between side longitudinal bulkhead and hopper sloping plating	
Building tolerances	The nominal distance between the centres of thickness of the two abutting members should not exceed 1/3 of the as-built thickness of the side stringer.
Welding requirements	Partial penetration welding is applied to connection of side stringers to side longitudinal bulkhead, connection of double side tank transverse webs to side longitudinal bulkhead and to side stringers, connection of hopper transverse webs to sloped side longitudinal bulkhead and to side stringers in way of hopper corners. Small scallops of suitable shape, which are to be closed by welding after completion of the continuous welding of side stringers to longitudinal bulkhead, are to be provided where scallops are eliminated. Definition of full and partial penetration welding and their required extent are given in Ch 12, Sec 3.

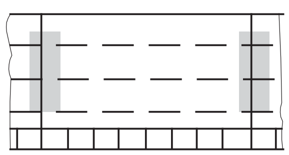
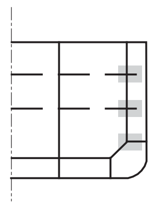
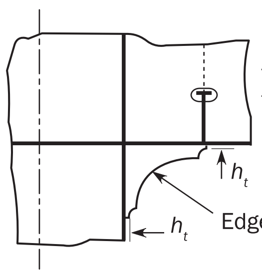
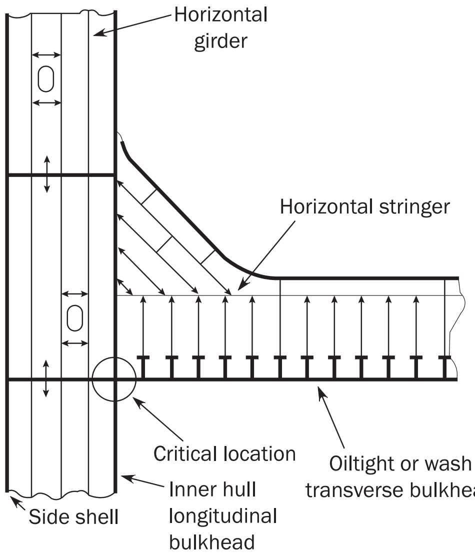
5 HORIZONTAL STRINGER HEEL

5.1 Design standard I

5.1.1

The horizontal stringer heel location between transverse oil-tight/swash bulkhead plating and inner hull longitudinal bulkhead plating for double hull oil tankers are required to be designed according to design standard I, as shown in Table 9.

Table 9 : Design Standard I – transverse bulkhead horizontal stringer heel

Connections of horizontal stringer on plane oil-tight transverse bulkheads or wash bulkheads to inner hull longitudinal bulkheads	
Critical areas	**Design standard I**
 	 Note 1: Where a face plate is considered necessary, it is recommended that design features be adopted to reduce the stress concentration at the face plate termination (e.g. taper and soft nose). Adequate fatigue life of the weld on the bracket edge in way of such terminations is to be confirmed. Note 2: 'Slit type cut-outs are to be adopted in way of the bracket toe as shown. Alternatively, cut-outs with insert type collars will be accepted. Scallops are to be avoided.'
Critical locations	
	

Connections of horizontal stringer on plane oil-tight transverse bulkheads or wash bulkheads to inner hull longitudinal bulkheads	
Critical location	Intersections of webs of transverse bulkhead horizontal stringer and double side tank horizontal girder forming square corners.
Detail design standard	A soft toe backing bracket is to be fitted. The following bracket sizes are recommended: • VLCC: 800×800×30, *R*600 with soft toe as shown in figure above, • Other tankers: 800×600×25, *R*550 with soft toe as shown in figure above, where the longer arm length is in way of the inner skin. The specified minimum yield stress for the bracket is not to be less than 315 N/mm². The free edge is to be ground smooth with corners rounded.
Building tolerances	The nominal distance between the centres of thickness of the two abutting members should not exceed 1/3 of the as-built plate thickness of the inner hull longitudinal bulkhead.
Welding requirements	Vertical weld between the inner hull plating and transverse bulkhead plating, fillet welding having minimum weld factor 0.44. Welding between the backing bracket and the adjoining plates is to be double sided fillet welding having minimum weld factor 0.44 except in way of the bracket toes. Full penetration welding is to be used for the connection of bracket toes to the inner hull and transverse bulkhead plating for a distance of 200 mm from the toes and the weld toes are to be ground smooth in way.

6 BULKHEAD CONNECTION TO LOWER AND UPPER STOOL

6.1 Design standard J, K and L

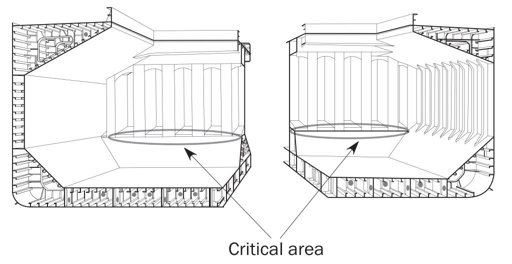
6.1.1

The welded connection of bulkhead to lower stool of bulk carriers and oil tankers are to be designed according to the design standard J and K respectively, as shown in Table 10 and Table 11.

6.1.2

The welded connection of bulkhead to upper stool of bulk carriers are to be designed according to the design standard M, as shown in Table 12.

Table 10 : Design standard J – transverse bulkhead connection detail, bulk carrier

<table>
<tr><th colspan="2">Connections of transverse bulkhead with lower stool</th></tr>
<tr><th>Critical areas</th><th>Design standard J</th></tr>
<tr><td>


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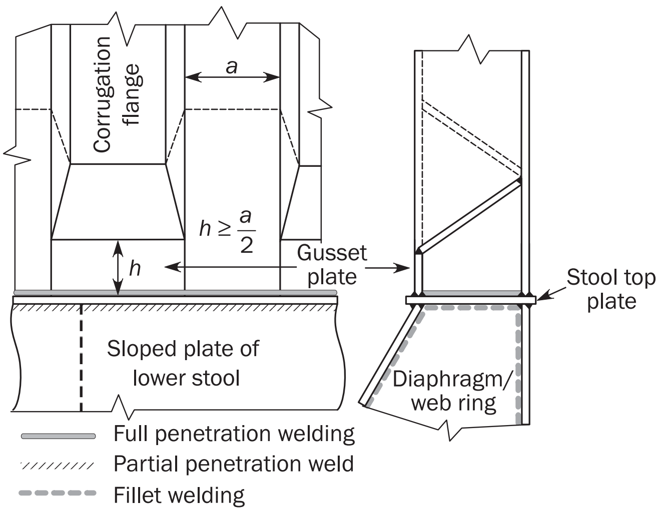
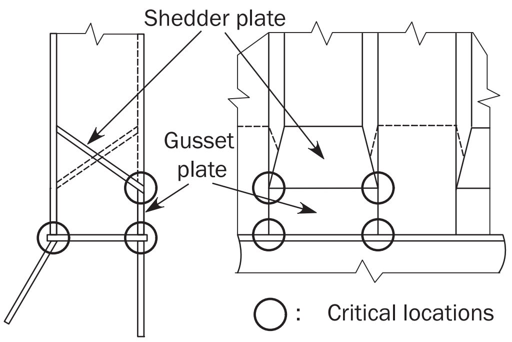


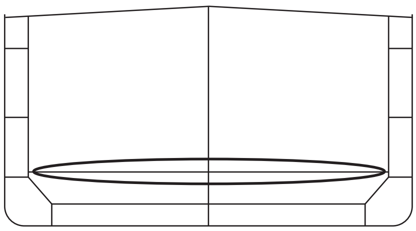
</td></tr>
<tr><th>Critical locations</th></tr>
<tr><td>


</td></tr>
</table>

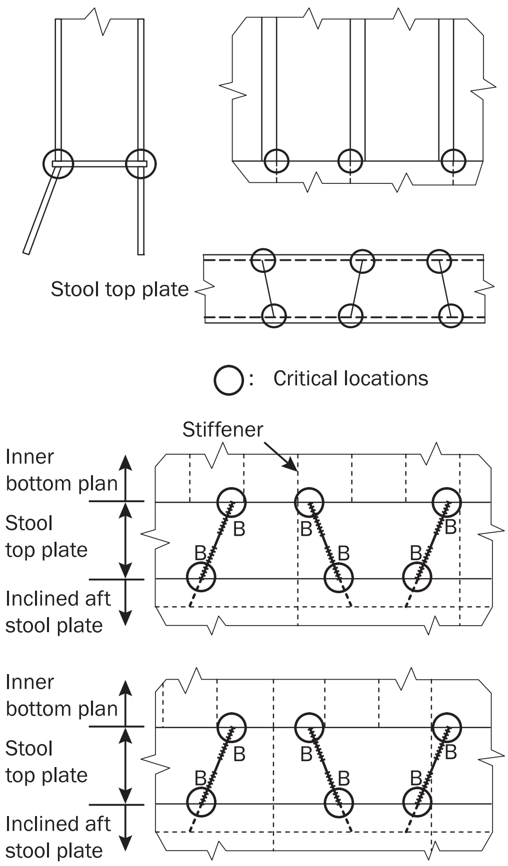
Critical location	Connections of lower stool shelf plate to lower stool and corrugated transverse bulkheads. Connections of shedder plates to corrugated transverse bulkhead.
Detail design standard	The use of scallops is to be avoided on diaphragms/web at lower stool top plates. Gusset plates are to be fitted to corrugated bulkheads. Gusset plates are to be made out of the same material and have the same as-built thickness as corrugated bulkheads; and, the height of gusset plates is to be greater than half of breadth of the corrugation. To reduce stress concentrations at the crossing of the shedder plates one plate is to be moved higher than the other (as shown in Figure). Alternatively, bracketed stiffener can be fitted at the crossing points underneath the shedder plating facing the ballast hold.
Building tolerances	Ensure alignment between lower stool sloping plates and corrugation faces according to IACS Recommendation No. 47.
Welding requirement	Full penetration welding is to be applied between lower stool top plates and the side plating of lower stools and corrugated bulkheads. Partial or full penetration welding is to be applied around gusset plates. However, full penetration welding is to be applied between lower stool top plates and gusset plates. Partial or full penetration welding is to be applied between lower stool top plates and diaphragms/web rings. Ensure start and stop of welding is as far away as practicable from the critical corners.

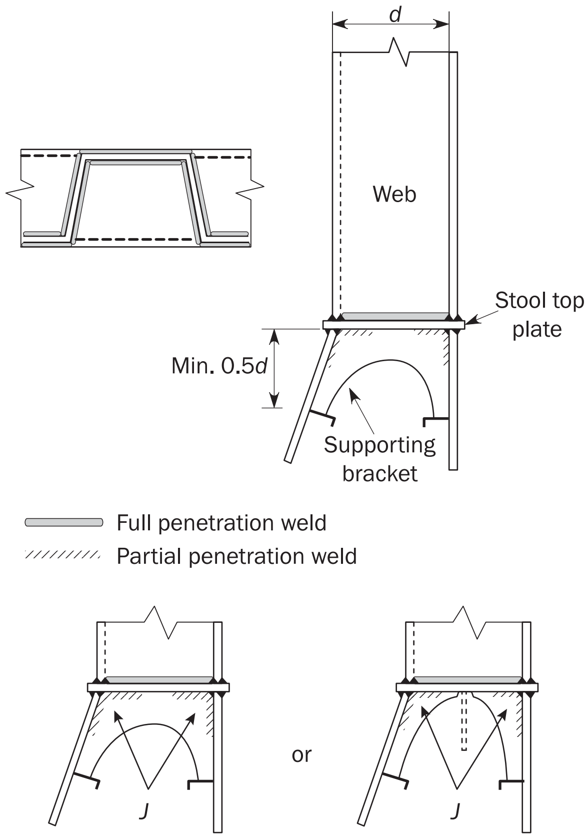
Table 11 : Design standard K – transverse bulkhead connection detail, oil tanker

Connections of transverse bulkhead with lower stool - oil tanker	
Critical areas	**Design standard K**



Critical locations

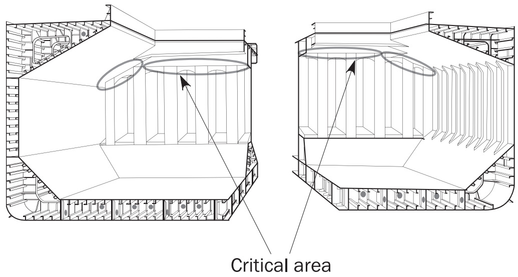
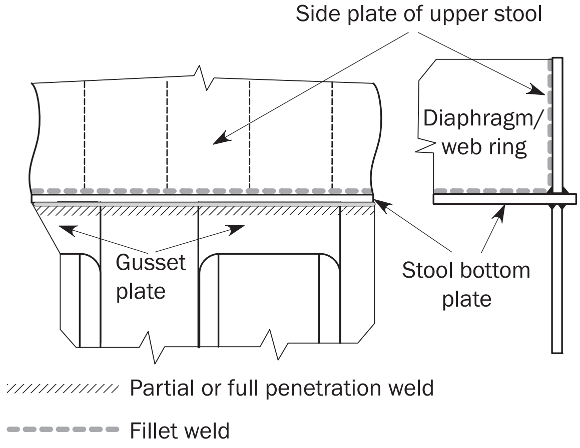
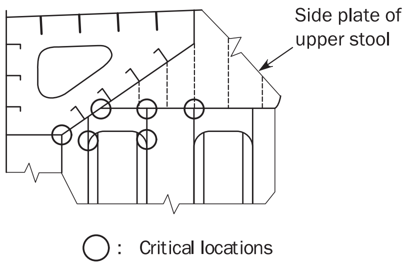




Critical location	Connections of lower stool top plate to corrugated transverse bulkheads.
Detail design standard	The use of scallops is to be avoided on diaphragms/web at lower stool top plates. Supporting brackets are to be fitted in line with corrugation web as required in Ch 6, Sec 4, [2.6.2]. Scallop is not permitted in the supporting bracket.
Building tolerances	Ensure alignment between lower stool side plates and corrugation faces according to IACS Recommendation No. 47.

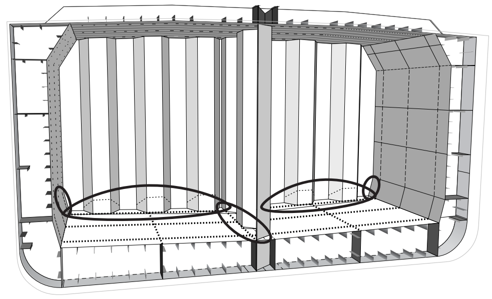
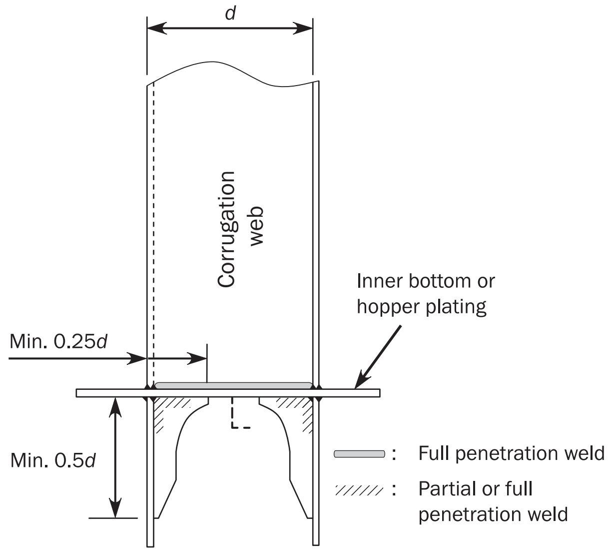
Connections of transverse bulkhead with lower stool - oil tanker	
Welding requirement	Full or partial penetration welding is to be applied between lower stool top plates and the side plating of lower stools. Full penetration welding is to be applied between lower stool top plates and vertical corrugated bulkheads. Full or partial penetration welding is to be applied between lower stool top plates and supporting brackets. Ensure start and stop of welding is as far away as practicable from the critical corners. Connection 'J', as shown in the figure, of in line supporting bracket to stool top plate and side plate of lower stool is to be full or partial penetration welding, on minimum 300 mm from the corner.

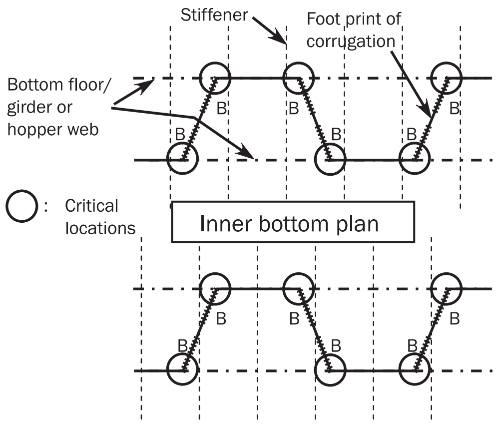
Table 12 : Design standard L – transverse bulkhead connection detail, bulk carrier

<table>
<tr><th colspan="2">Connections of transverse bulkhead with sloped plate of upper stool</th></tr>
<tr><th>Critical areas</th><th>Design standard L</th></tr>
<tr><td>
</td><td rowspan="3">
</td></tr>
<tr><th>Critical locations</th></tr>
<tr><td>
</td></tr>
</table>

Critical location	Connections of corrugated transverse bulkhead to the topside tank sloping plating and upper stool.
Detail design standard	The use of scallops is to be avoided on diaphragms/web at upper stool bottom plates. Gusset plates are to be fitted between the face plates of corrugated bulkheads in way of heavy ballast hold. In way of heavy ballast hold, a deep transverse web or well-stiffened backing stiffener is to be provided in the topside tank in line with the face plate of the bulkhead corrugations to ensure that the loads are effectively dissipated. Gusset plates are to have a thickness and material properties not less than those required for corrugation flanges.
Building tolerances	Ensure alignment between the face plates of corrugated bulkheads with the stool side plates as well as the watertight bulkheads and deep transverse web (or well-stiffened backing stiffener) in the topside tanks according to IACS Recommendation No. 47.
Welding requirement	In the case of ballast holds: • Partial or full penetration welding is to be applied between upper stool bottom plates and corrugation. • Fillet welding having minimum weld factor of 0.44 is to be applied between upper stool bottom plates and upper stool side plating. • Fillet welding having minimum weld factor of 0.44 is to be applied between upper stool bottom plates and diaphragms/web rings. Ensure start and stop of welding is as far away as practicable from the critical corners in all holds.

Table 13 : Design standard M – connection details for vertically corrugated bulkheads in cargo tanks and heavy ballast hold

<table>
<tr><th colspan="2">Connections of vertically corrugated bulkhead to inner bottom/hopper plating without stool</th></tr>
<tr><th>Critical areas</th><th>Design standard M</th></tr>
<tr><td></td><td rowspan="3">Detail of in line bracket:


Note 1: Brackets are to be arranged below inner bottom and hopper tank plating in line with corrugation webs.
Note 2: Where gusset plate with shedder plate according to Ch 6, Sec 4, [2.6.4] item b, is provided, in line bracket may be omitted on the side of gusset plate.</td></tr>
<tr><th>Critical locations</th></tr>
<tr><td>
</td></tr>
</table>

Critical location	-
Material and scantling requirement	Inner bottom and hopper tank plating in way of corrugations is to be in accordance to Ch 6, Sec 4, [2.6.4]. Floors/girders and hopper web that support corrugation flange is to be in accordance to Ch 6, Sec 4, [2.6.4]. Supporting bracket aligned with corrugation web is to be in accordance with Ch 8, Sec 2, [5.2] and Ch 6, Sec 4, [2.6.4].
Detail design standard	Supporting brackets are to be fitted in line with corrugation web as required in Ch 6, Sec 4, [2.6.2]. Scallop is not permitted in the supporting bracket.
Building tolerances	Median line of corrugation is to be in line with the median line of the supporting members with an allowable tolerance of $t_{as\text{-}built}$ /3 or 5 mm, whichever is less, where $t_{as\text{-}built}$ is the inner bottom thickness.
Welding requirement	For the connection of vertically corrugated bulkheads to the inner bottom/hopper plating, full penetration welding is to be provided in according to Ch 12, Sec 3, [2.4] For the connection of supporting structures to inner bottom/hopper plating, partial or full penetration welding is to be provided in accordance with Ch 12, Sec 3, [2.4]. Partial or full penetration welding is also to be applied for the connection of in line brackets below corrugation web in accordance with Ch 12, Sec 3, [2.4] on minimum 300 mm from the corner.

7 BULKHEAD CONNECTION TO INNER BOTTOM

7.1 Design standard M

7.1.1

The connection of vertically corrugated bulkhead to inner bottom/hopper plating of cargo tanks and heavy ballast hold are to be designed according to the design standard M, as shown in Table 13.

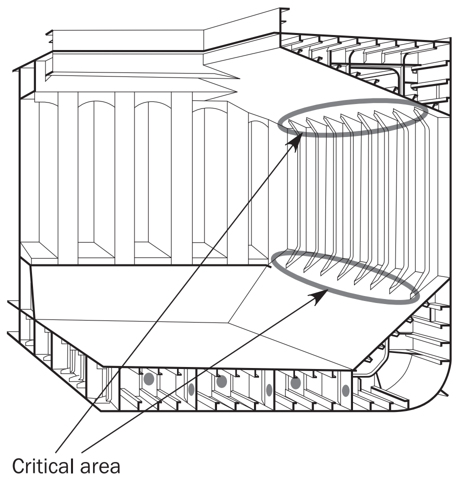
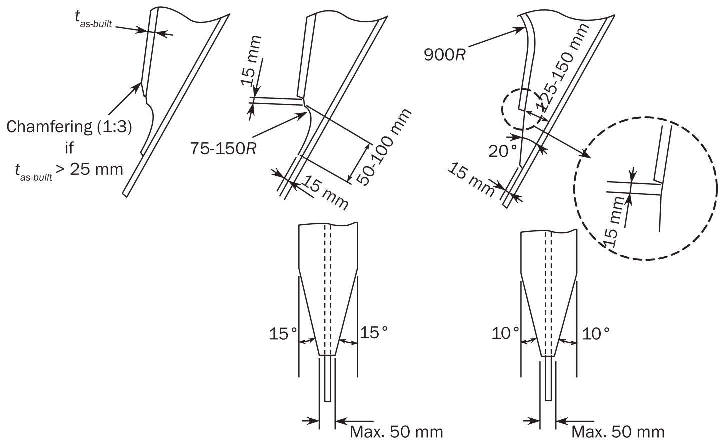
8 LOWER AND UPPER TOE OF HOLD FRAME

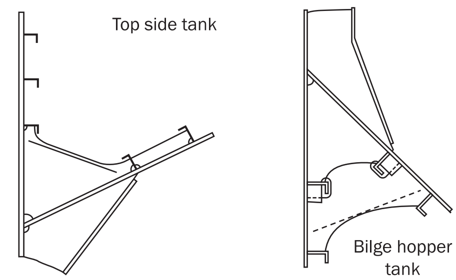
8.1 Design standard N

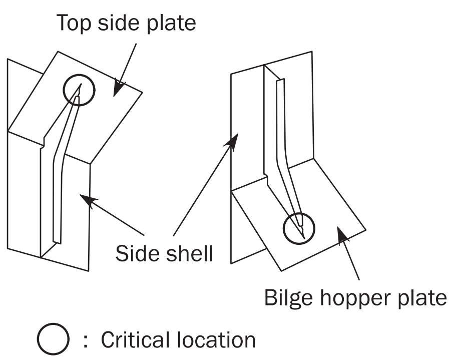
8.1.1

The welded connections of lower and upper bracket toes of hold frame of bulk carriers are to be designed according to design standard N, as shown in Table 14

Table 14 : Design standard N – lower and upper toe detail of hold frame - bulk carrier

<table>
<tr><th colspan="2">Lower and upper hold frame connections</th></tr>
<tr><th>Critical areas</th><th>Design standard N</th></tr>
<tr><td>
</td><td rowspan="3">

Examples of the soft and extended toes at the end of hold frames.


Connection of lower and upper end bracket of hold frame.</td></tr>
<tr><th>Critical locations</th></tr>
<tr><td>
</td></tr>
<tr><td>Minimum requirement</td><td>As a minimum the detail design standard N is to be applied. Tapered extended toes are more effective and are to be considered for high tensile steel side shell frame.</td></tr>
</table>

Lower and upper hold frame connections	
Critical location	Toe connection of side shell frame lower and upper brackets to the hopper and topside sloping plates, including face plate terminations.
Detail design standard	Alternative geometries than stipulated above are permissible subject to demonstration of satisfactory fatigue performance. However, the maximum angles shown on the figures for thickness chamfering and face width tapering are not to be exceeded. Bracket toe height and the distance between the face plate termination and start of the toe radius (or toe taper) are to be kept to a minimum. The face plates of hold frames at lower or upper brackets are to be tapered and chamfered as shown. While chamfering may be dispensed with if the thickness of the face plates is less than 25 mm, it is nevertheless a recommended practice, with a larger gradient if necessary. Frames are to be built-up symmetrical sections with integral upper and lower brackets and are to be arranged with soft or elongated toes as shown. The side frame flange is to be curved (not knuckled) at the connection with the end brackets. Where the frame upper brackets are not positioned directly below a ring web, supporting brackets are to be provided. In the design ensure that if a topside tank stiffener is positioned above the end of frame upper bracket, the stiffener cut-out is avoided or closed with a full collar. Increasing the size of supporting brackets will reduce stress concentrations in the critical area. Where the frame lower brackets are not positioned directly above a ring web, supporting brackets are to be provided. In the design ensure that if a hopper tank stiffener is positioned below the end of the frame lower bracket, the stiffener cut-out is avoided or closed with a full collar. Increasing the size of supporting brackets will reduce stress concentrations in the critical area.
Building tolerances	Ensure alignment between side shell frame lower and upper bracket and transverse ring webs or supporting brackets according to IACS Recommendation No. 47. Maximum misalignment is to be not greater than $t_{as\text{-}built}/3$ where $t_{as\text{-}built}$ is the thinner as-built thickness of the webs to be aligned and misalignment is the overhang of the as-built thinner thickness.
Welding requirement	Welding is to comply with Ch 12, Sec 3, [3]. In way of the wrap around weld at the face plate termination, care should be taken to ensure no over- run onto the radius part and the toe is free from notches and undercut.

9 HATCH CORNER

9.1 Design standard O

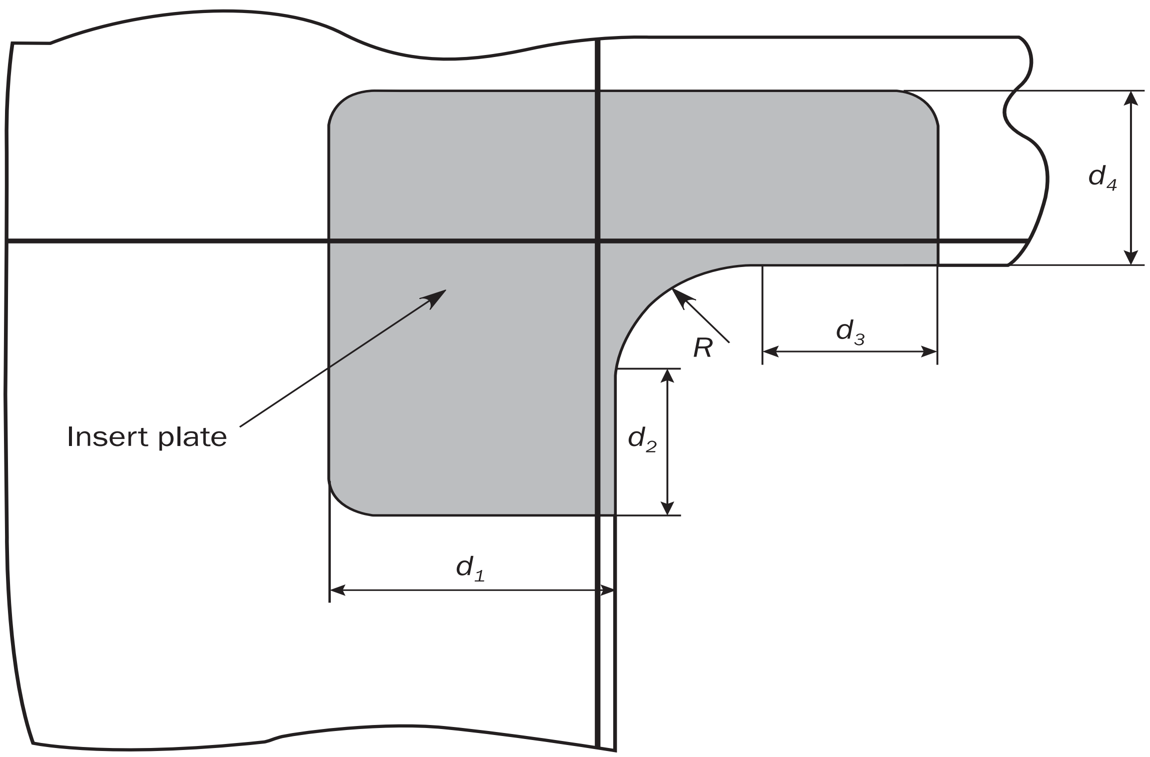
9.1.1

Hatch corners in the cargo hold region, located on the strength deck of bulk carriers are required to be designed according to design standard O, as shown in Table 15.

Table 15 : Design standard O – hatch corner of bulk carriers

Hatch corner (bulk carriers)

Design standard O



	without insert plate	**with insert plate**
Critical location	Hatch corner curve	Curved Radius Transition insert plate to deck plating
Detail design standard	Shape of hatch corner as required by Pt 2, Ch 1, Sec 2	Radius and insert plate dimensions and thickness as required by Pt 2, Ch 1, Sec 2. Insert plate has to be tapered for smooth thickness transition to deck plating, the transition taper length has to be not less than 3 times the offset.
Post-treatment	Grinding of cut edge within the radius	Grinding of cut edge within the radius

PART 1 CHAPTER 10

OTHER STRUCTURES

Table of Contents

SECTION 1
FORE PART

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

α_p : Correction factor for the panel aspect ratio to be taken as:

$$\alpha_p = 1.2 - \frac{b}{2.1\ a}$$ but not to be taken as greater than 1.0.

f_{bdg} : Bending moment factor taken as:

$$f_{bdg} = 8\left(1 + \frac{n_s}{2}\right)$$

n_s : End fixation factor taken as:

n_s = 0 for both ends with low end fixity (simply supported).

n_s = 1 for one end equivalent to built in and one end simply supported.

n_s = 2 for continuous members or members with bracketed fitted at both ends

1 GENERAL

1.1 Application

1.1.1

The requirements of this section apply to the following structures of the fore part as defined in Ch 1, Sec 1, [2.4.2]:

- Fore peak structures.
- Stem.

In addition, the requirements of this section apply to structure subjected to impact loads:

- Flat bottom forward, according to [3.2].
- Bow area, according to [3.3].

2 STRUCTURAL ARRANGEMENT

2.1 Floors and bottom girders

2.1.1 Floors

In case of transverse framing, solid floors are to be fitted at each web frame location.

In case of longitudinal framing, the spacing of solid floors is not to be greater than 3.5 m or four transverse frame spaces, whichever is smaller.

The minimum depth of the floor at the centreline is not to be less than the required depth of the double bottom of the foremost cargo hold. See Ch 2, Sec 3, [2.3].

2.1.2 Bottom girders

A supporting structure is to be provided at the centreline either by extending the centreline girder to the stem or by providing a deep girder or centreline bulkhead.

Where a centreline girder is fitted, the minimum depth and thickness is not to be less than that required for the depth of the double bottom in the neighbouring cargo tank region, and the upper edge is to be stiffened.

In case of transverse framing, the spacing of bottom girders is not to exceed 2.5 m.

In case of longitudinal framing, the spacing of bottom girders is not to exceed 3.5 m.

2.1.3 Alternative design verification

This spacing, defined in [2.1.1] and [2.1.2] may be increased, if the designer performs a verification of the bottom structure by means of grillage analysis or FE analysis and provides their full documentation. The acceptance criteria to be applied are defined in Ch 6, Sec 6, [3]. A FE analysis is to be performed under consideration of the requirements provided in Ch 7.

2.2 Wash bulkheads

2.2.1

Where a centreline wash bulkhead is fitted, the lowest strake is to have thickness not less than required for a centreline girder.

Where a longitudinal wash bulkhead supports bottom transverses, the details and arrangements of openings in the bulkhead are to be configured to avoid areas of high stresses in way of the connection of the wash bulkhead with bottom transverses.

2.3 Side shell supporting structure

2.3.1 Web frames

The spacing of web frames, S, in m as defined in Ch 1, Sec 4, Table 5, is to be taken as:

$S = 2.6 + 0.005\,L$, but not to be taken greater than 3.5 m.

Perforated flats are to be fitted to limit the effective span of web frames to not greater than 10 m.

2.3.2 Stringers

The transverse framing forward of the collision bulkhead stringers are to be spaced approximately 3.5 m apart. Stringers are to have an effective span not greater than 10 m, and are to be adequately supported by web frame structures.

2.3.3 Alternative design verification

The spacing of web frames and stringers may be increased, if the designer performs a verification of the side shell supporting structure by means of beam analysis or FE analysis and provides their full documentation.

The acceptance criteria to be applied are defined in Ch 6, Sec 6, [3]. A FE analysis is to be performed under consideration of the requirements provided in Ch 7.

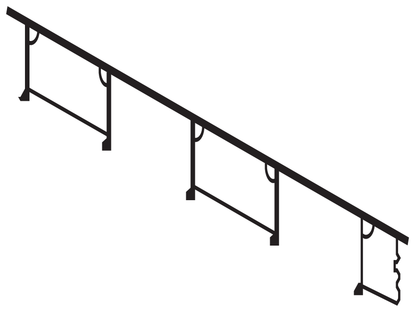
2.4 Tripping brackets

2.4.1

For side shell and tank walls, located forward of the collision bulkhead and vertically framed, tripping brackets spaced not more than 2.6 m are to be fitted, according to Figure 1, between primary supporting members, decks and/or platforms.

The as-built thickness of the tripping brackets is not to be less than the as-built thickness of the side frame webs to which they are connected.

Figure 1 : Tripping brackets



2.5 Bulbous bow

2.5.1 General

Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure.

2.5.2 Diaphragm plates

At the forward end of the bulb the structure is generally to be supported by horizontal diaphragm plates spaced about 1m apart in conjunction with a deep centreline web.

In general, vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing.

2.5.3 Special bulbous bow designs

In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is generally to be fitted.

In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or substantial web frames is to be fitted.

2.5.4 Strengthening for anchor and chain cable contact

The shell plating is to be increased in thickness at the forward end of the bulb and also in areas likely to be subjected to contact with anchors and chain cables during anchor handling. The increased plate thickness is to be the same as that required for plated stems given in [4.1.1].

3 STRUCTURE SUBJECTED TO IMPACT LOADS

3.1 General

3.1.1 Application

The requirements of this sub-section cover the strengthening requirements for local impact loads that may occur in the forward structure. The impact loads to be applied in [3.2] and [3.3] are described in Ch 4, Sec 5, [3].

3.1.2 General scantling requirements

The requirements of [3.2] and [3.3] are to be applied in addition to applicable scantling requirements in Ch 6. Local scantling increases due to impact loads are to be made with due consideration given to details and avoidance of hard spots, notches and other harmful stress concentrations.

3.2 Bottom slamming

3.2.1 Application

Where the minimum draughts forward, T_{F-e} or T_{F-f}, as specified in Ch 4, Sec 5, [3.2.1], are less than 0.045 L, the bottom forward is to be additionally strengthened to resist bottom slamming pressures.

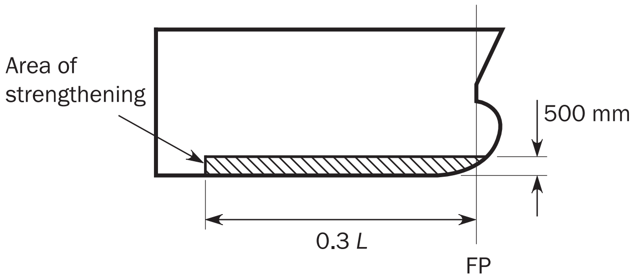
The draughts for which the bottom has been strengthened are to be indicated on the shell expansion plan and loading guidance information, as required in Ch 1, Sec 5.

The load calculation point of the primary supporting members is specified in Ch 3, Sec 7, [4].

3.2.2 Extent of strengthening

The strengthening is to extend forward of 0.3 L from the FP over the flat of bottom and adjacent plating with attached stiffeners up to a height of 500 mm above the baseline, see Figure 2.

Figure 2 : Extent of strengthening against bottom slamming



Outside the region strengthened to resist bottom slamming the scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.

3.2.3 Design to resist bottom slamming loads

The design of end connections of stiffeners in the bottom slamming region is to provide end fixity, either by making the stiffeners continuous through supports or by providing end brackets complying with Ch 3, Sec 6, [3.2]. Where it is not practical to comply with this requirement, the net plastic section modulus, $Z_{pl\text{-}alt}$, in cm^3, for alternative end fixity arrangements is not to be less than:

$$Z_{pl-alt} = \frac{16 Z_{pl}}{f_{bdg}}$$

where:

Z_{pl} : Net plastic section modulus, in cm^3, as required by [3.2.5].

Scantlings and arrangements of primary supporting members, including bulkheads in way of stiffeners, are to comply with [3.2.7].

3.2.4 Shell plating

The net thickness of the hull envelope plating, t, in mm, is not to be less than:

$$t = \frac{0.0158 \alpha_p\, b}{C_d} \sqrt{\frac{P_{SL}}{C_a\, R_{eH}}}$$

where:

C_d : Plate capacity correction coefficient taken as:

$C_d = 1.3$.

C_a : Permissible bending stress coefficient taken as:

$C_a = 1.0$ for acceptance criteria set AC-I.

3.2.5 Shell stiffeners

The shell stiffeners within the strengthening area defined in [3.2.2] are to comply with the following criteria:

a) The net plastic section modulus, Z_{pl}, in cm^3, is not to be less than:

$$Z_{pl} = \frac{P_{SL}\, s\, \ell_{bdg}^{\ 2}}{f_{bdg}\, C_s\, R_{eH}}$$

where:

C_s : Permissible bending stress coefficient taken as:

$C_s = 0.9$ for acceptance criteria set AC-I.

b) The net web thickness, t_w, in mm, is not to be less than:

$$t_w = \frac{P_{SL}\, s\, \ell_{shr}}{2 d_{shr}\, C_t\, \tau_{eH}}$$

where:

C_t : Permissible shear stress coefficient taken as:

$C_t = 1.0$ for acceptance criteria set AC-I.

c) The slenderness ratio is to comply with Ch 8, Sec 2.

3.2.6 Bottom slamming load area for primary supporting members

The scantlings of primary supporting members according to [3.2.7] are based on the application of the slamming pressure defined in Ch 4, Sec 5, [3.2] to an idealised slamming load area of hull envelope plating, A_{SL}, in m^2, given by:

$$A_{SL} = \frac{1.1\ L\ B\ C_b}{1000}$$

3.2.7 Primary supporting members

The size and number of openings in web plating of the floors and girders is to be minimised considering the required shear area as given in a):

a) Net shear area

The net shear area, $A_{shr\text{-}n50}$, in cm^2, of each primary supporting member web at any position along its span is not to be less than:

$$A_{shr-n50} = 10\frac{Q_{SL}}{C_t\, \tau_{eH}}$$

where:

Q_{SL} : The greatest shear force due to slamming for the position being considered, in kN, based on the application of a patch load, F_{SL} to the most onerous location, as determined in accordance with b) or c).

C_t : Permissible shear stress coefficient taken as:

$C_t = 0.9$ for acceptance criteria set AC-I.

b) Simplified calculation of slamming shear force

For simple arrangements of primary supporting members, where the grillage affect may be ignored, the shear force, Q_{SL}, in kN, is given by:

$$Q_{SL} = f_{pt}\, f_{dist}\, F_{SL}$$

where:

f_{pt} : Correction factor for the proportion of patch load acting on a single primary supporting member, taken as

$$f_{pt} = 0.5\ (f_{SL}^{\ 3} - 2\ f_{SL}^{\ 2} + 2)$$

f_{SL} : Patch load modification factor taken as:

$$f_{SL} = 0.5\ \frac{b_{SL}}{S}$$

f_{dist} : Factor for the greatest shear force distribution along the span, according to Figure 3.

F_{SL} : Patch load, in kN, taken as:

$$F_{SL} = P_{SL}\ \ell_{SL}\ b_{SL}$$

ℓ_{SL} : Extent of slamming load area along the span, in m, taken as:

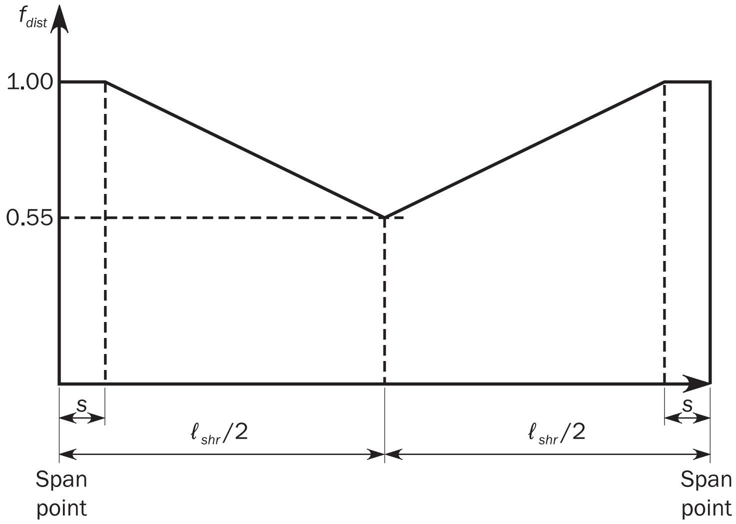
$\ell_{SL} = \sqrt{A_{SL}}$ but not to be greater than $0.5\ell_{shr}$.

b_{SL} : Breadth of impact area supported by primary supporting member, in m, taken as:

$b_{SL} = \sqrt{A_{SL}}$ but not to be greater than S.

A_{SL} : Surface defined in [3.2.6].

Figure 3 : Distribution of f_{dist} along the span of simple primary supporting members



c) Direct calculation method for slamming shear force

For complex arrangements of primary supporting members, the greatest shear force, Q_{SL}, at any location along the span of each primary supporting member is to be derived by direct calculation in accordance with Table 1.

d) Web thickness of primary supporting member

The net web thickness, t_w, in mm, of primary supporting members adjacent to the shell is not to be less than:

$$t_w = \frac{s_W}{70}\sqrt{\frac{R_{eH}}{235}}$$

where:

s_W : Plate breadth, in mm, taken as the spacing between the web stiffening.

Table 1 : Direct calculation methods for derivation of Q_{SL}

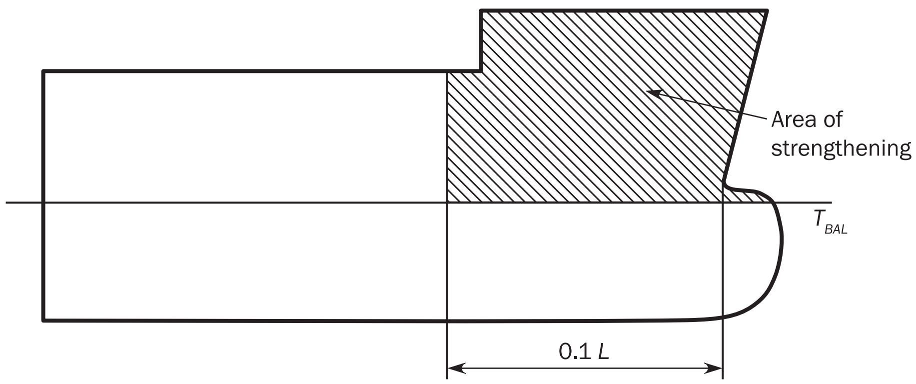
Type of analysis	Model extent	Assumed end fixity of floors
Beam theory	Overall span of member between effective bending supports.	Fixed at ends
Double bottom grillage	Longitudinal extent to be one cargo tank length. Transverse extent to be between inner hopper knuckle and centreline.	Floors and girders to be fixed at boundaries of the model.
Note 1: The envelope of greatest shear force along each primary supporting member is to be derived by applying the load patch on a square area as defined in [3.2.6], to a number of locations along the span. Note 2: A more extensive model in length and breadth can be considered.		

3.3 Bow impact

3.3.1 Application

The side structure in the ship forward area is to be strengthened against bow impact pressures. The strengthening is to extend forward of 0.1 L from the FP and vertically above the minimum design ballast draught, T_{BAL}, defined in Ch 1, Sec 4, [3.1.5] and forecastle deck if any. See Figure 4.

Figure 4 : Extent of strengthening against bow impact



Outside the strengthening area the scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.

3.3.2 Design to resist bow impact loads

a) In the bow impact strengthening area, longitudinal framing is to be carried as far forward as practicable.

The design of end connections of stiffeners in the bow impact region are to ensure end fixity, either by making the stiffeners continuous through supports or by providing end brackets complying with Ch 3, Sec 6, [3.2]. Where it is not practical to comply with this requirement, the net plastic section modulus, $Z_{pl\text{-}alt}$, in cm^3, for alternative end fixity arrangements is not to be less than:

$$Z_{pl-alt} = \frac{16Z_{pl}}{f_{bdg}}$$

where:

Z_{pl} : Effective net plastic section modulus, in cm^3, required by [3.3.4].

b) Scantlings and arrangements of primary supporting members, including decks and bulkheads, in way of the stiffeners, are to comply with [3.3.6]. In areas of the greatest bow impact load, the web stiffeners arranged perpendicular to the hull envelope plating and the double sided lug connections are to be provided.

The main stiffening direction of decks and bulkheads supporting shell framing is to be arranged parallel to the span direction of the supported shell frames, to protect against buckling.

3.3.3 Side shell plating

The net thickness of the side shell plating, t, in mm is not to be less than:

$$t = 0.0158\alpha_p\, b \sqrt{\frac{P_{FB}}{C_a\, R_{eH}}}$$

where:

C_a : Permissible bending stress coefficient taken as:

$C_a = 1.0$ for acceptance criteria set AC-I.

3.3.4 Side shell stiffeners

The side shell stiffeners within the strengthening area defined in [3.3.1] are to comply with the following criteria:

a) The effective net plastic section modulus, Z_{pl}, in cm^3 in association with the effective

plating to which it is attached, is not to be less than:

$$Z_{pl} = \frac{P_{FB}\, s\, \ell_{bdg}{}^2}{f_{bdg}\, C_s\, R_{eH}}$$

where:

C_s : Permissible bending stress coefficient taken as:

$C_s = 0.9$ for acceptance criteria set AC-I.

b) The net web thickness, t_w, in mm, is not to be less than:

$$t_w = \frac{P_{FB}\, s\, \ell_{shr}}{2d_{shr}\, C_t\, \tau_{eH}}$$

where:

d_{shr} : Effective web depth of stiffener, in mm, as defined in Ch 3, Sec 7, [1.4.3].

C_t : Permissible shear stress coefficient taken as:

$C_t = 1.0$ for acceptance criteria set AC-I.

c) The slenderness ratio is to comply with Ch 8, Sec 2.

d) The minimum net thickness of breasthooks/diaphragm plates, t_w, in mm, is not to be less than:

$$t_w = \frac{s}{70}\sqrt{\frac{R_{eH}}{235}}$$

where:

s : Spacing of stiffeners on the web, as defined in Ch 1, Sec 4, Table 5, in mm. Where no stiffeners are fitted, s is to be taken as the depth of the web.

3.3.5 Bow impact load area for primary supporting members

The scantlings of primary supporting members according to [3.3.6] are based on the application of the bow impact pressure, as defined in Ch 4, Sec 5, [3.3.1], to an idealised bow impact load area of hull envelope plating, A_{BI}, in m^2, is given by:

$$A_{BI} = \frac{1.1\, L\, B\, C_b}{1000}$$

3.3.6 Primary supporting members

a) The section modulus of the primary supporting member is to apply along the bending span clear of end brackets and cross sectional areas of the primary supporting member are to be applied at the ends/supports and may be gradually reduced along the span and clear of the ends/supports following the distribution of f_{dist} indicated in Figure 3.

b) Primary supporting members in the bow impact strengthening area are to be configured to provide effective continuity of strength and the avoidance of hard spots.

c) End brackets of primary supporting members are to be suitably stiffened along their edge. Consideration is to be given to the design of bracket toes to minimise abrupt changes of cross section.

d) Tripping arrangements are to comply with Ch 8, Sec 2, [5.1.1]. In addition, tripping brackets are to be fitted at the toes of end brackets and at locations where the primary supporting member flange is knuckled or curved.

e) The net section modulus of each primary supporting member, Z_{n50}, in cm^3, is not to be less than:

$$Z_{n50} = 1000 \frac{f_{bdg-pt} \, P_{FB} \, b_{BI} \, f_{BI} \, \ell_{bdg}^2}{f_{bdg} \, C_s \, R_{eH}}$$

where:

$f_{bdg\text{-}pt}$: Correction factor for the bending moment at the ends and considering the patch load taken as:

$$f_{bdg-pt} = 3 \, f_{BI}^3 - 8 \, f_{BI}^2 + 6 \, f_{BI}$$

f_{BI} : Patch load modification factor taken as:

$$f_{BI} = \frac{\ell_{BI}}{\ell_{bdg}}$$

ℓ_{BI} : Extent of bow impact load area, in m, along the span:

$\ell_{BI} = \sqrt{A_{BI}}$ but not to be taken as greater than ℓ_{bdg}.

b_{BI} : Breadth of impact load area, in m, supported by the primary supporting member, to be taken as the spacing between primary supporting members, S, as defined in Ch 1, Sec 4, Table 5, but not to be taken as greater than ℓ_{BI}.

A_{BI} : Bow impact load area, in m^2, as defined in [3.3.5].

f_{bdg} : Bending moment factor taken as:

f_{bdg} = 12 for primary supporting members with end fixed continuous flange or where brackets at both ends are fitted in accordance with Ch 3, Sec 6, [4.4].

C_s : Permissible bending stress coefficient taken as:

C_s = 0.8 for acceptance criteria set AC-I.

f) The net shear area of the web, $A_{shr\text{-}n50}$, in cm^2, of each primary supporting member at the support/toe of end brackets is not to be less than:

$$A_{shr-n50} = \frac{5 f_{PL} \, P_{FB} \, b_{BI} \, \ell_{shr}}{C_t \, \tau_{eH}}$$

where:

f_{PL} : Patch load modification factor taken as:

$$f_{PL} = \frac{\ell_{BI}}{\ell_{shr}}$$

ℓ_{BI} : Extent of bow impact load area, in m, along the span taken as,

$$\ell_{BI} = \sqrt{A_{BI}} \text{ but not greater than } \ell_{shr}.$$

C_t : Permissible shear stress coefficient taken as:

$C_t = 0.75$ for acceptance criteria set AC-I.

g) The net web thickness of each primary supporting member, t_w, in mm including decks/bulkheads in way of the side shell is not to be less than:

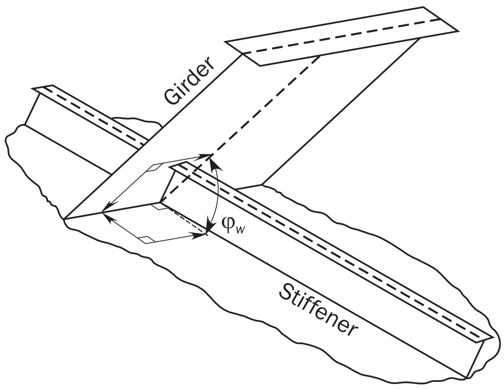
$$t_w = \frac{P_{FB}\, b_{BI}}{\sin\varphi_w\, \sigma_{crb}}$$

where:

φ_w : Angle, in deg, between the primary supporting member web and the shell plate, see Figure 5.

σ_{cr} : Critical buckling stress in compression of the web of the primary supporting member or deck/bulkhead panel in way of the applied load given by Ch 8, Sec 5, [3.1.1], in N/mm^2.

Figure 5 : Angle between shell primary member and shell plate



4 ADDITIONAL SCANTLING REQUIREMENTS

4.1 Plate stem

4.1.1

The net thickness, t_{Stm} in mm, is not to be less than:

$$t_{Stm} = (0.6 + 0.4S_B)\,(0.08\,L + 2.7)\,\sqrt{k} \text{ but need not be greater than } 22\sqrt{k} - 1$$

where:

S_B : Spacing, in m, between horizontal stringers (partial or not), breasthooks, or equivalent horizontal stiffening members.

Starting from 0.6 m above the summer load waterline up to $T_{SC} + C_w$, the net thickness may gradually be reduced to 0.8 t_{Stm}.

4.1.2 Breasthooks and diaphragm plating

The net thickness of breasthooks/diaphragm plates, t_w, in mm, is not to be less than:

$$t_w = \frac{s}{70}\sqrt{\frac{R_{eH}}{235}}$$

where:

s : Spacing of stiffeners on the web, as defined in Ch 1, Sec 4, Table 5, in mm. Where no stiffeners are fitted, s is to be taken as the depth of the web.

4.2 Thruster tunnel

4.2.1

The net thickness of the tunnel plating, t_{tun}, in mm, is not to be less than the net required thickness for the shell plating in the vicinity of the bow thruster.

In addition, t_{tun} is not to be taken less than:

$$t_{tun} = 0.008\ d_{tun} + 1.8$$

where:

d_{tun} : Inside diameter of the tunnel, in mm, but not to be taken less than 970 mm.

Where the outboard ends of the tunnel are provided with bars or grids, the bars or grids are to be effectively secured.

SECTION 2
MACHINERY SPACE

1 GENERAL

1.1 Application

1.1.1

The requirements of this section apply to the scantlings and arrangement of structures located in the machinery space. It is the shipyard responsibility to design the ship in accordance with the machinery manufacturer's requirements.

2 MACHINERY SPACE ARRANGEMENT

2.1 Structural arrangement

2.1.1

Where openings in decks/bulkheads are provided in the machinery space, the arrangements are to support the deck, side, and bottom structure.

2.1.2

All parts of the machinery, shafting, etc, are to be supported to distribute the loads into the ship's structure. The adjacent structure is to be suitably stiffened.

2.1.3

Primary supporting members are to be positioned giving consideration to the provision of through stiffeners and in line pillar supports to achieve an efficient structural design.

2.1.4

The spacing of web frames in way of transversely framed machinery spaces is generally not to exceed five transverse frame spaces. Web frames are to be connected at the top and bottom to members of suitable stiffness, and supported by deck transverses.

2.1.5

End connections of side longitudinals at transverse bulkheads are to provide fixity, lateral support, and when not continuous are to be provided with soft-toe brackets. Brackets lapped onto the longitudinals are not to be fitted.

2.1.6

Where a transverse framing system is adopted, deck stiffeners are to be supported by a suitable arrangement of longitudinal girders in association with pillars or pillar bulkheads. Where fitted, deck transverses are to be arranged in line with web frames to provide end fixity and transverse continuity of strength.

Where a longitudinal framing system is adopted, deck longitudinals are to be supported by deck transverses in line with web frames in association with pillars or pillar bulkheads.

2.1.7

Machinery casings are to be supported by a suitable arrangement of deck transverses and longitudinal girders in association with pillars or pillar bulkheads. In way of particularly large machinery casing openings, cross ties may be required. These are to be arranged in line with deck transverses.

2.1.8

The foundations for main propulsion units, reduction gears, shaft and thrust bearings, and the structure supporting those foundations are to maintain the required alignment and rigidity under all anticipated conditions of loading. Consideration is to be given to the submittal of the following plans to the machinery manufacturer for review:

a) Foundations for main propulsion units.

b) Foundations for reduction gears.

c) Foundations for thrust bearings.

d) Structure supporting a), b) and c).

2.2 Double bottom

2.2.1 Double bottom height

The double bottom height at the centreline, irrespective of the location of the machinery space, is to be not less than the value defined in Ch 2, Sec 3, [2.3.1]. This depth may need to be considerably increased in relation to the type and depth of main machinery seatings.

The above height is to be increased by the shipyard where the machinery space is very large and where there is a considerable variation in draught between light ballast and full load conditions.

Where the double bottom height in the machinery space differs from that in adjacent spaces, structural continuity of longitudinal members is to be provided by sloping the inner bottom over an adequate longitudinal extent. The knuckles in the sloped inner bottom are to be located in way of floors. Lesser double bottom height may be accepted in local areas provided that the overall strength of the double bottom structure is not thereby impaired.

2.2.2 Centreline girder

The double bottom is to be arranged with a centreline girder. In way of any openings for manholes on the centreline girder, permitted only where absolutely necessary for double bottom access and maintenance, local strengthening is to be arranged.

2.2.3 Side bottom girders

In the machinery space, the number of side bottom girders is to be adequately increased, with respect to the adjacent areas, to provide adequate rigidity of the structure. The side bottom girders in longitudinal stiffened double bottom, are to be a continuation of any bottom longitudinals in the areas adjacent to the machinery space and are generally to have a spacing not greater than 3 times that of longitudinals and in no case greater than 3 m.

2.2.4 Girders in way of machinery seatings

Additional side bottom girders are to be fitted in way of machinery seating.

2.2.5 Floors in longitudinally stiffened double bottom

Where the double bottom is longitudinally stiffened, plate floors are to be fitted at every frame under the main engine and thrust bearing. Outboard of the engine and bearing seatings, the floors may be fitted at alternate frames.

2.2.6 Floors in transversely framed double bottom

Where the double bottom in the machinery space is transversely stiffened, floors are to be arranged at every frame.

2.2.7 Manholes and wells

The number and size of manholes in floors located in way of seatings and adjacent areas are to be kept to the minimum necessary for double bottom access and maintenance.

In general, manhole edges are to be stiffened with flanges; failing this, the floor plate is to be adequately stiffened with flat bars at manhole sides.

Manholes with perforated portable plates are to be fitted in the inner bottom in the vicinity of wells arranged close to the aft bulkhead of the engine room.

Drainage of the tunnel is to be arranged through a well located at the aft end of the tunnel.

2.2.8 Inner bottom plating

Where main engines or thrust bearings are bolted directly to the inner bottom, the net thickness of the inner bottom plating is to be at least 19 mm. Hold-down bolts are to be arranged as close as possible to floors and longitudinal girders. Plating thickness and the arrangements of hold-down bolts are also to consider the manufacturer's recommendations.

2.2.9 Heavy equipment

Where heavy equipment is mounted directly on the inner bottom, the thickness of the floors and girders is to be suitably increased.

3 MACHINERY FOUNDATIONS

3.1 General

3.1.1

Main engines and thrust bearings are to be effectively secured to the hull structure by foundations of strength that is sufficient to resist the various gravitational, thrust, torque, dynamic, and vibratory forces which may be imposed on them.

3.1.2

In the case of higher power internal combustion engines or turbine installations, the foundations are generally to be integral with the double bottom structure. Consideration is to be given to substantially increase the inner bottom plating thickness in way of the engine foundation plate or the turbine gear case and the thrust bearing, see Type 1 of Figure 1.

3.1.3

For main machinery supported on foundations of Type 2, as shown in Figure 2, the forces from the engine into the adjacent structure are to be distributed as uniformly as possible. Longitudinal members supporting the foundation are to be aligned with girders in the double bottom, and transverse stiffening is to be arranged in line with the floors, see Type 2 of Figure 2.

Figure 1 : Machinery foundations Type 1

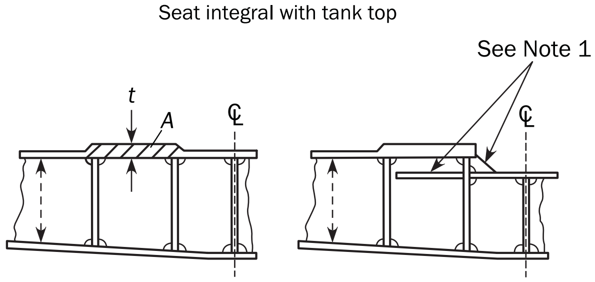
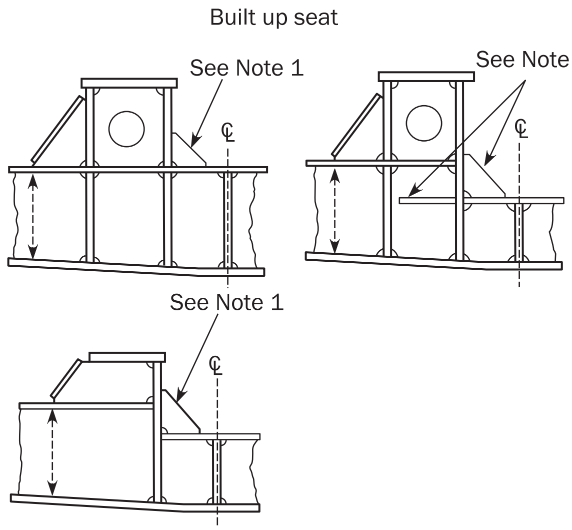


Figure 2 : Machinery foundations Type 2



Note 1: Brackets are to be as large as possible. Brackets may be omitted to avoid interference with the girders of the engine foundation, in accordance with recommendations of the engine manufacturer.

3.2 Foundations for internal combustion engines and thrust bearings

3.2.1

In determining the scantlings of foundations for internal combustion engines and thrust bearings, consideration is to be given to the general rigidity of the engine and to its design characteristics with regard to out of balance forces.

3.2.2

Generally, two girders are to be fitted in way of the foundation for internal combustion engines and thrust bearings.

3.3 Auxiliary foundations

3.3.1

Auxiliary machinery is to be secured on foundations that are of suitable size and arrangement to distribute the loads from the machinery evenly into the supporting structure.

SECTION 3
AFT PART

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

1 GENERAL

1.1 Application

1.1.1

The requirements of this section apply for the scantlings and arrangement of structures located aft of the aft peak bulkhead.

2 AFT PEAK

2.1 Structural arrangement

2.1.1 Floors

Floors are to be fitted at each frame space in the aft peak and carried to a height at least above the stern tube. Where floors do not extend to flats or decks, they are to be stiffened by flanges at their upper end.

Heavy plate floors are to be fitted in way of the aft face of the horn and in line with the webs in the rudder horn. They may be required to be carried up to the first deck or flat. In this area, cut outs, scallops or other openings are to be kept to a minimum.

2.1.2 Platforms and side girders

Platforms and side girders within the peak are to be arranged in line with those located in the area immediately forward.

Where this arrangement is not possible due to the shape of the hull and access needs, structural continuity between the peak and the structures of the area immediately forward is to be ensured by adopting wide tapering brackets.

Where the aft peak is adjacent to a machinery space whose side is longitudinally framed, the side girders in the aft peak are to be fitted with tapering brackets.

Where the depth from the peak tank top to the weather deck is greater than 2.6 m and the side is transversely framed, one or more side girders are to be fitted, preferably in line with similar structures existing forward.

2.1.3 Longitudinal bulkheads

A longitudinal non-tight bulkhead is to be fitted on the centreline of the ship, in general in the upper part of the peak, and stiffened at each frame spacing.

Where either the stern overhang is very large or the maximum breadth of the space divided by watertight and wash bulkheads is greater than 20 m, additional longitudinal wash bulkheads may be required.

2.1.4 Alternative design verification

The spacing and arrangement requirements, defined in [2.1.1], [2.1.2] and [2.1.3] may be increased, if the designer performs a verification by means of grillage analysis or FE analysis and provides their full documentation. The acceptance criteria to be applied are defined in Ch 6, Sec 6, [3]. A FE analysis is to be performed under consideration of the requirements provided in Ch 7.

2.2 Stiffening of floors and girders in aft peak

2.2.1

The height of stiffeners, h_{stf}, in mm, on the floors and girders are not to be less than:

$h_{stf} = 80\ \ell_{stf}$ for flat bar stiffeners.

$h_{stf} = 70\ \ell_{stf}$ for bulb profiles and flanged stiffeners.

where:

ℓ_{stf} : Length of stiffener, in m, as shown in Figure 1. Length need not be taken greater than 5 m.

2.2.2

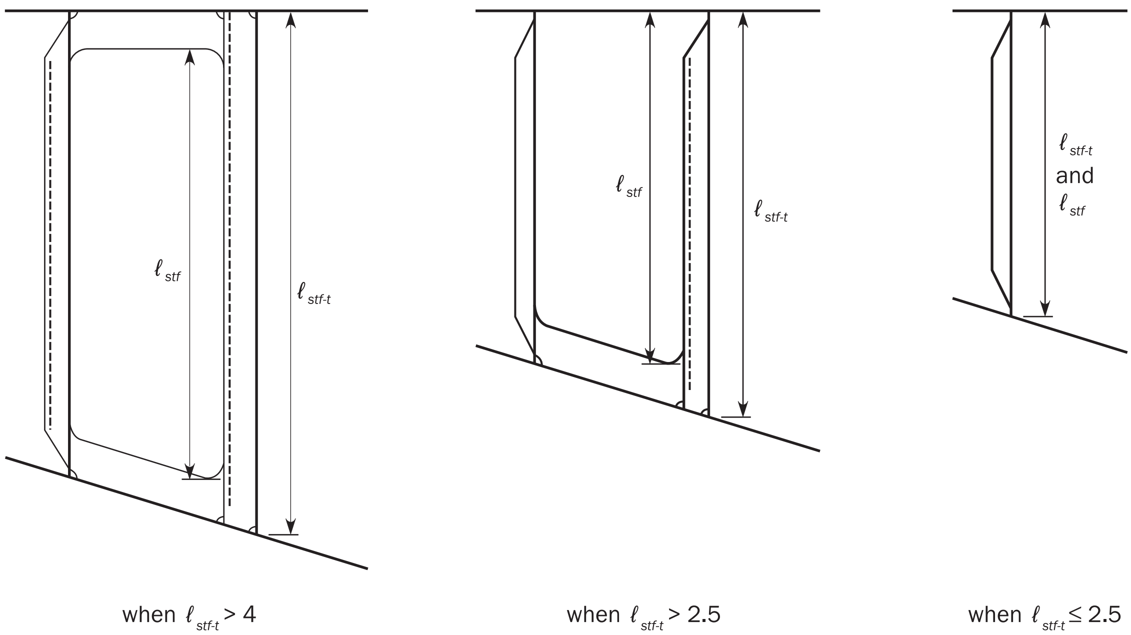
Stiffeners on the floors and girders in aft peak ballast or fresh water tanks above propeller are to be arranged with brackets. This apply for stiffeners located in an area extending longitudinally between the forward edge of the rudder and the after end of the propeller boss and transversely within the diameter of the propeller. End brackets are to be provided as follows:

- Brackets are to be fitted at the lower and upper ends when $\ell_{stf\text{-}t}$ exceeds 4 m.
- Brackets are to be fitted at the lower end when $\ell_{stf\text{-}t}$ exceeds 2.5 m.

  where:

  $\ell_{stf\text{-}t}$: Total length of stiffener, in m, as shown in Figure 1.

Figure 1 : Stiffening of floors and girders in the aft peak tank



3 STERN FRAMES

3.1 General

3.1.1

Stern frames may be fabricated from steel plates or made of cast steel with a hollow section. For applicable material specifications and steel grades, see Ch 3, Sec 1. Stern frames of other material or construction will be specially considered.

3.1.2

Cast steel and fabricated stern frames are to be strengthened by adequately spaced plates with gross thickness not less than 80% of required thickness for stern frames. Abrupt changes of section are to be avoided in castings; all sections are to have adequate tapering radius.

3.1.3

In the upper part of the propeller aperture, where the hull form is full and centreline supports are provided, the thickness of stern frames may be reduced to 80% of the applicable requirement in [3.2.1].

3.2 Propeller posts

3.2.1 Gross scantlings of propeller posts

The gross scantlings of propeller posts are not to be less than those obtained from the formulae in Table 1 for single screw ships and Table 2 for twin screw ships.

Scantlings and proportions of the propeller post which differ from those above may be considered acceptable provided that the section modulus of the propeller post section about its longitudinal axis is not less than that calculated with the propeller post scantlings in Table 1 or Table 2, as applicable.

Table 1 : Single screw ships - Gross scantlings of propeller posts

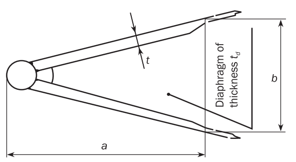
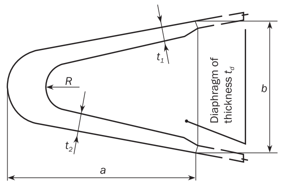
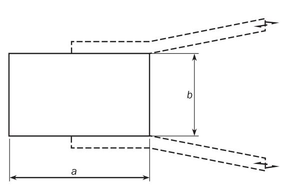
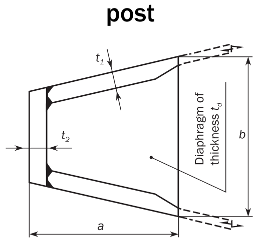
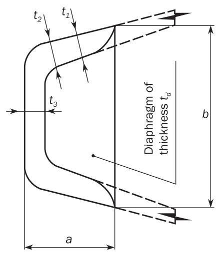
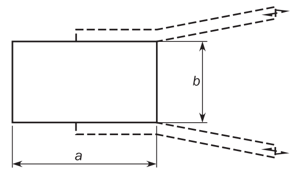
Gross scantlings of propeller posts, in mm	Fabricated propeller post 	Cast propeller post 	Bar propeller post, cast or forged, having rectangular section 
a	$50\ L_1^{1/2}$	$33\ L_1^{1/2}$	$10\sqrt{7.2L-256}$
b	$35\ L_1^{1/2}$	$23\ L_1^{1/2}$	$10\sqrt{4.6L-164}$
t_1	$2.5\ L_1^{1/2}$	$3.2\ L_1^{1/2}$	-
t_2	-	$4.4\ L_1^{1/2}$	-
t_d	$1.3\ L_1^{1/2}$	$2.0\ L_1^{1/2}$	-
R	-	50 mm	-

Table 2 : Twin screw ships - Gross scantlings of propeller posts

Gross scantlings of propeller posts, in mm	Fabricated propeller post 	Cast propeller post 	Bar propeller post, cast or forged, having rectangular section 
a	$25\ L_1^{1/2}$	$12.5\ L_1^{1/2}$	$2.4\ L + 6$
b	$25\ L_1^{1/2}$	$25\ L_1^{1/2}$	$0.8\ L + 2$
t_1	$2.5\ L_1^{1/2}$	$2.5\ L_1^{1/2}$	-
t_2	$3.2\ L_1^{1/2}$	$3.2\ L_1^{1/2}$	-
t_3	-	$4.4\ L_1^{1/2}$	-
t_d	$1.3\ L_1^{1/2}$	$2.0\ L_1^{1/2}$	-

3.2.2 Section modulus below the propeller shaft bossing

In the case of a propeller post without a sole piece, the section modulus of the propeller post may be gradually reduced below the propeller shaft bossing down to 85% of the value calculated with the scantlings in Table 1 or Table 2, as applicable.

In any case, the thicknesses of the propeller posts are not to be less than those obtained from the formulae in the Table 1 and Table 2.

3.2.3 Propeller shaft bossing

In single screw ships, the thickness of the propeller shaft bossing, included in the propeller post, is not to be less than 60% of the dimension *b* required in [3.2.1] for bar propeller posts with a rectangular section.

3.3 Connections

3.3.1 Connections with hull structure

Stern frames are to be effectively attached to the aft structure and the lower part of the stern frame is to be extended forward of the propeller post to a length not less than 1500 + 6 L_2 mm, in order to provide an effective connection with the keel. However, the stern frame need not extend beyond the aft peak bulkhead.

3.3.2 Connection with keel plate

The thickness of the lower part of the stern frames is to be gradually tapered to that of the solid bar keel or keel plate.

Where a keel plate is fitted, the lower part of the stern frame is to be designed to ensure an effective connection with the keel.

3.3.3 Connection with transom floors

Rudder posts and propeller posts are to be connected with transom floors having height not less than that of the double bottom height and a net thickness not less than that obtained, in mm, from the following formula:

$$t = 9 + 0.023\ L_1$$

3.3.4 Connection with centre keelson

Where the stern frame is made of cast steel, the lower part of the stern frame is to be fitted, as far as practicable, with a longitudinal web for connection with the centre keelson.

4 SPECIAL SCANTLING REQUIREMENTS FOR SHELL STRUCTURE

4.1 Shell plating

4.1.1 Shell plating connected with stern frame

The net thickness of shell plating connected with the stern frame is not to be less than that obtained, in mm, from the following formula:

$$t = 0.094\ (L_2 - 43) + 0.009\, b$$

In way of the boss and heel plate, the net thickness, t, of shell plating, in mm, is not to be less than:

$$t = 0.105\ (L_2 - 47) + 0.011\ b$$

where:

b : Breadth of plate panel, in mm, as defined in Ch 3, Sec 7, [2.2.2].

4.1.2 Heavy shell plates

Heavy shell plates are to be fitted locally in way of the heavy plate floors as required by [2.1.1]. Outboard of the heavy floors, the heavy shell plates may be reduced in thickness in as gradual a manner as practicable. Where the horn plating is radiused into the shell plating, the radius at the shell connection, r in mm, is not to be less than:

$$r = 150 + 0.8\ L_2$$

4.1.3 Thruster tunnel plating

The net thickness of the tunnel plating, t_{tun} in mm, is to comply with the requirements in Ch 10, Sec 1, [4.2.1].

SECTION 4
TANKS SUBJECT TO SLOSHING

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

α_p : Correction factor for the panel aspect ratio to be taken as:

$$\alpha_p = 1.2 - \frac{b}{2.1\ a} \quad \text{but not to be taken as greater than 1.0.}$$

a : Length of plate panel, in mm, as defined in Ch 3, Sec 7, [2.2.2].

b : Breadth of plate panel, in mm, as defined in Ch 3, Sec 7, [2.2.2].

ℓ_{bdg} : Effective bending span, as defined in Ch 3, Sec 7, [1.1.2], in m.

ℓ_{slh} : Effective sloshing length, in m, as defined in Ch 4, Sec 6, [6.3.2].

b_{slh} : Effective sloshing breadth, in m, as defined in Ch 4, Sec 6, [6.4.2].

$I_{y\text{-}n50}$: Net horizontal hull girder moment of inertia, at the longitudinal position being considered, as defined in Ch 5, Sec 1, [1.5], in m^4.

M_{sw} : Permissible hull girder hogging and sagging still water bending moment for seagoing operation at the location being considered, in kNm, as defined in Ch 4, Sec 4, [2.2.2].

z_n : Distance from the baseline to the horizontal neutral axis, as defined in Ch 5, Sec 1, in m.

z : Vertical coordinate of the load calculation point or at the reference point under consideration, in m.

σ_{hg} : Hull girder bending stress, in N/mm^2, calculated at the load calculation point defined in Ch 3, Sec 7, [2.2] or in Ch 3, Sec 7, [3.2], as the case may be:

$$\sigma_{hg} = \left(\frac{(z - z_n)\ M_{sw}}{I_{y-n50}}\right)10^{-3}$$

1 GENERAL

1.1 Application

1.1.1

The requirements of this section cover the strengthening requirements for localised sloshing loads that may occur in tanks carrying liquid.

Sloshing loads due to the free movement of liquid in tanks are given in Ch 4, Sec 6, [6].

1.2 General requirements

1.2.1 Filling heights of cargo and ballast tanks

The scantlings of all cargo and ballast tanks are to comply with the sloshing requirements given in this section for the following cases:

- Unrestricted filling height for ballast tanks,

- Unrestricted filling height for cargo tanks with cargo density equal to ρ_L, as defined in Ch 4, Sec 6,
- All filling levels up to h_{part} for cargo tanks with cargo density equal to ρ_{part} taken as:

$$h_{part} = \frac{h_{tk} \cdot \rho_L \cdot f_{CD}}{\rho_{part}}$$

where:

h_{part} : Maximum permissible filling height, in m, associated with a partial filling of the considered cargo tank with a high liquid density equal to ρ_{part}.

h_{tk} : Maximum tank height, in m.

ρ_L : Cargo density as defined in Ch 4, Sec 6.

f_{cd} : Factor defined in Ch 4, Sec 6.

ρ_{part} : Maximum permissible high liquid density as defined in Ch 4, Sec 6.

1.2.2 Cargo holds of bulk carrier intended for the carriage of ballast water

Cargo holds of bulk carrier intended for the carriage of ballast water are assumed either full or empty in seagoing condition and are not required to be assessed for sloshing pressures.

1.2.3 Structural details

Local scantling increases due to sloshing loads are to be made with due consideration given to details and avoidance of hard spots, notches and other harmful stress concentrations.

1.3 Application of sloshing pressure

1.3.1 General

The structural members of the following tanks are to be assessed for the design sloshing pressures $P_{slh\text{-}lng}$ and $P_{slh\text{-}t}$ in accordance with [1.3.4] and [1.3.5].

a) Cargo and slop tanks of oil tankers.

b) Fore peak and aft peak ballast tanks.

c) Other tanks which allow free movement of liquid, e.g. ballast tanks, fuel oil bunkering tanks and fresh water tanks, etc.

Where the effective sloshing length, ℓ_{slh} is less than 0.03 L, calculations involving $P_{slh\text{-}lng}$ are not required and where the effective sloshing breadth b_{slh} is less than 0.32 B, calculations involving $P_{slh\text{-}t}$ are not required.

1.3.2 Minimum sloshing pressure

The minimum sloshing pressure, $P_{slh\text{-}min}$, as defined in Ch 4, Sec 6, [6.2] is to apply to tanks in which the effective sloshing length, ℓ_{slh} or breadth b_{slh}, is less than defined in [1.3.1].

1.3.3 Structural members to be assessed

The following structural members are to be assessed:

a) Plates and stiffeners forming boundaries of tanks.

b) Plates and stiffeners on wash bulkheads.

c) Web plates and web stiffeners of primary supporting members located in tanks.

d) Tripping brackets supporting primary supporting members in tanks.

1.3.4 Application of design sloshing pressure due to longitudinal liquid motion

The design sloshing pressure due to longitudinal liquid motion, $P_{slh-lng}$, as defined in Ch 4, Sec 6, [6.3.3] is to be applied to the following members as shown in Figure 1.

a) Transverse tight bulkheads.

b) Transverse wash bulkheads.

c) Stringers on transverse tight and wash bulkheads.

d) Plating and stiffeners on the longitudinal bulkheads, deck and inner hull within a distance from the transverse bulkhead taken as:

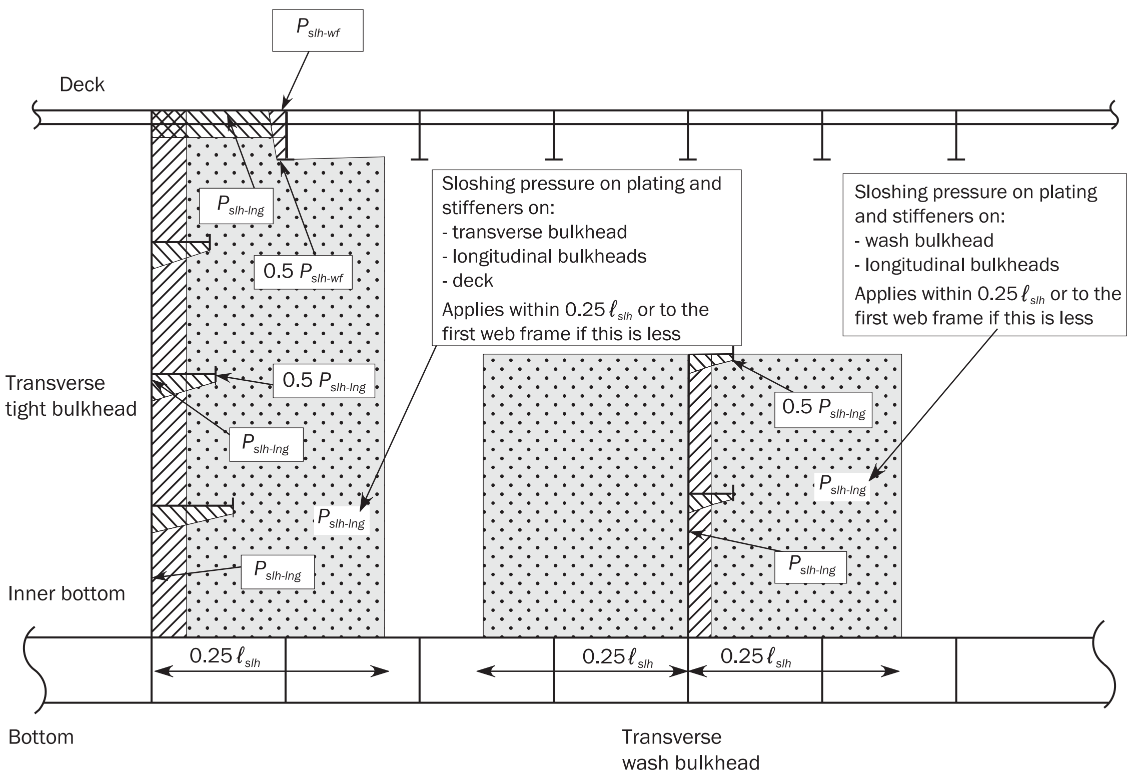
- 0.25 ℓ_{slh},
- The distance between the transverse bulkhead and the first web frame if located inside the tank at the considered level,

whichever is less.

In addition, the first web frame next to a transverse tight or wash bulkhead if the web frame is located within 0.25 ℓ_{slh} from the bulkhead, as shown in Figure 1, is to be assessed for the web frame reflected sloshing pressure, P_{slh-wf}, as defined in Ch 4, Sec 6, [6.3.4].

The minimum sloshing pressure, $P_{slh-min}$, as defined in Ch 4, Sec 6, [6.2] is to be applied to all other members.

Figure 1 : Application of sloshing loads due to longitudinal liquid motion



1.3.5 Application of design sloshing pressure due to transverse liquid motion

The design sloshing pressure due to transverse liquid motion, P_{shl-t}, as defined in Ch 4, Sec 6, [6.4.3], is to be applied to the following members as shown in Figure 2.

a) Longitudinal tight bulkhead.

b) Longitudinal wash bulkhead.

c) Horizontal stringers and vertical webs on longitudinal tight and wash bulkheads.

d) Plating and stiffeners on the transverse tight bulkheads including stringers and deck within a distance from the longitudinal bulkhead taken as:

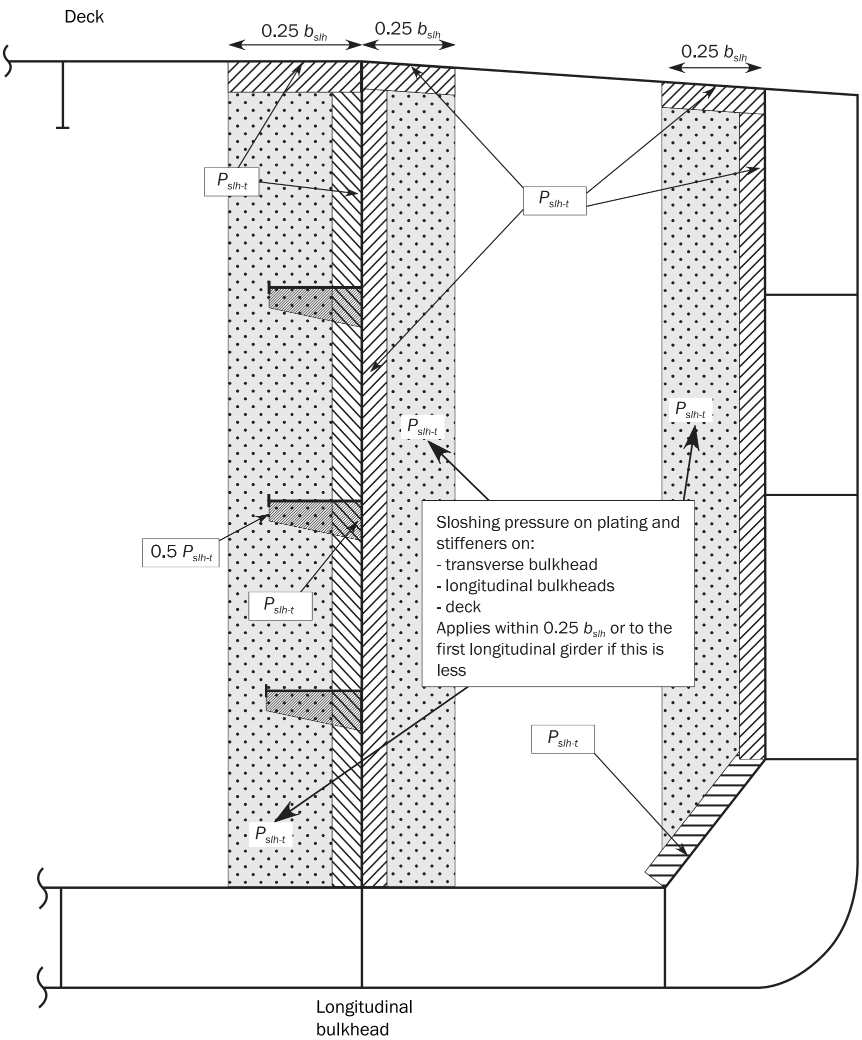
- $0.25\ b_{slh}$,
- The distance between the longitudinal bulkhead and the first girder if located inside the tank at the considered level,

whichever is less.

In addition, the first girder next to the longitudinal tight or wash bulkhead if the girder is located within $0.25\ b_{slh}$ from the longitudinal bulkhead, as shown in Figure 2, is to be assessed for the reflected sloshing pressure, $P_{slh-grd}$ as defined in Ch 4, Sec 6, [6.4.4].

The minimum sloshing pressure, $P_{slh-min}$, as defined in Ch 4, Sec 6, [6.2], is to be applied to all other members.

Figure 2 : Application of sloshing loads due to transverse liquid motion



1.3.6 Combination of transverse and longitudinal fluid motion

The sloshing pressures due to transverse and longitudinal fluid motion are assumed to act independently. Structural members are therefore to be evaluated based on the greatest sloshing pressure due to longitudinal and transverse fluid motion.

1.3.7 Additional sloshing impact assessment

For tanks with effective sloshing breadth, b_{slh}, greater than 0.56 B or effective sloshing length, ℓ_{slh}, greater than 0.13 L, an additional sloshing impact assessment is to be carried out in accordance with the individual Society's procedures.

2 SCANTLING REQUIREMENTS

2.1 Plating

2.1.1 Net thickness

The net thickness of plating, *t* in mm, subjected to sloshing pressures is not to be less than:

$$t = 0.0158\ \alpha_p\ b \sqrt{\frac{P_{slh}}{C_a\ R_{eH}}}$$

where:

C_a : Permissible bending stress coefficient to be taken as:

$$C_a = \beta_a - \alpha_a \frac{|\sigma_{hg}|}{R_{eH}}$$ with coefficients defined in Table 1, but not to be taken greater than $C_{a\text{-}max}$.

σ_{hg} : Hull girder bending stress, in N/mm^2, corresponding to the greatest of the sagging and hogging bending moment in absolute value.

P_{slh} : The greater of $P_{slh\text{-}lng}$, $P_{slh\text{-}t}$ or $P_{slh\text{-}min}$ as specified in [1.3].

Table 1 : Definition β_a, α_a and $C_{a\text{-}max}$

<table>
<tr><th>Acceptance criteria set</th><th colspan="2">Structural member</th><th>β_a</th><th>α_a</th><th>$C_{a\text{-}max}$</th></tr>
<tr><td rowspan="3">AC-S</td><td rowspan="2">Longitudinal strength members in the cargo hold region including but not limited to:
• Deck.
• Longitudinal plane bulkhead.
• Horizontal corrugated longitudinal bulkhead.
• Longitudinal girders and stringers.</td><td>Longitudinally stiffened plating</td><td>0.9</td><td>0.5</td><td>0.8</td></tr>
<tr><td>Transversely or vertically stiffened plating</td><td>0.9</td><td>1.0</td><td>0.8</td></tr>
<tr><td colspan="2">Other strength members including:
• Vertical corrugated longitudinal bulkhead.
• Transverse plane bulkhead.
• Transverse corrugated bulkhead.
• Transverse stringers and web frames.
• Plating of tank boundaries and primary supporting members outside the cargo hold region.</td><td>0.8</td><td>0</td><td>0.8</td></tr>
</table>

2.2 Stiffeners

2.2.1 Net section modulus

The net section modulus, *Z* in cm^3, of stiffeners subjected to sloshing pressures is not to be less than:

$$Z = \frac{P_{slh}\ s\ \ell_{bdg}^{\ 2}}{f_{bdg}\ C_s\ R_{eH}}$$

where:

f_{bdg} : Bending moment factor:

f_{bdg} = 12 for stiffeners fixed against rotation at each end. This is generally to be applied for scantlings of all continuous stiffeners.

f_{bdg} = 8 for stiffeners with one or both ends not fixed against rotation. This is generally to be applied to discontinuous stiffeners.

C_s : Permissible bending stress coefficient to be taken as defined in Table 2.

P_{slh} : The greater of $P_{slh\text{-}ing}$, $P_{slh\text{-}t}$ or $P_{slh\text{-}min}$ as specified in [1.3].

Table 2 : Permissible bending stress coefficient C_s

Sign of hull girder bending stress, σ_{hg} (1)	Lateral pressure acting on (2)	Stiffener boundary condition (3)	f_{bdg}	Coefficient C_s
Tension (positive)	Stiffener side	F - F	12	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
		F - S	8	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
		S - S	8	$C_s = C_{s\text{-}max}$
	Plate side	F - F	12	$C_s = C_{s\text{-}max}$
		F - S	8	$C_s = C_{s\text{-}max}$
		S - S	8	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
Compression (negative)	Stiffener side	F - F	12	$C_s = C_{s\text{-}max}$
		F - S	8	$C_s = C_{s\text{-}max}$
		S - S	8	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
	Plate side	F - F	12	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
		F - S	8	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
		S - S	8	$C_s = C_{s\text{-}max}$

(1) σ_{hg} is to be considered for the hogging and sagging situations.

(2) For primary supporting members located inside the considered tank and for wash bulkheads, the sloshing pressure is to be applied both on stiffener and plate sides.

(3) F - F stands for both ends of the stiffener fixed against rotation
F - S stands for one end of the stiffener fixed and the other not fixed against rotation
S - S stands for both ends of the stiffener not fixed against rotation

Table 3 : Definition β_s, α_s and C_{s-max}

Acceptance criteria set	Structural member		β_s	α_s	C_{s-max}
AC-S	Longitudinal strength members in the cargo hold region including but not limited to: • Deck stiffeners. • Stiffeners on longitudinal bulkheads. • Stiffeners on longitudinal girders and stringers.	Longitudinal stiffeners	0.85	1.0	0.75
		Transverse or vertical stiffeners	0.7	0	0.7
	Other strength members including: • Stiffeners on transverse bulkheads. • Stiffeners on transverse stringers and web frames. • Stiffeners on tank boundaries and primary supporting members outside the cargo hold region.		0.75	0	0.75

2.3 Primary supporting members

2.3.1 Web plating

The web plating net thickness of primary supporting members, t in mm, is not to be less than:

$$t = 0.0158\,\alpha_p\,b\sqrt{\frac{P_{slh}}{C_a\,R_{eH}}}$$

where:

P_{slh} : The greater of $P_{slh-lng}$, P_{slh-t}, P_{slh-wf}, $P_{slh-grd}$ and $P_{slh-min}$ as specified in [1.3]. The pressure is to be calculated at the load application point, defined in Ch 3, Sec 7, [4.1], taking into account the distribution over the height of the member, as shown in Figure 1 and Figure 2.

C_a : Permissible plate bending stress coefficient, as given in [2.1.1].

2.3.2 Stiffeners on web plating

The net section modulus, Z in cm^3, of each individual stiffener on the web plating of primary supporting members subjected to sloshing pressures is not to be less than:

$$Z = \frac{P_{slh}\,s\,\ell_{bdg}^{\;2}}{f_{bdg}\,C_s\,R_{eH}}$$

where:

P_{slh} : The greater of $P_{slh-lng}$, P_{slh-t}, P_{slh-wf}, $P_{slh-grd}$ and $P_{slh-min}$ as specified in [1.3]. The pressure is to be calculated at the load application point, defined in Ch 3, Sec 7, [3.2], taking into account the distribution over the height of the member, as shown in Figure 1 and Figure 2.

C_s : Permissible bending stress coefficient as given in [2.2.1].

f_{bdg} : Bending moment factor as given in [2.2.1].

2.3.3 Tripping brackets supporting primary supporting members

The net section modulus, Z in cm^3 in way of the base within the effective length, d, of tripping brackets and net shear area, A_{shr} in cm^2, after deduction of cut-outs and slots, of tripping brackets supporting primary supporting members is not to be less than:

$$Z = \frac{1000\,P_{slh}\,s_{trip}\,h^2}{2\,C_s\,R_{eH}}$$

$$A_{shr} = 10\,\frac{P_{slh}\,s_{trip}\,h}{C_t\,\tau_{eH}}$$

where:

P_{slh} : The greater of $P_{slh\text{-}lng}$, $P_{slh\text{-}t}$, $P_{slh\text{-}wf}$, $P_{slh\text{-}grd}$ and $P_{slh\text{-}min}$ as specified in [1.3]. The average pressure may be calculated at mid point of the tripping bracket taking into account the distribution as shown Figure 1 and Figure 2.

s_{trip} : Mean spacing, between tripping brackets or other primary supporting members or bulkheads, in m.

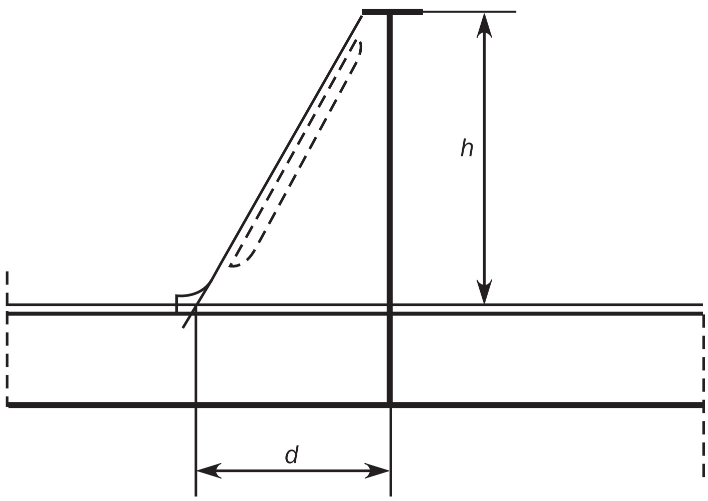
h : Height of tripping bracket, see Figure 3, in m.

C_s : Permissible bending stress coefficient for tripping brackets to be taken as 0.75.

C_t : Permissible shear stress coefficient for tripping brackets to be taken as 0.75.

The effective breadth of the attached plate to be used for calculating the section modulus of the tripping bracket is to be taken as $h/3$.

Figure 3 : Effective length of tripping bracket



PART 1 CHAPTER 11

SUPERSTRUCTURE, DECKHOUSES AND HULL OUTFITTING

Table of Contents

SECTION 1
SUPERSTRUCTURES, DECKHOUSES AND COMPANIONWAYS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

P : Pressure applied on the considered superstructure side or deck, in kN/m²

$P = P_D$ for external decks,
$P = P_{dl}$ for unexposed deck,
$P = P_{Sl}$ for superstructure side.

P_D : Lateral pressure for exposed decks, in kN/m², as defined in Ch 4, Sec 5, [2] and in Ch 4, Sec 5, [4.2].

P_{dl} : Lateral pressure for unexposed decks, in kN/m², as defined in Ch 4, Sec 6, [5].

P_{Sl} : Lateral pressure for superstructure side, in kN/m², as defined in Ch 4, Sec 5, [4.3].

P_{FB} : Lateral pressure for side shell plating, in kN/m², affected by bow impact requirements according to Ch 4, Sec 5, [3.3.1].

P_A : External pressure for end bulkheads of superstructure and deckhouse walls, in kN/m² according to Ch 4, Sec 5, [4.4.1].

ℓ_{bdg} : Effective bending span, in m, as defined in Ch 3, Sec 7.

ℓ_{shr} : Effective shear span, in m, as defined in Ch 3, Sec 7.

c : Coefficient taken as:

c = 0.75 for beams, girders and transverses which are simply supported in one or both ends.

c = 0.55 in other cases.

m_a : Coefficient taken as:

$$m_a = 0.204 \frac{s}{1000\ell_{bdg}}\left[4-\left(\frac{s}{1000\ell_{bdg}}\right)^2\right] \quad \text{with} \quad \frac{s}{1000\ell_{bdg}} \le 1$$

1 GENERAL

1.1 Application

1.1.1

The requirements of this section are applicable to superstructures, deckhouses and companionways, made of steel.

The requirements of Pt 1, Ch 6 apply in addition to those of this section for exposed decks of superstructure and the side of superstructure or deckhouse when this side is part of the side shell.

1.1.2

For the application of this section, a superstructure is considered being located aft or forward 0.4 *L* amidships or having a length of less than 0.15 *L*.

1.1.3

For the application of this section, the length of a deckhouse located within 0.4 *L* amidships is considered not exceeding 0.2 *L*.

1.2 Gross scantlings

1.2.1

With reference to Ch 3, Sec 2, [1.1.3], all scantlings and dimensions referred to in [3] are gross.

2 STRUCTURAL ARRANGEMENT

2.1 Structural continuity

2.1.1 Bulkheads and sides of deckhouses

The aft, front and side bulkheads are to be effectively supported by under deck structures such as bulkheads, girders and pillars.

Sides and main longitudinal and transverse bulkheads are to be in line in the various tiers of deckhouses. Where such arrangement in line is not possible, other effective support is to be provided.

Arrangements are to be made to minimise the effect of discontinuities in erections. All openings cut in the sides are to be framed and have well-rounded corners. Continuous coamings or girders are to be fitted below and above doors and similar openings.

2.1.2 Deckhouse corners

At the corners where the deckhouse is attached to the strength deck, attention is to be given to the arrangements to transmit load into the under deck supporting structure.

2.2 End connections

2.2.1 Deck stiffeners

Transverse beams are to be connected to side frames by brackets according to Ch 3, Sec 6, [3.2]. Beams crossing longitudinal walls and girders may be attached to the stiffeners of longitudinal walls and the webs of girders respectively by welding without brackets.

2.2.2 Longitudinal and transverse deck girders

Face plates are to be stiffened by tripping brackets according to Ch 3, Sec 6, [4.3].

2.2.3 End connections of superstructure frames

Vertical frames are to be welded to the main frames below, or to the deck under provision of a sufficient supporting structure.

2.3 Local reinforcement on bulkheads

2.3.1

Local reinforcement is to be provided in way of large openings and areas supporting life saving appliances or high loads from other equipment, fittings, etc.

3 SCANTLINGS

3.1 Superstructures sides and decks

3.1.1 Exposed sides and exposed deck plating

Exposed sides and exposed deck plating inclusive their supporting structure are to comply with the requirements given in [3.2.1] to [3.2.5] and bow impact requirements in Ch 10, Sec 1, [3.3], if applicable.

3.1.2 Deck plating of unexposed decks

The deck plating and supporting structures of unexposed decks of superstructures are to comply with requirements given in [3.2.2] to [3.2.5].

3.2 Deckhouses

3.2.1 Plating

The gross thickness of the plating, $t_{gr\text{-}exp}$, in mm, is not to be less than

$$t_{gr-exp} = 7.5\sqrt{\frac{ks}{s_{std}}}$$, on first tier.

$$t_{gr-exp} = 7.0\sqrt{\frac{ks}{s_{std}}}$$, on second tier.

$$t_{gr-exp} = 6.5\sqrt{\frac{ks}{s_{std}}}$$, on third tier and above.

where:

s_{std} : Standard reference spacing of stiffeners or beams, in mm, taken as:

$$s_{std} = 470 + 1.67\ L_1$$

Where deck is protected by sheathing, the gross thickness of the deck plating may be reduced by 1.5 mm, without being less than 5 mm.

Where sheathing other than wood is used, attention is to be paid that the sheathing does not affect the steel. The sheathing is to be effectively fitted to the deck.

3.2.2 Deck plating of unexposed decks

The gross thickness of the unexposed deck plating, $t_{gr\text{-}unexp}$, in mm, is not to be less than the greater value of:

$$t_{gr-unexp} = 0.9\ t_{gr-exp}$$ at the tier considered, and

$$t_{gr-unexp} = \left(5.8\frac{s}{1000} + 1\right)\sqrt{k}$$ but not less than 5.5 mm.

3.2.3 Beams and stiffeners

The gross section modulus Z_{gr}, in cm^3, and the gross shear area $A_{gr\text{-}sh}$, in cm^2, of transverse beams and of stiffeners are not to be less than:

$$Z_{gr} = c\ k\ P\frac{s}{1000}\ell_{bdg}^{\ 2}$$

$$A_{gr-sh} = 0.05\ (1 - 0.817\ m_a)\ k\ P\frac{s}{1000}\ell_{shr}$$

3.2.4 Girders and transverses

The gross section modulus Z_{gr}, in cm^3, and the gross shear area $A_{gr\text{-}sh}$, in cm^2, of girders and transverses are not to be less than:

$Z_{gr} = c\ k\ P\ S\ \ell_{bdg}^{\ 2}$

$A_{gr-sh} = 0.05\ k\ P\ S\ \ell_{shr}$

The girder depth is not to be less than $\ell/25$. The web depth of girders scalloped for continuous deck beams is to be at least 1.5 times the depth of the deck beams.

3.2.5 Alternative grillage analysis for girders and transverses

Where arrangements of deck girders and transverses are such that these members act as a grillage structure, additional analysis may be carried out with a structural model based on the gross scantling.

The resulting stresses are not to exceed the following permissible bending, shear and equivalent stresses, in N/mm², taken as:

$\sigma_b = 150/k$

$\tau = 100/k$

$\sigma_{eqv} = 180/k$

3.3 Deckhouse walls and end bulkheads of superstructure

3.3.1 Application

The requirements in [3.3] apply to end bulkhead of superstructure and deckhouse walls forming the only protection for openings and for accommodations.

Special consideration may be given to the bulkhead scantlings of deckhouses which do not protect openings in the freeboard deck, superstructure deck or in the top of a lowest tier deckhouse. Special consideration may also be given to the bulkhead scantlings of deckhouses which do not protect machinery casings, provided they do not contain accommodation or do not protect equipment essential to the operation of the ship.

3.3.2 Plate thickness

The gross thickness of the plating t_{gr}, in mm, is not to be less than the greater of:

$$t_{gr} = 0.9\ \frac{s}{1000}\sqrt{kP_A} + 1.5$$

$t_{gr} = \left(5.0 + \dfrac{L_2}{100}\right)\sqrt{k}$, for the lowest tier.

$t_{gr} = \left(4.0 + \dfrac{L_2}{100}\right)\sqrt{k}$, for the upper tiers, without being less than 5.0 mm.

3.3.3 Stiffeners

The gross section modulus Z_{gr}, in cm³, of the stiffeners is not to be less than:

$$Z_{gr} = 0.35\ k\ P_A\ \frac{s}{1000}\ \ell^2$$

This requirement assumes the webs of lowest tier stiffeners to be efficiently welded to the decks. Scantlings for other types of end connections are to be specially considered.

The section modulus of deckhouse side stiffeners needs not to be greater than that of side frames on the deck situated directly below, taking account of spacing s and span ℓ.

3.4 Companionways

3.4.1

The scantlings of companionways are to be determined in accordance with [3.2] and [3.3].

SECTION 2
BULWARK AND GUARD RAILS

1 GENERAL REQUIREMENTS

1.1 Application

1.1.1

Bulwarks or guard rails are to be provided at the boundaries of exposed freeboard and superstructure decks, at the boundary of first tier of deckhouses and at the ends of superstructures.

1.2 Minimum height

1.2.1

Bulwarks, or guard rails, are to be a minimum of 1.0 m in height, measured above sheathing, and are to be constructed as required in [2.2] and [3.2]. Where this height would interfere with the normal operation of the ship, a lesser height may be accepted, on the basis of justifying information to be submitted.

2 BULWARKS

2.1 General

2.1.1

Plate bulwarks are to be stiffened at the upper edge by a suitable rail and supported either by stays or plate brackets spaced not more than 2.0 m apart.

The free edge of the stay or the plate bracket is to be stiffened.

2.1.2

Within 0.6 *L* amidships, bulwarks are to be arranged to ensure that they are free from hull girder stresses.

2.1.3

Bulwarks are to be adequately strengthened and increased in thickness in way of mooring pipes.

Cut-outs in bulwarks for gangways or other openings are to be kept clear of breaks of superstructures.

2.1.4

Bulwark plating and stays are to be adequately strengthened in way of eye plates used for shrouds or other tackles in use for cargo gear operation, as well as in way of hawser holes or fairleads provided for mooring or towing.

2.1.5

Openings in bulwarks are to be arranged so that the protection of the crew is to be at least equivalent to that provided by the horizontal courses in [3.1.2].

For this purpose, vertical rails or bars spaced approximately 230 mm apart may be accepted in lieu of rails or bars arranged horizontally.

2.1.6

In the case of ships intended for the carriage of timber deck cargoes, the specific provisions of the freeboard regulations are to be complied with.

2.1.7

Where mooring fittings subject the bulwark to large forces, the stays are to be adequately strengthened.

2.2 Construction of bulwarks

2.2.1 Plating

The gross thickness of bulwark plating, at the boundaries of exposed freeboard and superstructure decks, is not to be less than that given in Table 1.

Table 1 : Thickness of bulwark plates

Height of bulwark	Gross thickness
1.8 m or more	Thickness required for a superstructure in the same position, obtained from Ch 11, Sec 1, [3.1]
1.0 m	6.5 mm
Intermediate height	To be determined by linear interpolation

2.2.2 Stays

The gross section modulus of stays, $Z_{stay\text{-}gr}$, in cm^3, is not to be less than:

$$Z_{stay-gr} = 77\ h_{blwk}{}^2\ s_{stay}$$

where:

h_{blwk} : Height of bulwark from the top of the deck plating to the top of the rail, in m.

s_{stay} : Spacing of the stays, in m.

In the calculation of the section modulus, only the material connected to the deck is to be included. The bulb or flange of the stay may be taken into account where connected to the deck. Where the bulwark plating is connected to the sheer strake, a width of attached plating, not exceeding 600 mm, may also be included.

2.2.3

Where bulwarks are cut completely, stays or plate brackets of increased strength are to be fitted at the ends of openings.

Bulwark stays are to be supported by, or are to be in line with, suitable under deck stiffening. The stiffening is to be connected by double continuous fillet welds in way of bulwark stay connections.

2.2.4

At the ends of superstructures and for the distance over which their side plating is tapered into the bulwark, the latter is to have the same thickness as the side plating. Where openings are cut in the bulwark at these positions, adequate compensation is to be provided either by increasing the thickness of the plating or by other suitable means.

3 GUARD RAILS

3.1 General

3.1.1

Where superstructures are connected by trunks, open rails are to be fitted for the whole length of the exposed parts of the freeboard deck.

3.1.2

In Type B-100 and Type A ships, open rails on the weather parts of the freeboard deck for at least half the length of the exposed parts are to be fitted.

Alternatively, freeing ports complying with ICLL are to be fitted.

3.2 Construction of guard rails

3.2.1

Stanchions of guard rails are to comply with the following requirements:

a) Fixed, removable or hinged stanchions are to be fitted approximately 1.5 m apart.

b) At least every third stanchion is to be supported by a bracket or stay.

c) Removable or hinged stanchions are to be capable of being locked in the upright position.

d) In the case of ships with rounded sheer strake, the stanchions are to be placed on the flat of the deck.

e) In the case of ships with welded sheer strake, the stanchions are not to be attached to the sheer strake, upstand or a continuous gutter bar.

3.2.2

The size of openings, below the lowest course of rails and the deck or upstand, is to be a maximum of 230 mm. The distance between other courses is not to be greater than 380 mm.

3.2.3

Wire ropes may be accepted, in lieu of guard rails, only in special circumstances and then only in limited lengths. In such cases, they are to be made taut by means of turnbuckles.

3.2.4

Chains may be accepted, in lieu of guard rails, only where they are fitted between two fixed stanchions and/or bulwarks. if the opening is wide, the chains are to be fitted with vertical courses to prevent the horizontal courses from spreading apart.

SECTION 3
EQUIPMENT

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

1 GENERAL

1.1 Application

1.1.1

The anchoring equipment specified in this section is intended for temporary mooring of a ship within a harbour or sheltered area when the ship is awaiting berth, tide, etc.

1.1.2

The equipment specified is not intended to be adequate to hold a ship off fully exposed coasts in rough weather or to stop a ship that is moving or drifting. In such a condition, the loads on the anchoring equipment increase to such a degree that its components may be damaged or lost.

1.1.3

The Equipment Number (*EN*) formula for the required anchoring equipment is based on an assumed current speed of 2.5 m/s, wind speed of 25 m/s and a scope of chain cable between 6 and 10. The scope of chain cable is defined as the ratio between the length of chain paid out and the waters depth.

It is assumed that under normal circumstances a ship will use only one bow anchor and chain cable at a time.

2 EQUIPMENT NUMBER CALCULATION

2.1 Requirements

2.1.1

Anchors and chains are to be in accordance with Table 1 and the quantity, mass and sizes of these are to be determined by the equipment number (EN), given by:

$$EN = \Delta^{2/3} + 2\ B\ h + 0.1\ A$$

where:

h : Effective height, in m, from the summer load waterline to the top of the uppermost house, to be obtained in accordance with the following formula:

$$h = h_{FB} + \Sigma h_n$$

When calculating h, sheer and trim are to be disregarded.

h_{FB} : Freeboard amidships from the summer load waterline to the upper deck, in m.

h_n : Height, in m, at the centreline of superstructure or of deckhouse tier 'n' having a breadth greater than $B/4$. Where a house having a breadth greater than $B/4$ is above a house with a breadth of $B/4$ or less, the upper house is to be included and the lower ignored (see in Figure 1).

A : Area, in m^2, in profile view, of the parts of the hull, superstructures and houses above the summer load waterline which are within the length L and also have a breadth greater than $B/4$.

Fixed screens or bulwarks 1.5 m or more in height are to be regarded as parts of houses when determining h and A. In particular, the hatched area shown in Figure 2 is to be included.

The height of hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining h and A.

2.1.2

For ships with EN greater than 16000, the determination of the equipment will be considered by the Society on a case-by-case basis.

Figure 1 : Effective heights of deckhouses

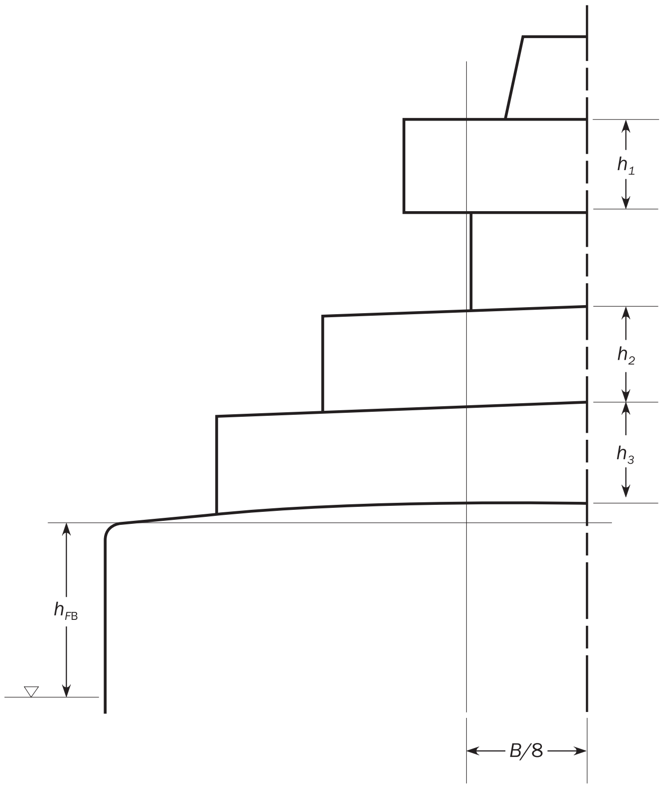


Figure 2 : Profile areas of screens and bulwarks

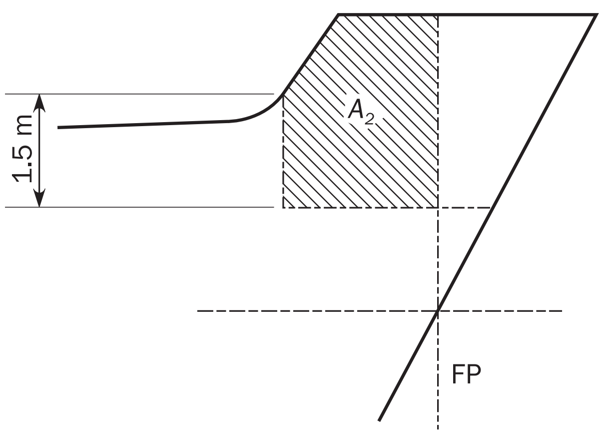


Table 1 : Equipment - Bower anchors and chain cables

Equipment Number		Stockless bower anchors		Chain cable stud link bower chain			
					Diameter, in mm		
Greater than	Equal to or less than	Number of anchors (1)	Mass per anchor, in kg	Length, in m	Normal strength steel (Grade 1)	High strength steel (Grade 2)	Extra high strength steel (Grade 3)
150	175	2	480	275	22	19	*
175	205	2	570	302.5	24	20.5	*
205	240	2	660	302.5	26	22	20.5
240	280	2	780	330	28	24	22
280	320	2	900	357.5	30	26	24
320	360	2	1020	357.5	32	28	24
360	400	2	1140	385	34	30	26
400	450	2	1290	385	36	32	28
450	500	2	1440	412.5	38	34	30
500	550	2	1590	412.5	40	34	30
550	600	2	1740	440	42	36	32
600	660	2	1920	440	44	38	34
660	720	2	2100	440	46	40	36
720	780	2	2280	467.5	48	42	36
780	840	2	2460	467.5	50	44	38
840	910	2	2640	467.5	52	46	40
910	980	2	2850	495	54	48	42
980	1060	2	3060	495	56	50	44
1060	1140	2	3300	495	58	50	46
1140	1220	2	3540	522.5	60	52	46
1220	1300	2	3780	522.5	62	54	48
1300	1390	2	4050	522.5	64	56	50
1390	1480	2	4320	550	66	58	50
1480	1570	2	4590	550	68	60	52
1570	1670	2	4890	550	70	62	54
1670	1790	2	5250	577.5	73	64	56
1790	1930	2	5610	577.5	76	66	58
1930	2080	2	6000	577.5	78	68	60
2080	2230	2	6450	605	81	70	62
2230	2380	2	6900	605	84	73	64
2380	2530	2	7350	605	87	76	66
2530	2700	2	7800	632.5	90	78	68
2700	2870	2	8300	632.5	92	81	70
2870	3040	2	8700	632.5	95	84	73
3040	3210	2	9300	660	97	84	76
3210	3400	2	9900	660	100	87	78
3400	3600	2	10500	660	102	90	78
3600	3800	2	11100	687.5	105	92	81
3800	4000	2	11700	687.5	107	95	84

(1) Spare anchors are not included in the number of required anchors.

Note 1: '*' chain grade not to be used at this diameter.

Equipment Number		Stockless bower anchors		Chain cable stud link bower chain			
					Diameter, in mm		
Greater than	Equal to or less than	Number of anchors (1)	Mass per anchor, in kg	Length, in m	Normal strength steel (Grade 1)	High strength steel (Grade 2)	Extra high strength steel (Grade 3)
4000	4200	2	12300	687.5	111	97	87
4200	4400	2	12900	715	114	100	87
4400	4600	2	13500	715	117	102	90
4600	4800	2	14100	715	120	105	92
4800	5000	2	14700	742.5	122	107	95
5000	5200	2	15400	742.5	124	111	97
5200	5500	2	16100	742.5	127	111	97
5500	5800	2	16900	742.5	130	114	100
5800	6100	2	17800	742.5	132	117	102
6100	6500	2	18800	742.5	*	120	107
6500	6900	2	20000	770	*	124	111
6900	7400	2	21500	770	*	127	114
7400	7900	2	23000	770	*	132	117
7900	8400	2	24500	770	*	137	122
8400	8900	2	26000	770	*	142	127
8900	9400	2	27500	770	*	147	132
9400	10000	2	29000	770	*	152	132
10000	10700	2	31000	770	*	*	137
10700	11500	2	33000	770	*	*	142
11500	12400	2	35500	770	*	*	147
12400	13400	2	38500	770	*	*	152
13400	14600	2	42000	770	*	*	157
14600	16000	2	46000	770	*	*	162

(1) Spare anchors are not included in the number of required anchors.

Note 1: '*' chain grade not to be used at this diameter.

3 ANCHORING EQUIPMENT

3.1 General

3.1.1 General

Two bower anchors are to be connected to chain cable and stowed in position ready for use.

A third anchor is recommended to be provided as a spare bower anchor and is listed for guidance only; it is not required as a condition of classification.

3.1.2 Design

Anchors are to be of an approved design. The design of anchor heads is to be such as to minimise stress concentrations. In particular, the radii, on all parts of cast anchor heads are to be as large as possible, especially where there is considerable change of section.

If the anchor design is different from standard or approved anchor types, drawing of the anchor, including material specification, is to be submitted for approval.

3.1.3 Testing

All anchors and chain cables are to be tested at establishments and on machines recognised by the Society, under the supervision of surveyors or other representatives of the Society and in accordance with the relevant requirements for materials of the Society.

Test certificates showing particulars of weights of anchors, or size and weight of cable and of the test loads applied are to be available. These certificates are to be examined by the surveyor when the anchors and cables are placed onboard the ship.

3.2 Ordinary anchors

3.2.1 Anchor mass

The mass per anchor of bower anchors given in Table 1 is for anchors of equal mass. The mass of individual anchors may vary 7% above or below the tabulated value, provided that the combined mass of all anchors is not less than that required for anchors of equal mass.

Anchors are to be of the stockless type. The mass of the head of anchor, including pins and fittings, is not to be less than 60% of the total mass of the anchor.

3.3 High and Super High Holding power anchors

3.3.1 General

Where agreed by the owner, consideration will be given to the use of special types of anchors. High Holding Power (HHP) and Super High Holding Power (SHHP) anchors, i.e. anchors for which a holding power higher than that of ordinary anchors has been proved according to the applicable requirements of the Society's Rules for Materials, do not require prior adjustment or special placement on the sea bottom.

3.3.2 HHP or SHHP anchor mass

Where HHP or SHHP anchors are used as bower anchors, the mass of each anchor is to be not less than 75% or 50%, respectively, of that required for ordinary stockless anchors in Table 1.

The mass of SHHP anchors is to be, in general, less than or equal to 1500 kg.

3.3.3 Application

High holding power anchors are to be of a design that will ensure that the anchors will take effective hold of the sea bed without undue delay and will remain stable, for holding forces up to those required by [3.3.4], irrespective of the angle or position at which they first settle on the sea bed when dropped from a normal type of hawse pipe. A demonstration of these abilities may be required.

The design approval of high holding power anchors may be given as a general/type approval, and listed in a published document by the Society.

3.3.4 Testing

An anchor for which approval is sought as a high holding power (HHP) anchor, is to be tested at sea to show that it has a holding power of twice that approved for a standard stockless anchor of the same mass.

If approval is sought for a range of sizes, then at least two are to be tested. The smaller of the two anchors is to have a mass not less than one-tenth of that of the larger anchor. The larger of the two anchors tested is to have a mass not less than one-tenth of that of the largest anchor for which approval is sought.

Each test is to comprise a comparison between at least two anchors: one ordinary stockless bower anchor and one HHP anchor. The masses of the anchors are to be approximately equal.

The tests are generally to be carried out by means of a tug. The pull is to be measured by a dynamometer or determined from recently verified data of the tug's bollard pull as a function of propeller rpm.

During the test, the length of the chain cable on each anchor is to be sufficient to obtain an approximately horizontal pull on the anchor. Generally, a horizontal distance between anchor and tug equal to 10 times the water depth will be sufficient.

For SHHP, the tests are to be conducted on at least three different types of bottom, which may be soft mud or silt, sand or gravel, and hard clay or similarly compacted material.

3.4 Chain cables

3.4.1 General

The chain cables are classified as Grade 1, 2 or 3 depending on the type of steel used and its manufacture.

The characteristics of the steel used and the method of manufacture of chain cables are to be approved by the Society for each manufacturer. The material from which chain cables are manufactured and the completed chain cables themselves are to be tested in accordance with the applicable requirements of the Society's Rules for Materials.

Chain cables which are intended to form part of the equipment are not to be used as check chains when the ship is launched.

3.4.2 Application

The total length of chain required to be carried onboard, as given in Table 1, is to be divided approximately equally between the two anchors.

Where the owner requires equipment for anchoring at depths greater than 82.5 m, it is the owner's responsibility to specify the appropriate total length of the chain cable required. In such a case, consideration can be given to dividing the chain cable into two unequal lengths.

3.5 Chain lockers

3.5.1 General

The chain locker is to have adequate capacity and be of a suitable form to provide for the proper stowage of the chain cable, allowing an easy direct lead for the cable into the chain pipes when the cable is fully stowed. Port and starboard cables are to have separate spaces.

The chain locker boundaries and access openings are to be watertight. Provisions are to be made to minimise the probability of the chain locker being flooded in bad weather. Adequate drainage facilities for the chain locker are to be provided.

Chain or spurling pipes are to be of suitable size and provided with chafing lips.

3.5.2 Application

Provisions are to be made for securing the inboard ends of the chain to the structure. This attachment and its supporting structure are to be able to withstand a force of not less than 15% or more than 30% of the minimum breaking strength of the fitted chain cable.

The fastening of the chain to the ship is to be arranged in such a way that in case of an emergency, when the anchor and chain have to be sacrificed, the chain can be readily released from an accessible position outside the chain locker.

3.6 Chain stoppers

3.6.1 General

Chain stoppers are to be provided to secure each chain cable once it is paid out.

3.6.2 Application

Securing arrangements of chain stoppers are to be capable of withstanding a load equal to 80% of the breaking load of the chain cable as required by [3.4.1], without undergoing permanent deformation.

3.7 Windlass

3.7.1 General

A windlass of sufficient power and suitable for the size of chain is to be fitted to the ship in accordance with the requirements of the Society. Where an owner requires equipment significantly in excess of Rule requirements, it is the owner's responsibility to specify increased windlass power.

The windlass is to be capable of heaving in either cable.

3.7.2 Application

The design of the windlass is to be such that access to the chain pipe is adequate to permit the fitting of a cover or seal of sufficient strength over the spurling pipe.

Special consideration will be given to the acceptance of equivalent arrangements that minimise the probability of the chain locker or forecastle being flooded.

3.7.3 Anchor windlass trial

Each windlass is to be tested under working conditions after installation onboard to demonstrate satisfactory operation. Each unit is to be independently tested for the following:

a) Braking.

b) Clutch functioning.

c) Lowering and hoisting of chain cable and anchor.

d) Proper riding of the chain over the chain lifter.

e) Proper transit of the chain through the hawse pipe and the chain pipe.

f) Effecting proper stowage of the chain and the anchor.

During trials onboard ship, the windlass is to be shown to:

a) For all specified design anchorage depths, raise the anchor from a depth of 82.5 m to a depth of 27.5 m at a mean speed of 9 m/min.

b) For specified design anchorage depths greater than 82.5 m, in addition to (a), raise the anchor from the specified design anchorage depth to a depth of 82.5 m at a mean speed of 3 m/min.

c) Where the depth of the water in the trial area is inadequate, suitable equivalent simulating conditions will be considered as an alternative.

3.8 Hawse pipes

3.8.1 General

Hawse pipes are to be of a suitable size and configuration to ensure adequate clearance and an easy lead of the chain cable from the chain stopper through the ship's side.

Hawse pipes are to be of sufficient strength.

Their position and slope are to be so arranged as to create an easy lead for the chain cables and efficient housing for the anchors, where the latter are of the retractable type, avoiding damage to the hull during these operations.

For this purpose, chafing lips of suitable form with ample lay-up and radius adequate to the size of the chain cable are to be provided at the shell and deck. The shell plating in way of the hawse pipes is to be reinforced as necessary.

Where hawse pipes are not fitted, alternative arrangements will be specially considered.

3.8.2 Application

Hawse pipes are to be securely attached to thick, doubling or insert plates, by continuous welds.

3.8.3 Stowage and deployment arrangements for anchors

Hawse pipes and anchor pockets are to have full-rounded flanges or rubbing bars in order to minimise the nip on the cables and to minimise the probability of cable links being subjected to high bending stresses. The radius of curvature is to be such that at least three links of chain will bear simultaneously on the rounded parts of the upper and lower ends of the hawse pipes in those areas where the chain cable is supported during paying out and hoisting and when the ship is at anchor.

On ships provided with a bulbous bow, where it is not possible to obtain a suitable clearance between shell plating and the anchors during anchor handling, local reinforcements of the bulbous bow are to be provided in the form of increased shell plate thickness.

SECTION 4
SUPPORTING STRUCTURE FOR DECK EQUIPMENT AND FITTINGS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

SWL : Safe working load as defined in [4.1.4].

1 GENERAL

1.1 Application

1.1.1

Information pertaining to the supporting structure for deck equipment and fittings, as listed in this section, is to be submitted for approval.

This section includes scantling requirements to the supporting structure and foundations of the following pieces of equipment and fittings:

a) Anchor windlasses.

b) Anchoring chain stoppers.

c) Mooring winches.

d) Deck cranes, derricks and lifting masts.

e) Bollards and bitts, fairleads, stand rollers, chocks and capstans.

1.1.2

Where deck equipment is subject to multiple load cases, such as operational loads and green sea load, the loads are be applied independently for the evaluation of strength of foundations and support structure.

1.2 Documents to be submitted

1.2.1

The documents to be submitted are indicated in Ch 1, Sec 3.

2 ANCHORING WINDLASS AND CHAIN STOPPER

2.1 General

2.1.1

The windlass is to be efficiently bedded and secured to the deck.

2.1.2

The builder and the windlass manufacturer are to ensured that the foundation is suitable for the safe operation and maintenance of the windlass equipment.

2.1.3

The supporting structure is to be dimensioned to ensure that for each of the load scenarios specified in [2.1.5] and [2.1.6], the stresses do not exceed the permissible values given in [2.1.12] to [2.1.15].

2.1.4

These requirements are to be assessed based on gross scantlings.

2.1.5

The following load cases are to be examined for the anchoring operation, as appropriate:

a) Windlass where chain stopper is provided: 45% of *BS*.

b) Windlass where chain stopper is not provided: 80% of *BS*.

c) Chain stopper: 80% of *BS*.

where:

BS : Minimum breaking strength of the chain cable.

2.1.6

The following forces are to be applied in the independent load cases that are to be examined for the design loads due to green sea over the forward 0.25 *L*, see Figure 1:

$P_x = 200\ A_x$, in kN, acting normal to the shaft axis.

$P_y = 150\ A_y\ f$, in kN, acting parallel to the shaft axis (inboard and outboard directions to be examined separately).

where:

A_x : Projected frontal area, in m^2.

A_y : Projected side area, in m^2.

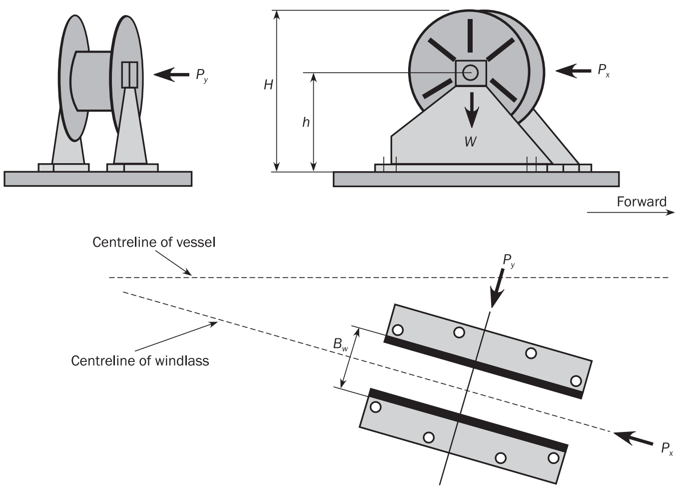
f : Coefficient taken as:

$f = 1 + B_w/H$, but not to be taken greater than 2.5.

B_W : Breadth of windlass measured parallel to the shaft axis, in m, see Figure 1.

H : Overall height of windlass, in m, see Figure 1.

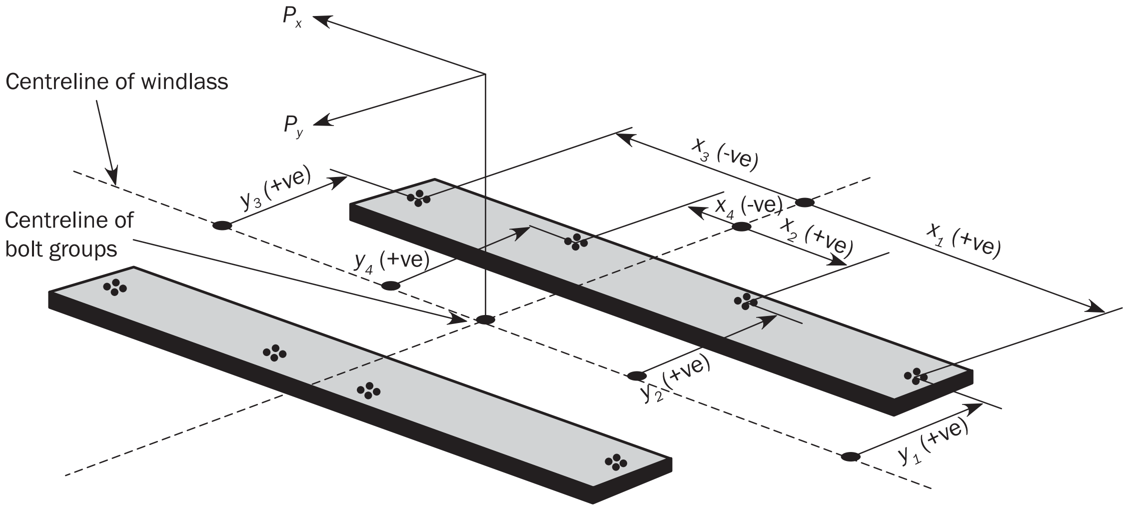
Figure 1 : Directions of forces and weight



2.1.7

Forces resulting from green sea design loads in the bolts, chocks and stoppers securing the windlass to the deck are to be calculated. The windlass is supported by a number of bolt groups, *N*, each containing one or more bolts. See Figure 2.

Figure 2 : Bolting arrangements and sign conventions



2.1.8

The axial forces, R_{xi} and R_{yi}, in bolt group (or bolt) *i*, positive in tension, are given by:

$$R_{xi} = P_x\ h\ x_i\ A_i / I_x$$

$$R_{yi} = P_y\ h\ y_i\ A_i / I_y$$

$$R_i = R_{xi} + R_{yi} - R_{si}$$

where:

P_x : Force acting normal to the shaft axis, in kN.

P_y : Force acting parallel to the shaft axis, either inboard or outboard, whichever gives the greater force in bolt group *i*, in kN.

h : Shaft centre height above the windlass mounting, in cm, see Figure 1.

x_i, y : *x* and *y* coordinates of bolt group *i* from the centroid of all *N* bolt groups, in cm. Positive in the direction opposite to that of the applied force.

A_i : Cross sectional area of all bolts in group *i*, in cm^2.

I_x : Inertia in x direction for *N* bolt groups, in cm^4, taken as:

$$I_x = \Sigma A_i\, x_i^2$$

I_y : Inertia in y direction for *N* bolt groups, in cm^4, taken as:

$$I_y = \Sigma A_i\, y_i^2$$

R_{si} : Static reaction at bolt group *i*, due to the weight of windlass, in kN.

2.1.9

The shear forces, F_{xi} and F_{yi}, applied to the bolt group i, and the resultant combined force F_i, are given by:

$$F_{xi} = (P_x - C_1\ mg)/N$$

$$F_{yi} = (P_y - C_1\ mg)/N$$

$$F_i = \sqrt{F_{xi}^{\ 2} + F_{yi}^{\ 2}}$$

where:

C_1 : Coefficient of friction, taken equal to 0.5.

m : Mass of windlass, in t.

g : Acceleration due to gravity, taken equal to 9.81 m/s^2.

N : Number of bolt groups.

2.1.10

The resultant forces from the application of the loads specified in [2.1.5] and [2.1.6] are to be considered in the design of the supporting structure.

2.1.11

Where a separate foundation is provided for the windlass brake, the distribution of resultant forces is to be calculated on the assumption that the brake is applied for load cases (a) and (b) defined in [2.1.5].

2.1.12

The stresses resulting from anchoring design loads induced in the supporting structure are not to be greater than the following permissible values:

- Normal stress, 1.00 R_{eH}
- Shear stress, 0.58 R_{eH}

2.1.13

The tensile axial stresses resulting from green sea design loads in the individual bolts in each bolt group i are not to exceed 50% of the bolt proof strength. The load is to be applied in the direction of the chain cable. Where fitted bolts are designed to support shear forces in one or both directions, the von Mises equivalent stresses are not to exceed 50% of the bolt proof strength.

2.1.14

The horizontal forces resulting from the green sea design loads, F_{xi} and F_{yi} may be supported by shear chocks. Where pourable resins are incorporated in the holding down arrangements, due account is to be taken in the calculation.

2.1.15

The stresses resulting from green sea design loads induced in the supporting structure are not to be greater than the following permissible values:

- Normal stress, 1.00 R_{eH}.
- Shear stress, 0.58 R_{eH}.

3 MOORING WINCHES

3.1 General

3.1.1

Mooring winches are to be efficiently bedded and secured to the deck.

3.1.2 Foundation

The builder and mooring winch manufacturer are to ensured that the foundation is suitable for the safe operation and maintenance of the mooring winch equipment.

3.1.3 Rated pull

The Rated Pull is defined as the maximum load which the mooring winch is designed to exert during operation.

3.1.4 Holding load

The Holding Load is defined as the maximum load which the mooring winch is designed to resist during operation and is to be taken as the design brake holding load or equivalent.

3.1.5 Supporting structure

The supporting structure is to be dimensioned to ensure that for each of the load cases specified in [2.1.5], the stresses do not exceed the permissible values given in [2.1.12] to [2.1.15].

For mooring winches situated within the forward 0.25 *L*, the supporting structure is to be dimensioned to ensure that for the load case specified in [3.1.7], the stresses do not exceed the permissible values given in [2.1.12] to [2.1.15].

3.1.6 Corrosion model

These requirements are to be assessed based on gross scantlings.

3.1.7

Each of the following load cases are to be examined for design loads due to mooring operation:

a) Mooring winch at maximum pull: 100% of the Rated Pull.

b) Mooring winch with brake effective: 100% of the Holding Load.

c) Line strength: 125% of the breaking strength of the mooring line (hawser) according to Ch 11, Sec 3, Table 1 for the ship’s corresponding equipment number.

Rated pull and holding load are defined in [3.1.3] and [3.1.4]. The design load is to be applied through the mooring line according to the arrangement shown on the mooring arrangement plan.

3.1.8

For mooring winches situated within the forward 0.25 *L*, the resultant forces in the bolts obtained from green sea design loads are to be calculated in accordance with [2.1.6] to [2.1.9].

3.1.9

Where a separate foundation is provided for the mooring winch brake, the distribution of resultant forces is to take into account of the different load path. The brake is only to be considered in relation to the forces in [3.1.7] item (b).

4 CRANES, DERRICKS, LIFTING MASTS AND LIFE SAVING APPLIANCES

4.1 General

4.1.1

Supporting structure of life saving appliances and supporting structures of cranes, derricks and lifting masts with a Safe Working Load greater than 30 kN, or a maximum overturning moment to the supporting structure greater than 100 kNm, are to comply with these requirements.

4.1.2

These requirements apply to the connection to the deck and the supporting structure of cranes, derricks and lifting masts. Where the crane, derrick or lifting mast is to be certified by the Society, additional requirements may be applied by the Society.

4.1.3

These requirements do not cover the following items:

a) Supports of lifting appliances for personnel or passengers, except foundation for life saving appliances.

b) The structure of the lifting appliance pedestals or post above the area of the deck connection.

c) Holding down bolts and their arrangement, which are considered part of the lifting appliance.

The term 'lifting appliance' is defined as a crane, derrick or lifting mast.

4.1.4 SWL Definition

The Safe Working Load (SWL) is defined as the maximum load which the lifting appliance is certified to lift at any specified outreach.

4.1.5 Self weight

The self weight is the calculated gross self weight of the lifting appliance, including the weight of any lifting gear.

4.1.6 Overturning moment

The overturning moment is the maximum bending moment, calculated at the connection of the lifting appliance to the ship structure, due to the lifting appliance operating at Safe Working Load, taking into account outreach and self weight.

4.1.7

The crane pedestal and derrick mast are as defined in Figure 3.

4.1.8

Deck plating and under deck structure is to provide adequate support for derrick masts and crane pedestals against the loads and maximum overturning moment. Where the deck is penetrated, the deck plating is to be suitably strengthened.

4.1.9

Structural continuity of the deck structure is to be maintained.

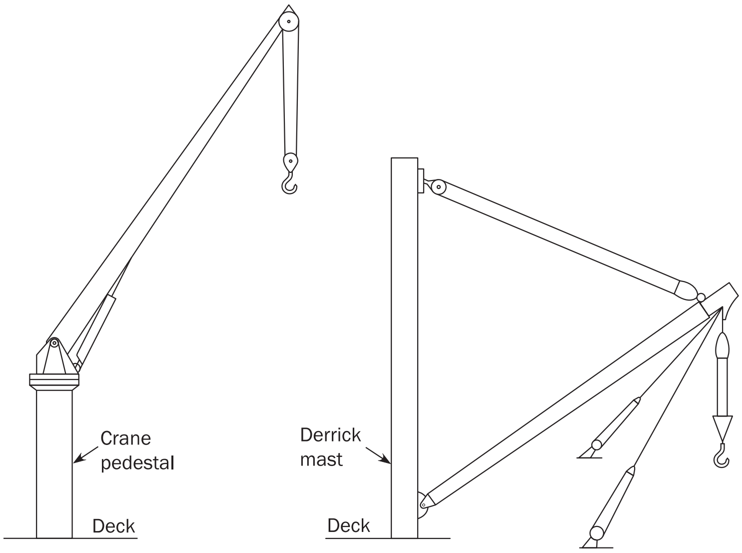
Under deck members are to be provided to support the crane pedestal and to comply with:

a) Where the pedestal is directly connected to the deck, without above deck brackets, adequate under deck structure directly in line with the crane pedestal is to be provided. Where the crane pedestal is attached to the deck without bracketing or where the crane pedestal is not continuous through the deck, welding to the deck of the crane pedestal and its under deck support structure is to be made by

suitable full penetration welding. The design of the weld connection is to be adequate for the calculated stress in the welded connection, in accordance with [4.1.15].

b) Where the pedestal is directly connected to the deck with brackets, under deck support structure is to be fitted to ensure a satisfactory transmission of the load, and to avoid structural hard spots. Above deck brackets may be fitted inside or outside of the pedestal and are to be aligned with deck girders and webs. The design is to avoid stress concentrations caused by an abrupt change of section. Brackets and other direct load carrying structure and under deck support structure are to be welded to the deck by suitable full penetration welding. The design of the connection is to be adequate for the calculated stress, in accordance with [4.1.15].

Figure 3 : Crane pedestal and derrick mast



4.1.10

Deck plating are to be of a material strength compatible with the crane pedestal. Where necessary, a thicker insert plate is to be fitted. In no case are doublers to be used where structures are subject to tension.

4.1.11

The supporting structure is to be dimensioned to ensure that for the load cases specified in [4.1.13] and [4.1.14], the stresses do not exceed those given in [4.1.15].

The capability of the supporting structure to resist buckling failure is to be assured.

4.1.12

These requirements are to be assessed based on gross scantlings.

4.1.13

For lifting appliances which are limited to use in harbour, design load is to be taken equal to 1.3 times SWL added to the lifting appliances self weight.

4.1.14

For life saving appliances, design load is to be taken as 2.2 times SWL.

4.1.15

The stresses induced in the supporting structure are not to exceed the following permissible values:

- Normal stress, 0.67 R_{eH}
- Shear stress, 0.39 R_{eH}

5 BOLLARDS AND BITTS, FAIRLEADS, STAND ROLLERS, CHOCKS AND CAPSTANS

5.1 General

5.1.1

Shipboard fittings (bollards and bitts, fairleads, stand rollers and chocks) and capstans used for mooring and towing operations are to be fitted to the deck or bulwark structures.

5.1.2

Where fairleads are fitted in bulwarks, the thickness of bulwarks may need to be increased. See Ch 11, Sec 2, [2.2].

5.1.3

The structural arrangement is to provide continuity of strength.

The structural arrangement of the ship's structure in way of the shipboard fittings and their seats and in way of capstans is to be such that abrupt changes of shape or section are to be avoided in order to minimise stress concentrations. Sharp corners and notches are to be avoided, especially in highly stressed areas.

5.1.4

The supporting structure is to be dimensioned to ensure that for the loads specified in [5.1.6] to [5.1.8], the stresses do not exceed the permissible values given in [5.1.9].

The capability of the structure to resist buckling failure is to be assured.

5.1.5

These requirements are to be assessed based on net scantlings.

5.1.6

Design loads for the supporting structure for shipboard fittings are to be according to:

a) In the case of normal towing in harbour or manoeuvring operations, 125% of the maximum towline load as indicated on the towing and mooring arrangement plan.

b) In the case of towing service other than that experienced in harbour or manoeuvring operations, such as escort service, the nominal breaking strength of towline.

c) In the case of mooring operations, 125% of the nominal breaking strength of the mooring line (hawser) or towline according to Ch 11, Sec 3, Table 1 for the ship's corresponding equipment number.

5.1.7

The design load for the supporting structure for capstans is to taken as 125% of the maximum hauling in force.

5.1.8

The assessment of the structure is to consider lines of action of the applied design load, taking into account the particular arrangements proposed; however, the total load applied for towing and mooring scenarios described in [5.1.6] need not be more than twice the design load on the mooring line or towline. The acting point for the force on the shipboard fittings is to be taken as the attachment point of the mooring line or towline, or at a change in its direction.

5.1.9

For the design load specified in [5.1.6] to [5.1.8], the stresses induced in the supporting structure and welds are not to exceed the following permissible values:

- Normal stress, 1.00 R_{eH}.
- Shear stress, 0.60 R_{eH}.

5.1.10

The following requirements on Safe Working Load apply for a single post basis (i.e. no more than one turn of one cable).

a) The SWL used for normal towing operations, e.g. harbour/manoeuvring is not to exceed 80% of the design load per [5.1.6] item (a); and the SWL used for other towing operations, e.g. escort is not to exceed the design load per [5.1.6] item (b). For deck fittings used for both normal and other towing operations, the greater of the design loads of [5.1.6] item (a) and [5.1.6] item (b) is to be used.

b) The SWL for mooring operations is not to exceed 80% of the design load per [5.1.6] item (c).

c) The SWL of each deck fitting is to be marked (by weld bead or equivalent) on the deck fittings used for towing and/or mooring.

d) The towing and mooring arrangements plan mentioned in [5.1.11] is to define the method of use of towing lines and/or mooring lines.

5.1.11

The SWL for the intended use for each deck fitting is to be stated in the towing and mooring arrangements plan available onboard for consistency for the guidance of the Master. For each deck fitting, the following is to be included:

a) Location on the ship.

b) Fitting type.

c) SWL.

d) Purpose (mooring/harbour towing/escort towing).

e) Manner of applying towing or mooring line load including limiting fleet angles.

This information is to be incorporated into the pilot card in order to provide the pilot with proper information on harbour/escorting operations.

6 MISCELLANEOUS DECK FITTINGS

6.1 Support and attachment

6.1.1

The following requirements are to be considered in the design of the support and attachment of miscellaneous fittings which impose relatively small loads on the ship's structure. The arrangement of such details and their approval is considered on a case-by-case basis by the Society.

6.1.2

Support positions are to be arranged so that the attachment to the ship structure is clear of deck openings and stress concentrations, such as the toes of end brackets. Design of supports is to be such that the attachment to the deck minimises the creation of hard points.

SECTION 5
SMALL HATCHWAYS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

1 GENERAL

1.1 Application

1.1.1

The requirements in [1.2] to [1.6] apply to small hatchways at weather deck in positions 1 and 2 as defined in Ch 1, Sec 4, [3.2]. The requirements in [2] apply to small hatchways fitted on the exposed fore deck over the forward 0.25 *L*.

Hatchways of bulk carriers not covered by the definition of small hatchways in [1.4.1] are to comply with applicable requirements in Pt 2, Ch 1.

1.2 Materials

1.2.1

Materials used for the construction of steel hatch covers are to comply with the applicable requirements of the Society.

1.2.2

The use of materials other than steel is considered by the Society on a case-by-case basis.

1.3 Height of hatch coamings

1.3.1

The height above the deck of hatch coamings is not to be less than:

- 600 mm in position 1.
- 450 mm in position 2.

1.3.2

The height, given in [1.3.1], of hatch coamings closed by steel covers provided with gaskets and securing devices may be reduced or the coamings may be omitted entirely, on condition that the Flag Administration is satisfied that the safety of the ship is not thereby impaired in any sea conditions.

In such cases the scantlings of the covers, their gasketing, their securing arrangements and the drainage of recesses in the deck are considered by the Society on a case-by-case basis.

1.4 Small hatchways

1.4.1

Small hatches are hatches designed for access to spaces below the deck and are capable to be closed weathertight or watertight, as applicable. Their opening is generally equal to or less than 2.5 m^2.

Hatch covers on exposed decks are to be weathertight.

Hatch covers fitted in way of ballast tanks, fuel oil tanks or other tanks are to be watertight.

1.4.2

Securing arrangements and stiffening of hatch cover edges are to be such that weathertightness can be maintained in any sea condition. At least one securing device is to be fitted at each side. Circular hole hinges are considered equivalent to securing devices.

1.4.3

Hatchways of special design are considered by the Society on a case-by-case basis.

1.4.4

The gross thickness of covers is to be not less than 8 mm. This thickness is to be increased or an efficient stiffening is to be fitted where the greatest horizontal dimension of the cover exceeds 0.6 m.

1.4.5

The gross thickness of coaming plate is not to be less than the lesser of the following values:

- The gross thickness for the deck in way of hatch coaming, assuming as spacing of stiffeners the lesser of the values of the height of the coaming and the distance between its stiffeners.
- 10 mm.

Coamings are to be strengthened where their height exceeds 0.8 m or their greatest horizontal dimension exceeds 1.2 m, unless their shape ensures an adequate rigidity.

1.5 Cargo tank access hatchways

1.5.1

Requirements given in [1.2] to [1.4] have to be considered as minimum requirements for cargo tank hatchways.

The requirements of [1.5.4] do not apply to dished covers or covers of other specially approved design.

1.5.2

Covers for access hatches, tank cleaning and other openings for cargo tanks and adjacent spaces are to be manufactured from the following material:

a) Normal strength steel in accordance with Ch 3, Sec 1.

b) Non-ferrous material may be considered, such as bronze or brass. Aluminium alloy is not to be used for covers of any opening to cargo tanks and spaces adjacent thereto.

c) Synthetic materials may be considered, taking into account their fire resistance and their physical and chemical properties in relation to the intended operating conditions. Details of the properties of the material, the design of the cover, and the method of manufacture are to be submitted for approval.

The hatch cover packing material is to be compatible with the cargoes that are intended to be carried and is to be effectively held in place.

1.5.3

The height of the hatch coaming above the upper surface of the freeboard deck is not to be less than 600 mm. Lower heights may be permitted by the Flag Administration. In addition, the top of the hatch coaming is not to be lower than the highest point of the tank over which it is fitted and is to be of sufficient height for the purpose of damage stability.

The gross thickness of the coaming plate is not to be less than 10 mm. Where the coaming height, as fitted, exceeds 600 mm, the thickness may be required to be increased or edge stiffening fitted. The scantlings of coaming plates of tank access coamings that enclose an area of 1.2 m^2 or more, and/or those that are not configured with a well rounded shape, may be subject to additional requirements.

1.5.4

The gross thickness of unstiffened plate covers with an area less than 1.2 m^2 is not to be less than 12.5 mm. The gross thickness of covers of a larger area will need to be increased or the cover will require stiffening.

Flat and unstiffened covers on circular hatchways are to be secured by fastenings with a spacing of not more than 600 mm.

On rectangular hatchways, the spacing of fastenings is generally not to be greater than 450 mm and the distance between hatch corners and adjacent fastenings is not to be greater than 230 mm.

Where the cover is hinged, adequate stiffening of the coaming and cover in way of the hinge is to be provided. In general, hinges are not to be considered securing devices for the cover and are to be designed so as to prevent the gasket from being over-tightened.

1.6 Gaskets

1.6.1

The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness.

1.6.2

Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

2 SMALL HATCHWAYS FITTED ON THE EXPOSED FORE DECK

2.1 General

2.1.1

These requirements apply to small hatchways (generally openings 2.5 m^2 or less) on the exposed deck within 0.25 L from the FP and located at a height less than 0.1 L or 22 m, whichever is less, from the summer load water line at the location of the hatch.

2.1.2

Hatchways designed for emergency escape need not comply with the requirements [2.3.1] items (a) and (b), [2.4.3] and [2.5.1].

2.1.3

Securing devices of hatches designed for emergency escape are to be of a quick-acting type (e.g. one action wheel handles are provided as central locking devices for latching/unlatching of hatch cover) operable from both sides of the hatch cover.

2.2 Strength

2.2.1

For small rectangular steel hatch covers, the gross plate thickness, stiffener arrangement and scantlings are to be not less than those obtained, in mm, from Table 1 and Figure 2. Stiffeners, where fitted, are to be aligned with the metal-to-metal contact points, required in [2.4.1] and shown in Figure 2. Primary stiffeners are to be continuous. All stiffeners are to be welded to the inner edge stiffener, see Figure 1.

Table 1 : Gross scantlings for small steel hatch covers on the fore deck

Nominal size, in mm	Cover plate thickness, in mm	Primary stiffeners	Secondary stiffeners
		Flat bar size, in mm ; number of stiffeners	
630 × 630	8	-	-
630 × 830	8	100 × 8 ; 1	-
830 × 630	8	100 × 8 ; 1	-
830 × 830	8	100 × 10 ; 1	-
1030 × 1030	8	120 × 12 ; 1	80 × 8 ; 2
1330 × 1330	8	150 × 12 ; 2	100 × 10 ; 2

2.2.2

The upper edge of the hatchway coaming is to be suitably reinforced by a horizontal member, normally not more than 190 mm from the upper edge of the coaming.

2.2.3

For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement is to provide strength and stiffness equivalent to the requirements for small rectangular hatches.

2.2.4

For small hatch covers constructed of materials other than normal strength steel, the required scantlings are to provide equivalent strength and stiffness.

2.3 Primary securing devices

2.3.1

The primary securing devices are to be fitted such that the hatch cover can be secured in place and be made weathertight by means of a closing mechanism employing any one of the following methods:

a) Butterfly nuts tightening onto forks (clamps),

b) Quick acting cleats, or

c) A central locking device.

Dogs (twist tightening handles) with wedges are not acceptable.

2.4 Requirement to primary securing

2.4.1

The hatch cover is to be fitted with a gasket of elastic material. This is to be designed to allow a metal to metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged. The metal-to-metal contacts are to be arranged close to each securing device in accordance with Figure 2 and of sufficient capacity to withstand the bearing force.

2.4.2

The primary securing method is to be designed and manufactured such that the designed compression pressure is achieved by one person without the need of any tools.

2.4.3

For a primary securing method using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed to minimise the risk of butterfly nuts being dislodged while in use; by means of curving the forks upward, a raised surface on the free end, or a similar method. The plate thickness of unstiffened steel forks is to be not less than 16 mm. An example arrangement is shown in Figure 1.

2.4.4

For small hatch covers located on the exposed deck forward of the foremost cargo hatch, the hinges are to be fitted such that the predominant direction of green seas will cause the cover to close, which means that the hinges are normally to be located on the fore edge.

2.4.5

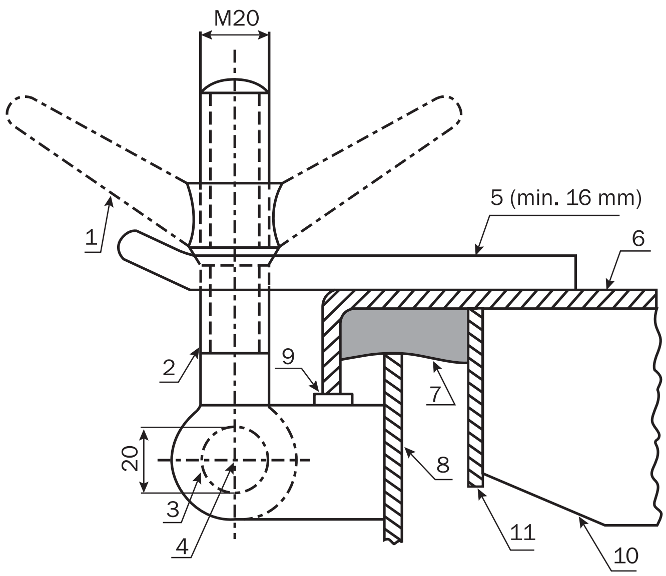
On small hatches located between the main hatches, for example between No. 1 and No. 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green water in beam sea and bow quartering conditions.

2.5 Secondary securing devices

2.5.1

Small hatches on the fore deck are to be fitted with an independent secondary securing device, e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

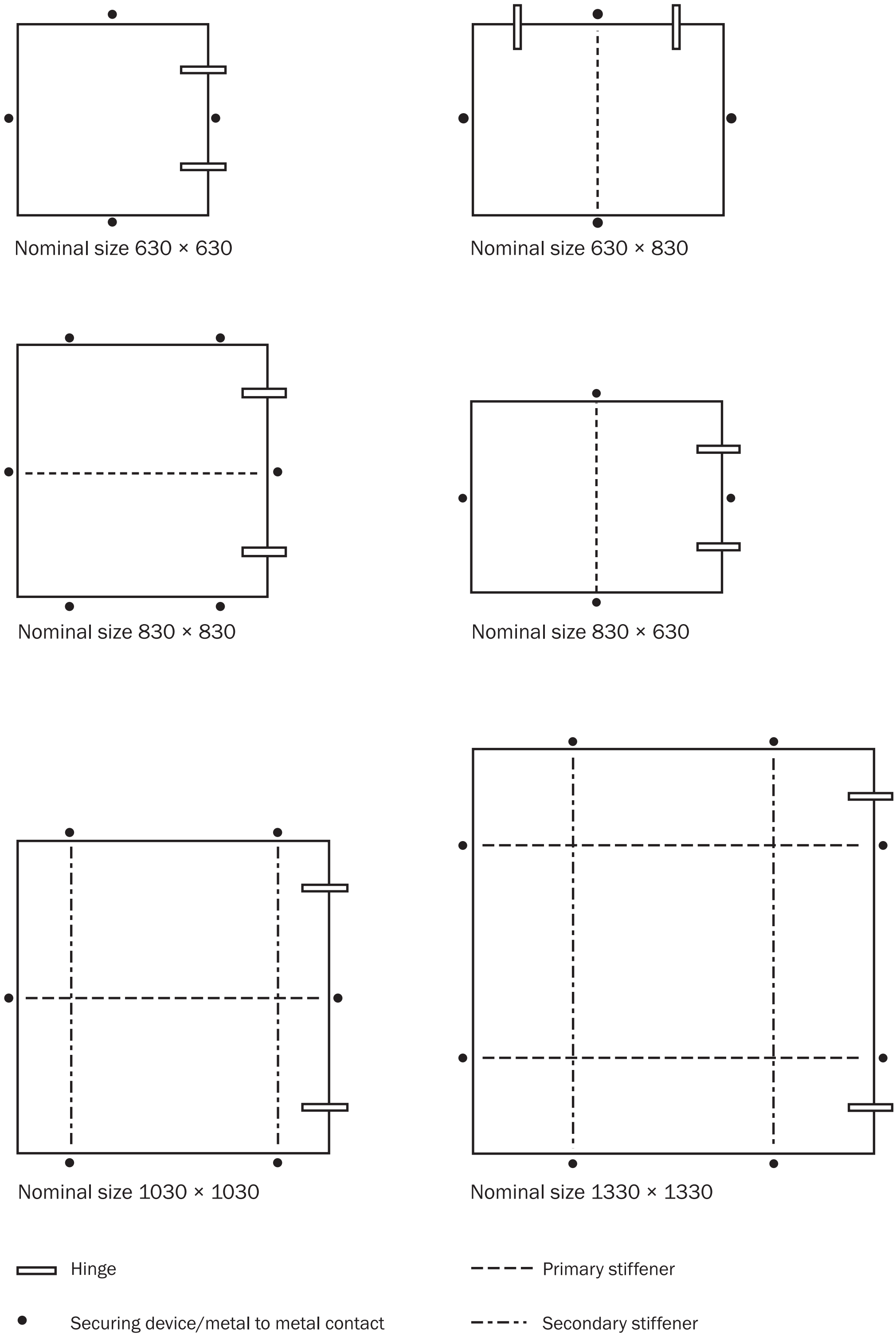
Figure 1 : Example or primary securing device



1. Butterfly nut
2. Bolt
3. Pin
4. Centre of pin
5. Fork (clamp) plate
6. Hatch cover
7. Gasket
8. Hatch coaming
9. Bearing pad welded on the bracket of a toggle bolt for metal to metal contact
10. Stiffener
11. Inner edge stiffener

(Note: Dimensions in millimetres)

Figure 2 : Arrangement of stiffeners



PART 1 CHAPTER 12

CONSTRUCTION

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SECTION 1
CONSTRUCTION AND FABRICATION

1 GENERAL

1.1 Workmanship

1.1.1

All workmanship is to be of commercial marine quality and acceptable to the surveyor. Welding is to be in accordance with the requirements of Ch 12, Sec 2. Any defect is to be rectified to the satisfaction of the surveyor before the material is covered with paint, cement or any other composition.

1.2 Fabrication standard

1.2.1

Structural fabrication is to be carried out in accordance with IACS Recommendation No. 47 or with a recognised fabrication standard which has been accepted by the Society prior to the commencement of fabrication/construction.

1.2.2

The fabrication standard to be used during fabrication/construction is to be made available to the attending representative of the Society prior to the commencement of the fabrication/construction.

1.2.3

The fabrication standard is to include information, to establish the range and the tolerance limits, for the items specified as follows:

a) Cut edges: the slope of the cut edge and the roughness of the cut edges.

b) Flanged stiffeners and brackets and built-up sections: the breadth of flange and depth of web, angle between flange and web, and straightness in plane of flange or at the top of face plate.

c) Pillars: the straightness between decks and cylindrical structure diameter.

d) Brackets and flat bar stiffeners: the distortion at the free edge line of tripping brackets and flat bar stiffeners.

e) Sub-assembly stiffeners: details of sniped end of face plates and webs.

f) Plate assembly: for flat and curved blocks, the dimensions (length and breadth), distortion and squareness, and the deviation of interior members from the plate.

g) Cubic assembly: in addition to the criteria for plate assembly, twisting deviation between upper and lower plates, for flat and curved cubic blocks.

h) Special assembly: the distance between upper and lower gudgeons, distance between aft edge of propeller boss and aft peak bulkhead, twist of stern frame assembly, breadth and length of top plate of main engine bed. Where boring out of the propeller boss and stern frame, skeg or solepiece are to be carried out after completing the major part of the welding of the aft part of the ship. Where block boring is used, the shaft alignment is to be carried out using a method and sequence submitted to and recognised by the Society. The fit-up and alignment of the rudder, pintles and axles are to be carried out after completing the major parts of the welding of the aft part of the ship. The contacts between the conical surfaces of pintles, rudder stocks and rudder axles are to be checked before the final mounting.

i) Butt joints in plating: alignment of butt joint in plating.

j) Cruciform joints: alignment measured on the median line and measured on the heel line of cruciform joints.

k) Alignment of interior members: alignments of flange of T profiles, alignment of panel stiffeners, gaps in T joints and lap joints, and distance between scallop and cut-outs for continuous stiffeners in assembly and in erection joints.

l) Keel and bottom sighting: deflections for whole length of the ship, and for the distance between two adjacent bulkheads, cocking-up of fore body and of aft body, and rise of floor amidships.

m) Dimensions: length between perpendiculars, moulded breadth and depth at midship, and length between aft edge of propeller boss and main engine.

n) Fairness of plating between frames: deflections between frames of shell, tank top, bulkhead, upper deck, superstructure deck, deckhouse deck and wall plating.

o) Fairness of plating in way of frames: deflections of shell, tank top, bulkhead, strength deck plating and other structures measured in way of frames.

2 CUT-OUTS, PLATE EDGES

2.1 General

2.1.1

The free edges (cut surfaces) of cut-outs, hatch corners, etc are to be properly prepared and are to be free from notches. As a general rule, cutting draglines, etc are to be smoothly ground. All edges are to be broken or in cases of highly stressed parts, be rounded off.

Free edges on flame or machine cut plates or flanges are not to be sharp cornered and are to be finished off as specified above. This also applies to cutting drag lines, etc, in particular to the upper edge of sheer strake and analogously to weld joints, changes in sectional areas or similar discontinuities.

2.1.2

Corners in hatch opening are to be machine cut.

3 COLD FORMING

3.1 Special structural members

3.1.1

For highly stressed components of the hull girder where notch toughness is of particular concern (e.g. items required to be Class III in Ch 3, Sec 1, Table 3, such as radius gunwales (bent sheer plates) and bilge strakes), the inside bending radius, in cold formed plating, is not to be less than 10 times the as-built plate thickness for carbon-manganese steels (see Ch 3, Sec 1). The allowable inside bending radius may be reduced provided the requirements stated in [3.3] are complied with.

3.2 Corrugated bulkheads and hopper knuckles

3.2.1

For corrugated bulkheads and hopper knuckles, the inside bending radius, in cold formed plating, is not to be less than 4.5 times the as-built plate thickness for carbon-manganese steels (see Ch 3, Sec 1). The allowable inside bending radius may be reduced provided the requirements stated in [3.3] are complied with.

3.3 Low bending radius

3.3.1

When the inside bending radius is reduced below 10 times or 4.5 times the as-built plate thickness according to [3.1] and [3.2] respectively, supporting data is to be provided. The bending radius is in no case to be less than 2 times the as-built plate thickness. As a minimum, the following additional requirements are to be complied with:

a) For all bent plates:

- 100% visual inspection of the bent area is to be carried out.
- Random checks by magnetic particle testing are to be carried out.

b) In addition to a), for bent plates subject to lateral liquid pressure:

- The steel is to be of Grade D/DH or higher.
- The material is impact tested in the strain-aged condition and satisfies the requirements stated herein. The deformation is to be equal to the maximum deformation to be applied during production, calculated by the formula $t_{as\text{-}built} / (2r_{bdg} + t_{as\text{-}built})$, where $t_{as\text{-}built}$ is the as-built thickness of the plate material and r_{bdg} is the bending radius. One sample is to be plastically strained at the calculated deformation or 5%, whichever is greater and then artificially aged at 250°C for one hour then subject to Charpy V-notch testing. The average impact energy after strain ageing is to meet the impact requirements specified for the grade of steel used.

4 HOT FORMING

4.1 Temperature requirements

4.1.1

Steel is not to be formed between the upper and lower critical temperatures. If the forming temperature exceeds 650°C for as-rolled, controlled rolled, thermo-mechanical controlled rolled or normalised steels, or is not at least 28°C lower than the tempering temperature for quenched and tempered steels, mechanical tests are to be made to assure that these temperatures have not adversely affected both the tensile and impact properties of the steel. Where curve forming or fairing, by line or spot heating, is carried out in accordance with [4.2.1] these mechanical tests are not required.

4.1.2

After further heating, other than specified in [4.1.1], of Thermo-Mechanically Controlled Steels (TMCP plates) for forming and stress relieving, it is to be demonstrated that the mechanical properties meet the requirements specified by a procedure test using representative material.

4.2 Line or spot heating

4.2.1

Curve forming or fairing, by linear or spot heating, is to be carried out using approved procedures in order to ensure that the properties of the material are not adversely affected. Heating temperature on the surface is to be controlled so as not to exceed the maximum allowable limit applicable to the plate grade.

5 ASSEMBLY AND ALIGNMENT

5.1 General

5.1.1

The use of excessive force is to be avoided during the assembly of individual structural components or during the erection of sections. Major distortions of individual structural components are to be corrected before further assembly.

After completion of welding, straightening and aligning are to be carried out in such a manner that the material properties are not influenced significantly. In case of doubt, the Society may require a procedure test or a working test to be carried out.

5.1.2

Structural members are to be aligned following the provisions of IACS Recommendation No. 47, Tables 7 or according to the requirements of a recognised fabrication standard that has been accepted by the Society. In the case of critical components, control drillings are to be made where necessary, which are then to be welded up again on completion.

SECTION 2
FABRICATION BY WELDING

1 GENERAL

1.1 Application

1.1.1

The requirements of this section apply to the preparation, execution and inspection of welded connections in hull structures.

1.2 Limits of application to welding procedures

1.2.1 Weld type, size and materials

The requirements of this section for weld type, size and materials are based on the following considerations:

- Joint type.
- Criticality of the joint.
- Magnitude, type and direction of the stresses in the joint.
- Material properties of the parent and weld material.
- Weld gap size.

1.2.2 Preparation, execution and inspection

The requirements of this section are to be complemented by the general requirements relevant to fabrication by welding and qualification of welding procedures given by the Society when deemed appropriate by the Society.

2 WELDING PROCEDURES, WELDING CONSUMABLES AND WELDERS

2.1 General

2.1.1

All welding is to be carried out by approved welders, in accordance with approved welding procedures, using approved welding consumables, in compliance with the Rules of the Society.

Personnel manning automatic welding machines and equipment are to be competent, sufficiently trained and certified by the Society as specified in Society Rules or Guidelines for welding.

3 WELD JOINTS

3.1 General

3.1.1

Welding of connections is to be executed according to the approved plans.

3.1.2

The quality standard adopted by the shipyard is to be submitted to the Society and it applies to all welded connections unless otherwise specified on a case-by-case basis.

3.1.3

Consideration is to be given to the assembly sequence and the effect of the overall shrinkage of plate panels, assemblies, etc, resulting from the welding processes employed. Welding is to proceed systematically, with each welded joint being completed in correct sequence, without undue interruption. When practicable, welding is to commence at the centre of a joint and proceed outwards, or at the centre of assembly and progress outwards towards the perimeter so that each part has freedom to move in one or more directions.

3.1.4

Completed welded joints are to be to the satisfaction of the attending surveyor. Edge preparations and root gaps are to be in accordance with the approved welding procedure. The gap between the members being joined should not exceed the maximum values given in IACS Recommendation No. 47 or as specified in recognised fabrication standard approved by the Society. Where the gap between members being joined exceeds the specified values, corrective measures are to be taken in accordance with an approved welding procedure specification.

3.1.5

Where small fillets are used to attach heavy plates or sections, welding is to be based on approved welding procedure specifications. Special precautions, such as the use of preheating, low-hydrogen electrodes or low-hydrogen welding processes, are accepted.

3.1.6

When heavy structural members are attached to relatively light plating, the weld size and sequence may require modification.

3.1.7

Where quality control systems are in place which ensure that the grade of welding consumable used is higher than the minimum required for the particular strength steel being welded, the welding consumables that are used may have a weld deposit material yield strength that is greater than the minimum specified in Ch 12, Sec 3, [2.5.2] and the size of the weld may be determined based on the yield strength of the higher grade welding consumable.

3.1.8

In general, butt joints are to be welded from both sides. Before welding is carried out on the second side, unsound metal is to be removed at the root by a suitable method. Butt welding from one side will only be permitted for specific applications with an approved welding procedure specification.

3.1.9 Arrangements at junctions of welds

Welds are to be made flush in way of the faying surface where stiffening members, attached by continuous fillet welds, cross the completely finished butt or seam welds. Similarly, butt welds in webs of stiffening members are to be completed and made flush with the stiffening member before the fillet weld is made. The ends of the flush portion are to run out smoothly without notches or sudden changes of section. Where these conditions can not be complied with, a scallop is to be arranged in the web of the stiffening member. Scallops are to be of the size, and in a position, that a satisfactory return weld can be made.

3.1.10 Leak stoppers

Where structural members pass through the boundary of a tank, leakage into adjacent space could be hazardous or undesirable, and full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively, a small scallop of suitable shape may be cut in a member close to the boundary outside of the compartment, and carefully welded all around.

4 NON-DESTRUCTIVE EXAMINATION (NDE)

4.1 General

4.1.1

The NDE plan to be submitted for approval has to contain the necessary data relevant to the locations and number of examinations, welding procedures applied, method of NDE applied, etc. Visual inspection of finished welds is to be carried out by the shipyard to ensure that all welding has been satisfactory completed. In addition to visual inspection, welded joints are to be examined using any one or a combination of ultrasonic, radiographic, magnetic particle, eddy current, dye penetrant or other acceptable methods appropriate to the configuration of the weld. Above inspections are to be carried out as per the requirements of the Society.

4.1.2

NDE of welding is to be carried out at the positions indicated by the NDE plan in order to ensure that the welds are free from cracks and unacceptable internal defects with regards to the requirements of the Society. NDE is to be carried out by qualified personnel certified by recognised bodies in compliance with recognised standards.

SECTION 3
DESIGN OF WELD JOINTS

SYMBOLS

A_{weld} : Effective fillet weld area, in cm^2.

f : Root face, in mm.

f_{weld} : Weld factor.

f_{yd} : Correction factor taking into account the yield strength of the weld deposit as defined in [2.5.2].

ℓ_{dep} : Total length of deposit of weld metal, in mm.

ℓ_{leg} : Leg length of continuous, lapped or intermittent fillet weld, in mm.

ℓ_{weld} : Length of the welded connection in mm.

R_{eH_weld} : Minimum yield stress of weld deposit, in N/mm^2.

$t_{as\text{-}built}$: As-built thickness of the member being joined, in mm.

t_{gap} : Allowance for fillet weld gap, is to be taken equal to 2.0 mm.

t_{throat} : Throat thickness of fillet weld in mm, as defined in [2.5.3].

1 GENERAL

1.1 Application

1.1.1

The requirements of this section apply to the design of welded connections in hull structures and are based on the considerations mentioned in Ch 12, Sec 2, [1.2.1].

1.1.2

Plans and/or specifications showing weld sizes and weld details are to be submitted for approval.

1.1.3

The leg length of welds is to comply with the minimum leg length given in Table 1.

1.2 Alternatives

1.2.1

The requirements given in this section are considered minimum for electric-arc welding in hull construction, but alternative methods, arrangements and details will be specially considered for approval.

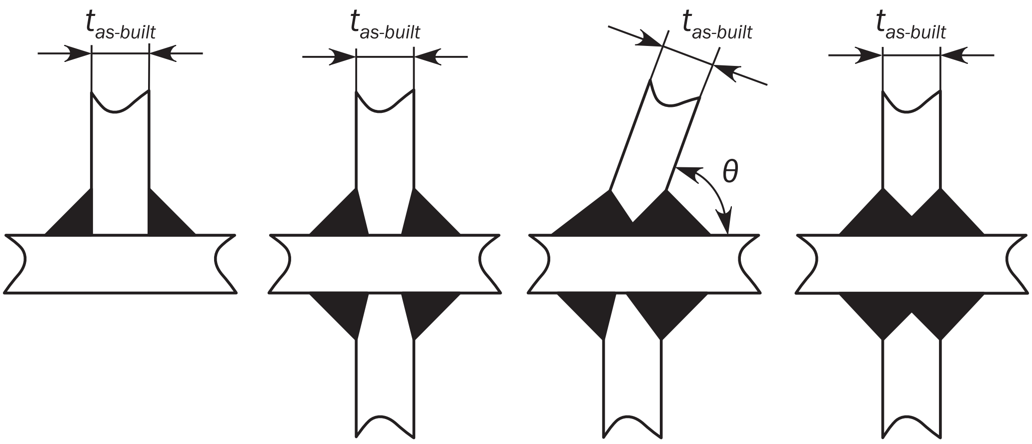
2 TEE OR CROSS JOINT

2.1 Application

2.1.1

The connection of primary supporting members, stiffener webs to plating as well as the plating abutting on another plating, are to be made by fillet or penetration welding, as shown on Figure 1.

Figure 1 : Tee or cross joints



$t_{as\text{-}built}$: As-built thickness of the member being attached, mm.

θ : Connecting angle, in deg.

2.1.2

Where the connection is highly stressed or otherwise considered critical, a partial or full penetration weld is to be achieved by bevelling the edge of the abutting plate.

2.2 Continuous fillet welds

2.2.1

Continuous welding is to be adopted in the following locations:

a) Connection of the web to the face plate for all members.

b) All fillet welds where higher strength steel is used.

c) Boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings.

d) Boundaries of tanks and watertight compartments.

e) All structures inside tanks and cargo holds.

f) Stiffeners and primary supporting members at tank boundaries.

g) All structures in the aft peak and stiffeners and primary supporting members of the aft peak bulkhead.

h) All structures in the fore peak.

i) Welding in way of all end connections of stiffeners and primary supporting members, including end brackets, lugs, scallops, and at orthogonal connections with other members.

j) All lap welds in the main hull.

k) Primary supporting members and stiffener members to bottom shell in the 0.3 L forward region.

l) Flat bar longitudinals to plating.

m) The attachment of minor fittings to higher strength steel plating and other connections or attachments.

n) Pillars to heads and heels.

o) Hatch coaming stay webs to deck plating, see [2.4.5].

2.3 Intermittent fillet welds

2.3.1

Where continuous welding is not required, intermittent welding may be applied.

2.3.2

Where beams, stiffeners, frames, etc, are intermittently welded and pass through slotted girders, shelves or stringers, there is to be a pair of matched intermittent welds on each side of every intersection. In addition, the beams, stiffeners and frames are to be efficiently attached to the girders, shelves and stringers.

Where intermittent welding or one side continuous welding is permitted, double continuous welds are to be applied for one-tenth of their shear span, in accordance with [2.5.2] and [2.5.3].

2.3.3 Deckhouses

One side continuous fillet welding is acceptable in the dry spaces of deckhouses.

2.3.4 Size for one side continuous weld

The size for one side continuous weld is to be of fillet required by [2.5.2] for intermittent welding, where f_2 factor is to be taken as 2.0.

2.4 Partial and full penetration welds

2.4.1 High stress area definition

For the application of this section, high stress area means an area where fine mesh finite element analysis is to be carried out and the fine mesh yield utilisation factor in elements adjacent to the weld is more than 90% of the fine mesh permissible utilisation factor, as defined in Ch 7, Sec 3, [6.2].

2.4.2 Partial or full penetration welding

In areas with high tensile stresses or areas considered critical, full or partial penetration welds are to be used.

In case of full penetration welding, the root face is to be removed, e.g. by gouging before welding of the back side.

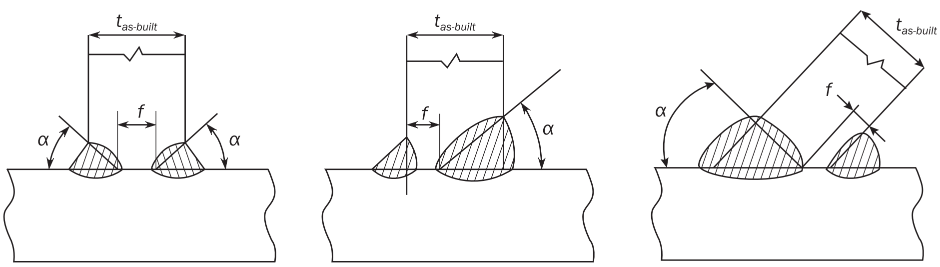
For partial penetration welds the root face, f, is, to be taken between 3 mm and $t_{as\text{-}built}/3$.

The groove angle made to ensure welding bead penetrating up to the root of the groove, α, is usually from 40° to 60°.

The welding bead of the full/partial penetration welds is to cover root of the groove.

Examples of partial penetration welds are given on Figure 2.

Figure 2 : Partial penetration welds



2.4.3 One side partial penetration weld

For partial penetration welds with one side bevelling the fillet weld at the opposite side of the bevel is to satisfy the requirements given in [2.5.2].

2.4.4 Extent of full or partial penetration welding

The extent of full or partial penetration welding in each particular location listed in [2.4.5] and [2.4.6] is to be approved by the Society. However, the minimum extent of full/partial penetration welding from the reference point (i.e. intersection point of structural members, end of bracket toe, etc.) is not to be taken less than 300 mm.

2.4.5 Locations required for full penetration welding

Full penetration welds are to be used in the following locations and elsewhere as required by the rules, see Figure 3:

a) Floors to hopper/inner bottom plating in way of radiused hopper knuckle.

b) Radiused hatch coaming plate at corners to deck.

c) Connection of vertical corrugated bulkhead to the lower hopper plate and to the inner bottom plate within the cargo hold region, when the vertical corrugated bulkhead is arranged without a lower stool.

d) Connection of vertical corrugated bulkhead to top plating of lower stool.

e) Edge reinforcement or pipe penetration both to strength deck, sheer strake and bottom plating within 0.6 L amidships, when the dimensions of the opening exceeds 300 mm.

f) Abutting plate panels with as-built thickness less than or equal to 12 mm, forming outer shell boundaries below the scantling draught, including but not limited to: sea chests, rudder trunks, and portions of transom. For as-built thickness greater than 12 mm, partial penetration in accordance with [2.4.2].

g) Crane pedestals and associated bracketing and support structure.

h) For toe connections of longitudinal hatch coaming end bracket to the deck plating, full penetration weld for a distance of 0.15 H_c from toe of side coaming termination bracket is required, where H_c is the hatch coaming height.

i) Rudder horns and shaft brackets to shell structure.

j) Thick flanges of long transverse web frames to side web frames. Thick flanges of long longitudinal girder to bulkhead web frames.

2.4.6 Locations required for full or partial penetration welding

Partial penetration welding as defined in [2.4.2], is to be used in the following locations. Additional locations may be required based on other criteria, such as fatigue assessment as given in Ch 9 (see Figure 3):

a) Connection of hopper sloping plate to longitudinal bulkhead (inner hull).

b) Longitudinal/transverse bulkhead primary supporting member end connections to the double bottom.

c) Corrugated bulkhead lower stool side plating to lower stool top plate.

d) Corrugated bulkhead lower stool side plating to inner bottom.

e) Corrugated bulkhead lower stool supporting floors to inner bottom.

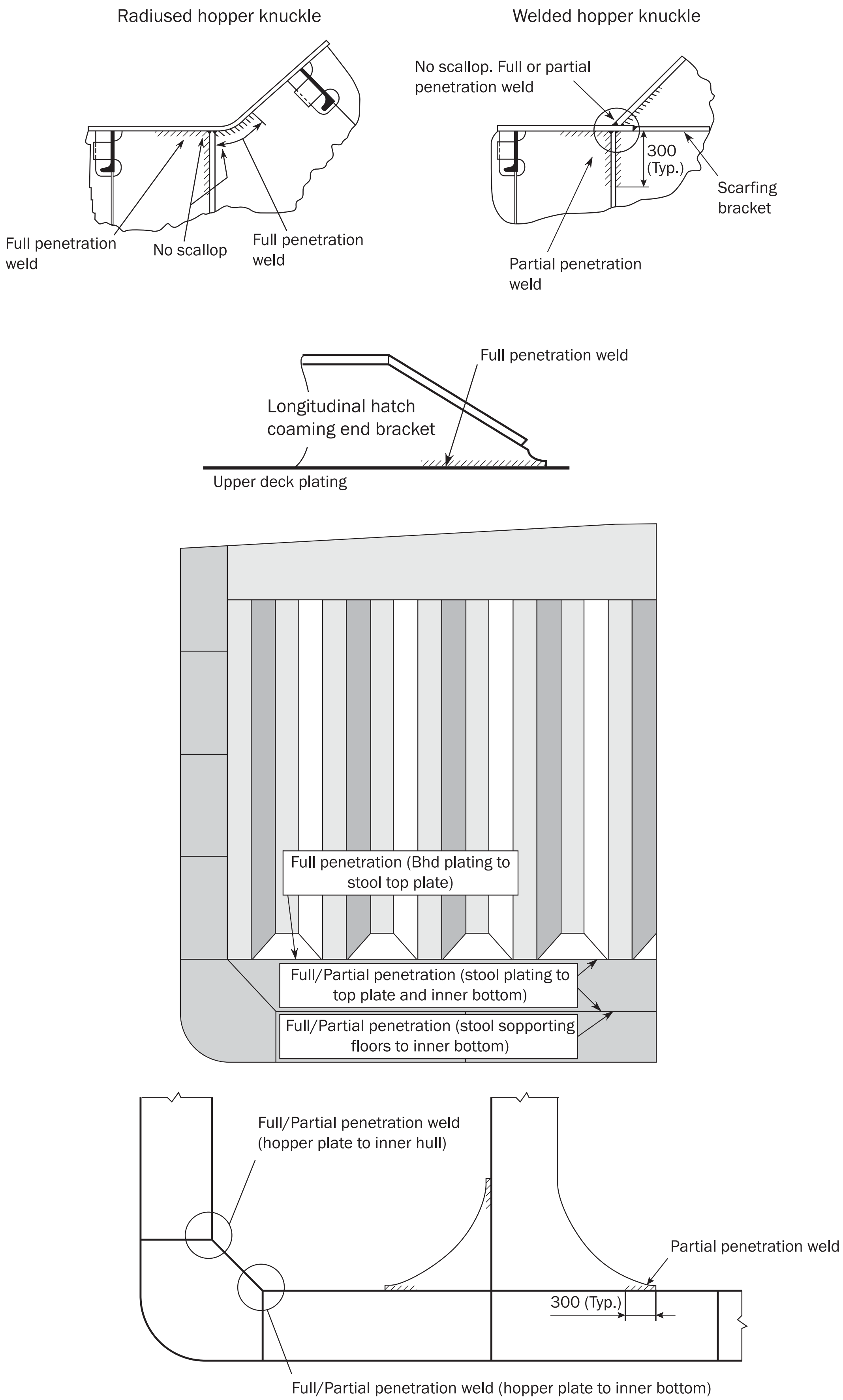
f) Corrugated bulkhead gusset and shedder plates.

g) Structural elements in double bottom below bulkhead primary supporting members and stool plates.

h) Lower hopper plate to inner bottom.

i) Horizontal stringers on bulkheads in way of their bracket toe and the heel.

Figure 3 : High stress areas welding (examples)



2.4.7 Fine mesh finite element analysis

In high stress area, at least partial penetration welds as defined in [2.4.2] are to be used. The minimum extent of full or partial penetration welding in that case is to be the greater of the following:

- 150 mm in either direction from the element with the highest yield utilisation factor.
- The extent covering all elements that exceed the above mentioned yield utilisation factor criteria.

2.4.8 Shedder plates

In case where shedder plates are fitted at the lower end of corrugated bulkhead, the shedder plates are to be welded to the corrugation and the top plate of the transverse lower stool by one side penetration welds.

2.5 Weld size criteria

2.5.1

The required weld sizes are to be rounded to the nearest half millimetre.

2.5.2

The leg length, ℓ_{leg} in mm, of continuous, lapped or intermittent fillet welds is not to be taken less than the greater of the following values:

$$\ell_{leg} = f_1 \, f_2 \, t_{as-built}$$

$$\ell_{leg} = f_{yd} \, f_{weld} \, f_2 \, f_3 \, t_{as-built} + t_{gap}$$

ℓ_{leg} as given in Table 1.

where:

f_1 : Coefficient depending on welding type:

$f_1 = 0.30$ for double continuous welding.

$f_1 = 0.38$ for intermittent welding.

f_2 : Coefficient depending on the edge preparation:

$f_2 = 1.0$ for double continuous welding without bevelling.

$f_2 = 0.85$ for partial penetration welds with one side bevelling and $f = t_{as\text{-}built}/2$.

$f_2 = 0.70$ for partial penetration welds with one side bevelling and $f = t_{as\text{-}built}/3$.

f_{yd} : Coefficient not to be taken less than the following:

$$f_{yd} = \left(\frac{1}{k}\right)^{0.5} \left(\frac{235}{R_{eH\_weld}}\right)^{0.75}$$

$f_{yd} = 0.71$.

R_{eH_weld} : Specified minimum yield stress for the weld deposit in N/mm^2, not to be less than:

: $R_{eH\_weld} = 305$ N/mm^2 for welding of normal strength steel with $R_{eH} = 235$N/mm^2.

: $R_{eH\_weld} = 375$ N/mm^2 for welding of higher strength steels with R_{eH} from 265 to 355 N/mm^2.

: $R_{eH\_weld} = 400$ N/mm^2 for welding of higher strength steel with $R_{eH} = 390$N/mm^2.

f_{weld} : Weld factor dependent on the type of the structural member, see Table 2 and Table 3.

k : Material factor of the abutting member.

f_3 : Correction factor for the type of weld:

f_3 = 1.0 for double continuous weld.

$f_3 = s_{ctr} / \ell_{weld}$ for intermittent or chain welding.

s_{ctr} : Distance between successive fillet welds, in mm.

2.5.3

The throat size t_{throat}, in mm, as shown in Figure 4, is not to be less than:

$$t_{throat} = \frac{\ell_{leg}}{\sqrt{2}}$$

Figure 4 : Weld scantlings definitions

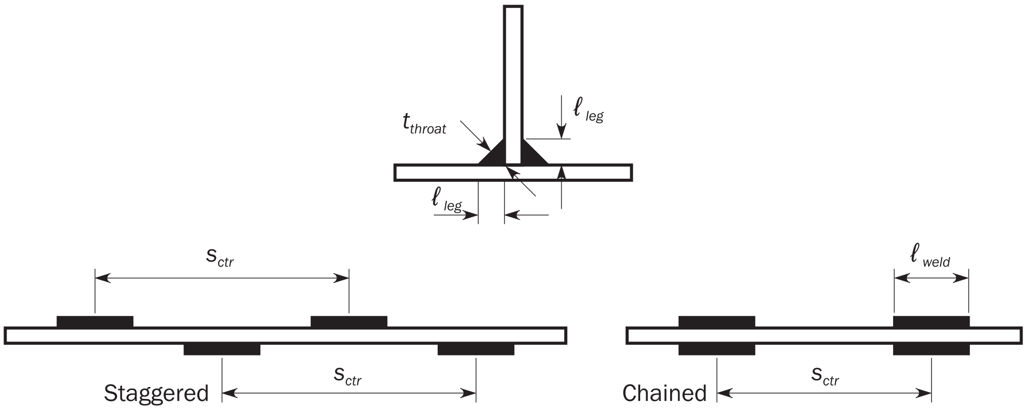


Table 1 : Minimum leg size

Area	Type of space		Minimum length, in mm
Cargo hold region	Cargo tanks and holds	Welds within 3m below top of compartment	6.5 (1)
		Elsewhere	6.0 (1)
	Water ballast and fresh water tanks	Welds within 3m below top of compartment	6.5 (1)
		Elsewhere	6.0 (1)
	Dry spaces and voids		5.0
	Other tanks		6.0 (1)
Other areas	Water ballast and fresh water tanks	Welds within 3m below top of compartment	6.0 (1)
		Elsewhere	5.5 (1)
	Fuel oil, diesel oil and other tanks	Welds within 3m below top of compartment	5.0
		Elsewhere	4.5
	Dry spaces and voids	Welds within 3m below top of compartment	4.5
		Elsewhere	4.0

(1) If the as-built thickness of the element is less than 12 mm, the minimum leg length may be reduced by 0.5 mm.

Table 2 : Weld factors for different structural members

<table>
<tr><th rowspan="2">Hull area</th><th colspan="4">Connection</th><th rowspan="2">f_{weld}</th></tr>
<tr><th colspan="2">Of</th><th colspan="2">To</th></tr>
<tr><td rowspan="8">General, unless otherwise specified in the table (1)</td><td colspan="2">Watertight plate</td><td colspan="2">Boundary plating</td><td>0.48</td></tr>
<tr><td colspan="2">Oil-tight plate</td><td colspan="2">Boundary plating</td><td>0.51</td></tr>
<tr><td colspan="4">Brackets at ends of members</td><td>0.48</td></tr>
<tr><td colspan="2" rowspan="2">Ordinary stiffener and collar plates</td><td colspan="2">Deep tank bulkheads</td><td>0.24</td></tr>
<tr><td colspan="2">Web of primary supporting members and collar plates</td><td>0.38</td></tr>
<tr><td colspan="2" rowspan="3">Web of stiffener</td><td colspan="2">Plating (except deep tank bulkhead)</td><td>0.20</td></tr>
<tr><td rowspan="2">Face plates of built-up stiffeners</td><td>At ends (15% of span)</td><td>0.38</td></tr>
<tr><td>Elsewhere</td><td>0.20</td></tr>
<tr><td rowspan="9">Bottom and double bottom</td><td colspan="2">Ordinary stiffener</td><td colspan="2">Bottom and inner bottom plating</td><td>0.24</td></tr>
<tr><td colspan="2" rowspan="2">Centre girder</td><td colspan="2">Shell plates</td><td>0.38</td></tr>
<tr><td colspan="2">Inner bottom plate</td><td>0.38</td></tr>
<tr><td colspan="2">Side girder including intercostal plates</td><td colspan="2">Bottom and inner bottom plating</td><td>0.24</td></tr>
<tr><td colspan="2" rowspan="3">Floor</td><td>Shell plates and inner bottom plates</td><td>At ends, on a length equal to two frame spaces</td><td>0.38</td></tr>
<tr><td colspan="2">Centre girder and side girders in way of hopper tanks</td><td>0.38</td></tr>
<tr><td colspan="2">Elsewhere</td><td>0.24</td></tr>
<tr><td colspan="2">Bracket on centre girder</td><td colspan="2">Centre girder, inner bottom, floors and shell plates</td><td>0.38</td></tr>
<tr><td colspan="2">Web stiffener</td><td colspan="2">Floor and girder</td><td>0.20</td></tr>
<tr><td rowspan="4">Side and inner side in double side structure</td><td colspan="2" rowspan="4">Web of primary supporting members</td><td colspan="2">Side plating</td><td>0.30</td></tr>
<tr><td rowspan="3">Inner side plating and web of primary supporting members</td><td>in way of deck transverse and end connections</td><td>0.43</td></tr>
<tr><td>in way of cross tie</td><td>0.36</td></tr>
<tr><td>elsewhere</td><td>0.30</td></tr>
<tr><td rowspan="8">Deck</td><td rowspan="3">Strength deck</td><td rowspan="2">$t_{as\_built} \geq 13$</td><td colspan="2">Side shell plating within 0.6L midship</td><td>PPW (4)</td></tr>
<tr><td colspan="2">Elsewhere</td><td>0.48</td></tr>
<tr><td>$t_{as\_built} < 13$</td><td colspan="2">Side shell plating</td><td>0.48</td></tr>
<tr><td colspan="2" rowspan="2">Other deck</td><td colspan="2">Side shell plating</td><td>0.38</td></tr>
<tr><td colspan="2">Stiffeners</td><td>0.20</td></tr>
<tr><td colspan="2" rowspan="2">Hatch coamings</td><td rowspan="2">Deck plating</td><td>At corners of hatchways for 15% of the hatch length</td><td>FPW (5) (2)</td></tr>
<tr><td>Elsewhere</td><td>0.38</td></tr>
<tr><td colspan="2">Web stiffeners</td><td colspan="2">Coaming webs</td><td>0.20 (3)</td></tr>
<tr><td rowspan="2">Bulkheads</td><td colspan="2">Non-watertight bulkhead structure</td><td>Boundaries</td><td>Swash bulkheads</td><td>0.24</td></tr>
<tr><td colspan="2">Stiffener</td><td>Bulkhead plating</td><td>At ends (25% of span), where no end brackets are fitted</td><td>0.48</td></tr>
<tr><td rowspan="2">Aft peak</td><td colspan="2" rowspan="2">Internal members</td><td colspan="2">Boundaries and each other: below waterline</td><td>0.38</td></tr>
<tr><td colspan="2">Above waterline</td><td>0.20</td></tr>
<tr><td>Fore peak</td><td colspan="2">Internal members</td><td colspan="2">Boundaries and each other</td><td>0.20</td></tr>
</table>

Hull area	Connection Of	Connection To	f_{weld}
Machinery space	Centre girder	Keel and inner bottom	0.48
	Floor	Centre girder	0.48
	Engine foundation girders	Top plate and primary hull structure	PPW (4)
	Floors and girders	Inner bottom and shell plate	0.38
Super-structure	External bulkhead (first and second tier erections)	Deck, external bulkhead	0.48
	External bulkheads and internal bulkheads	Elsewhere	0.20
Hatch cover	Watertight/oil-tight joints		0.48
	Hatch cover	At ends of stiffeners	0.38 (1)
		Elsewhere	0.24 (1)
Ventilator	Coaming	Deck	0.48

(1) For bulk carrier hatch covers use weld factor of 0.38 for watertight joints and 0.24 at ends of stiffeners.
(2) f_{weld} =0.43 for hatch coaming other than in cargo holds.
(3) Continuous welding.
(4) PPW: Partial penetration welding in accordance with [2.4.2].
(5) FPW: Full penetration welding in accordance with [2.4.2].

2.5.4

For primary supporting members connections not listed in Table 2, the weld factors from Table 3 are to be used.

Table 3 : Weld factors for primary supporting members

Hull structural member	Connection Of	Connection To		f_{weld}
Primary supporting member	Web plate	Shell plating, deck plating, inner bottom plating, bulkhead	Within 15% of shear span at ends	0.48
			Elsewhere	0.38
		Face plate	In tanks/holds Members located within 0.125L from fore peak	0.38
			Elsewhere if cross section area of face plate exceeds 65 cm^2	0.38
			Elsewhere	0.24
	End connections		In way of boundaries of ballast and cargo tanks	0.48
			Elsewhere	0.38

2.5.5

Where the as-built web thickness of the abutting longitudinal stiffener is greater than 15 mm and exceeds the thickness of the attached plating, the welding is to be double continuous and the leg length of the weld is not to be less than the largest of the following:

a) 0.30 $t_{as\text{-}built}$, where $t_{as\text{-}built}$ is the as-built thickness of the attached plating without being taken greater than 30 mm.

b) 0.27 $t_{as\text{-}built}$ + 1, where $t_{as\text{-}built}$ is the as-built thickness of the abutting member. The leg size resulting of this formula needs not to be taken greater than 8.0 mm.

c) Leg length given in the Table 1.

2.5.6

Where the minimum weld size is determined by the requirements of second formula shown in [2.5.2], the weld connections to shell, decks or bulkheads are to take account of the material lost in the cut out, where stiffeners pass through the member. In cases where the width of the cut-out exceeds 15 % of the stiffener spacing, the size of weld leg length is to be multiplied by:

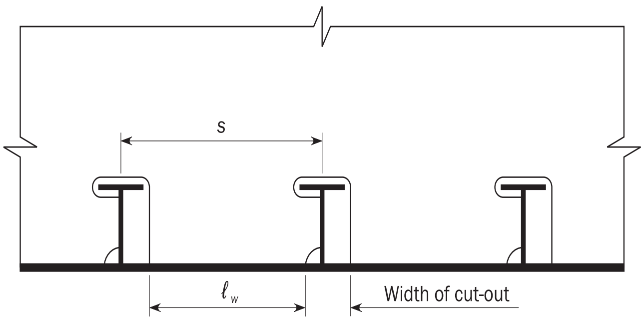
$$\frac{0.85\,s}{\ell_w}$$

where:

s : Stiffener spacing in mm, as shown in Figure 5.

ℓ_w : Length of web plating between notches, in mm, as shown in Figure 5.

Figure 5 : Effective material in web cut-outs for stiffeners



2.5.7 Shear area of primary supporting member end connections

Welding of the end connections, inclusive 10% of shear span, of primary supporting members is to be such that the weld area is to be equivalent to the gross cross sectional area of the member. The weld leg length in mm, ℓ_{leg}, is to be taken as:

$$\ell_{leg} = 1.41\ f_{yd}\ \frac{h_w\ t_{gr-req}}{\ell_{dep}}$$

where:

h_w : Web height of primary supporting members, in mm.

t_{gr_req} : Required gross thickness of the web in way of the end connection, including 10% of shear span, based on the highest average usage factor for yield from cargo hold FE analysis or the shear area requirement for PSM outside cargo hold region, in mm.

ℓ_{weld} : Length of the welded connection in mm, as shown in Figure 6.

ℓ_{dep} : Total length of deposit of weld metal, in mm, see Figure 6 taken as:

$$\ell_{dep} = 2\ \ell_{weld}$$

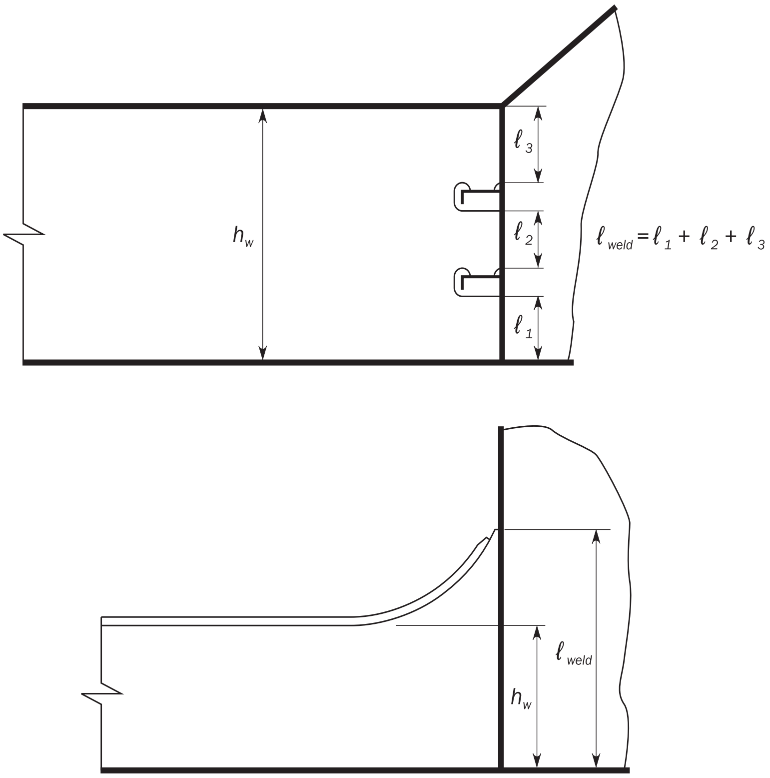
The size of weld is not to be less than the value calculated in accordance with [2.5.2].

2.5.8 Longitudinals

Welding of longitudinals to plating is to be doubled continuous at the ends of the longitudinals at the extent of 15 % of shear span as defined in Ch 3, Sec 7, [1.1.3].

In way of primary supporting members, the length of the double continuous weld is to be equal to the depth of the longitudinal or the end bracket, whichever is greater.

Figure 6 : Shear area of primary supporting member



Note 1: The length ℓ_{weld} is the length of the welded connection. The total length of the weld deposit ℓ_{dep} if welded with double continuous fillet welds is twice the length of the welded connection ℓ_{weld}.

2.5.9 Deck longitudinals

For deck longitudinals, a matched pair of welds is required at the intersection of longitudinals with primary supporting members.

2.5.10 Longitudinal continuity provided by brackets

Where a longitudinal strength member is to cut at a primary supporting structure and the continuity of strength is provided by brackets, the weld area A_{weld} is not to be less than the gross cross sectional area of the member. The weld area, A_{weld} in cm^2, is to be determined by the following formula:

$$A_{weld} = \frac{f_{yd}\ t_{throat}\ \ell_{dep}}{100}$$

2.5.11 Unbracketed stiffeners

Where intermittent welding is permitted, unbracketed stiffeners of shell, watertight and oil-tight bulkheads, and deckhouse fronts are to have double continuous welds for one-tenth of their length at each end. Unbracketed stiffeners of non-tight structural bulkheads, deckhouse sides and aft ends are to have a pair of matched intermittent welds at each end.

2.5.12 Reduced weld size

Where an approved automatic deep penetration procedure is used and quality control facilitates are working to a gap between members of 1 mm and less, the weld factors given in Table 2 may be reduced by 15% but not more than fillet weld leg size of 1.5 mm. Reductions of up to 20%, but not more than the fillet weld leg size of 1.5 mm, will be accepted provided that the shipyard is able to consistently meet the following requirements:

a) The welding is performed to a suitable process selection confirmed by welding procedure tests covering both minimum and maximum root gaps.

b) The penetration at the root is at least the same amount as the reduction into the members being attached.

c) Demonstrate that an established quality control system is in place.

2.5.13 Reduced weld size justification

Where any of the methods for reduction of the weld size are adopted, the specific requirements giving justification for the reduction are to be indicated on the drawings. The drawings are to document the weld design and dimensioning requirements for the reduced weld length and the required weld leg length given by [2.5.2] without the leg length reduction. Also, notes are to be added to the drawings to describe the difference in the two leg lengths and the requirements for their application.

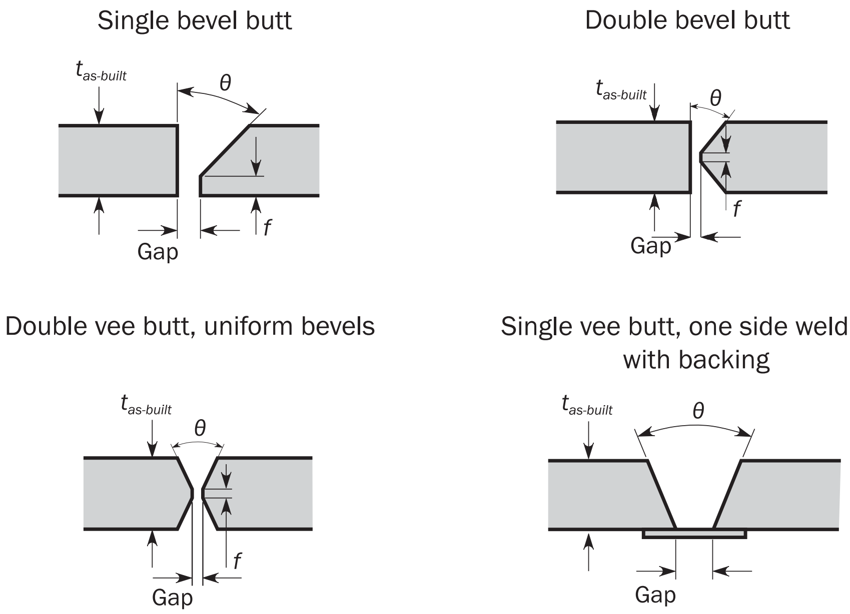
3 BUTT JOINT

3.1 General

3.1.1

Joints in the plate components of stiffened panel structures are generally to be joined by butt welds, see Figure 7.

Figure 7 : Typical butt welds



3.2 Thickness difference

3.2.1 Taper

In the case of welding of plates with difference in as-built thickness equal to or greater than 4 mm, the thicker plate is normally to be tapered. The taper has to have a length of not less than 3 times the difference in as-built thickness. If the width of groove is not less than 3 times the difference the transition taper is to be avoided.

4 OTHER TYPES OF JOINTS

4.1 Lapped joints

4.1.1 Areas

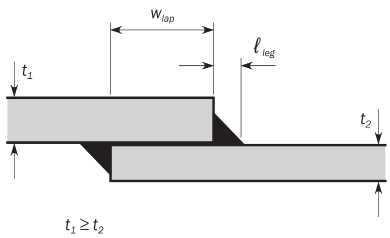
Lap joint welds may be adopted in very specific cases subject to the approval of the Society. Lap joint welds may be adopted for the following:

- Peripheral connections of doublers.
- Internal structural elements subject to very low stresses.

4.1.2 Overlap width

Where overlaps are adopted, the width of the overlap is not to be less than three times, but not greater than four times the as-built thickness of the plates being joined, see Figure 8. Where the as-built thickness of the thinner plate being joined has a thickness of 25 mm or more, the overlap will be subject to special consideration.

Figure 8 : Fillet weld in lapped joint



4.1.3 Overlaps for lugs

The overlaps for lugs and collars in way of cut-outs for the passage of stiffeners through webs and bulkhead plating are not to be less than three times the thickness of the lug but not be greater than 50 mm.

4.1.4 Lapped end connections

Lapped end connections are to have continuous welds on each edge with leg length, ℓ_{leg} in mm, as shown on Figure 8 such that the sum of the two leg lengths is not less than 1.5 times the as-built thickness of the thinner plate.

4.1.5 Overlapped seams

Overlapped seams are to have continuous welds on both edges, of the sizes required by [2.5.2] for the boundaries of tank/hold or watertight bulkheads. Seams for plates with as-built thickness of 12.5 mm or less, which are clear of tanks/holds, may have one edge with intermittent welds in accordance with [2.5.2] for watertight bulkhead boundaries.

4.2 Slot welds

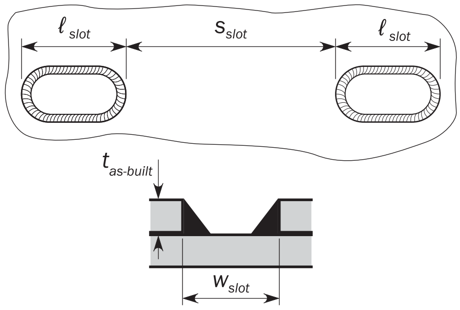
4.2.1

Slot welds may be adopted in very specific cases subject to the approval of the Society. However, slot welds of doublers on the outer shell and strength deck are not permitted within 0.6 *L* amidships.

4.2.2

Slots are to be well-rounded and have a minimum slot length, ℓ_{slot} of 75 mm and width, w_{slot} of twice the as-built plate thickness. Where used in the body of doublers and similar locations, such welds are in general to be spaced a distance, s_{slot} of 2 ℓ_{slot} to 3 ℓ_{slot} but not greater than 250 mm, see Figure 9. The size of the fillet welds is to be determined from second formula shown in [2.5.2] using $t_{as\text{-}built}$ of the thinner plate and a weld factor of 0.48.

Figure 9 : Slot welds



4.2.3 Closing plates

For the connection of plating to internal webs, where access for welding is not practicable, the closing plating may be attached by slot welds to face plates fitted to the webs.

4.2.4

Slots are to be well-rounded and have a minimum slot length, ℓ_{slot} of 90 mm and a minimum width, w_{slot} of twice the as-built plate thickness. Slots cut in plating are to have smooth, clean and square edges and are in general to be spaced a distance, s_{slot} not greater than 140 mm. Slots are not to be filled with welding.

4.3 Stud and lifting lug welds

4.3.1

Where permanent or temporary studs or lifting lugs are to be attached by welding to main structural parts in areas subject to high stress, the proposed locations are to be submitted for approval.

5 CONNECTION DETAILS

5.1 Bilge keels

5.1.1

The ground bar is to be connected to the shell with a continuous fillet weld, and the bilge keel to the ground bar with a continuous fillet weld in accordance with Table 4.

Table 4 : Connections of bilge keels

Structural items being joined	Leg length of weld, in mm	
	At ends	Elsewhere
Ground bar to the shell	0.62 t_{1as_built}	0.48 t_{1as_built}
Bilge keel web to ground bar	0.48 t_{2as_built}	0.30 t_{2as_built}

$t_{1as\text{-}built}$: As-built thickness of ground bar, in mm.
$t_{2as\text{-}built}$: As-built thickness of web of bilge keel, in mm.

5.1.2

Butt welds, in the bilge keel and ground bar, are to be well clear of each other and of butts in the shell plating as shown in Figure 10. In general, shell butts are to be flush in way of the ground bar and ground bar butts are to be flush in way of the bilge keel. Direct connection between ground bar butt welds and shell plating is not permitted. This may be obtained by use of removable backing.

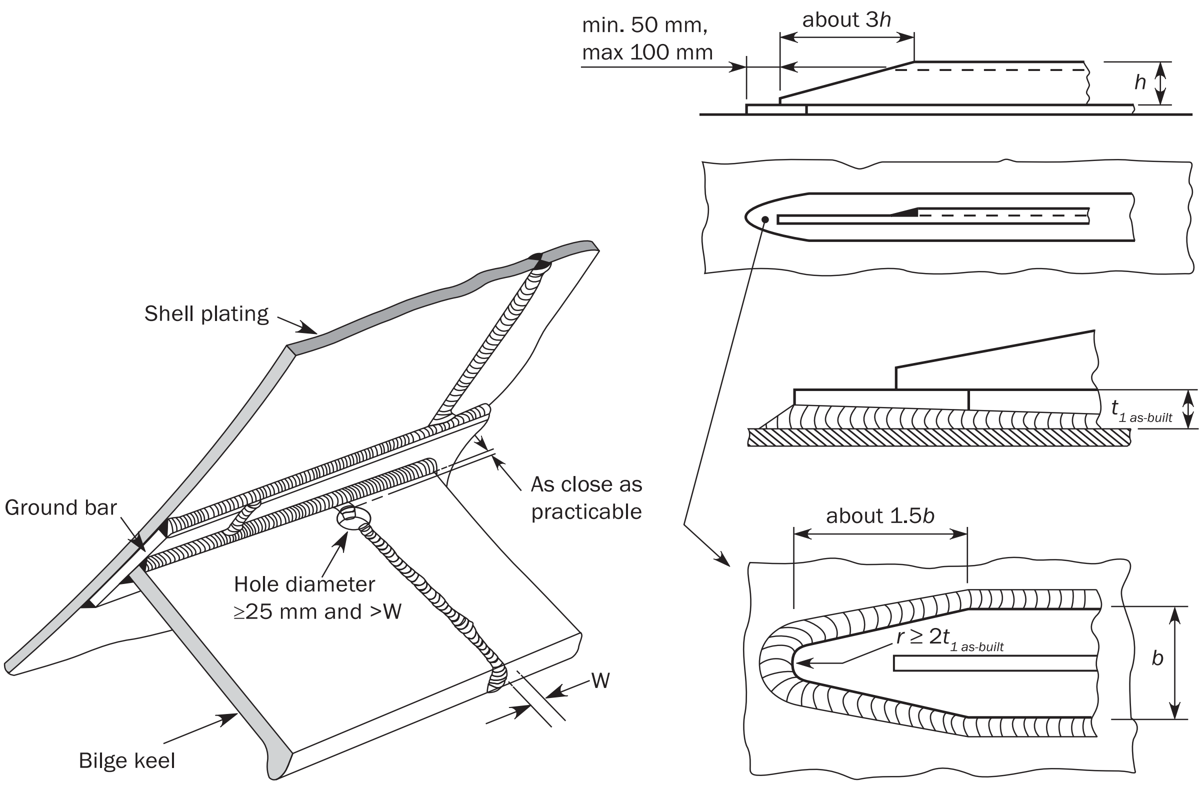
5.1.3

The ground bar is to be continuously fillet welded with a leg length as given in Table 4. At the ends of the ground bar, the leg length is to be increased as given in Table 4, without exceeding the as-built thickness of the ground bar as shown in Figure 10. The welded transition at the ends of the ground bar to the plating connection should be formed with the weld flank angle of 45 deg or less.

5.1.4

In general, scallops and cut-outs are not to be used. Crack arresting holes are to be drilled in the bilge keel butt welds as close as practicable to the ground bar. The diameter of the hole is to be greater than the width of the butt weld and is to be a minimum of 25 mm. Where the butt weld has been subject to non-destructive examination, the crack arresting hole may be omitted.

Figure 10 : Bilge keel



5.2 Bulk carrier side frames

5.2.1

The following requirements are applicable to side frames, end brackets and tripping brackets of single side skin bulk carriers.

5.2.2

For zones '*a*' and '*b*' as shown in Figure 11, double continuous fillet welding should be used with leg lengths of 0.62 $t_{as\text{-}built}$ and 0.57 $t_{as\text{-}built}$ respectively, where $t_{as\text{-}built}$ is the as-built thickness of the thinner of two connected members, in mm.

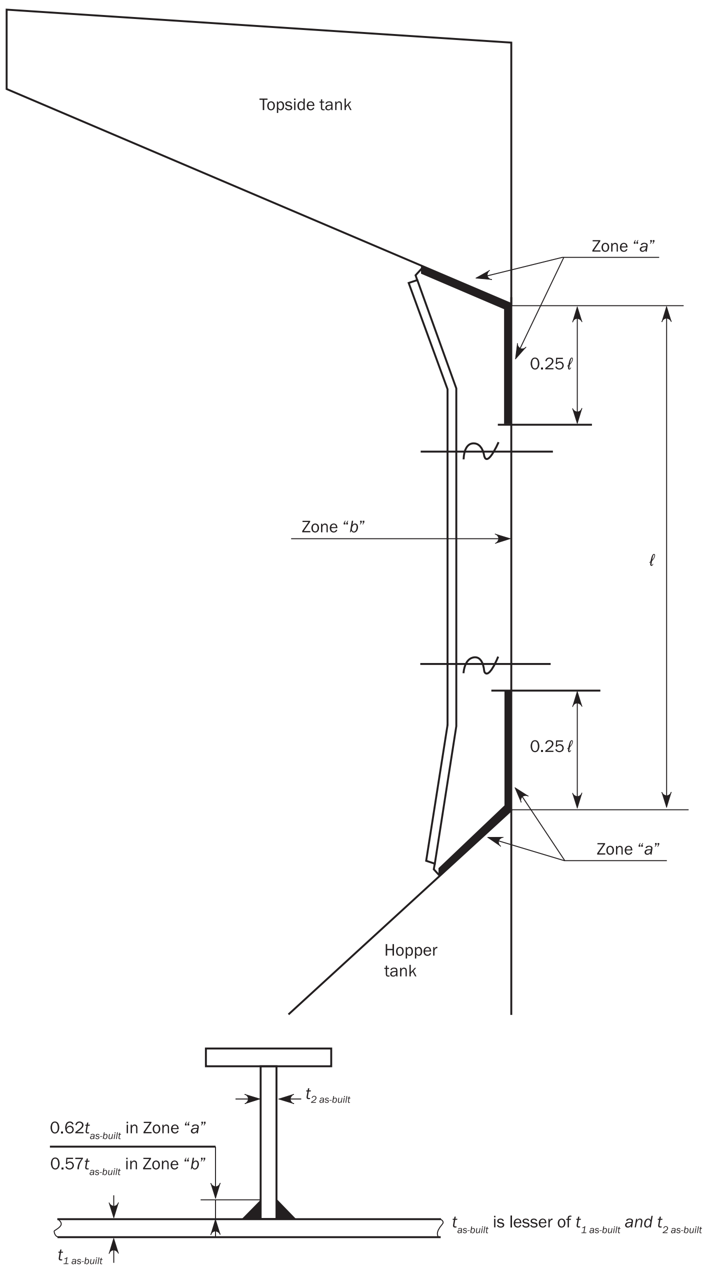
5.2.3

Double continuous welding is to be adopted for the connections of tripping brackets with side shell frames and plating. The leg length, ℓ_{leg} in mm, for these connections should be taken as:

- $0.5\ t_{as\_built} + 1.0$ if $t_{as\text{-}built} < 10$
- $0.4\ t_{as\_built} + 2.0$ if $10 \leq t_{as\text{-}built} < 20$
- $0.3\ t_{as\_built} + 4.0$ if $t_{as\text{-}built} \geq 20$.

In these formulas $t_{as\text{-}built}$ is as-built thickness of the abutting plate.

Figure 11 : Bulk carrier side frames



5.3 End connections of pillars and cross ties

5.3.1

The end connections of pillars and cross ties are to have an effective fillet weld area, in cm^2, (weld throat multiplied by weld length) not less than:

$$A_{weld} = f_3 \left(\frac{235}{R_{eH\_weld}} \right)^{0.75} F$$

where:

F : Design load, for the structure under consideration, in kN.

f_3 : Coefficient equal to:

f_3 = 0.05 when pillar or cross tie is in compression only.

f_3= 0.14 when pillar or cross tie is in tension.

5.4 Abutting plates with small angles

5.4.1

Where the angle θ between the abutting plate and the connected plate is less than 75 deg as shown in Figure 12, the size of fillet welds ℓ_θ, in mm, for the side of larger angle is to be increased in accordance with:

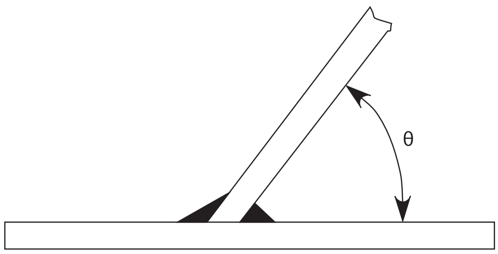
$$\ell_\theta = \frac{\ell_{leg}}{\sqrt{2}\sin\dfrac{\theta}{2}}$$

where:

ℓ_{leg} : Leg length of fillet weld, in mm, as defined in [2.5.2].

θ : Connecting angle, in deg, as shown in Figure 12.

Figure 12 : Connecting angle



5.4.2

Connections of main strength members where θ is less than 45 deg, see Figure 12, may be applied only in dry spaces and voids.

PART 1 CHAPTER 13

SHIP IN OPERATION - RENEWAL CRITERIA

Table of Contents

SECTION 1

PRINCIPLES AND SURVEY REQUIREMENTS

1 PRINCIPLES

1.1 Application

1.1.1

The purpose of this chapter is to provide criteria for the allowable thickness diminution of ships' hull structures.

1.1.2

The criteria apply only to ships in operation that are classed in accordance with these Rules.

1.1.3

Thickness measurement is to be used to assess ships' hull structures against the specified renewal criteria.

1.1.4

The hull survey requirements are those given, as applicable, in the Rules and/or documents of the individual Society which incorporate:

- UR Z10.2 for single side skin bulk carriers.
- UR Z10.4 for double hull oil tankers.
- UR Z10.5 for double side skin bulk carriers.

1.2 Corrosion allowance concept

1.2.1 Corrosion allowance

Corrosion allowance is comprised of two aspects: local and global corrosion, as defined in Ch 3, Sec 2, [1.1.2].

1.2.2 Assessment

Assessment against both local and global corrosion renewal criteria is required during the operational life of ships.

Assessment against the newbuilding requirements which incorporate corrosion additions, given in Ch 3, Sec 3, and which consider all relevant loads and limit states, e.g. yielding, buckling, and fatigue is not required during the operational life of ships, provided that the measured thickness of any structural members remain greater than the renewal thickness specified in Ch 13, Sec 2, [2].

1.2.3 Steel renewal

Steel renewal is required if either the local or global corrosion allowance is exceeded.

1.3 Requirements for documentation

1.3.1 Plans

The plans to be supplied onboard the ship, as required in Ch 1, Sec 3, are to include, for each structural element, both the as-built and renewal thickness as defined in Ch 13, Sec 2. Any thickness for voluntary addition is also to be clearly indicated on the plans.

For the list of plans and information to be supplied onboard the ship, reference is made to the Rules and/or documents of the individual Society which incorporate IACS UR Z10.2, Z10.4 or Z10.5 as applicable.

1.3.2 Hull girder sectional properties

The Midship section plan to be supplied onboard the ship is to include the minimum required hull girder sectional properties, as defined in Ch 5, Sec 1, for the transverse sections of all cargo holds.

2 HULL SURVEY REQUIREMENTS

2.1 General

2.1.1 Minimum hull survey requirements

The minimum hull survey requirements including thickness measurements for the maintenance of class are given in the Rules and/or documents of the individual Society which incorporate IACS UR Z10.2, Z10.4 and Z10.5.

SECTION 2
ACCEPTANCE CRITERIA

SYMBOLS

$t_{as\text{-}built}$: As built thickness, in mm.

t_c : Corrosion addition in mm, as defined in Ch 3, Sec 2.

t_{res} : Reserve thickness, taken equal to 0.5 mm.

t_{vol_add} : Thickness for voluntary addition, in mm.

1 GENERAL

1.1 Application

1.1.1

This section gives requirements for the application of the acceptance criteria.

1.2 Definition

1.2.1 Deck zone

The deck zone includes all the following items contributing to the hull girder strength:

- For bulk carriers: elements above or crossed by the 0.9 *D* level line above the baseline such as:
    - Strength deck plating.
    - Deck stringer.
    - Sheer strake.
    - Side shell plating.
    - Inner hull and other longitudinal bulkhead plating, if any.
    - Topside tank sloped plating, including horizontal and vertical strakes.
    - Longitudinal stiffeners, girders and stringers connected to the above mentioned plating.
- For oil tankers:
    - Strength deck plating.
    - Deck stringer.
    - Sheer strake.
    - Inner hull and other longitudinal bulkheads upper strake.
    - Longitudinal stiffeners, girders and stringers connected to the above mentioned plating.

1.2.2 Bottom zone

The bottom zone includes the following items contributing to the hull girder strength:

- For bulk carriers: elements up to the upper level of the hopper sloping plating or up to and including the inner bottom plating if there is no hopper tank:
  - Keel plate.
  - Bottom plating.
  - Bilge plating.
  - Bottom girders.
  - Inner bottom plating.
  - Hopper tank sloping plating, and horizontal plating, if any.
  - Longitudinal stiffeners connected to the above mentioned plating.
  - Side shell plating.
- For oil tankers:
  - Keel plate.
  - Bottom plating.
  - Bilge plating.
  - Longitudinal bulkheads lower strake.
  - Bottom girders.
  - Longitudinal stiffeners connected to the above mentioned plating.

1.2.3 Neutral axis zone

The neutral axis zone includes the following items between the deck zone and the bottom zone, as for example:

- Side shell plating.
- Inner hull plating and longitudinal bulkheads, if any.
- Topside tank sloped plating.

For the longitudinal strength members forming the web of the hull girder which are inclined to the vertical, the area of the member to be included in the zone area is to be based on the projected area onto the vertical plane.

2 RENEWAL CRITERIA

2.1 Local corrosion

2.1.1 Renewal thickness of local structural elements

Local structural elements include local supporting members and primary supporting members.

Steel renewal is required if the measured thickness, t_m in mm, is less than the renewal thickness, t_{ren} defined as:

$$t_{ren} = t_{as-built} - t_c - t_{vol\_add}$$

2.1.2 Renewed area

Areas which need to be renewed based on the renewal criteria in [2.1.1] are, in general, to be repaired with inserted material which is to have the same or greater grade and yield stress as the original, and to have a thickness, t_{repair} in mm, not less than:

$$t_{repair} = t_{as-built} - t_{vol\_add}$$

2.1.3 Alternative solutions

Alternative solutions may be adopted in accordance with the requirements of the Rules and/or documents of the individual Society which incorporate IACS UR Z10.2, Z10.4 and Z10.5, where the measured thickness, t_m is such as:

$t_{ren} \le t_m < t_{ren} + t_{res}$

2.2 Global corrosion

2.2.1 Application

The ship's longitudinal strength is to be evaluated by using the thickness of structural members measured, renewed and reinforced, as appropriate, during special surveys, for ships over 10 years of age.

2.2.2 Renewal criteria

The hull girder strength criteria are given as detailed below.

a) Deck and bottom zones:
   The current hull girder section modulus at deck and at bottom determined with the thickness measurements are not to be less than 90% of the section modulus calculated according to Ch 5, Sec 1 with the gross offered thickness.
   Alternatively, the current sectional areas of the bottom zone and of the deck zone which are the sum of the measured item areas of the considered zones are not to be less than 90% of the sectional area of the corresponding zones determined with the gross offered thickness.

b) Neutral axis zone:
   The current sectional area of the neutral axis zone, which is the sum of the measured plating areas of this zone, is not to be less than the sectional area of the neutral axis zone calculated with the gross offered thickness minus 0.5 t_c.

If the actual reduction of the gross offered thickness of all items, of a given transverse section, which contribute to the hull girder strength is less than 10% for the deck and bottom zones and $0.5t_c$ for the neutral axis zone, the hull girder strength criteria of this transverse section is satisfied and the calculations of the different zone areas with measured thicknesses need not be carried out.

The gross offered thickness is defined in Ch 3, Sec 2.

PART 2
SHIP TYPES

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PART 2 CHAPTER 1

BULK CARRIERS

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SECTION 1
GENERAL ARRANGEMENT DESIGN

1 FORECASTLE

1.1 General

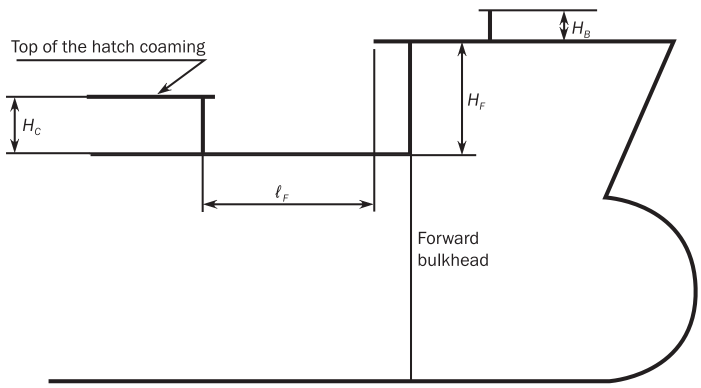
1.1.1

An enclosed forecastle is to be fitted on the freeboard deck.

The aft bulkhead of the enclosed forecastle is to be fitted in way or aft of the forward bulkhead of the foremost hold, as shown in Figure 1.

However, if this requirement hinders hatch cover operation, the aft bulkhead of forecastle may be fitted forward of the forward bulkhead of the foremost cargo hold provided the forecastle length is not less than 7% of ship length for freeboard as specified in Pt 1, Ch 1, Sec 4, [3.1.2] abaft the fore side of stem.

Figure 1 : Forecastle arrangement



1.1.2

The forecastle height, H_F above the main deck is not to be less than the greater of the following values:

- The standard height of a superstructure as specified in Pt 1, Ch 1, Sec 4, [3.3].
- H_C + 0.5 m, where H_C is the height of the forward transverse hatch coaming of the foremost cargo hold, i.e. cargo hold No. 1.

1.1.3

All points of the aft edge of the forecastle deck are to be located at a distance less than or equal to ℓ_F, taken as:

$$\ell_F = 5\sqrt{H_F - H_C}$$

from the hatch coaming plate.

1.1.4

A breakwater is not to be fitted on the forecastle deck with the purpose of protecting the hatch coaming or hatch covers. If fitted for other purposes, it is to be located such that its upper edge at centreline is not less than $H_B / \tan 20°$ forward of the aft edge of the forecastle deck, where H_B is the height of the breakwater above the forecastle, see Figure 1.

SECTION 2
STRUCTURAL DESIGN PRINCIPLES

SYMBOLS

For symbols not defined in this section, refer to Pt 1, Ch 1, Sec 4.

1 APPLICATION

1.1

1.1.1

This section applies to structures in all parts of bulk carriers, in addition to requirements given in Pt 1, Ch 3, Sec 6.

2 CORROSION PROTECTION

2.1 General

2.1.1 Void double side skin spaces

Void double side skin spaces are to have a corrosion protective system fitted in accordance with [2.2].

2.1.2 Cargo holds and ballast holds

Cargo holds and ballast holds are to have a corrosion protective system fitted in accordance with [2.3].

2.2 Protection of void double side skin spaces

2.2.1

Void double side skin spaces in the cargo area for ships having a freeboard length L_{LL} of not less than 150 m are to have an efficient corrosion prevention system, such as hard protective coatings or equivalent.

2.3 Protection of cargo hold spaces

2.3.1 Coating

It is the responsibility of the builder and of the owner to choose coatings suitable for the intended cargoes, in particular for the compatibility with the cargo.

2.3.2 Application

All internal and external surfaces of hatch coamings and hatch covers, and all internal surfaces of cargo holds (side and transverse bulkheads), excluding the inner bottom area and part of the hopper tank sloping plate and lower stool sloping plate, are to have an efficient protective coating, of an epoxy type or equivalent, applied in accordance with the manufacturer's recommendation.

The side and transverse bulkhead areas to be coated are specified in [2.3.3] and [2.3.4] respectively.

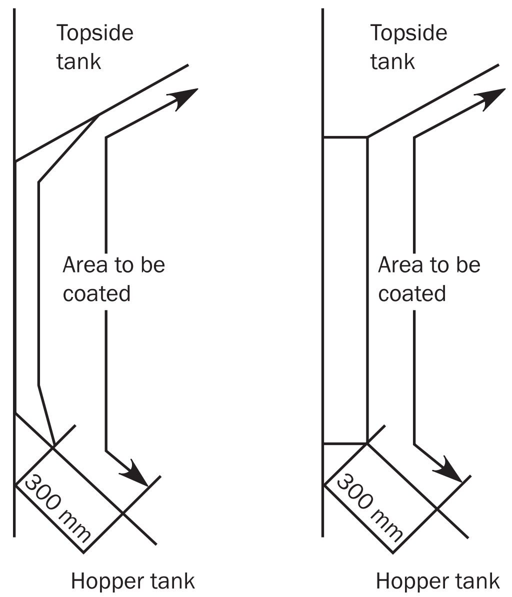
2.3.3 Side areas to be coated

The areas to be coated are the internal surfaces of:

- The inner side plating.
- The internal surfaces of the topside tank sloping plates.
- The internal surfaces of the hopper tank sloping plates for a distance of 300 mm below the frame end bracket for holds of single side skin construction, or below the hopper tank upper end for holds of double side skin construction.

These areas are shown in Figure 1.

Figure 1 : Side areas to be coated



2.3.4 Transverse bulkhead areas to be coated

The areas of transverse bulkheads to be coated are all the areas located above an horizontal level located at a distance of 300 mm below the frame end bracket for holds of single side skin construction or below the hopper tank upper end for holds of double side skin construction.

3 STRUCTURAL DETAIL PRINCIPLES

3.1 Double bottom structure

3.1.1 Application

In addition to the requirements provided in Pt 1, Ch 2, Sec 3, [2], the requirements of this sub-article are applicable to the following ships:

- All bulk carriers of less than 150 m in length,
- Bulk carriers with a length of 150 m or above, with one or more cargo holds arranged for carriage of water ballast.

3.1.2 Double bottom height

Height of double bottom in cargo area, d_{DB}, in m, measured from keel line at mid-length of each cargo hold is not to be less than:

$$d_{DB} = 0.032B + 0.19\sqrt{T_{SC}}$$

A lower double bottom height may be accepted, provided all of the following requirements are satisfied:

- The spacing of adjacent girders is not to be greater than 4.6 m or 5 times the spacing of bottom or inner bottom stiffeners, whichever is the smaller.
- The spacing of floors is not to be greater than 3.5 m or 4 times the side frame spacing, whichever is the smaller. Where side frames are not transverse, the nominal frame spacing as specified by the designer is to be used.

3.1.3 Girder spacing

The spacing of adjacent girders is generally not to be greater than 4.6 m or 5 times the spacing of bottom or inner bottom stiffeners, whichever is the smaller.

3.1.4 Floor spacing

The spacing of floors is generally not to be greater than 3.5 m or 4 times the side frame spacing, whichever is the smaller. Where side frames are not transverse, the nominal frame spacing as specified by the designer is to be used.

3.2 Single side structure

3.2.1 Application

This article applies to the single side structure with transverse framing of single side bulk carrier.

If single side structure is supported by transverse or longitudinal primary supporting members, the requirements in Pt 1, Ch 3, Sec 6, [8] apply to these primary supporting members as regarded to ones in double side skin.

3.2.2 General arrangement

Side frames are to be arranged at every frame space.

If air pipes are passing through the cargo hold, they are to be protected by appropriate measures to avoid a mechanical damage.

3.2.3 Side frames

Frames are to be built-up symmetrical sections with integral upper and lower brackets and are to be arranged with soft toes.

The side frame flange is to be curved (not knuckled) at the connection with the end brackets. The radius of curvature is not to be less than r, in mm, given by:

$$r = \frac{0.4\ b_f^2}{t_f + t_c}$$

where:

t_c : Corrosion addition, in mm, specified in Pt 1, Ch 3, Sec 3.

b_f, t_f : Flange width and net thickness of the curved flange, in mm. The end of the flange is to be sniped.

In ships less than 190 m in length, mild steel frames may be asymmetric and fitted with separate brackets. The face plate or flange of the bracket is to be sniped at both ends. Brackets are to be arranged with soft toes.

The dimensions of side frames are defined in Figure 2.

Figure 2 : Dimensions of side frames

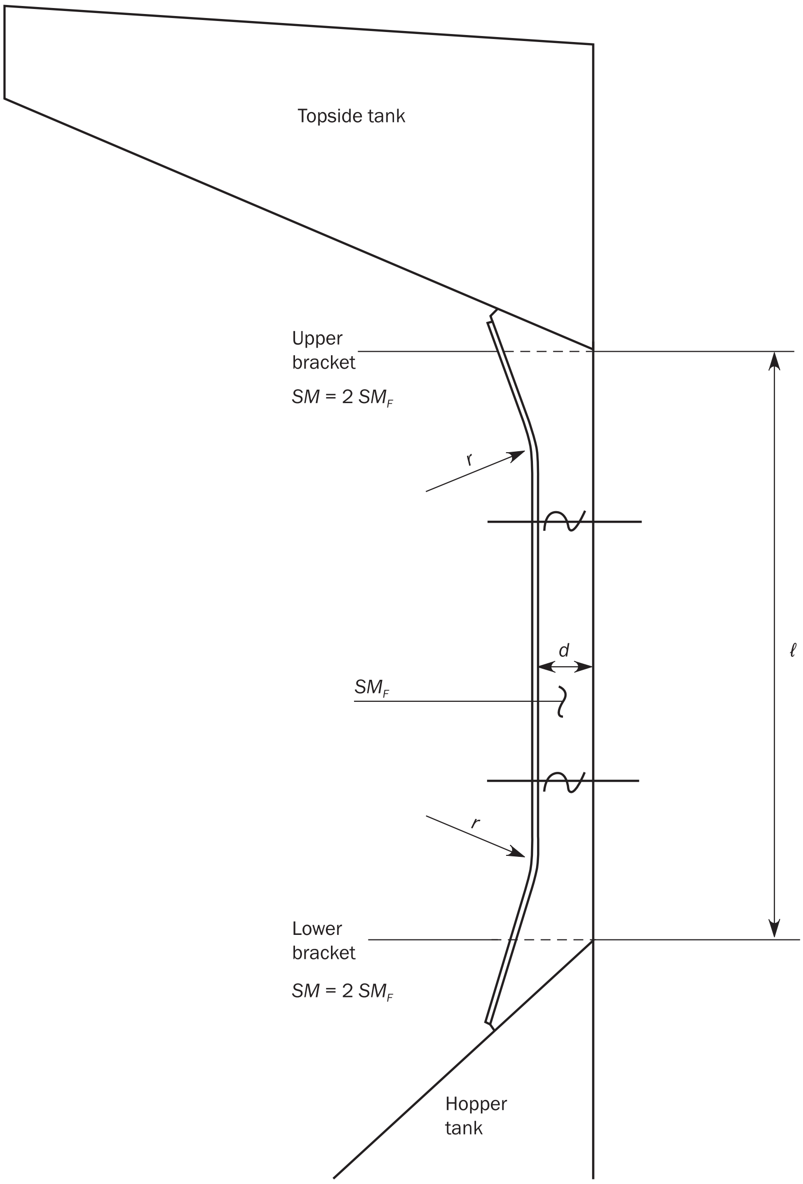
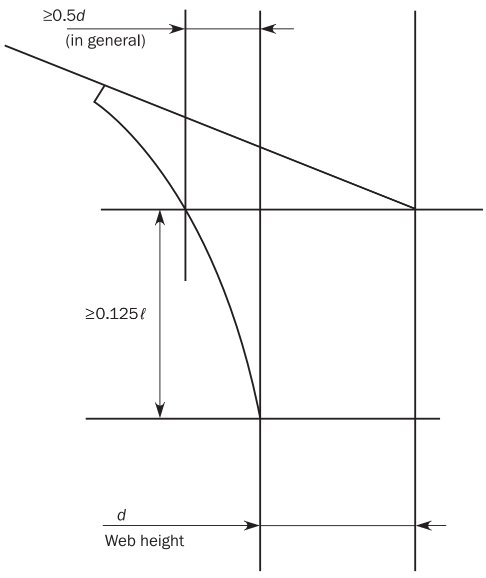


Figure 3 : Dimensions of lower and upper brackets



3.2.4 Upper and lower brackets

The face plates or flange of the brackets is to be sniped at both ends. Brackets are to be arranged with soft toes. The as-built thickness of the brackets is not to be less than the as-built thickness of the side frame webs to which they are connected.

The dimensions (in particular the height and length) of the lower brackets and upper brackets are not to be less than those shown in Figure 3.

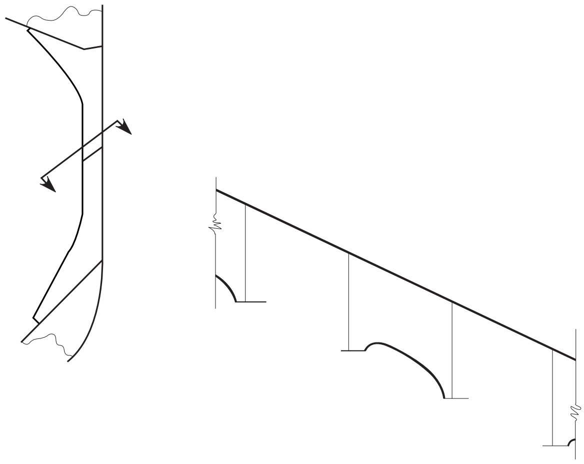
3.2.5 Tripping brackets

In way of the foremost hold and in the holds of BC-A ships, side frames of asymmetrical section are to be fitted with tripping brackets at every two frames, as shown in Figure 4.

The as-built thickness of the tripping brackets is not to be less than the as-built thickness of the side frame webs to which they are connected.

Double continuous welding is to be adopted for the connections of tripping brackets with side shell frames and plating.

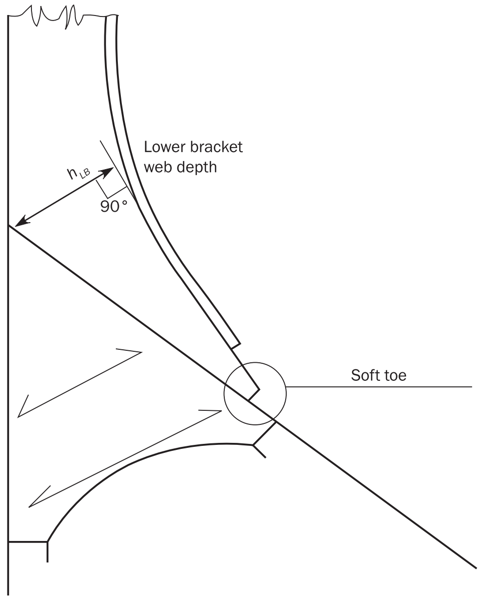
Figure 4 : Tripping brackets to be fitted in way of foremost hold



3.2.6 Support structure

Structural continuity with the lower and upper end connections of side frames is to be ensured within hopper and topside tanks by connecting brackets as shown in Figure 5.

Figure 5 : Example of support structure for lower end



3.3 Deck structures

3.3.1 Web frame spacing in topside tanks

For bulk carriers less than 150 m in length, the spacing of web frames in topside tanks is generally not to be greater than 6 frame spaces.

3.3.2 Cross deck between hatches of bulk carriers

Inside the line of openings, where a transversely framed structure is adopted for the cross deck structures, hatch end beams and cross deck beams are to be adequately supported by girders and extended outward to the second longitudinal from the hatch side girders towards the deck side. Where the extension of girders outward is impracticable, intercostal stiffeners are to be fitted between the hatch side girder and the second longitudinal and checks of the structure are to be performed in compliance with the requirements in Pt 1, Ch 7 or by means deemed appropriate by the Society.

The transverse primary members supporting the cross deck are to be supported by side or topside tank primary supporting members.

Smooth connection of the strength deck at side with the transversely framed cross deck is to be ensured by a plate of intermediate thickness.

3.3.3 Topside tank structures

The topside tank sloping plates are to be longitudinally framed.

Topside tank structures, where fitted, are to extend as far as possible within the machinery space and are to be adequately tapered.

Where a double side primary supporting member is fitted outside the plane of the topside tank web frame, special attention is to be paid to structural continuity.

3.3.4 Openings in strength deck - Corner of hatchways

For hatchways located within the cargo hold region, insert plates, whose thicknesses are to be determined according to the formula given after, are to be fitted in way of corners where the plating cut-out has a circular profile.

The radius of circular corners is not to be less than 5% of the hatch width, where a continuous longitudinal deck girder is fitted below the hatch coaming.

Corner radius, in the case of the arrangement of two or more hatchways athwartship, is considered by the Society on a case-by-case basis.

For hatchways located within the cargo hold region, insert plates are, in general, not required in way of corners where the plating cut-out has an elliptical or parabolic profile and the half axes of elliptical openings, or the half lengths of the parabolic arch, are not less than:

- 1/20 of the hatchway width or 600 mm, whichever is the lesser, in the transverse direction.
- Twice the transverse dimension, in the fore and aft direction.

Where insert plates are required, their net thickness is to be obtained, in mm, from the following formula:

$$t_{INS} = \left(0.8 + 0.4\frac{b}{\ell}\right) t_{off}$$

without being taken less than t_{off} or greater than 1.6 t_{off}.

where:

ℓ : Width, in m, in way of the corner considered, of the cross deck strip between two consecutive hatchways, measured in the longitudinal direction, see Pt 1, Ch 3, Sec 6, Figure 15.

b : Width, in m, of the hatchway considered, measured in the transverse direction, see Pt 1, Ch 3, Sec 6, Figure 15.

t_{off} : Offered net thickness, in mm, of the deck at the side of the hatchways.

For the extreme corners of end hatchways, insert plates are required. The net thickness of these insert plates is to be 60% greater than the net offered thickness of the adjacent deck plating. A lower thickness may be accepted by the Society on the basis of calculations showing that stresses at hatch corners are lower than permissible values.

Where insert plates are required, the arrangement is shown in Pt 1, Ch 9, Sec 6, Table 15, in which d_1, d_2, d_3 and d_4 are to be greater than the stiffener spacing.

For hatchways located outside the cargo hold region, a reduction in the thickness of the insert plates in way of corners may be considered by the Society on a case-by-case basis.

For ships having length L of 150 m or above, the corner radius, the thickness and the extent of insert plate may be determined by the results of a direct strength assessment according to Pt 1, Ch 7, including buckling check and fatigue strength assessment of hatch corners according to Pt 1, Ch 8 and Pt 1, Ch 9 respectively.

3.3.5 Protection against wire rope

Wire rope grooving in way of cargo holds openings is to be prevented by fitting suitable protection such as half-round bar on the hatch side girders (i.e. upper portion of topside tank plates) or hatch end beams in cargo hold and upper portion of hatch coamings.

SECTION 3
HULL LOCAL SCANTLINGS

SYMBOLS

For symbols not defined in this section, refer to Pt 1, Ch 1, Sec 4.

C_{XG}, C_{YS}, C_{YR}, C_{YG}, C_{ZP}, C_{ZR} : Load combination factors, as defined in Pt 1, Ch 4, Sec 2.

d_{shr} : Effective shear depth of the stiffener as defined in Pt 1, Ch 3, Sec 7, [1.4.3].

F_R : Resultant force, in kN, as defined in Pt 1, Ch 4, Sec 6, Table 7.

$F_{sc-ib-s}$: Static load, in kN, as defined in Pt 1, Ch 4, Sec 6, [4.3.1].

F_{sc-ib} : Total load, in kN, as defined in Pt 1, Ch 4, Sec 6, [4.2.1].

$F_{sc-hs-s}$: Static load, in kN, as defined in Pt 1, Ch 4, Sec 6, [4.3.2].

F_{sc-hs} : Total load, in kN, as defined in Pt 1, Ch 4, Sec 6, [4.2.2].

ℓ : Distance, in m, as defined in Pt 1, Ch 4, Sec 6.

ℓ_{lp} : Distance, in m, as defined in Pt 1, Ch 4, Sec 6.

ℓ_{SF} : Side frame span ℓ, in m, as defined in Ch 1, Sec 2, Figure 2, not to be taken less than 0.25 *D.*

P : Design pressure in kN/m^2, for the design load set being considered according to Pt 1, Ch 6, Sec 2, [2] and calculated at the load calculation point defined in Pt 1, Ch 3, Sec 7, [3.2].

P_R : Resultant pressure, in kN/m^2, as defined in Pt 1, Ch 4, Sec 6, Table 7.

s_{CW} : Plate width, in mm, taken as the width of the corrugation flange *a* or the web *c*, whichever is greater, see Pt 1, Ch 3, Sec 6, Figure 21.

s_C : Half pitch, in mm, of the corrugation flange as defined in Pt 1, Ch 3, Sec 6, Figure 21.

1 CARGO HOLD SIDE FRAMES OF SINGLE SIDE BULK CARRIERS

1.1 Strength criteria

1.1.1 Net section modulus and net shear sectional area

The net section modulus Z, in cm^3, and the net shear sectional area A_{shr}, in cm^2, in the mid-span area of side frames subjected to lateral pressure are not to be taken less than:

$$Z = 1.125\alpha_m \frac{P\, s\ell_{SF}^2}{f_{bdg}\, C_s\, R_{eH}}$$

$$A_{shr} = 5.5 \cdot \alpha_S \frac{P \cdot s\ell_{SF}}{C_t\, \tau_{eH}} \left(\frac{\ell_{SF} - 2\ell_B}{\ell_{SF}}\right) 10^{-3}$$

where:

α_m : Coefficient taken as:

α_m = 0.42 for BC-A ships.

α_m = 0.36 for other ships.

f_{bdg} : Bending coefficient taken as 10.

C_s : Permissible bending stress coefficient for the design load set being considered taken as:

C_s = 0.75 for acceptance criteria set AC-S.

C_s = 0.90 for acceptance criteria set AC-SD.

α_S : Coefficient taken as:

α_S = 1.1 for side frames of empty holds in alternate condition of BC-A ships.

α_S = 1.0 for other side frames.

ℓ_B : Lower bracket length, in m, as defined in Figure 1.

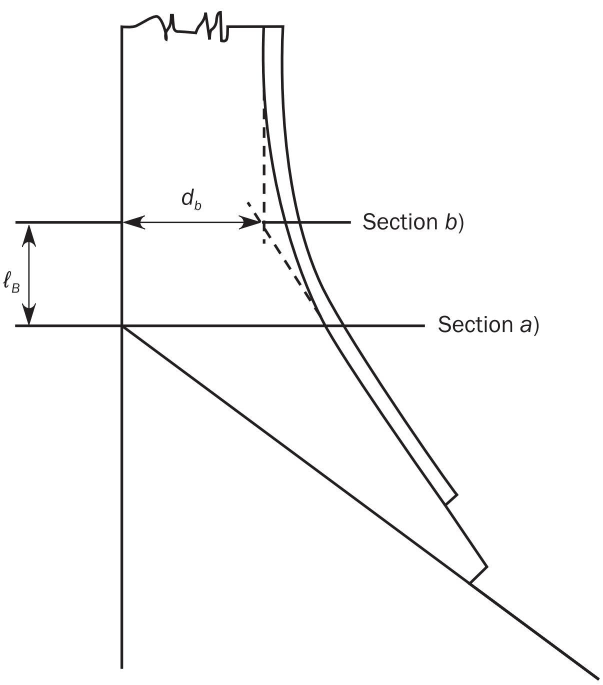
P : Design pressures, in kN/m², for design load sets as defined in Pt 1, Ch 6, Sec 2, Table 1, excluding the design load sets WB-4 to WB-6.

C_t : Permissible shear stress coefficient for the design load set being considered, taken as:

C_t = 0.75 for acceptance criteria set AC-S.

C_t = 0.90 for acceptance criteria set AC-SD.

Figure 1 : Side frame lower bracket length



1.1.2 Side frames in ballast holds

In addition to [1.1.1], for side frames in cargo holds designed to carry ballast water in heavy ballast condition, the net section modulus Z, in cm³, and the net web thickness, t_w, in mm, all along the span are to be in accordance with Pt 1, Ch 6, Sec 5 where the span of the side frame is ℓ as defined in Pt 1, Ch 3, Sec 7, [1.1] with consideration to brackets at ends.

1.1.3 Additional strength requirements

The net moment of inertia I, in cm⁴, of the three side frames located immediately abaft the collision bulkhead is not to be taken less than:

$$I = 0.18 \frac{P \, \ell_{SF}^4}{n}$$

where:

n : Frame number of considered side frame counted from the collision bulkhead to the frame in question, taken equal to 1, 2 or 3.

As an alternative, supporting structures, such as horizontal stringers, are to be fitted between the collision bulkhead and a side frame which is in line with transverse webs fitted in both the topside tank and hopper tank, maintaining the continuity of the forepeak stringers within the foremost hold.

1.2 Lower bracket of side frame

1.2.1

At the level of the lower bracket as shown in Ch 1, Sec 2, Figure 2, the net section modulus of the frame and bracket, or integral bracket, with associated shell plating, is not to be taken less than twice the required net section modulus Z, in cm^3,for the frame mid-span area obtained from [1.1.1].

1.2.2

For holds intended to carry ballast water in heavy ballast condition, the net section modulus Z, in cm^3, at the level of the lower bracket is not to be taken less than twice the greater of the required net section moduli given in [1.1.1] and [1.1.2].

1.2.3

The net thickness t_{LB}, in mm, of the lower bracket is not to be taken less than:

$t_{LB =} = t_w + 1.5$

where t_w is the net thickness of the side frame web, in mm.

1.2.4

The net thickness t_{LB} of the lower bracket is to comply with the following formula:

- For symmetrically flanged frames:

$$\frac{h_{LB}}{t_{LB}} \leq 87\sqrt{k}$$

- For asymmetrically flanged frames:

$$\frac{h_{LB}}{t_{LB}} \leq 73\sqrt{k}$$

The web depth h_{LB} of lower bracket is to be measured from the intersection between the hopper tank sloping plating and the side shell plate, perpendicularly to the face plate of the lower bracket as shown in Ch 1, Sec 2, Figure 5.

For the three side frames located immediately abaft the collision bulkhead, where the frames are strengthened in accordance with [1.1.2] and the offered t_{LB} is greater than 1.73 t_w, the t_{LB} applied in [1.2.4] may be taken as t'_{LB} given by:

$$t'_{LB} = (t_{LB}^2\ t_w)^{1/3}$$

where t_w is the net thickness of the side frame web, in mm, corresponding to A_{shr} determined in accordance to [1.1.1].

1.3 Upper bracket of side frame

1.3.1

At the level of the upper bracket as shown in Ch 1, Sec 2, Figure 2 the net section modulus of the frame and bracket, or integral bracket, with associated shell plating, is not to be taken less than twice the net section modulus Z required for the frame mid-span area obtained from [1.1.1].

1.3.2

For holds intended to carry ballast water in heavy ballast condition, the net section modulus Z, in cm3, at the level of the upper bracket is not to be taken less than twice the greater of the required net sections modulus obtained from [1.1.1] and [1.1.2].

The net thickness t_{UB} of the upper bracket, in mm, is not to be less than the net thickness of the side frame web.

1.4 Provided support at upper and lower connections of side frames

1.4.1 Net section modulus

The net section modulus of the:

- Side shell and hopper tank longitudinals supporting the lower connecting brackets.
- Side shell and topside tank longitudinals supporting the upper connecting brackets.

is to comply with the following formula:

$$\sum_{n} z_{pli}\ d_i \geq \alpha_T \frac{P\ \ell_{SF}^2\ \ell_1^2}{16 R_{eH}}$$

where:

n : Number of the longitudinal stiffeners on the side shell and hopper/topside tank supporting the lower/upper end connecting bracket of the side frame, as applicable.

$Z_{pl\,i}$: Net plastic section modulus, in cm^3, of the *i*-th longitudinal stiffener on the side shell or hopper/topside tank supporting the lower/upper end connecting bracket of the side frame, as applicable.

d_i : Distance, in m, of the above *i*-th longitudinal stiffener from the intersection point of the side shell and hopper/topside tank.

ℓ_1 : Spacing, in m, of transverse supporting webs in hopper/topside tank, as applicable.

R_{eH} : Lowest value of specified yield stress, in N/mm^2, among the materials of the longitudinal stiffeners of side shell and hopper/topside tanks that support the lower/upper end connecting bracket of the side frame.

α_T : Coefficient taken as:

α_T =150 for the longitudinal stiffeners supporting the lower connecting brackets.

α_T = 75 for the longitudinal stiffeners supporting the upper connecting brackets.

1.4.2 Net connection area of brackets

The net connection area, A_i, in cm^2, of the lower or upper connecting bracket to the *i*-th supporting longitudinal stiffener is not to be taken less than:

$$A_i = 0.4 \frac{z_i\ s\ k_{bkt}}{\ell_1^2\ k_{lg,\,i}} 10^{-3}$$

where:

Z_i : Net section modulus, in cm^3, of the i-th longitudinal stiffener on the side or hopper/topside tank supporting the lower/upper end connecting bracket of the side frame, as applicable.

ℓ_1 : As defined in [1.4.1].

k_{bkt} : Material factor for the bracket.

$k_{lg,i}$: Material factor for the i-th longitudinal stiffener.

2 STRUCTURE LOADED BY STEEL COILS ON WOODEN DUNNAGE

2.1 General

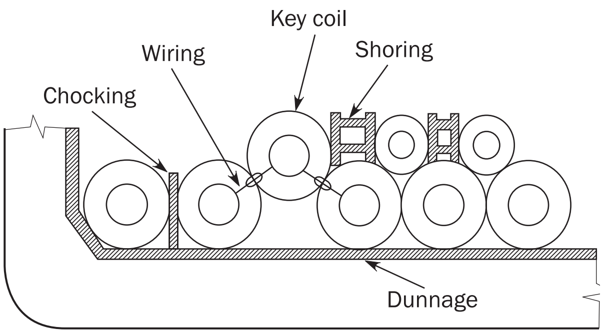
2.1.1

The net thickness of inner bottom plating, hopper side plating and inner hull plating for ships intended to carry steel coils is to comply with [2.3.1] and [2.4.1] up to a height not less than the one corresponding to the top of upper tier in touch with hopper or inner hull plating.

The net section modulus and the net shear sectional area of longitudinal stiffeners on inner bottom, hopper tank top and inner hull for ships intended to carry steel coils are to comply with [2.3.2] and [2.4.2] up to a height not less than the one corresponding to the top of upper tier in touch with hopper or inner hull plating.

Standard terminology and means for securing of steel coils is described in Figure 2.

Figure 2 : Inner bottom loaded by steel coils



2.2 Load application

2.2.1 Design load sets

The static and dynamic load components are to be determined in accordance with Pt 1, Ch 4, Sec 7, Table 1.

Radius of gyration, k_r, and metacentric height, GM, are to be in accordance with Pt 1, Ch 4, Sec 3, Table 2 for the considered loading condition specified in the design load set. The design load sets for steel coil loading is given in Table 1.

Table 1 : Design load sets

Item	Design load set	Load component	Draught	Design load	Loading condition
Inner bottom, hopper sloping plate and inner hull	BC-9	$F_{sc-ib-s}$ or $F_{sc-hs-s}$	T_{SC}	S	Steel Coil condition
Inner bottom, hopper sloping plate and inner hull	BC-10	F_{sc-ib} or F_{sc-hs}	T_{SC}	S+D	Steel Coil condition

2.3 Inner bottom

2.3.1 Inner bottom plating

The net thickness t, in mm, of plating of longitudinally framed inner bottom is not to be taken less than:

$$t = K_1\sqrt{\frac{F_{sc-ib-s}\times 10^3}{C_a\ R_{eH}}} \quad \text{for design load set BC-9}$$

$$t = K_1\sqrt{\frac{F_{sc-ib}\times 10^3}{C_a\ R_{eH}}} \quad \text{for design load set BC-10}$$

where:

K_1 : Coefficient taken as:

$$K_1 = \sqrt{\frac{1.7\frac{s}{1000}\ell K_2 - 0.73\left(\frac{s}{1000}\right)^2 K_2^2 - (\ell - \ell_{lp})^2}{2\ell_{lp}\left(2\frac{s}{1000} + 2\ell K_2\right)}}$$

K_2 : Coefficient taken as:

$$K_2 = -\frac{s}{1000\ell} + \sqrt{\left(\frac{s}{1000\ell}\right)^2 + 1.37\left(\frac{1000\ell}{s}\right)^2\left(1 - \frac{\ell_{lp}}{\ell}\right)^2 + 2.33}$$

C_a : Permissible bending stress coefficient, as defined in Pt 1, Ch 6, Sec 4, [1.1.1].

2.3.2 Stiffeners of inner bottom plating

The net section modulus Z, in cm^3, and the net web thickness, t_w, in mm, of single span stiffeners located on inner bottom plating are not to be taken less than:

$$Z = K_3\frac{F_{sc-ib-s}}{8\ C_s\ R_{eH}}10^3 \quad \text{and} \quad t_w = \frac{0.5\ F_{sc-ib-s}}{d_{shr}C_t\tau_{eH}}\times 10^3 \quad \text{for design load set BC-9.}$$

$$Z = K_3\frac{F_{sc-ib}}{8\ C_s\ R_{eH}}10^3 \quad \text{and} \quad t_w = \frac{0.5\ F_{sc-ib}}{d_{shr}C_t\tau_{eH}}\times 10^3 \quad \text{for design load set BC-10.}$$

where:

K_3 : Coefficient as defined in Table 2.

$K_3 = 2\ell/3$, when $n_2 > 10$.

C_s : Permissible bending stress coefficient, as defined in Pt 1, Ch 6, Sec 5, [1.1.2].

C_t : Permissible shear stress coefficient for the design load set being considered, to be taken as:

$C_t = 0.85$ for acceptance criteria set AC-S.

$C_t = 1.00$ for acceptance criteria set AC-SD.

n_2 : Number of load points per EPP of the inner bottom, see Pt 1, Ch 4, Sec 6, [4.1.3].

Table 2 : Coefficient K_3

n_2	1	2	3	4	5	6	7	8	9	10
K_3	ℓ	$\ell - \frac{\ell_{lp}^2}{\ell}$	$\ell - \frac{2\ell_{lp}^2}{3\ell}$	$\ell - \frac{5\ell_{lp}^2}{9\ell}$	$\ell - \frac{\ell_{lp}^2}{2\ell}$	$\ell - \frac{7\ell_{lp}^2}{15\ell}$	$\ell - \frac{4\ell_{lp}^2}{9\ell}$	$\ell - \frac{3\ell_{lp}^2}{7\ell}$	$\ell - \frac{5\ell_{lp}^2}{12\ell}$	$\ell - \frac{11\ell_{lp}^2}{27\ell}$

2.4 Hopper tank and inner hull

2.4.1 Hopper side plating and inner hull plating

The net thickness t, in mm, of plating of longitudinally framed bilge hopper sloping plate and inner hull is not to be taken less than:

$$t = K_1 \sqrt{\frac{F_{sc-hs-s}}{C_a R_{eH}} 10^3}$$, applicable for design load set BC-9.

$$t = K_1 \sqrt{\frac{F_{sc-hs}}{C_a R_{eH}} 10^3}$$, applicable for design load set BC-10.

where:

K_1 : Coefficient as defined in [2.3.1].

C_a : As defined in [2.3.1].

2.4.2 Stiffeners of hopper side plating and inner hull plating

The net section modulus Z, in cm^3, and the net web thickness, t_w, in mm, of single span ordinary stiffeners located on bilge hopper sloping plate and inner hull plate are not to be taken less than:

$$Z = K_3 \frac{F_{sc-hs-s}}{8\ C_s R_{eH}} 10^3 \quad \text{and} \quad t_w = \frac{0.5\ F_{sc-hs-s} \times 10^3}{d_{shr} C_t \tau_{eH}}$$, applicable for design load set BC-9.

$$Z = K_3 \frac{F_{sc-hs}}{8\ C_s\ R_{eH}} 10^3 \quad \text{and} \quad t_w = \frac{0.5\ F_{sc-hs} \times 10^3}{d_{shr} C_t \tau_{eH}}$$, applicable for design load set BC-10.

where:

K_3 : Coefficient as defined in Table 2.

$K_3 = 2\ell/3$ when $n_2 > 10$.

C_s, C_t : As defined in [2.3.2].

3 TRANSVERSE VERTICALLY CORRUGATED WATERTIGHT BULKHEADS SEPARATING CARGO HOLDS IN FLOODED CONDITION

3.1 Net thickness of corrugation

3.1.1 Cold formed corrugation

The net plate thickness t, in mm, of transverse vertically corrugated watertight bulkheads separating cargo holds is not to be taken less than:

$$t = 14.9 \cdot 10^{-3}\, s_{CW} \sqrt{\frac{1.05\ P_R}{R_{eH}}}$$

The net thicknesses is also to comply with the requirements given in Pt 1, Ch 6, Sec 4, [1.2.1].

3.1.2 Built-up corrugation

Where the thicknesses of the flange and web of built-up corrugations of transverse vertically corrugated watertight bulkheads separating cargo holds are different, the net plate thicknesses are not to be taken less than that obtained from the following formula.

The net thickness t_N, in mm, of the narrower plating is not to be taken less than:

$$t_N = 14.9 \cdot 10^{-3} s_N \sqrt{\frac{1.05\ P_R}{R_{eH}}}$$

s_N : Plate width, in mm, of the narrower plating.

The net thickness t_W, in mm, of the wider plating is not to be taken less than the greater of the following formulae:

$$t_W = 14.9 \cdot 10^{-3}\ s_{CW} \sqrt{\frac{1.05\ P_R}{R_{eH}}}$$

$$t_W = \sqrt{\frac{4.62\ s_{CW}^{\ 2}\ P_R}{R_{eH}\ 10^4} - t_{NO}^2}$$

where:

t_{NO} : Net offered thickness of the narrower plating, in mm, not to be taken greater than:

$$t_{NO} = 14.9 \cdot 10^{-3}\ s_{CW} \sqrt{\frac{1.05\ P_R}{R_{eH}}}$$

The net thicknesses is also to comply with the requirements given in Pt 1, Ch 6, Sec 4, [1.2.2].

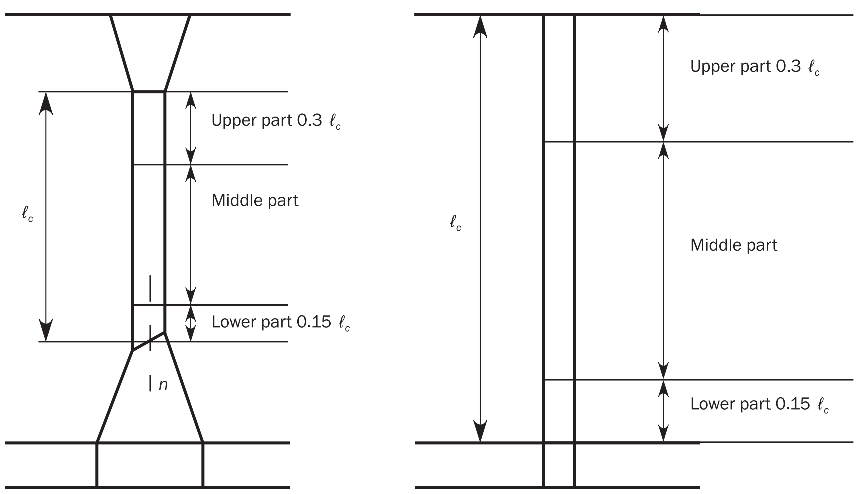
3.1.3 Lower part of corrugation

The net thickness of the lower part of corrugations is to be maintained for a distance of not less than 0.15 ℓ_C measured from the top of the lower stool, or from the inner bottom where no lower stool is fitted. The span of the corrugations ℓ_C, in m, is to be taken as given in Pt 1, Ch 3, Sec 6, [10.4.5].

3.1.4 Middle part of corrugation

The net thickness of the middle part of corrugations is to be maintained for a distance not greater than 0.3 ℓ_C from the bottom of the upper stool, or from the deck if no upper stool is fitted. The net thickness is also to comply with the requirements in [3.2.1] and Pt 1, Ch 6, Sec 4, [1.2].

Figure 3 : Parts of corrugation



3.2 Bending, shear and buckling check

3.2.1 Bending capacity and shear capacity

The bending capacity and the shear capacity of the corrugations of transverse watertight corrugated bulkheads separating cargo holds are to comply with the following formulae:

$$0.5 W_{LE} + W_M \geq \frac{M}{0.95\ R_{eH}}\ 10^3$$

$$\tau \leq \frac{R_{eH}}{2}$$

where:

M : Bending moment in a corrugation, in kNm, taken as:

$$M = \frac{F_R\ \ell_C}{8}$$

F_R : Resultant force, in kN, given in Pt 1, Ch 4, Sec 6, [3.1.7].

ℓ_C : Span of the corrugations, in m, as given in Pt 1, Ch 3, Sec 6, [10.4.5].

W_{LE} : Net section modulus, in cm^3, of one half pitch corrugation, to be calculated at the lower end of the corrugations according to [3.3], not to be taken greater than:

$$W_{LE,M} = W_G + \frac{Q\ h_G 10^3 - 0.5\ h_G^2\ s_C\ P_R}{R_{eH}}$$

W_G : Net section modulus, in cm^3, of one half pitch corrugation, to be calculated in way of the upper end of shedder or gusset plates, as applicable, according to [3.3].

Q : Shear force, in kN, at the lower end of a corrugation, to be taken as:

$$Q = 0.8\ F_R$$

h_G : Height, in m, of shedders or gusset plates, as applicable as shown in Figure 4 to Figure 6.

P_R : Resultant pressure, in kN/m^2, to be calculated in way of the middle of the shedders or gusset plates, as applicable, according to Pt 1, Ch 4, Sec 6, [3.1.7].

W_M : Net section modulus, in cm^3, of one half pitch corrugation, to be calculated at the mid-span of corrugations according to [3.3] without being taken greater than 1.15 W_{LE}.

τ : Shear stress, in N/mm^2, in the corrugation to be taken as:

$$\tau = 10\ \frac{Q}{A_{shr}}$$

A_{shr} : Net shear area, in cm^2, of one half pitch corrugation. The calculated net shear area is to consider possible reduced shear efficiency due to non-straight angles between the corrugation webs and flanges. In general, the reduced shear area may be obtained by multiplying the web sectional area by sin φ.

φ : Angle between the web and the flange, see Pt 1, Ch 3, Sec 6, Figure 21.

The net section modulus of the corrugations in the upper part of the bulkhead, as defined in Figure 3, is not to be taken less than 75% of that of the middle part complying with this requirement and Pt 1, Ch 6, Sec 4, [1.2], corrected for different minimum yield stresses.

3.2.2 Shear buckling check of the bulkhead corrugation webs

The shear stress τ, calculated according to [3.2.1], is to comply with the following formula:

$$\tau \le \tau_C$$

where:

τ_C : Critical shear buckling stress, in N/mm², to be taken as:

$$\tau_C = \tau_E \qquad \text{for } \tau_E \le \frac{R_{eH}}{2\sqrt{3}}$$

$$\tau_C = \frac{R_{eH}}{\sqrt{3}}\left(1 - \frac{R_{eH}}{4\sqrt{3}\,\tau_E}\right) \qquad \text{for } \tau_E > \frac{R_{eH}}{2\sqrt{3}}$$

τ_E : Euler shear buckling stress, in N/mm², to be taken as:

$$\tau_E = 0.9\,k_t\,E\left(\frac{t_w}{c}\right)^2$$

k_t : Coefficient, to be taken equal to 6.34.

t_w : Net thickness, in mm, of the corrugation webs.

c : Width, in mm, of the corrugation webs as shown in Pt 1, Ch 3, Sec 6, Figure 21.

3.3 Net section modulus at the lower end of the corrugations

3.3.1 Effective flange width

The net section modulus at the lower end of the corrugations is to be calculated with the compression flange having an effective flange width b_{eff} not larger than the following formula:

$$b_{eff} = C_E\,a$$

where:

C_E : Coefficient to be taken equal to:

$$C_E = \frac{2.25}{\beta} - \frac{1.25}{\beta^2} \qquad \text{for } \beta > 1.25$$

$$C_E = 1.0 \qquad \text{for } \beta \le 1.25$$

β : Coefficient to be taken equal to:

$$\beta = \frac{a}{t_f}\sqrt{\frac{R_{eH}}{E}}$$

a : Width, in mm, of the corrugation flange as shown in Pt 1, Ch 3, Sec 6, Figure 21.

t_f : Net flange thickness, in mm.

3.3.2 Webs not supported by local brackets

Unless welded to a sloping stool top plate as defined in [3.3.5], if the corrugation webs are not supported by local brackets below the stool top plate (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs 30% effective.

3.3.3 Effective shedder plates

Provided that effective shedder plates are fitted as shown in Figure 4, when calculating the section modulus at the lower end of the corrugations (Sections '1' in Figure 4), the net area, in cm², of flange plates may be increased by the factor I_{SH} to be taken as:

$$I_{SH} = 2.5 \cdot 10^{-3} a \sqrt{t_f\, t_{SH}}$$ without being taken greater than $2.5\, a\, t_f\, 10^{-3}$

where:

a : Width, in mm, of the corrugation flange as shown in Pt 1, Ch 3, Sec 6, Figure 21.

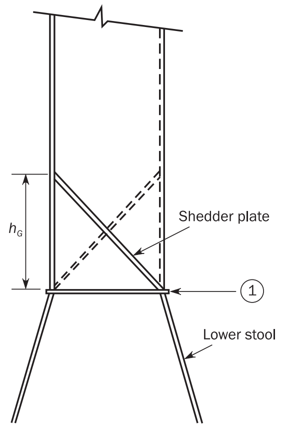
t_{SH} : Net shedder plate thickness, in mm.

t_f : Net flange thickness, in mm.

Effective shedder plates are those which:

- are not knuckled,
- are welded to the corrugations and the lower stool top plate according to Pt 1, Ch 12,
- are fitted with a minimum slope of 45°, their lower edge being in line with the lower stool side plating,
- have thickness not less than 75% of that required for the corrugation flanges,
- have material properties not less than those required for the flanges.

Figure 4 : Symmetrical and unsymmetrical shedder plates



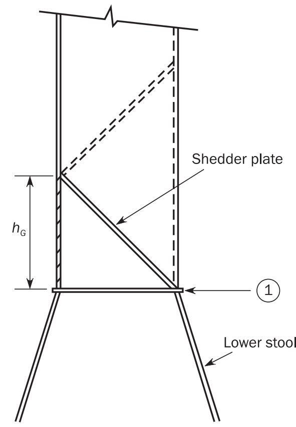
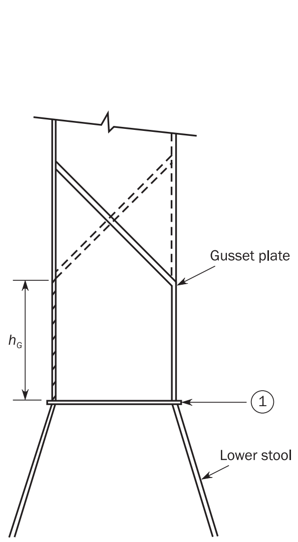


Figure 5 : Symmetrical and unsymmetrical gusset / shedder plates



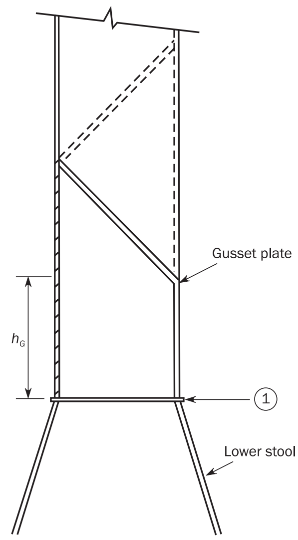
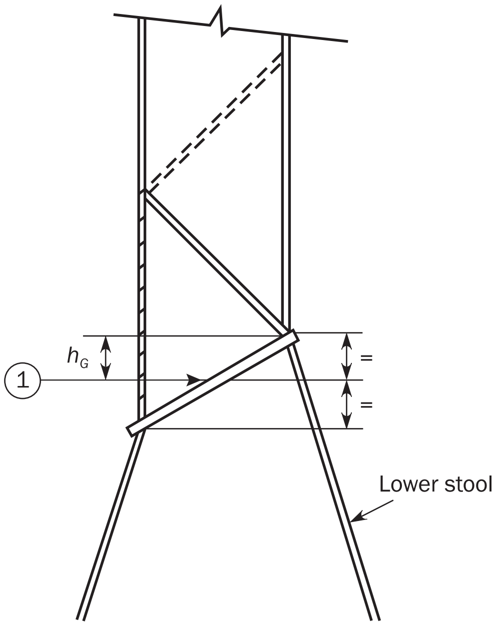


Figure 6 : Asymmetrical gusset / shedder plates



3.3.4 Effective gusset plates

Provided that effective gusset plates are fitted, when calculating the section modulus at the lower end of the corrugations (Sections '1' in Figure 5 and Figure 6), the net area, in cm^2, of flange plates may be increased by the factor I_G to be taken as:

$$I_G = 7\ h_G\ t_f$$

where:

h_G : Height, in m, of gusset plates as shown in Figure 5 and Figure 6 but not to be taken greater than:

$$\frac{10\ S_{GU}}{7}$$

S_{GU} : Width, in m, of gusset plates.

t_f : Net flange thickness, in mm.

Effective gusset plates are those which:

- are in combination with shedder plates having thickness, material properties and welded connections as requested for shedder plates in [3.3.3],
- have a height not less than half of the flange width,
- are fitted in line with the lower stool side plating,
- are welded to the lower stool top plate, corrugations and shedder plates according to Pt 1, Ch 12, Sec 3, [2.4.6],
- have thickness and material properties not less than those required for the flanges.

3.3.5 Sloping stool top plate

Where the corrugation webs are welded to a sloping stool top plate which has an angle not less than 45° with the horizontal plane, the section modulus at the lower end of the corrugations may be calculated considering the corrugation webs fully effective. For angles less than 45°, the effectiveness of the web may be obtained by linear interpolation between 30% efficient for 0° and 100% efficient for 45°.

Where effective gusset plates are fitted, when calculating the net section modulus of corrugations, the net area of flange plates may be increased as specified in [3.3.4] above. No credit may be given to shedder plates only.

4 ALLOWABLE HOLD LOADING FOR BC-A & BC-B SHIPS IN FLOODED CONDITIONS

4.1 Evaluation of double bottom capacity and allowable hold loading

4.1.1 Shear capacity of the double bottom

The shear capacity of the double bottom is to be calculated as the sum of the shear strength at each end of:

- Floors connected to hopper tanks, less one half of the shear strength of the two floors adjacent to each stool, or transverse bulkhead if no stool is fitted as shown in Figure 7. The shear strength of floors is to be calculated according to [4.1.2].
- Double bottom girders connected to stools, or transverse bulkheads if no stool is fitted. The shear strength of girders is to be calculated according to [4.1.3].

The floors and girders to be considered when calculating the shear capacity of the double bottom are those inside the hold boundaries formed by the hopper tanks and stools or transverse bulkheads if no stool is fitted. Where both ends of girders or floors are not directly connected to the hold boundaries, their strength is to be evaluated for the connected end only.

The hopper tank side girders and the floors directly below the connection of the stools or transverse bulkheads if no stool is fitted to the inner bottom may not be included.

For special double bottom designs, the shear capacity of the double bottom is to be calculated by means of direct calculations carried out in accordance with requirements specified in Pt 1, Ch 7, as applicable.

4.1.2 Floor shear strength

The floor shear strength, in kN, is to be taken as given in the following formulae:

- In way of the floor panel adjacent to the hopper tank:

$$S_{f1} = A_f \frac{\tau_A}{\eta_1} 10^{-3}$$

- In way of the openings in the outermost bay (i.e., that bay which is closer to the hopper tank):

$$S_{f2} = A_{f,h} \frac{\tau_A}{\eta_2} 10^{-3}$$

where:

A_f : Net sectional area, in mm^2, of the floor panel adjacent to the hopper tank.

$A_{f,h}$: Net sectional area, in mm^2, of the floor panels in way of the openings in the outermost bay (i.e., the bay which is closer to the hopper tank).

τ_A : Allowable shear stress, in N/mm^2, to be taken as the lesser of:

$$\tau_A = 0.645 \frac{R_{eH}^{0.6}}{(s/t)^{0.8}} \quad \text{and} \quad \tau_A = \frac{R_{eH}}{\sqrt{3}}$$

For floors adjacent to the stools or transverse bulkheads, τ_A is taken as:

$$\frac{R_{eH}}{\sqrt{3}}$$

t : Floor web net thickness, in mm.

s : Spacing, in m, of stiffening members of the panel considered.

η_1 : Coefficient to be taken equal to 1.1.

η_2 : Coefficient to be taken equal to 1.2. It may be reduced to 1.1 where appropriate reinforcements are fitted in way of the openings in the outermost bay, to be examined by the Society on a case-by-case basis.

4.1.3 Girder shear strength

The girder shear strength, in kN, is to be taken as given in the following formulae:

- In way of the girder panel adjacent to the stool or transverse bulkhead, if no stool is fitted:

$$S_{g1} = A_g \frac{\tau_A}{\eta_1} 10^{-3}$$

- In way of the largest opening in the outermost bay (i.e., that bay which is closer to the stool) or transverse bulk-head, if no stool is fitted:

$$S_{g2} = A_{g,h} \frac{\tau_A}{\eta_2} 10^{-3}$$

A_g : Net sectional area, in mm^2, of the girder panel adjacent to the stool (or transverse bulkhead, if no stool is fitted).

$A_{g,h}$: Net sectional area, in mm^2, of the girder panel in way of the largest opening in the outermost bay (i.e. that bay which is closer to the stool) or transverse bulkhead, if no stool is fitted.

τ_A : Allowable shear stress, in N/mm^2, as defined in [4.1.2] where t_N is the girder web net thickness.

η_1 : Coefficient to be taken equal to 1.1.

η_2 : Coefficient to be taken equal to 1.15. It may be reduced to 1.1 where appropriate reinforcements are fitted in way of the largest opening in the outermost bay, to be examined by the Society on a case-by-case basis.

4.1.4 Allowable hold loading

The allowable hold loading, in t, is to be taken as:

$$W = \rho_C V \frac{1}{F}$$

where:

ρ_C : Density of the dry bulk cargo, in t/m^3, as defined Pt 1, Ch 4, Sec 6, [2.3.3].

V : Volume, in m^3, occupied by the cargo up to the level h_B.

F : Coefficient to be taken as:

F = 1.1 in general.

F = 1.05 for steel mill products.

h_B : Level of cargo, in m, to be taken as:

$$h_B = \frac{P}{\rho_C g}$$

P : Pressure, in kN/m^2, to be taken as:

- For dry bulk cargoes, the lesser of:

$$P = \frac{Z + \rho g (z_F - 0.1 D_1 - h_F)}{1 + \frac{\rho}{\rho_C}(perm - 1)}$$

$$P = Z + \rho g (z_F - 0.1 D_1 - h_F \; perm)$$

- For steel mill products:

$$P = \frac{Z + \rho g\ (z_F - 0.1\ D_1 - h_F)}{1 - \frac{\rho}{\rho_C}}$$

D_1 : Distance, in m, from the baseline to the freeboard deck at side amidships.

h_F : Inner bottom flooded height, in m, measured vertically with the ship in the upright position, from the inner bottom to the flooded level z_F.

z_F : Flooded level, in m, as defined in Pt 1, Ch 4, Sec 6, [3.1.3].

perm : Permeability of cargo, which need not be taken greater than 0.3.

Z : Pressure, in kN/m^2, to be taken as the lesser of:

$$Z = \frac{C_H}{A_{DB,\,H}}$$

$$Z = \frac{C_E}{A_{DB,\,E}}$$

C_H : Shear capacity of the double bottom, in kN, to be calculated according to [4.1.1], considering, for each floor, the lesser of the shear strengths S_{f1} and S_{f2} as defined in [4.1.2] and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} as defined in [4.1.3].

$A_{DB,H}$: Area, in m^2, taken as:

$$A_{DB,\,H} = \sum_{i=1}^{n} S_i\ B_{DB,\,i}$$

C_E : Shear capacity of the double bottom, in kN, to be calculated according to [4.1.1], considering, for each floor, the shear strength S_{f1} as defined in [4.1.2] and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} as defined in [4.1.3].

$A_{DB,E}$: Area, in m^2, taken as:

$$A_{DB,\,E} = \sum_{i=1}^{n} S_i\ (B_{DB} - s)$$

n : Number of floors between stools or transverse bulkheads, if no stool is fitted.

S_i : Space of *i*-th floor, in m.

$B_{DB,i}$: Length, in m, to be taken equal to:

$B_{DB,i} = B_{DB}$ - s for floors for which $S_{f1} < S_{f2}$.

$B_{DB,i} = B_{DB,h}$ for floors for which $S_{f1} \geq S_{f2}$.

B_{DB} : Breadth, in m, of double bottom between the hopper tanks as shown in Figure 8.

$B_{DB,h}$: Distance, in m, between the two openings considered as shown in Figure 8.

s : Spacing, in m, of inner bottom longitudinal ordinary stiffeners adjacent to the hopper tanks.

Figure 7 : Double bottom structure

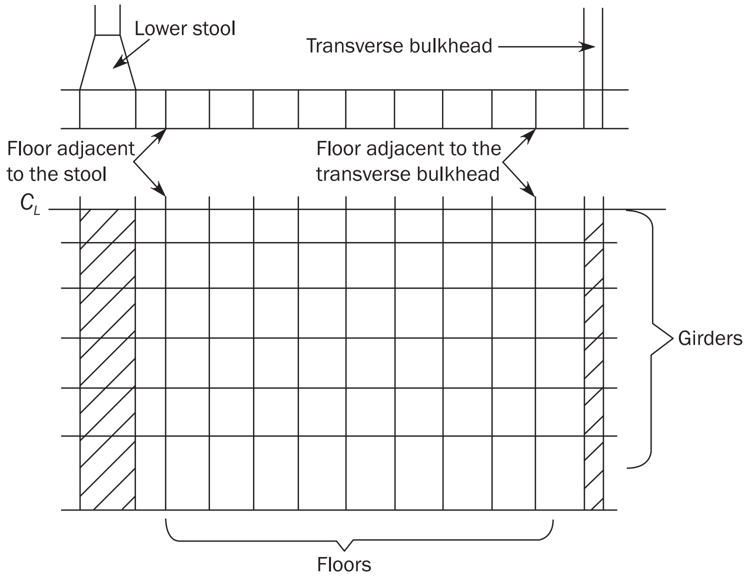
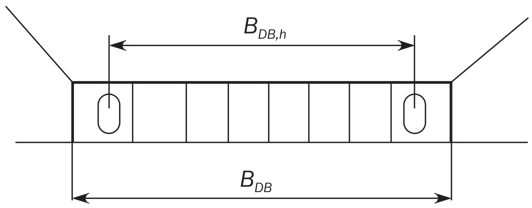


Figure 8 : Dimensions B_{DB} and $B_{DB,h}$



SECTION 4

HULL LOCAL SCANTLINGS FOR BULK CARRIERS *L*<150M

SYMBOLS

For symbols not defined in this section, refer to Pt 1, Ch 1, Sec 4.

$C_{t\text{-}pr}$: Permissible shear stress coefficient for primary supporting members taken equal to:

$C_{t\text{-}pr}$ = 0.70 for AC-S.

$C_{t\text{-}pr}$ = 0.85 for AC-SD.

ℓ_{DB} : Length of the double bottom within hold under consideration, in m. Where stools are provided at transverse bulkheads, ℓ_{DB} may be taken as the distance between the toes.

B_{DB} : Distance between the toes of hopper tanks at centre of ℓ_{DB} within hold under consideration, in m.

x_c : *X* coordinate, in m, of the centre of double bottom structure under consideration with respect to the reference coordinate system, as defined in Pt 1, Ch 1, Sec 4, [3.6].

x, y, z : *X*, *Y* and *Z* coordinates, in m, of the evaluation point with respect to the reference coordinate system, as defined in Pt 1, Ch 1, Sec 4, [3.6].

ϕ : Major diameter of the openings, in m.

α : The greater of a or S_1, in m.

1 GENERAL

1.1 Application

1.1.1

Unless otherwise defined, the requirements of this section define the strength criteria applicable to bulk carriers of less than 150 m in length.

2 STRUTS CONNECTING STIFFENERS

2.1 Scantling requirements

2.1.1 Net sectional area and moment of inertia

The net sectional area A_{SR}, in cm^2, and the net moment of inertia I_{SR} about the main axes, in cm^4, of struts connecting stiffeners are not to be less than the values obtained from the following formulae:

$$A_{SR} = \frac{P_{SR}\, s\ell}{20000}$$

$$I_{SR} = \frac{0.75\, s\ell\, (P_{SR1} + P_{SR2})\, A_{ASR}\, \ell^2{}_{SR}}{47200\, A_{ASR} - s\ell\, (P_{SR1} + P_{SR2})}$$

where:

P_{SR} : Pressure to be taken as the greater of the following values, in kN/m²:

$$P_{SR} = 0.5\ (P_{SR1} + P_{SR2})$$
$$P_{SR} = P_{SR3}$$

P_{SR1} : External pressure in way of the strut, in kN/m², acting on one side, outside the compartment in which the strut is located.

P_{SR2} : External pressure in way of the strut, in kN/m², acting on the opposite side, outside the compartment in which the strut is located.

P_{SR3} : Internal pressure at mid-span of the strut, in kN/m², in the compartment in which the strut is located.

s : Spacing, in mm, of stiffeners, measured at mid-span along the chord.

ℓ : Span, in m, of stiffeners connected by the strut defined in Pt 1, Ch 3, Sec 7, [1.1.5].

ℓ_{SR} : Length of the strut, in m.

A_{ASR} : Actual net sectional area of the strut, in cm².

3 TRANSVERSE CORRUGATED BULKHEADS OF BALLAST HOLDS

3.1 Plate thickness

3.1.1

The net thickness of web and flange plating is not to be less than the values obtained in Pt 1, Ch 6, Sec 3, [1.1.1] and Pt 1, Ch 6, Sec 4, [1.2].

3.2 Net section modulus

3.2.1

The net section modulus Z, in cm³, of corrugated bulkhead of ballast holds, subjected to lateral pressure are not to be less than the values obtained from the following formula:

$$Z = K\frac{Ps_C\ \ell^2}{f_{bdg}\ C_s\ R_Y}$$

where:

K : Coefficient given in Table 1 and Table 2, according to the type of end connection. When $d_H < 2.5\ d_0$, both section modulus per half pitch of corrugated bulkhead and section modulus of lower stool at inner bottom are to be calculated.

P : Design pressure for the design load set as defined in Pt 1, Ch 6, Sec 2, Table 1 and calculated at the load calculation point defined in Pt 1, Ch 3, Sec 7, [3.2], in kN/m².

s_C : Half pitch length, in mm, of the corrugation, as defined in Pt 1, Ch 3, Sec 6, Figure 21.

ℓ : Length, in m, between the supports, as indicated in Figure 1.

C_s : Coefficient defined in Pt 1, Ch 6, Sec 5, [1.1.2].

f_{bdg} : Coefficient defined in Pt 1, Ch 6, Sec 5, [1.1.2].

The effective width of the corrugation flange in compression is to be considered according to Ch 1, Sec 3, [3.3.1] when the net section modulus of corrugated bulkhead is calculated.

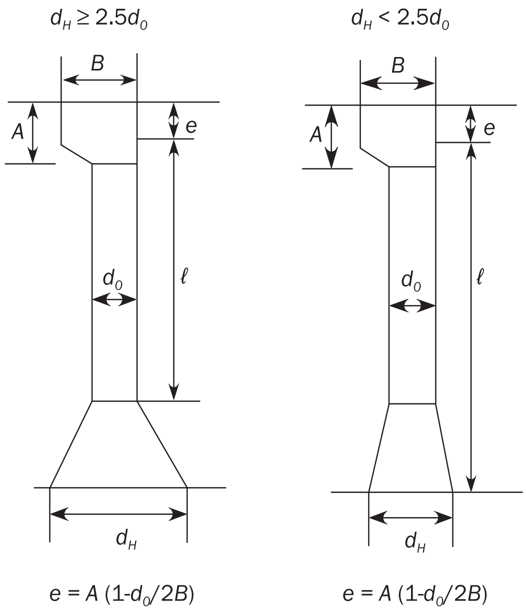
Table 1 : Values of K, in case $d_H \geq 2.5d_0$

Upper end support		
Supported by girders	**Welded directly to deck**	**Welded to stool efficiently supported by ship structure**
1.25	1.00	0.83

Table 2 : Values of K, in case $d_H < 2.5d_0$

Section modulus of	Upper end support		
	Supported by girders	**Connected to deck**	**Connected to stool**
Corrugated bulkhead	0.83	0.71	0.65
Stool at bottom	0.83	1.25	1.13

Figure 1 : Measurement of ℓ



4 PRIMARY SUPPORTING MEMBERS

4.1 Application

4.1.1

The requirements of this section apply to the strength check of primary supporting members in cargo hold structures, subjected to lateral pressure for ships having a length L less than 150 m.

4.1.2

As an alternative to [4.1.1], the strength check may be verified by direct strength assessment deemed as appropriate by the Society.

4.2 Design load sets

4.2.1 Application

Design load sets as given in Table 3 are to be considered for primary supporting members on cargo hold boundaries of bulk carriers less than 150 m in length.

4.2.2 Loading conditions

The severest loading conditions from the loading manual or otherwise specified by the designer are to be considered for the calculation of P_{in} in design load sets BC-9 to BC-10.

If primary supporting members support deck structure or tank/watertight boundaries, applicable design load sets in Pt 1, Ch 6, Sec 2, Table 1 are also to be considered.

Table 3 : Design load sets for primary supporting members in cargo hold region

Item	Design load set	Load component	Draught	Design load	Loading condition
Bulk cargo hold assigned as ballast hold	WB-4	$P_{in} - P_{ex}$ **(1)**	T_{BAL-H} **(3)**	S+D	Heavy ballast condition
	WB-6	P_{in}	-	S	Harbour/test condition
Bulk cargo hold	BC-9	$P_{in} - P_{ex}$ **(1)**	T_{SC}	S+D	Cargo loading condition
	BC-10	$P_{in} - P_{ex}$ **(1)**	-	S	Harbour condition
Compartments not carrying liquids	FD-1 **(2)**	P_{in}	T_{SC}	S+D	Flooded condition
	FD-2 **(2)**	P_{in}		S	Flooded condition

(1) P_{ex} is to be considered for external shell only.
(2) FD-1 and FD-2 are not applicable to external shell.
(3) Minimum draught among heavy ballast conditions is to be used.

4.3 Centre girders and side girders

4.3.1 Net web thickness

The net thickness of girders in double bottom structure, in mm, is not to be less than the greater of the value t_1 and t_2 specified in the followings according to each location:

$$t_1 = C_1 \frac{|P| S\,|x - x_c|}{(d_0 - d_1)\, C_{t-pr}\, \tau_{eH}} \left\{ 1 - 4 \left(\frac{y}{B_{DB}} \right)^2 \right\}$$

in which $|x - x_c|$ is to be taken less than or equal to 0.25 ℓ_{DB}.

$$t_2 = 1.75 \sqrt[3]{\frac{H^2\, a^2\, C_{t-pr}\, \tau_{eH}}{C_1'}} \cdot t_1$$

where:

P : Design pressure in kN/m^2, for the design load set being considered according to Pt 1, Ch 6, Sec 2, [2.1.3], calculated at mid-point of a floor located midway between transverse bulkheads or transverse bulkhead and toe of stool, where fitted.

S : Distance between the centres of the two spaces adjacent to the centre or side girder under consideration, in m.

d_0 : Depth of the centre or side girder under consideration, in m.

d_1 : Depth of the opening, if any, at the point under consideration, in m.

C_1 : Coefficient given in Table 4 depending on B_{DB} / ℓ_{DB}. For intermediate values of B_{DB} / ℓ_{DB}, C_1 is to be obtained by linear interpolation.

a : Depth of girders at the point under consideration, in m. However, where horizontal stiffeners are fitted on the girder, a is the distance from the horizontal stiffener under consideration to the bottom shell plating or inner bottom plating, or the distance between the horizontal stiffeners under consideration.

S_1 : Spacing, in m, of vertical stiffeners or floors.

C'_1 : Coefficient given in Table 5 depending on S_1 /a. For intermediate values of S_1 /a, C'_1 is to be determined by linear interpolation.

H : Value obtained from the following formulae:

- Where the girder is provided with an unreinforced opening:

$$H = 1 + 0.5\frac{\phi}{\alpha}$$

- In other cases:

$H = 1.0$.

Table 4 : Coefficient C_1

B_{DB}/ℓ_{DB}	0.4 and under	0.6	0.8	1.0	1.2	1.4	1.6 and over
C_1	0.5	0.71	0.83	0.88	0.95	0.98	1.00

Table 5 : Coefficient C'_1

S_1/a	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C'_1	64	38	25	19	15	12	10	9	8	7

4.4 Floors

4.4.1 Net web thickness

The net thickness of floors in the double bottom structure, in mm, is not to be less than the greatest of values t_1 and t_2 specified in the following according to each location:

$$t_1 = C_2\frac{|P|\ S\ B_{DB}}{(d_0 - d_1)\ C_{t-pr}\ \tau_{eH}}\left(\frac{2\ |y|}{B'_{DB}}\right)\left\{1 - 2\left(\frac{x - x_c}{\ell_{DB}}\right)^2\right\}$$

in which $|x - x_c|$ is to be taken less than or equal to $0.25\ \ell_{DB}$ and $|y|$ is to be taken less than or equal to $B'_{DB}/4$.

$$t_2 = 1.75\sqrt[3]{\frac{H^2\ a^2\ C_{t-pr}\ \tau_{eH}}{C'_2}} - t_1$$

where:

P : Design pressure in kN/m², for the design load set being considered according to Pt 1, Ch 6, Sec 2, [2.1.3], calculated at mid-point of a floor located midway between transverse bulkheads or transverse bulkhead and toe of stool, where fitted.

S : Spacing of solid floors, in m.

d_0 : Depth of the solid floor at the point under consideration in m.

d_1 : Depth of the opening, if any, at the point under consideration in m.

B'_{DB} : Distance between toes of hopper tanks at the position of the solid floor under consideration, in m.

C_2 : Coefficient given in Table 6 depending on B_{DB}/ℓ_{DB}. For intermediate values of B_{DB}/ℓ_{DB}, C_2 is to be obtained by linear interpolation.

a : Depth of the solid floor at the point under consideration, in m. However, where horizontal stiffeners are fitted on the floor, a is the distance from the horizontal stiffener under consideration to the bottom shell plating or the inner bottom plating or the distance between the horizontal stiffeners under consideration.

S_1 : Spacing, in m, of vertical stiffeners or girders.

C'_2 : Coefficient given in Table 7 depending on S_1 /d_0. For intermediate values of S_1 /d_0, C'_2 is to be determined by linear interpolation.

H : Value obtained from the following formulae:

Where openings with reinforcement or no opening are provided on solid floors:

- Where slots without reinforcement are provided:

$$H = \sqrt{4.0\frac{d_2}{S_1} - 1.0}$$ without being taken less than 1.0.

- Where slots with reinforcement are provided:

$H = 1.0$.

Where openings without reinforcement are provided on solid floors:

- Where slots without reinforcement are provided:

$$H = \left(1 + 0.5\frac{\phi}{d_0}\right)\sqrt{4.0\frac{d_2}{S_1} - 1.0}$$ without being taken less than $1 + 0.5\frac{\phi}{d_0}$

- where slots with reinforcement are provided:

$$H = 1 + 0.5\frac{\phi}{d_0}$$

d_2 : Depth of slots without reinforcement provided at the upper and lower parts of solid floors, in m, whichever is greater.

Table 6 : Coefficient C_2

B_{DB}/ℓ_{DB}	0.4 and under	0.6	0.8	1.0	1.2	1.4	1.6 and over
C_2	0.48	0.47	0.45	0.43	0.40	0.37	0.34

Table 7 : Coefficient C'_2

S_1/d_0	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C'_2	64	38	25	19	15	12	10	9	8	7

4.5 Stringer of double side structure

4.5.1 Net web thickness

The net thickness of stringers in double side structure, in mm, is not to be less than the greater of the value t_1 and t_2 specified in the followings according to each location:

$$t_1 = C_3\frac{|P|S|x - x_c|}{(d_0 - d_1)\,C_{t-pr}\,\tau_{eH}}$$

in which $|x - x_c|$ is to be taken less than or equal to 0.25 ℓ_{DS}.

$$t_2 = 1.75\sqrt[3]{\frac{H^2 a^2 C_{t-pr}\,\tau_{eH}}{C'_3}} - t_1$$

where:

P : Design pressure in kN/m^2, for the design load set being considered according to Pt 1, Ch 6, Sec 2, [2.1.3], as measured vertically at the upper end of hopper tank, longitudinally at the centre of ℓ_{DS}.

S : Breadth of part supported by stringer, in m.

d_0 : Depth of stringers, in m.

d_1 : Depth of opening, if any, at the point under consideration, in m.

ℓ_{DS} : Length of the double side structure between the transverse bulkheads under consideration, in m.

h_{DS} : Height of the double side structure between the upper end of hopper tank and the lower end of topside tank located midway between transverse bulkheads of hold under consideration, in m.

C_3 : Coefficient given in Table 8 depending on h_{DS}/ℓ_{DS}. For intermediate values of h_{DS}/ℓ_{DS}, C_3 is to be obtained by linear interpolation.

a : Depth of stringers at the point under consideration, in m. However, where horizontal stiffeners are fitted on the stringer, a is the distance from the horizontal stiffener under consideration to the side shell plating or the longitudinal bulkhead of double side structure or the distance between the horizontal stiffeners under consideration.

S_1 : Spacing, in m, of transverse stiffeners or web frames.

C'_3 : Coefficient given in Table 9 depending on S_1/a. For intermediate values of S_1/a, C'_3 is to be obtained by linear interpolation.

H : Value obtained from the following formulae:

- Where the stringer is provided with an unreinforced opening:

$$H = 1 + 0.5\frac{\phi}{\alpha}$$

- In other cases:

$H = 1.0$.

Table 8 : Coefficient C_3

h_{DS}/ℓ_{DS}	0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_3	0.16	0.23	0.30	0.36	0.41	0.44	0.47	0.50	0.54

Table 9 : Coefficient C'_3

S_1/a	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C'_3	64	38	25	19	15	12	10	9	8	7

4.6 Transverse web in double side structure

4.6.1 Net web thickness

The net thickness of transverse webs in double side structure, in mm, is not to be less than the greater of the value t_1 and t_2 specified in the followings according to each location:

$$t_1 = C_4\frac{|P|\ Sh_{DS}}{(d_0 - d_1)\ C_{t-pr}\ \tau_{eH}}\left(1 - 1.75\frac{z - z_{BH}}{h'_{DS}}\right)$$

in which $z - z_{BH}$ is to be taken greater than or equal to $0.4\ h'_{DS}$.

$$t_2 = 1.75\sqrt[3]{\frac{H^2\ a^2\ C_{t-pr}\ \tau_{eH}}{C'_4}t_1}$$

where:

P : Design pressure in kN/m^2, for the design load set being considered according to Pt 1, Ch 6, Sec 2, [2.1.3], as measured vertically at the upper end of hopper tank, longitudinally at the centre of ℓ_{DS}.

S : Breadth of part supported by transverses, in m.

d_0 : Depth of transverses, in m.

d_1 : Depth of opening at the point under consideration, in m.

C_4 : Coefficient given in Table 10 depending on h_{DS}/ℓ_{DS}. For intermediate values of h_{DS}/ℓ_{DS}, C_4 is to be obtained by linear interpolation.

z_{BH} : Z coordinate, in m, of the upper end of hopper tank with respect to the reference coordinate system defined in Pt 1, Ch 1, Sec 4, [3.6].

h_{DS} : As defined in the requirements of [4.5.1].

h'_{DS} : Height of the double side structure between the upper end of hopper tank and the lower end of topside tank at the position under consideration, in m.

ℓ_{DS} : As defined in the requirements of [4.5.1].

a : Depth of transverses at the point under consideration, in m. However, where vertical stiffeners are fitted on the transverse, a is the distance from the vertical stiffener under consideration to the side shell or the longitudinal bulkhead of double side hull or the distance between the vertical stiffeners under consideration.

S_1 : Spacing, in m, of horizontal stiffeners or stringers.

C'_4 : Coefficient given in Table 11 depending on S_1 /a. For intermediate values of S_1 /a, C'_4 is to be obtained by linear interpolation.

H : Value obtained from the following formulae:

- Where the transverse is provided with an unreinforced opening:

$$H = 1 + 0.5\frac{\phi}{\alpha}$$

- In other cases:

$H = 1.0$.

α : The greater of a or S_1, in m.

Table 10 : Coefficient C_4

h_{DS}/ℓ_{DS}	0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_4	0.62	0.61	0.59	0.55	0.52	0.49	0.46	0.43	0.41

Table 11 : Coefficient C'_4

S_1/a	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C'_4	64	38	25	19	15	12	10	9	8	7

4.7 Primary supporting member in bilge hopper tanks and topside tanks

4.7.1 Boundary conditions

The requirements of this sub-article apply to primary supporting members considered as clamped at both ends. For boundary conditions deviated from the above, the yielding check is to be considered on a case-by-case basis.

4.7.2 Net section modulus, net shear sectional area and web thickness

The net section modulus Z, in cm^3, the net shear sectional area A_{shr}, in cm^2, and the net web thickness t_w, in mm, subjected to lateral pressure are not to be less than the values obtained from the following formulae:

$$Z = \frac{|P|\ S\ell_{bdg}^{\ 2}}{f_{bdg}\ C_{s-pr}\ R_{eH}}\ 10^3$$

$$A_{shr} = \frac{5\ |P|\ S\ell_{shr}}{C_{t-pr}\ \tau_{eH}}$$

$$t_w = 1.75\ \sqrt[3]{\frac{h_w\ C_{t-pr}\ \tau_{eH}}{10^4\ C_5}\ A_{shr}}$$

where:

P : Design pressure in kN/m^2, for the design load set being considered according to Pt 1, Ch 6, Sec 2, [2.1.3], calculated at the mid-point of span ℓ of a web frame located midway between transverse bulkheads of holds.

S : Spacing of primary supporting members, in m.

ℓ_{bdg} : Effective bending span, in m, of primary supporting members, measured between the supporting members as defined in Pt 1, Ch 3, Sec 7, [1.1.6].

ℓ_{shr} : Effective shear span, in m, of primary supporting members, measured between the supporting members as defined in Pt 1, Ch 3, Sec 7, [1.1.7].

f_{bdg} : Bending moment factor:

- For continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having as fixed ends and is not to be taken higher than:

  $f_{bdg} = 10$.

- For stiffeners with reduced end fixity, the yield check is to be considered on a case-by-case basis.

C_{s-pr} : Permissible bending stress coefficient for primary supporting members taken equal to:

$C_{s-pr} = 0.70$ for AC-S.

$C_{s-pr} = 0.85$ for AC-SD.

h_w : Web height, in mm.

C_5 : Coefficient defined in Table 12 according to s_1 and d_0. For intermediate values of s_1 / d_0, coefficient C_5 is to be obtained by linear interpolation.

s_1 : Spacing of stiffeners or tripping brackets on web plate, in m.

d_0 : Spacing of stiffeners parallel to shell plate on web plate, in m.

Table 12 : Coefficient C_5

s_1/d_0	0.3 and less	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0 and over
C_5	60.0	40.0	26.8	20.0	16.4	14.4	13.0	12.3	11.1	10.2

SECTION 5
CARGO HATCH COVERS

SYMBOLS

For symbols not defined in this section, refer to Pt 1, Ch 1, Sec 4.

P_S : Still water pressure, in kN/m^2, as defined in [4.1].

P_W : Wave pressure, in kN/m^2, as defined in [4.1].

P_C : Pressure acting on the hatch coaming, in kN/m^2, as defined in [6.2].

F_S, F_W : Coefficients taken equal to:
F_S = 0 and F_W = 0.9 for ballast water loads on hatch covers of the ballast hold.

F_S = 1.0 and F_W = 1.0 in other cases.

b_p : Effective breadth, in mm, of the plating attached to the stiffener or primary supporting member, as defined in [3].

A_{shr} : Net shear sectional area, in cm^2, of the stiffener or primary supporting member.

f_{bc} : Boundary coefficient for stiffeners and primary supporting members, taken equal to:

f_{bc} = 8, in the case of stiffeners and primary supporting members simply supported at both ends or supported at one end and clamped at the other end.

f_{bc} = 12, in the case of stiffeners and primary supporting members clamped at both ends.

t_c : Total corrosion addition, in mm, as defined in [1.4].

σ_a, τ_a : Allowable stresses, in N/mm^2, as defined in [1.5].

1 GENERAL

1.1 Application

1.1.1

The requirements in [1] to [8] apply to steel hatch covers in positions 1 and 2 on weather decks, as defined in Pt 1, Ch 1, Sec 4, [3.2].

1.2 Materials

1.2.1 Steel

The formulae for scantlings given in [5] are applicable to steel hatch covers.

Materials used for the construction of steel hatch covers are to comply with the applicable requirements of the Society.

1.2.2 Other materials

The use of materials other than steel is to be considered by the Society on a case-by-case basis, by checking that criteria adopted for scantlings are such as to ensure strength and stiffness equivalent to those of steel hatch covers.

1.3 Net scantlings

1.3.1

All scantlings referred to in this section are net, i.e. they do not include any margin for corrosion.

When calculating the stresses σ and τ in [5.3] and [5.4], the net scantlings are to be used.

The gross scantlings are obtained as specified in Pt 1, Ch 3, Sec 2.

The corrosion additions are given in [1.4].

1.4 Corrosion additions

1.4.1

The total corrosion addition for both sides to be considered for the plating and internal members of hatch covers is equal to the value specified in Table 1.

The corrosion addition for hatch coamings and coaming stays is defined according to Pt 1, Ch 3, Sec 3.

Table 1 : Corrosion addition t_c for hatch covers

Corrosion addition t_c, in mm, for both sides	
Plating and stiffeners of single skin hatch cover	2.0
Top and bottom plating of double skin hatch cover	2.0
Internal structures of double skin hatch cover	1.5

1.5 Allowable stresses

1.5.1

The allowable stresses σ_a and τ_a, in N/mm^2, are to be obtained from Table 2.

Table 2 : Allowable stresses, in N/mm^2

Members of	Subjected to	σ_a, in N/mm^2	τ_a, in N/mm^2
Weathertight hatch cover	External pressure, as defined in [4.1.2]	0.80 R_{eH}	0.46 R_{eH}
Weathertight hatch cover	Other loads, as defined in [4.1.3] to [4.1.6]	0.90 R_{eH}	0.51 R_{eH}

The allowable buckling utilisation factors are given in Table 3:

Table 3 : Allowable buckling utilisation factors

Structural component	Subject to	η_{all}, Allowable buckling utilisation factor
Plates and stiffeners Web of PSM	External pressure, as defined in [4.1.2]	0.80 for load combination: S+D
	Other loads, as defined in [4.1.3] to [4.1.6]	0.80 for load combination: S+D 0.64 for load combination: S

2 ARRANGEMENTS

2.1 Height of hatch coamings

2.1.1

The height of hatch coamings is not to be less than:

- 600 mm in position 1.
- 450 mm in position 2.

2.1.2

The height of hatch coamings in positions 1 and 2 closed by steel covers provided with gaskets and securing devices may be reduced with respect to the above values or the coamings may be omitted entirely, on condition that the Administration is satisfied that the safety of the ship is not thereby impaired in any sea conditions.

In such cases the scantlings of the covers, their gasketing, their securing arrangements and the drainage of recesses in the deck are considered by the Society on a case-by-case basis.

2.2 Hatch covers

2.2.1

The stiffeners and primary supporting members of the hatch covers are to be continuous over the breadth and length of the hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to ensure sufficient load carrying capacity.

2.2.2

The spacing of primary supporting members parallel to the direction of stiffeners is not to be greater than 1/3 of the span of primary supporting members.

2.2.3

The breadth of the primary supporting member face plate is not to be less than 40% of their depth for laterally unsupported spans greater than 3 m. Tripping brackets attached to the face plate may be considered as a lateral support for primary supporting members.

The face plate outstand is not to exceed 15 times the gross face plate thickness.

2.2.4

Efficient retaining arrangements are to be provided to prevent translation of the hatch cover under the action of the longitudinal and transverse forces exerted by cargoes on the cover, if any. These retaining arrangements are to be located in way of the hatch coaming side brackets.

2.2.5

The width of each bearing surface for hatch covers is to be at least 65 mm.

2.3 Hatch coamings

2.3.1

Coamings, stiffeners and brackets are to be capable of withstanding the local forces in way of the clamping devices and handling facilities necessary for securing and moving the hatch covers as well as those due to cargo stowed on the latter.

2.3.2

Special attention is to be paid to the strength of the fore transverse coaming of the forward hatch and to the scantlings of the closing devices of the hatch cover on this coaming.

2.3.3

Longitudinal coamings are to be extended at least to the lower edge of deck beams.

- Where they are not part of continuous deck girders, the lower edge of longitudinal coamings are to extend for at least two frame spaces beyond the end of the openings.
- Where longitudinal coamings are part of deck girders, their scantlings are to be as required in Pt 1, Ch 6, Sec 6 and Pt 1, Ch 8, Sec 3.

2.3.4

A web frame or a similar structure is to be provided below the deck in line with the transverse coaming. Transverse coamings are to extend below the deck and to be connected with the web frames.

3 WIDTH OF ATTACHED PLATING

3.1 Stiffeners

3.1.1

The width of the attached plating b_p, in mm, to be considered for the check of stiffeners is to be taken as:

- Where the attached plating extends on both sides of the stiffener:

  $b_p = s$

- Where the attached plating extends on one side of the stiffener:

  $b_p = 0.5\ s$

3.2 Primary supporting members

3.2.1

The effective breadth, in mm, of the attached plating to be considered for the yielding and buckling checks of primary supporting members analysed through isolated beam or grillage model is to be taken as:

- Where the plating extends on both sides of the primary supporting member:

  $b_p = b_{p1} + b_{p2}$

- Where the plating extends on one side of the primary supporting member:

  $b_p = b_{p1}$

where:

$b_{p1} = \min(0.165\ \ell_p, S_{p1})$

$b_{p2} = \min(0.165\ \ell_p, S_{p2})$

ℓ_p : Span, in m, of the considered primary supporting member.

S_{p1}, S_{p2} : Half distance, in m, between the considered primary supporting member and the adjacent ones, S_{p1} for one side, S_{p2} for the other side.

For structural evaluations based on isolated beam or grillage models, the areas of stiffeners are not to be included in the idealisation of the attached plating of the primary members.

4 LOAD MODEL

4.1 Lateral pressures and forces

4.1.1 General

The lateral pressures and forces to be considered as acting on hatch covers are given in [4.1.2] to [4.1.6]. When two or more panels are connected by hinges, each individual panel is to be considered separately.

In any case, the sea pressures defined in [4.1.2] are to be considered for hatch covers located on exposed decks.

Additionally, when the hatch cover is intended to carry uniform cargoes, special cargoes or containers, the pressures and forces defined in [4.1.3] to [4.1.6] are to be considered independently from the sea pressures.

4.1.2 Sea pressures

The still water and wave lateral pressures are to be considered and are to be taken equal to:

- Still water pressure: $P_S = 0$.
- Wave pressure $P_W = P_{HC}$, as defined in Pt 1, Ch 4, Sec 5, [5.2].

4.1.3 Internal pressures due to ballast water

If applicable, the internal static and dynamic lateral pressures due to ballast water are to be considered and are defined in Pt 1, Ch 4, Sec 6, [1].

4.1.4 Pressures due to uniform cargoes

If applicable, the static and dynamic pressures due to uniform cargoes are to be considered and are defined in Pt 1, Ch 4, Sec 5, [5.3.1].

4.1.5 Pressures or forces due to special cargoes

In the case of carriage of special cargoes (e.g. pipes, etc) on the hatch covers which may temporarily retain water during navigation, the lateral pressures or forces to be applied are considered by the Society on a case-by-case basis.

4.1.6 Forces due to containers

In the case of carriage of containers on the hatch covers, the concentrated forces under the containers corners are to be determined in accordance with the applicable requirements of the Society.

4.1.7 Self weight

The effect of the hatch cover structure weight is to be included in the static loads but not in the dynamic loads.

4.2 Load point

4.2.1 Wave lateral pressure for hatch covers on exposed decks

The wave lateral pressure to be considered as acting on each hatch cover is to be calculated at a point located:

- Longitudinally, at the hatch cover mid-length.
- Transversely, on the longitudinal plane of symmetry of the ship.
- Vertically, at the top of the hatch cover.

4.2.2 Lateral pressures other than the wave pressure

The lateral pressure is to be calculated at the level of the tight boundary of the cover:

- In way of the geometrical centre of gravity of the plate panel, for plating.
- At mid-span, for stiffeners and primary supporting members.

5 STRENGTH CHECK

5.1 General

5.1.1 Application

The strength check is applicable to rectangular hatch covers subjected to a uniform pressure, designed with primary supporting members arranged in one direction or as a grillage of longitudinal and transverse primary supporting members.

In the latter case, i.e. when the hatch cover is arranged as a grillage of longitudinal and transverse primary supporting members, or when the Society deems it necessary, the stresses in the primary supporting members are to be determined by a grillage or a finite element analysis.

It is to be checked that stresses induced by concentrated loads are in accordance with the criteria in [5.4.4].

When FE analysis is carried out, the buckling assessment as described in [5.2.3], [5.3.4] and [5.4.6] can be made considering only the stresses given by the FE analysis

5.1.2 Hatch covers supporting containers

The scantlings of hatch covers supporting containers are to comply with the applicable requirements of the Society.

5.1.3 Hatch covers subjected to special cargoes

For hatch covers supporting special cargoes, stiffeners and primary supporting members are generally to be checked by direct calculations, taking into account the stiffener arrangements and their relative inertia. It is to be checked that stresses induced by special cargoes are in accordance with the criteria in [5.4.4].

5.2 Plating

5.2.1 Net thickness

The net thickness, in mm, of steel hatch cover top plating is not to be taken less than:

$$t = 0.0158\ F_p b \sqrt{\frac{F_s\ P_s + F_W\ P_W}{0.95\ R_{eH}}}$$

where:

F_p : Factor for combined membrane and bending response, equal to:

$F_p = 1.5$ in general.

$F_p = 1.9\dfrac{\sigma}{\sigma_a}$ for $\sigma \geq 0.8\sigma_a$ for the attached plating of primary supporting members.

σ : Normal stress, in N/mm^2, in the attached plating of primary supporting members, calculated according to [5.4.3] or determined through a grillage analysis or a finite element analysis.

5.2.2 Minimum net thickness

In addition to [5.2.1], the net thickness, in mm, of the plating forming the top of the hatch cover is not to be taken less than the greater of the following values:

$$t = \frac{b}{100}$$

$t = 6$

5.2.3 Buckling strength

The buckling strength of the hatch cover plating subjected to loading conditions as defined in [4.1] is to comply with the following formula:

$\eta_{Plate} \leq \eta_{all}$

where:

η_{Plate} : Maximum plate utilisation factor calculated according to Method A, as defined in Pt 1, Ch 8, Sec 5, [2.2].

- For stresses obtained from beam theory, i.e. not calculated by means of finite element analysis:

- σ_x or σ_y is selected for the uniaxial check of the plate in the direction parallel to the primary supporting member,
- $\tau = 0$.

- For stresses calculated by means of finite element analysis: σ_x, σ_y, τ obtained from FE analysis.

η_{all} : Allowable utilisation factor, as given in Table 3.

5.3 Stiffeners

5.3.1

For flat bar stiffeners, the ratio h_w / t_w is to comply with the following formula:

$$\frac{h_w}{t_w} \leq 15 \sqrt{\frac{235}{R_{eH}}}$$

5.3.2 Minimum net thickness of web

The net thickness, in mm, of the stiffener web is to be taken not less than 4 mm.

5.3.3 Net section modulus and net shear sectional area

The net section modulus Z, in cm^3, and the net shear sectional area A_{shr}, in cm^2, of a stiffener subject to lateral pressure are to be taken not less than given by the following formulae:

$$Z = \frac{(F_S\ P_S + F_W\ P_W)\ s \cdot \ell_s^2}{f_{bc}\ \sigma_a}\ 10^{-3}$$

$$A_{shr} = \frac{5(F_S\ P_S + F_W\ P_W)\ s\ \ell_s}{\tau_a}$$

where:

ℓ_s : Stiffener span, in m, to be taken as the spacing, in m, of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all stiffener spans, the stiffener span may be reduced by an amount equal to 2/3 of the minimum brackets arm length, but not greater than 10% of the gross span, for each bracket.

5.3.4 Buckling strength

The buckling strength of the hatch cover stiffeners subjected to loading conditions as defined in [4.1] is to comply with the following formula:

$\eta_{Stiffener} \leq \eta_{all}$

where:

$\eta_{Stiffener}$: Maximum stiffener utilisation factor calculated according to Pt 1, Ch 8, Sec 5, [2.3].

- For uniaxial stresses obtained by beam theory, i.e. not calculated by means of finite element analysis:
  - σ_x : stiffener axial stress,
  - $\sigma_y = 0$,
  - $\tau = 0$.

- For stresses calculated by means of finite element analysis:
    - σ_x : stiffener axial stress from FE analysis,
    - σ_y : stress perpendicular to the stiffener,
    - τ : shear stress in the attached plate.

η_{all} : Allowable utilisation factor, as given in Table 3.

5.4 Primary supporting members

5.4.1 Application

The requirements in [5.4.3] to [5.4.5] apply to primary supporting members which may be analysed through isolated beam models.

Primary supporting members whose arrangement is of a grillage type and which cannot be analysed through isolated beam models are to be checked by direct calculations, using the checking criteria in [5.4.4].

5.4.2 Minimum net thickness of web

The web net thickness of primary supporting members, in mm, is not to be less than 6 mm.

5.4.3 Normal and shear stress for isolated beam

In case that grillage analysis or finite element analysis are not carried out, according to the requirements in [5.1.1], the maximum normal stress σ and shear stress τ, in N/mm², in the primary supporting members are to be taken as given by the following formulae:

$$\sigma = \frac{s\ (F_S\ P_S + F_W\ P_W)\ \ell_m^2}{f_{bc}\ Z}$$

$$\tau = \frac{5\ s(F_S\ P_S + F_W\ P_W)\ \ell_m}{A_{shr}}$$

where:

ℓ_m : Bending span, in m, of the primary supporting member.

5.4.4 Checking criteria

The normal stress σ and the shear stress τ, calculated according to [5.4.3] or determined through a grillage analysis or finite element analysis, as the case may be, are to comply with the following formulae:

$$\sigma \le \sigma_a$$

$$\tau \le \tau_a$$

5.4.5 Deflection limit

The net moment of inertia of a primary supporting member, when loaded by sea pressure, excluding the self-weight of the structure, is to be such that the deflection does not exceed $\mu\ \ell_{max}$.

where:

μ : Coefficient taken equal to:

μ = 0.0056 for weathertight hatch covers.

ℓ_{max} : Greatest span, in m, of primary supporting members.

5.4.6 Buckling strength of the web panels of the primary supporting members

The web of primary supporting members subject to loading conditions as defined in [4.1] is to be taken as:

$$\eta_{Plate} \le \eta_{all}$$

where:

η_{Plate} : Maximum plate utilisation factor calculated according to Method A, as defined in Pt 1, Ch 8, Sec 5, [2.4].

- Shear stress obtained by beam theory (i.e. calculated according to [5.4.3] or determined through a grillage analysis), or
- σ_x, σ_y, τ obtained by FE analysis.

η_{all} : Allowable utilisation factor, as given in Table 3.

5.4.7 Slenderness criteria

For buckling stiffeners on webs of primary supporting members, the ratio h_w/t_w is to comply with the following formula:

$$\frac{h_w}{t_w} \le 15\sqrt{\frac{235}{R_{eH}}}$$

5.5 Stiffeners and primary supporting members of variable cross section

5.5.1

The net section modulus Z, in cm^3, of stiffeners and primary supporting members with a variable cross section is to be taken not less than the greater of the values given by the following formulae:

$$Z = X_{CS}$$

$$Z = \left(1 + \frac{3.2\alpha - \psi - 0.8}{7\psi + 0.4}\right) Z_{CS}$$

where:

Z_{CS} : Net section modulus, in cm^3, for a constant cross section, complying with the checking criteria in [5.4.4].

a : Coefficient taken equal to:

$$\alpha = \frac{\ell_1}{\ell_0}$$

ψ : Coefficient taken equal to:

$$\psi = \frac{Z_1}{Z_0}$$

ℓ_1 : Length of the variable section part, in m, as shown in Figure 1.

ℓ_0 : Span measured, in m, between end supports, as shown in Figure 1.

Z_1 : Net section modulus at end, in cm^3, as shown in Figure 1.

Z_0 : Net section modulus at mid-span, in cm^3, as shown in Figure 1.

Moreover, the net moment of inertia, in cm^4, of stiffeners and primary supporting members with a variable cross section is to be taken not less than the greater of the values given by the following formulae:

$$I = I_{CS}$$

$$I = \left[1 + 8\alpha^3\left(\frac{1-\varphi}{0.2 + 3\sqrt{\varphi}}\right)\right] I_{CS}$$

where:

I_{CS} : Net moment of inertia, in cm^4, with a constant cross section complying with [5.4.5].

φ : Coefficient taken equal to:

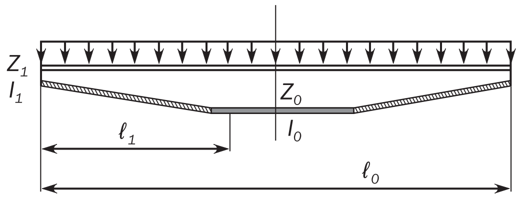
$$\varphi = \frac{I_1}{I_0}$$

I_1 : Net moment of inertia at end, in cm^4, as shown in Figure 1.

I_0 : Net moment of inertia at mid-span, in cm^4, as shown in Figure 1.

The use of these formulae is limited to the determination of the strength of stiffeners and primary supporting members in which abrupt changes in the cross section do not occur along their length.

Figure 1 : Variable cross section stiffener



6 HATCH COAMINGS

6.1 Stiffening

6.1.1

The stiffeners of the hatch coamings are to be continuous over the breadth and length of the hatch coamings.

6.1.2

Coamings are to be stiffened on their upper edges with a stiffener suitably shaped to fit the hatch cover closing appliances.

6.1.3

Where the height of the coaming exceeds 900 mm, additional strengthening may be required.

However, reductions may be granted for transverse coamings in protected areas.

6.1.4

When two hatches are close to each other, under deck stiffeners are to be fitted to connect the longitudinal coamings in order to maintaining the continuity of their strength.

Similar stiffening is to be provided over 2 frame spacings at ends of hatches exceeding 9 frame spacings in length.

In some cases, the Society may require the continuity of coamings to be maintained above the deck.

6.1.5

Where watertight metallic hatch covers are fitted, other arrangements of equivalent strength may be adopted.

6.2 Load model

6.2.1

The wave lateral pressure, P_C in kN/m^2, to be considered as acting on the hatch coamings is defined in [6.2.2] and [6.2.3].

6.2.2

The wave lateral pressure, P_C in kN/m^2, on the No. 1 forward transverse hatch coaming is to be taken equal to:

- P_C = 220, when a forecastle is fitted in accordance with Ch 1, Sec 1, [1].
- P_C = 290, in the other cases.

6.2.3

The wave lateral pressure, P_C in kN/ m^2, on the hatch coamings other than the No. 1 forward transverse hatch coaming is to be taken equal to:

P_C = 220

6.2.4

For cargo holds intended for the carriage of liquid cargoes, the liquid internal pressures applied on hatch coaming is also to be determined according to Pt 1, Ch 4, Sec 6.

6.3 Scantlings

6.3.1 Plating

The net thickness, in mm, of the hatch coaming plate is not to be taken less than the greater value given by the following formulae:

$$t = 0.016b\sqrt{\frac{P_C}{0.95R_{eH}}}$$

t = 9.5

6.3.2 Stiffeners

The net section modulus, Z, in cm^3, of longitudinal or transverse stiffeners fitted on hatch coamings is not to be taken less than:

$$Z = 1.21\frac{P_C\ s\ \ell^2}{f_{bc}\ c_p\ R_{eH}}$$

where:

f_{bc} : Coefficient taken equal to:

f_{bc} = 16 in general.

f_{bc} = 12 for the end span of stiffeners sniped at the coaming corners.

c_p : Ratio of the plastic section modulus to the elastic section modulus of the stiffeners with an attached plate breadth, in mm, equal to 40 t, where t is the plate net thickness.

c_p = 1.16 in the absence of more precise evaluation.

6.3.3 Coaming stays

At the connection with deck, the net section modulus Z, in cm^3, and the net thickness t_w, in mm, of the coaming stays designed as beams with flange connected to the deck or sniped and fitted with a bracket (examples shown in Figure 2 and Figure 3) are to be taken not less than:

$$Z = \frac{s_C\ P_C\ H_C^2}{1.9\ R_{eH}}$$

$$t_w = \frac{s_C \, P_C \, H_C}{0.5 \, h \, R_{eH}}$$

where:

H_C : Stay height, in m.

s_C : Stay spacing, in mm.

h : Stay depth, in mm, at the connection with deck.

Figure 2 : Coaming stay (example 1)

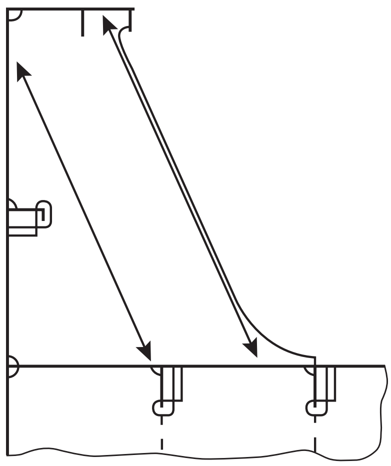
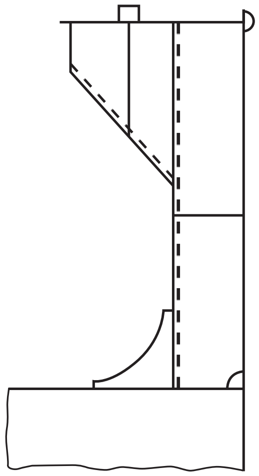


Figure 3 : Coaming stay (example 2)



For calculating of offered section modulus of coaming stays, the face plate area may be taken into account only when it is welded with full penetration welds to the deck plating and provided with adequate under deck structure supporting the coaming stay in the deck structure.

For other designs of coaming stays, such as those shown in Figure 4 and Figure 5, the stress levels determined through a grillage analysis or finite element analysis, as the case may be, apply and are to be checked at the highest stressed locations. The stress levels are to comply with the following formulae:

$\sigma \leq 0.95 \; R_{eH}$

$\tau \leq 0.5 \; R_{eH}$

Figure 4 : Coaming stay (example 3)

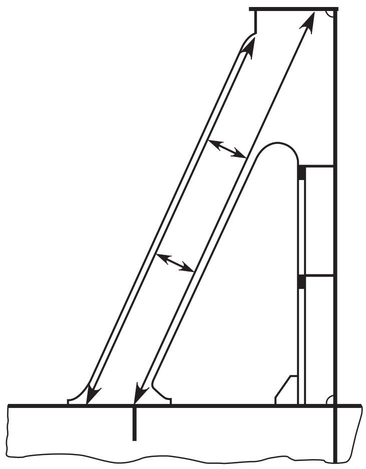
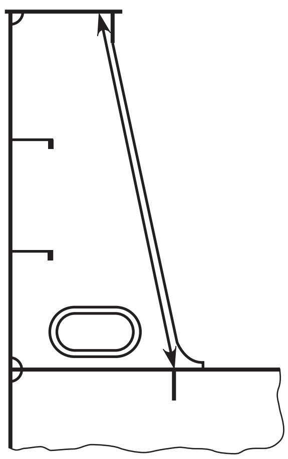


Figure 5 : Coaming stay (example 4)



6.3.4 Local details

The design of local details is to comply with the requirements in this section ensuring adequate structural continuity from the hatch covers into the supporting deck structure.

Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.

The normal stress σ and the shear stress τ, in N/mm^2, induced in the under deck structures by the loads transmitted by stays are to comply with the following formulae:

$\sigma \leq 0.95\ R_{eH}$

$\tau \leq 0.5\ R_{eH}$

Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the requirements of the Society.

Double continuous fillet welding is to be adopted for the connections of stay webs with deck plating and the weld leg length is not to be less than 0.62 t_w, where t_w is the gross thickness of the stay web.

Toes of stay webs are to be connected to the deck plating with partial penetration double bevel welds extending over a distance not less than 15% of the stay width.

7 WEATHERTIGHTNESS, CLOSING ARRANGEMENT, SECURING DEVICES AND STOPPERS

7.1 Weathertightness

7.1.1

Where the hatchway is exposed, the weathertightness is to be ensured by gaskets and clamping devices sufficient in number and quality.

7.1.2

In general, a minimum of two securing devices or equivalent is to be provided on each side of the hatch cover.

7.2 Gaskets

7.2.1

The weight of hatch covers and any cargo stowed thereon, together with inertia forces generated by ship motions, are to be transmitted to the ship's structure through steel to steel contact.

This may be achieved by providing continuous skirt plates on the hatch covers or by means of defined bearing pads.

7.2.2

The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness. Similar sealing is to be arranged between cross-joint elements.

Where fitted, compression flat bars or angles are to be well rounded where in contact with the gasket and to be made of a corrosion-resistant material.

7.2.3

The gasket and the securing arrangements are to maintain their efficiency when subjected to large relative movements between the hatch cover and the ship's structure or between hatch cover elements.

If necessary, suitable devices are to be fitted to limit such movements.

7.2.4

The gasket material is to be of a quality suitable for all environmental conditions likely to be encountered by the ship, and is to be compatible with the cargoes transported.

The material and form of gasket selected are to be considered in conjunction with the type of hatch cover, the securing arrangement and the expected relative movement between the hatch cover and the ship's structure.

The gasket is to be effectively secured to the hatch cover.

7.2.5

Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

7.2.6

Metallic contact is required to ensure earthing connection between the hatch cover and the hull structures.

7.3 Closing arrangement, securing devices and stoppers

7.3.1 General

Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced along the coamings and between cover elements.

Hatch covers provided with special sealing devices, insulated hatch covers, flush hatch covers and those having coamings of a reduced height according to [2.1.2] are to be considered by the Society on a case-by-case basis.

7.3.2 Arrangements

The securing and stopping devices are to be arranged so as to ensure sufficient compression on gaskets between hatch covers and coamings and between adjacent hatch covers.

Arrangement and spacing are to be determined with due attention to the effectiveness for weathertightness, depending on the type and the size of the hatch cover, as well as on the stiffness of the hatch cover edges between the securing devices.

At cross-joints of multi-panel covers, (male/female) vertical guides are to be fitted to prevent excessive relative vertical deflections between loaded/unloaded panels.

The location of stoppers is to be compatible with the relative movements between hatch covers and the ship's structure in order to prevent damage to them. The number of stoppers is to be as small as possible.

7.3.3 Spacing

The spacing of the securing arrangements is not to be greater than 6 m.

7.3.4 Construction

Securing arrangements with reduced scantlings may be accepted provided it can be demonstrated that the possibility of water reaching the deck is negligible.

Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or hatch covers.

Individual securing devices on each hatch cover are to have approximately the same stiffness characteristics.

7.3.5 Area of securing devices

The gross cross area of each securing device is not to be less than the value obtained, in cm^2, from the following formula:

$$A = 1.4\, S_S \left(\frac{235}{R_{eH}}\right)^{\alpha}$$

where:

S_S : Spacing, in m, of securing devices.

α : Coefficient taken equal to:

$\alpha = 0.75$ for $R_{eH} > 235$ N/mm^2.

$\alpha = 1.0$ for $R_{eH} \leq 235$ N/mm^2.

In the above calculations, R_{eH} may not be taken greater than 0.7 R_m.

Between hatch cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weathertightness is to be maintained by securing devices. For packing line pressures exceeding 5 N/mm, the net cross area A is to be increased in direct proportion. The packing line pressure is to be specified.

In the case of securing arrangements which are particularly stressed due to the unusual width of the hatchway, the net cross area A of the above securing arrangements is to be determined through direct calculations.

7.3.6 Inertia of edges elements

The hatch cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices.

The moment of inertia of edge elements is not to be less than the value obtained, in cm^4, from the following formula:

$I = 6\ P_L\ S_S^4$

where:

P_L : Packing line pressure, in N/mm, to be taken not less than 5.

S_S : Spacing, in m, of securing devices.

7.3.7 Diameter of rods or bolts

Rods or bolts are to have a gross diameter not less than 19 mm for hatchways exceeding 5 m^2 in area.

7.3.8 Stoppers

Hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m^2.

With the exclusion of No. 1 hatch cover, hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m^2.

No. 1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 230 kN/m^2. This pressure may be reduced to 175 kN/m^2 if a forecastle is fitted in accordance with Ch 1, Sec 1, [1].

The equivalent stress in stoppers, their supporting structures and calculated in the throat of the stopper welds is to be equal to or less than the allowable value, equal to 0.8 R_{eH}.

7.4 Cleats

7.4.1

Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

7.4.2

Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

8 DRAINAGE

8.1 Arrangement

8.1.1

Drainage is to be arranged inside the line of gaskets by means of a gutter bar or vertical extension of the hatch side and end coaming.

8.1.2

Drain openings are to be arranged at the ends of drain channels and are to be provided with efficient means for preventing ingress of water from outside, such as non-return valves or equivalent.

8.1.3

Cross-joints of multi-panel hatch covers are to be arranged with drainage of water from the space above the gasket and a drainage channel below the gasket.

8.1.4

If a continuous outer steel contact is arranged between the cover and the ship's structure, drainage from the space between the steel contact and the gasket is also to be provided.

SECTION 6
ADDITIONAL CLASS NOTATION GRAB

SYMBOLS

M_{GR} : Mass of unladen grab, in t.

1 GENERAL

1.1 Application

1.1.1

The additional class notation GRAB [X] is assigned, in accordance with Pt 1, Ch 1, Sec 1, [3.2.2], to ships with holds designed for loading/unloading by grabs having a maximum mass of unladen grab, in tons up to [X] tons, in compliance with the requirements of this section.

1.1.2

It is to be noted that this additional class notation does not negate the use of heavier grabs, but the owner and operators are to be made aware of the increased risk of local damage and possible early renewal of inner bottom plating if heavier grabs are used regularly or occasionally to discharge cargo.

2 SCANTLINGS

2.1 Plating

2.1.1 General

The net thickness of plating of inner bottom and vertical sloped cargo hold; excluding bilge wells, is to be taken as the greater of the following values:

- t, as obtained according to requirements in Pt 1, Ch 6 and Pt 1, Ch 7.
- t_{GR}, as defined in [2.1.2] and [2.1.3].

2.1.2 Inner bottom plating

The net thickness t_{GR}, in mm, of the inner bottom plating is to be obtained from the following formula:

$$t_{GR} = 0.62\sqrt{bk}\left(\frac{M_{GR}}{20}\right)^{0.25}$$

2.1.3 Vertical and sloped cargo hold boundaries

The net thickness t_{GR}, in mm, as defined in this sub-section apply to the following structural elements.

- Hopper tank sloped plating.
- Transverse lower stool plating.
- Transverse plane bulkhead plating.
- Face plates of transverse corrugated bulkheads without lower stool.
- Inner hull.

Up to a height of 3.0 m above, the lowest point of the inner bottom is to be obtained from the following formula:

$$t_{GR} = 0.55\sqrt{bk}\left(\frac{M_{GR}}{20}\right)^{0.25}$$

PART 2 CHAPTER 2

OIL TANKERS

Table of Contents

SECTION 1
GENERAL ARRANGEMENT DESIGN

1 GENERAL

1.1 General

1.1.1

This section covers the general structural arrangement requirements for oil tankers, which are based on national and international regulations.

2 SEPARATION OF CARGO TANKS

2.1 General

2.1.1

The cargo pump room, cargo tanks, slop tanks and cofferdams are to be positioned forward of machinery spaces. Main cargo control stations, control stations, accommodation and service spaces are to be positioned aft of cargo tanks, slop tanks and spaces which isolate cargo or slop tanks from machinery spaces, but not necessary aft of the oil fuel bunker tanks and ballast tanks.

2.1.2

A cofferdam is to be provided to separate the cargo tanks from the machinery space. Pump room, ballast tanks or fuel oil tanks may be considered as cofferdam for this purpose.

3 DOUBLE HULL ARRANGEMENT

3.1 General

3.1.1

All oil tankers are to be provided with double bottom tanks and spaces, and double side tanks and spaces, in accordance with Pt 1, Ch 2, Sec 3. The double bottom and double side tanks and spaces, protect the cargo tanks or spaces, and are not to be used for the carriage of oil cargoes.

3.1.2

Cargo tanks are to be of a size and arrangement that hypothetical oil outflow from side and bottom damage, anywhere in the length of the ship, is limited.

4 ACCESS ARRANGEMENTS

4.1 Special requirements for oil tankers

4.1.1

Where a duct keel or pipe tunnel is fitted, provision is to be made for at least two exits to the open deck arranged at a maximum distance from each other. The duct keel or pipe tunnel is not to pass into machinery

spaces. The aft access may lead from the pump room to the duct keel. Where an aft access is provided from the pump room to the duct keel, the access opening from the pump room to the duct keel is to be provided with an oil-tight cover plate or a watertight door.

Mechanical ventilation is to be provided and such spaces are to be sufficiently ventilated prior to entry. A notice board is to be fitted at each entrance to the pipe tunnel stating that before any attempt is made to enter, the ventilating fan must have been in operation for a sufficient period. In addition, the atmosphere in the tunnel is to be sampled by a gas monitor, and where an inert gas system is fitted in cargo tanks, an oxygen monitor is to be provided.

4.1.2

Where a watertight door is fitted in the pump room for access to the duct keel, the scantlings of the watertight door are to comply with the requirements of the individual Society and the following additional requirements:

a) The watertight door is to be capable of being manually closed from outside the main pump room entrance, in addition to bridge operation. A means of indicating whether the door is open or closed is to be provided locally and on the bridge.

b) A notice is to be affixed at each operating position to the effect that the watertight door is to be kept closed during normal operations of the ship, except when access to the pipe tunnel is required.

4.1.3

Special consideration is to be given to any proposals to fit permanent repair/maintenance access openings with oil-tight covers in cargo tank bulkheads. Attention is drawn to the relevant national regulations concerning load line and oil outflow aspects of such arrangements.

SECTION 2
STRUCTURAL DESIGN PRINCIPLES

1 CORROSION PROTECTION

1.1 General

1.1.1 Cathodic protection systems in cargo tanks

Cathodic protection systems, if fitted in cargo tanks, are to comply with [1.2].

1.1.2 Paint containing aluminium

Paint containing aluminium, when used in cargo tanks, is to comply with [1.3].

1.2 Internal cathodic protection systems

1.2.1

When a cathodic protection system is to be fitted to steel structures in tanks used for liquid cargo with flash point below 60°C, a plan of the fitting arrangement is to be submitted for approval. The arrangements are to be considered for safety against fire and explosion. This approval also applies to adjacent tanks.

1.2.2

Permanent anodes in tanks made of, or alloyed with magnesium are not acceptable, except in tanks solely intended for water ballast that are not adjacent to cargo tanks.

Impressed current systems are not to be used in cargo tanks due to the development of chlorine and hydrogen that can result in an explosion.

Aluminium anodes are accepted, however, in tanks with liquid cargo with flash point below 60°C and in adjacent ballast tanks, aluminium anodes are to be located so a kinetic energy of not more than 275 J is developed in the event of their loosening and becoming detached.

1.2.3

Aluminium anodes are to be located in such a way that they are protected from falling objects. They are not to be located under tank hatches or Butterworth openings unless protected by adjacent structure.

1.2.4

Tanks, in which anodes are installed, are to have sufficient holes for the circulation of air to prevent gas from collecting in pockets.

1.3 Paint containing aluminium

1.3.1

The use of aluminium coatings containing greater than 10% aluminium by weight in the dry film is prohibited in cargo tanks, cargo tank deck area, pump rooms, cofferdams or any other area where cargo vapour may accumulate unless it has been shown by appropriate tests that the paint to be used does not increase the incendiary sparking hazard. Tests need not be performed for coatings with less than 10% aluminium by weight.

1.3.2

Aluminised pipes may be permitted in ballast tanks, in inerted cargo tanks and, provided the pipes are protected from accidental impact, in hazardous areas on open deck.

SECTION 3
HULL LOCAL SCANTLING

SYMBOLS

For symbols not defined in this section, refer to Pt 1, Ch 1, Sec 4.

S : Primary supporting member spacing as defined in Pt 1, Ch 3, Sec 7, [1.2.2], in m.

$C_{t\text{-}pr}$: Permissible shear stress coefficient for primary supporting members taken equal to:

$C_{t\text{-}pr}$ = 0.70 for AC-S.

$C_{t\text{-}pr}$ = 0.85 for AC-SD.

$C_{s\text{-}pr}$: Permissible bending stress coefficient for primary supporting members taken equal to:

$C_{s\text{-}pr}$ = 0.70 for AC-S.

$C_{s\text{-}pr}$ = 0.85 for AC-SD.

s_{cg} : Half pitch length of corrugation, in mm. See Figure 4.

ℓ_{cg} : Length of corrugation, in m, which is defined as the distance between the lower stool and the upper stool. Where no lower or upper stool is fitted, ℓ_{cg} is to be measured to lower or upper end as shown in Figure 4.

1 PRIMARY SUPPORTING MEMBERS IN CARGO HOLD REGION

1.1 General

1.1.1

The following requirements relate to the determination of scantlings of the primary supporting members within 0.4 L amidships and those outside 0.4 L amidships provided that the geometry and fixation of primary supporting member is similar with those amidships.

1.1.2

The section modulus and shear area criteria for primary supporting members contained in this sub-section apply to structural configurations shown in Pt 1, Ch 1, Sec 1, Figure 3 and are applicable to the following structural elements:

a) Floors and girders within the double bottom,

b) Deck transverses,

c) Side transverses within double side structure,

d) Vertical web frames on longitudinal bulkheads with or without cross ties,

e) Horizontal stringers on transverse bulkheads, except those fitted with buttresses or other intermediate supports,

f) Cross ties in wing cargo and centre cargo tanks.

1.1.3

Floors, horizontal stringers, side transverses and vertical webs adjacent to transverse bulkheads which get additional supports by horizontal stringers or buttresses are excluded from the application of this section.

1.1.4

Webs of the primary supporting members are to be stiffened in accordance with Pt 1, Ch 8, Sec 2, [4].

1.1.5

Webs of the primary supporting members are to have a depth of not less than given by the requirements of [1.5.1], [1.7.1] and [1.8.1], as applicable.

1.1.6

In any case, primary supporting members that have open slots for stiffeners are to have a depth not less than 2.5 times the depth of the slots if slots are not closed.

1.1.7

Where it is impracticable to fit a primary supporting member with the required web depth, then it is permissible to fit a member with reduced depth provided that the fitted member has equivalent moment of inertia or deflection to the required member. The required equivalent moment of inertia is to be based on an equivalent section given by the effective width of plating at mid span with required plate thickness, web of required depth and thickness and face plate of sufficient width and thickness to satisfy the required mild steel section modulus.

The equivalent moment of inertia may be also demonstrated by an equivalent member having the same deflection as the required member.

All other rule requirements, such as minimum thicknesses, slenderness ratio, section modulus and shear area, are to be satisfied for the member of reduced depth.

1.2 Design load sets

1.2.1

The design load sets for the evaluation of primary supporting members are given in Table 1.

Table 1 : Design load sets for primary supporting members

Item	Design load set (1) (5) (6)	Load component	Draught	Design load	Loading condition
Double bottom floors and girders (3)	SEA-1	P_{ex}	$0.9T_{sc}$ (2)	S+D	Sea pressure only
	SEA-2	P_{ex}	T_{SC}	S	
	OT-4	$P_{in} - P_{ex}$	$0.6T_{sc}$	S+D	Net pressure difference between cargo pressure and sea pressure
	OT-5	$P_{in} - P_{ex}$	(4)	S	
Side transverses (3)	SEA-1	P_{ex}	$0.9T_{sc}$	S+D	Sea pressure only
	SEA-2	P_{ex}	T_{sc}	S	
	OT-1	P_{in}	T_{SC}	S+D	Cargo pressure only
	OT-2	P_{in}	$0.6T_{sc}$	S+D	
	OT-3	P_{in}	-	S	

Item	Design load set (1) (5) (6)	Load component	Draught	Design load	Loading condition
Deck transverses	SEA-1	P_{ex}	T_{sc}	S+D	Green sea pressure only or other loads on deck
	OT-1	P_{in}	T_{SC}	S+D	Cargo pressure only
	OT-2	P_{in}	$0.6T_{sc}$	S+D	
	OT-3	P_{in}	-	S	
Vertical web frames on longitudinal bulkheads	OT-1	P_{in}	T_{SC}	S+D	Pressure from one side only. Full cargo tank with adjacent cargo tank empty
	OT-2	P_{in}	$0.6T_{sc}$	S+D	
	OT-3	P_{in}	-	S	
Horizontal stringers on transverse bulkhead	OT-1	P_{in}	T_{SC}	S+D	Pressure from one side only. Full cargo tank with adjacent forward or aft cargo tank empty.
	OT-2	P_{in}	$0.6T_{sc}$	S+D	
	OT-3	P_{in}	-	S	
Cross ties in centre tanks	OT-1	$\dfrac{P_{in-pt}+P_{in-stb}}{2}$	T_{SC}	S+D	Full wing cargo tanks, centre tank empty.
	OT-2	$\dfrac{P_{in-pt}+P_{in-stb}}{2}$	$0.6T_{sc}$	S+D	
	OT-3	P_{in}	-	S	
Cross ties in wing tanks	OT-6	$\dfrac{P_{in}+P_{ex}}{2}$	T_{sc}	S+D	Full centre tank, wing cargo tanks empty.
	OT-7	$\dfrac{P_{in}+P_{ex}}{2}$	$0.6T_{sc}$	S+D	
	OT-8	$\dfrac{P_{in}+P_{ex}}{2}$	T_{sc}	S	

where:

P_{in-pt} : Design pressure from port side wing cargo tank, in kN/m^2.

P_{in-stb} : Design pressure from starboard side wing cargo tank, in kN/m^2.

(1) The static and dynamic load components are to be determined in accordance with Pt 1, Ch 4, Sec 7, Table 1.

(2) If the loading condition where the combination of an empty cargo tank and a mean ship's draught greater than 0.9 T_{sc} is included in ship's loading manual, the maximum corresponding draught is to be considered.

(3) Draughts specified for bottom floors, girders and side transverses are based on operational limits specified in Pt 1, Ch 4, Sec 8, [2] and Pt 1, Ch 4, Sec 8, [3]. Where the optional loading conditions exceed the minimum Rule required loading conditions, the draughts will be subject to special consideration.

(4) For tankers with two oil-tight longitudinal bulkheads, the draught is to be taken as 0.25 T_{sc}. For tankers with a centreline bulkhead, the draught is to be taken as 0.33 T_{sc}.

(5) When the ship's configuration cannot be described by the structural members or structural configurations identified above, then the applicable Design Load Sets to determine the scantling requirements of primary supporting member are to be selected so as to specify all applicable cases from the following:

- A full tank on one side of the member with the tank or space on the other side empty.
- A full tank on one side of the member with the external pressure minimised.
- External pressure maximised with the adjacent tank or space empty.

The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents and are to maximise the net pressure on the structural boundary, the draught to use is to be taken in accordance with the Design Load Set and this table. Design Load Sets covering the S and S+D design load combinations are to be selected.

(6) For a void or dry space, the pressure component from the void side is to be ignored.

1.3 Floors in double bottom

1.3.1 Structural arrangement

Plate floors are to be arranged in way of transverse bulkheads and bulkhead stools.

1.3.2 Net shear area

The net shear area, $A_{shr\text{-}n50}$ in cm^2, of the floors at any position in the floor is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\ \tau_{eH}}$$

where:

Q : Design shear force, in kN.

$$Q = f_{shr}\, P\, S\, \ell_{shr}$$

f_{shr} : Shear force distribution factor:

$$f_{shr} = f_{shr-i}\left(1 - \frac{2y_i}{\ell_{shr}}\right)$$ but not to be taken as less than 0.2.

$f_{shr\text{-}i}$: Shear force distribution factor at the end of the span, ℓ_{shr}, as given in Table 2.

ℓ_{shr} : Effective shear span, of the double bottom floor, in m, as shown in Figure 2. In way of bracket ends, the effective shear span is measured to the toes of the effective end bracket, as defined in Pt 1, Ch 3, Sec 7, [1.1.7]. Where the floor ends on a girder at a hopper or stool structure, the effective shear span is measured to a point that is one-half of the distance from the girder to the adjacent bottom and inner-bottom longitudinal, as shown in Figure 2.

y_i : Distance from the considered cross section of the floor to the nearest end of the effective shear span, ℓ_{shr} in m.

P : Design pressure given in Table 1 for the design load set being considered, calculated at mid point of effective shear span, ℓ_{shr} of a floor located midway between transverse bulkheads or transverse bulkhead and wash bulkhead, where fitted, in kN/m^2.

Table 2 : Shear force distribution factors of floors

Structural configuration	Centre tank (f_{shr3} in Figure 1)	Wing tank	
		At inboard end (f_{shr2} in Figure 1)	At hopper knuckle end (f_{shr1} in Figure 1)
Ships with centreline longitudinal bulkhead	-	0.40	0.60
Ships with two longitudinal bulkheads	0.5	0.50	0.65

Figure 1 : Shear force distribution factors of floors

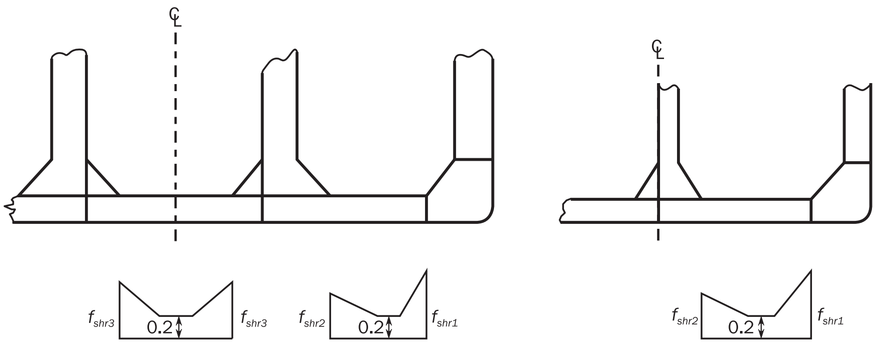
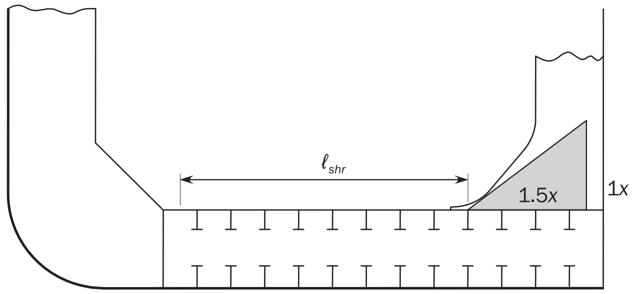
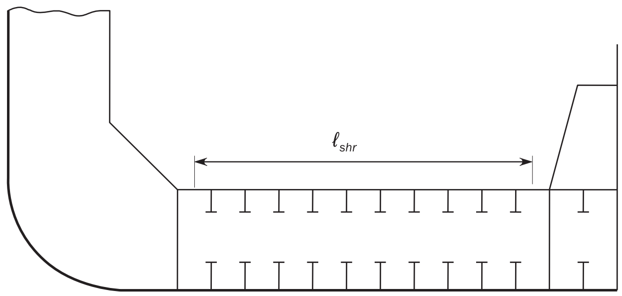


Figure 2 : Effective shear span of floors



Typical arrangement with hopper and end bracket



Typical arrangement with hopper and stool

1.4 Girders in double bottom

1.4.1 Structural arrangement

Continuous double bottom girders are to be arranged at the centreline or duct keel, at the hopper side and in way of longitudinal bulkheads and bulkhead stools.

1.4.2 Net shear area of centre girders

For double bottom centre girders where no longitudinal bulkhead is fitted above, the net shear area, $A_{shr\text{-}n50}$ in cm^2, of the double bottom centre girder in way of the first bay from each transverse bulkhead and wash bulkhead, where fitted, is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\,\tau_{eH}}$$

where:

Q : Design shear force, in kN, taken as:

$$Q = 0.21\, n_1\, n_2\, P\, \ell_{shr}^2$$

ℓ_{shr} : Effective shear span as defined in [1.3.2].

P : Design pressure, in kN/m^2, as defined in [1.3.2].

n_1 : Coefficient taken as:

$$n_1 = 0.00935\left(\frac{\ell_{shr}}{S}\right)^2 - 0.163\left(\frac{\ell_{shr}}{S}\right) + 1.289$$

n_2 : Coefficient taken as:

$$n_2 = 1.3 - \left(\frac{S}{12}\right)$$

1.4.3 Net shear area of side girders

For double bottom side girders where no longitudinal bulkhead is fitted above, the net shear area, $A_{shr\text{-}n50}$ in cm^2, of the double bottom side girder in way of the first bay from each transverse bulkhead and wash bulkhead, where fitted, is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\ \tau_{eH}}$$

where:

Q : Design shear force, in kN.

$$Q = 0.14\ n_3\ n_4\ P\ \ell_{shr}^2$$

n_3 : Coefficient taken as:

$$n_3 = 1.072 - 0.0357\left(\frac{\ell_{shr}}{S}\right)$$

n_4 : Coefficient taken as:

$$n_4 = 1.2 - \left(\frac{S}{18}\right)$$

ℓ_{shr} : Effective shear span as defined in [1.3.2].

P : Design pressure, in kN/m^2, as defined in [1.3.2].

1.5 Deck transverses

1.5.1 Web depth

The web depth of under deck transverses is not to be less than:

- 0.20 $\ell_{bdg\text{-}dt}$ for deck transverses in the wing cargo tanks of ships with two longitudinal bulkheads.
- 0.13 $\ell_{bdg\text{-}dt}$ for deck transverses in the centre cargo tanks of ships with two longitudinal bulkheads. The web depth of deck transverses in the centre cargo tank is not to be less than 90% of that of the deck transverses in the wing cargo tank.
- 0.10 $\ell_{bdg\text{-}dt}$ for the deck transverses of ships with a centreline longitudinal bulkhead.
- The web height required in [1.1.6].

The web depth of above deck transverses is not to be less than:

- 0.10 $\ell_{bdg\text{-}dt}$
- The web height required in [1.1.6].

where:

$\ell_{bdg\text{-}dt}$: Effective bending span, in m, as defined in [1.5.2].

1.5.2 Net section modulus of deck transverses fitted below the upper deck

The net section modulus of deck transverses fitted below the upper deck, in cm^3, is not to be less than $Z_{in\text{-}n50}$ and $Z_{ex\text{-}n50}$ as given by the following formulae.

The net section modulus of the deck transverses fitted below the upper deck in the wing cargo tanks is also not to be less than required for the deck transverses fitted below the upper deck in the centre tanks.

$$Z_{in-n50} = \frac{850\ M_{in}}{C_{s-pr}\ R_{eH}}$$

$$Z_{ex-n50} = \frac{850\ M_{ex}}{C_{s-pr}\ R_{eH}}$$

where:

M_{in} : Design bending moment due to cargo pressure, in kNm, taken as:

- For deck transverses in wing cargo tanks of ships with two longitudinal bulkheads, and for deck transverses in cargo tanks of ships with a centreline longitudinal bulkhead:

  $M_{in} = 0.042\ \varphi_t\ P_{in-dt}\ S\ \ell_{bdg-dt}^2 + M_{st}$ but is not to be taken as less than M_0.

- For deck transverses in centre cargo tank of ships with two longitudinal bulkheads:

  $M_{in} = 0.042\ \varphi_t\ P_{in-dt}\ S\ \ell_{bdg-dt}^2 + M_{vw}$ but is not to be taken as less than M_0.

M_{st} : Bending moment transferred from the side transverse, in kNm:

$$M_{st} = c_{st}\ \beta_{st}\ P_{in-st}\ S\ \ell_{bdg-st}^2$$

where a cross tie is fitted in a wing cargo tank and $\ell_{bdg-st-ct}$ is greater than 0.7 ℓ_{bdg-st}, then ℓ_{bdg-st} in the above formula may be taken as $\ell_{bdg-st-ct}$.

M_{vw} : Bending moment transferred from the vertical web frame on the longitudinal bulkhead, in kNm:

$$M_{vw} = c_{vw}\ \beta_{vw}\ P_{in-vw}\ S\ \ell_{bdg-vw}^2$$

where $\ell_{bdg-vw-ct}$ is greater than 0.7 ℓ_{bdg-vw}, then ℓ_{bdg-vw} in the above formula may be taken as $\ell_{bdg-vw-ct}$. For vertically corrugated bulkheads, M_{vw} is to be taken equal to bending moment in upper end of corrugation over the spacing between deck transverses.

M_0 : Minimum bending moment, in kNm.

$$M_0 = 0.083\ P_{in-dt}\ S\ \ell_{bdg-dt}^2$$

M_{ex} : Design bending moment due to green sea pressure, in kNm.

$$M_{ex} = 0.067\ P_{ex-dt}\ S\ \ell_{bdg-dt}^2$$

P_{in-dt} : Design cargo pressure given in Table 1 for the design load set being considered, calculated at mid-point of effective bending span, ℓ_{bdg-dt} of the deck transverse located at mid tank, in kN/m^2.

P_{in-st} : Corresponding design cargo pressure in wing cargo tank given in Table 1 for the design load set being considered, calculated at the mid-point of effective bending span, ℓ_{bdg-st} of the side transverse located at mid-tank, in kN/m^2.

P_{in-vw} : Corresponding design cargo pressure in the centre cargo tank of ships with two longitudinal bulkheads given in Table 1 for the design load set being considered, calculated at mid-point of effective bending span, ℓ_{bdg-vw} of the vertical web frame on the longitudinal bulkhead located at mid-tank, in kN/m^2.

P_{ex-dt} : Design green sea pressure given in Table 1 for the design load set being considered, calculated at mid-point of effective bending span, ℓ_{bdg-dt} of the deck transverse located at mid tank, in kN/m^2.

φ_t : Coefficient taken as:

$\varphi_t = 1 - 5\left(\frac{y_{toe}}{\ell_{bdg-dt}}\right)$ but not taken less than 0.6.

y_{toe} : Distance from the end of effective bending span, ℓ_{bdg-dt} to the toe of the end bracket of the deck transverse, in m.

β_{st} : Coefficient taken as:

$$\beta_{st} = 0.9\left(\frac{\ell_{bdg-st}}{\ell_{bdg-dt}}\right)\left(\frac{I_{dt-n50}}{I_{st-n50}}\right)$$ but not taken less than 0.10 or greater than 0.65.

β_{vw} : Coefficient taken as:

$$\beta_{vw} = 0.9\left(\frac{\ell_{bdg-vw}}{\ell_{bdg-dt}}\right)\left(\frac{I_{dt-n50}}{I_{vw-n50}}\right)$$ but not taken less than 0.10 or greater than 0.50.

ℓ_{bdg-dt} : Effective bending span of the deck transverse, in m, see Pt 1, Ch 3, Sec 7, [1.1.6] and Figure 3, but is not to be taken as less than 60% of the breadth of the tank at the location being considered.

ℓ_{bdg-st} : Effective bending span of the side transverse, in m, between the deck transverse and the bilge hopper, see Pt 1, Ch 3, Sec 7, [1.1.6] and Figure 3.

$\ell_{bdg-st-ct}$: Effective bending span of the side transverse, in m, between the deck transverse and the mid depth of the cross tie, where fitted in wing cargo tank, see Pt 1, Ch 3, Sec 7, [1.1.6].

ℓ_{bdg-vw} : Effective bending span of the vertical web frame on the longitudinal bulkhead, in m, between the deck transverse and the bottom structure, see Pt 1, Ch 3, Sec 7, [1.1.6] and Figure 3.

$\ell_{bdg-vw-ct}$: Effective bending span of the vertical web frame on longitudinal bulkhead, in m, between the deck transverse and the mid depth of the cross tie, see Pt 1, Ch 3, Sec 7, [1.1.6].

I_{dt-n50} : Net moment of inertia of the deck transverse at mid-span with an effective breadth of attached plating specified in Pt 1, Ch 3, Sec 7, [1.3.2], in cm^4.

I_{st-n50} : Net moment of inertia of the side transverse at mid-span with an effective breadth of attached plating specified in Pt 1, Ch 3, Sec 7, [1.3.2], in cm^4.

I_{vw-n50} : Net moment of inertia of the longitudinal bulkhead vertical web frame at mid-span with an effective breadth of attached plating specified in Pt 1, Ch 3, Sec 7, [1.3.2], in cm^4.

c_{st} : Coefficient given in Table 3.

c_{vw} : Coefficient given in Table 3.

Table 3 : Values of c_{st} and c_{vw} for deck transverses

Structural configuration			c_{st}	c_{vw}
Ships with centreline longitudinal bulkhead			0.056	-
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank	M_{vw} based on $\ell_{bdg-vw-ct}$	-	0.044
		M_{st} based on ℓ_{bdg-st} or M_{vw} based on ℓ_{bdg-vw}	0.044	0.016
	Cross ties in wing cargo tanks	M_{st} based on $\ell_{bdg-st-ct}$ or M_{vw} based on $\ell_{bdg-vw-ct}$	0.044	0.044
		M_{st} based on ℓ_{bdg-st} or M_{vw} based on ℓ_{bdg-vw}	0.041	0.015

1.5.3 Net shear area of deck transverses fitted below the upper deck

The net shear area of deck transverses fitted below the upper deck, in cm^2, is not to be less than $A_{shr-in-n50}$ and $A_{shr-ex-n50}$ as given by:

$$A_{shr-in-n50} = \frac{8.5Q_{in}}{C_{t-pr}\ \tau_{eH}}$$

$$A_{shr-ex-n50} = \frac{8.5Q_{ex}}{C_{t-pr}\ \tau_{eH}}$$

where:

Q_{in} : Design shear force due to cargo pressure, in kN.

$$Q_{in} = 0.65\ P_{in-dt}\ S\ \ell_{shr} + c_1\ D\ b_{ctr}\ S\ \rho_L\ g$$

Q_{ex} : Design shear force due to green sea pressure, in kN.

$$Q_{ex} = 0.65\ P_{ex-dt}\ S\ \ell_{shr}$$

$P_{in\text{-}dt}$: Design pressure in kN/m^2, defined in [1.5.2].

$P_{ex\text{-}dt}$: Design pressure in kN/m^2, defined in [1.5.2].

$\ell_{bdg\text{-}dt}$: Effective span, in m, defined in [1.5.2].

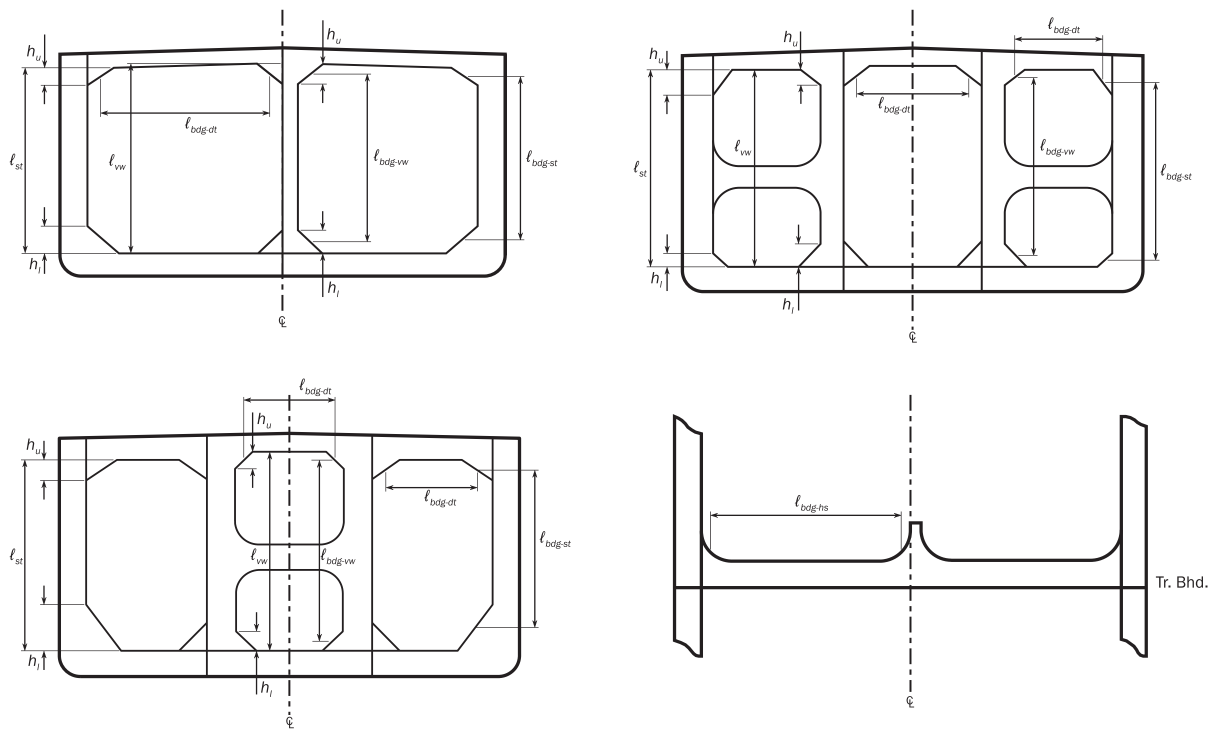
ℓ_{shr} : Effective shear span, of the deck transverse, in m, see Pt 1, Ch 3, Sec 7, [1.1.7].

c_1 : Coefficient taken as:

- c_1 = 0.04 in way of wing cargo tanks of ships with two longitudinal bulkheads.
- c_1 = 0.00 in way of centre tank of ships with two longitudinal bulkheads.
- c_1 = 0.00 for ships with a centreline longitudinal bulkhead.

b_{ctr} : Breadth of the centre tank, in m.

Figure 3 : Definition of spans of deck, side transverses, vertical web frames on longitudinal bulkheads and horizontal stringers on transverse bulkheads



1.5.4 Deck transverses fitted above the upper deck

When deck transverses are fitted above the upper deck, the net section modulus and shear area of deck transverses are not to be less than Z_{n50} and $A_{shr\text{-}n50}$, in cm^3 and cm^2 respectively, as given by the following formulae. The required section modulus and shear area are to be maintained over the full length of span.

$$z_{n50} = \frac{850\ |P| S \ell_{bdg}^2}{f_{bdg} C_{s-pr} R_{eH}}$$

$$A_{shr-n50} = \frac{8.5\ f_{shr} |P| S \ell_{shr}}{C_{t-pr}\ \tau_{eH}}$$

where:

P : Design pressure given in Table 1 for the design load set being considered, calculated at midpoint of effective bending span, ℓ_{bdg} of the deck transverse located at mid tank, in kN/m^2.

f_{bdg} : Coefficient taken as:

f_{bdg} = 12 for design load set OT-1, OT-2 and OT-3 as defined in Table 1.

f_{bdg} = 15 for design load set SEA-1 as defined in Table 1.

f_{shr} : Coefficient taken as:

f_{shr} = 0.5

l_{bdg} : Effective bending span of the deck transverse fitted above upper deck, in m, measured from inner hull welded to deck to longitudinal bulkhead, or upper stool plating where upper stool is fitted

l_{shr} : Effective shear span of the deck transverse fitted above upper deck, in m, measured from inner hull welded to deck to longitudinal bulkhead, or upper stool plating where upper stool is fitted

As an alternative, the required section modulus and shear area may be obtained by finite element method in accordance with Pt 1, Ch 7 and with in consideration of loading patterns A1, A2 or B1, B2 as defined in Pt 1, Ch 4, Sec 8, [3.2.9] with draught equal to T_{sc} and cargo density of 1.025 t/m^3.

1.5.5 Deck transverse adjacent to transverse bulkhead

The scantling of deck transverse adjacent to the transverse bulkhead is to comply with the requirements of [1.5.2] to [1.5.4] for design green sea pressure only.

1.6 Side transverses

1.6.1 Net shear area

The net shear area, $A_{shr-n50}$, in cm^2, of side transverses is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\ \tau_{eH}}$$

where:

Q : Design shear force as follows, in kN:

$Q = Q_u$ for upper part of the side transverse.

$Q = Q_l$ for lower part of the side transverse.

Q_u : Shear force, in kN, taken as:

$$Q_u = S\,[c_u\ \ell_{st}\,(P_u + P_l) - h_u\ P_u]$$

where a cross tie is fitted in a wing cargo tank and ℓ_{st-ct} is greater than 0.7 ℓ_{st}, then ℓ_{st} in the above formula is taken as ℓ_{st-ct}.

Q_l : Shear force, in kN, taken as the greater of the following:

- $S\,[c_l\ \ell_{st}\,(P_u + P_l) - h_l\ P_l]$
- $0.35\,c_l\,S\,\ell_{st}\ (P_u + P_l)$
- $1.2\,Q_u$

where a cross tie is fitted in a wing cargo tank and ℓ_{st-ct} is greater than 0.7 ℓ_{st}, then ℓ_{st} in the above formula is taken as ℓ_{st-ct}.

P_u : Design pressure given in Table 1 for the design load set being considered, in kN/m^2, calculated at mid length of tank and at mid height of h_u.

P_l : Design pressure given in Table 1 for the design load set being considered, calculated at mid height h_l located at mid length of tank, in kN/m^2.

ℓ_{st} : Length of the side transverse, in m, taken as follows:

- Where deck transverses are fitted below deck, ℓ_{st} is the length between the flange of the deck transverse and the inner bottom, see Figure 3.
- Where deck transverses are fitted above deck, ℓ_{st} is the length between the elevation of the deck at side and the inner bottom.

$\ell_{st\text{-}ct}$: Length of the side transverse, in m, taken as follows:

- Where deck transverses are fitted below deck, $\ell_{st\text{-}ct}$ is the length between the flange of the deck transverse and mid depth of cross tie, where fitted in wing cargo tank.
- Where deck transverses are fitted above deck, $\ell_{st\text{-}ct}$ is the length between the elevation of the deck at side and mid depth of the cross tie, where fitted in wing cargo tank.

h_u : Effective length of upper bracket of the side transverse, in m, taken as follows:

- Where deck transverses are fitted below deck, h_u is as shown in Figure 3.
- Where deck transverses are fitted above deck:
  - When an inner hull longitudinal bulkhead is arranged with a top wing structure as follows, h_u is taken as the distance between the deck at side and the lower end of slope plate of the top wing structure:
    - The breadth at top of the wing structure is greater than 1.5 times the breadth of the double side and.
    - The angle along a line between the point at base of the slope plate at its intersection with the inner hull longitudinal bulkhead and the point at the intersection of top wing structure and deck is 30 deg or more to vertical.
  - In the other cases: h_u is taken as 0.

h_l : Height of bilge hopper, in m, as shown in Figure 3.

c_u : Coefficient defined in Table 4.

c_l : Coefficient defined in Table 4.

Table 4 : Values of c_u and c_l for side transverses

<table>
<tr><th colspan="3">Structural configuration</th><th colspan="2">c_u</th><th colspan="2">c_l</th></tr>
<tr><td colspan="3">Number of side stringers</td><td>Less than three</td><td>Equal to or greater than three</td><td>Less than three</td><td>Equal to or greater than three</td></tr>
<tr><td colspan="3">Ships with a centreline longitudinal bulkhead</td><td rowspan="3">0.12</td><td rowspan="3">0.09</td><td rowspan="3">0.29</td><td rowspan="3">0.21</td></tr>
<tr><td rowspan="3">Ships with two longitudinal bulkheads</td><td colspan="2">Cross tie in centre cargo tank</td></tr>
<tr><td rowspan="2">Cross ties in wing cargo tanks</td><td>Q_u or Q_l based on $\ell_{st\text{-}ct}$</td></tr>
<tr><td>Q_u or Q_l based on ℓ_{st}</td><td colspan="2">0.08</td><td colspan="2">0.20</td></tr>
</table>

1.6.2 Shear area over the length of the side transverse

The shear area over the length of the side transverse is to comply with the following. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

a) The required shear area for the upper part is to be maintained over the upper 0.2 ℓ_{shr}.

b) The required shear area for the lower part is to be maintained over the lower 0.2 ℓ_{shr}.

c) Where Q_u and Q_l are determined based on $\ell_{st\text{-}ct}$, the required shear area for the lower part is also to be maintained below the cross tie.

d) For ships without cross ties in the wing cargo tanks, the required shear area between the upper and lower parts is to be reduced linearly towards 50% of the required shear area for the lower part at mid-span.

e) For ships with cross ties in the wing cargo tanks, the required shear area along the span is to be tapered linearly between the upper and lower parts.

where:

ℓ_{shr} : Effective shear span of the side transverse, in m.

$\ell_{shr} = \ell_{st} - h_u - h_l$ where Q_u and Q_l are determined based on ℓ_{st}.

$\ell_{shr} = \ell_{st-ct} - h_u$ where Q_u and Q_l are determined based on $\ell_{st\text{-}ct}$.

ℓ_{st}, $\ell_{st\text{-}ct}$, h_u, h_l, Q_u, Q_l : Parameters defined in [1.6.1].

1.7 Vertical web frames on longitudinal bulkhead

1.7.1 Web depth

The web depth of the vertical web frame on the longitudinal bulkhead is not to be less than:

- 0.14 $\ell_{bdg\text{-}vw}$ for ships with a centreline longitudinal bulkhead.
- 0.09 $\ell_{bdg\text{-}vw}$ for ships with two longitudinal bulkheads.
- The web height required in [1.1.6].

where:

$\ell_{bdg\text{-}vw}$: Effective bending span, in m, defined in [1.7.2].

1.7.2 Net section modulus

The net section modulus, Z_{n50} in cm^3, of the vertical web frame is not to be less than:

$$Z_{n50} = \frac{850M}{C_{s-pr}\, R_{eH}}$$

where:

M : Design bending moment, in kNm, as follows:

$M = c_u\, P\, S\, \ell_{bdg-vw}^2$ for upper part of the web frame.

$M = c_l\, P\, S\, \ell_{bdg-vw}^2$ for lower part of the web frame.

where a cross tie is fitted and $\ell_{bdg\text{-}vw\text{-}ct}$ is greater than 0.7 $\ell_{bdg\text{-}vw}$, then $\ell_{bdg\text{-}vw}$ in the above formula is to be taken as $\ell_{bdg\text{-}vw\text{-}ct}$.

P : Design pressure given in Table 1 for the design load set being considered, calculated at mid-point of the effective bending span, $\ell_{bdg\text{-}vw}$ of the vertical web frame located at mid tank, in kN/m^2.

$\ell_{bdg\text{-}vw}$: Effective bending span of the vertical web frame on the longitudinal bulkhead, between the deck transverse and the bottom structure, in m, see Figure 3.

$\ell_{bdg\text{-}vw\text{-}ct}$: Effective bending span of the vertical web frame on longitudinal bulkhead, between the deck transverse and mid-depth of the cross tie on ships with two longitudinal bulkheads, in m.

c_u : Coefficient defined in Table 5.

c_l : Coefficient defined in Table 5.

Table 5 : Values of c_u and c_l for vertical web frame on longitudinal bulkheads

Structural configuration			c_u	c_l
Ships with a centreline longitudinal bulkhead			0.057	0.071
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank	M based on $\ell_{bdg\text{-}vw\text{-}ct}$	0.057	0.071
		M based on $\ell_{bdg\text{-}vw}$	0.012	0.028
	Cross ties in wing cargo tanks	M based on $\ell_{bdg\text{-}vw\text{-}ct}$	0.057	0.071
		M based on $\ell_{bdg\text{-}vw}$	0.016	0.032

1.7.3 Section modulus over the length of the vertical web frame

The section modulus over the length of the vertical web frame on the longitudinal bulkhead is to comply with the following. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

a) The required section modulus for the upper part is to be maintained over the upper 0.2 $\ell_{bdg\text{-}vw}$ or 0.2 $\ell_{bdg\text{-}vw\text{-}ct}$ as applicable.

b) The required section modulus for the lower part is to be maintained over the lower 0.2 $\ell_{bdg\text{-}vw}$ or 0.2 $\ell_{bdg\text{-}vw\text{-}ct}$ as applicable.

c) Where the required section modulus is determined based on $\ell_{bdg\text{-}vw\text{-}ct}$, the required section modulus for the lower part is also to be maintained below the cross tie.

d) The required section modulus between the upper and lower parts is to be reduced linearly to 70% of the required section modulus for the lower part at mid-span.

where:

$\ell_{bdg\text{-}vw}$, $\ell_{bdg\text{-}vw\text{-}ct}$: Effective bending span, in m, defined in [1.7.2].

1.7.4 Net shear area

The net shear area, $A_{shr\text{-}n50}$ in cm^2, of the vertical web frame is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\ \tau_{eH}}$$

where:

Q : Design shear force as follows, in kN:

$Q = Q_u$ for upper part of the web frame.

$Q = Q_l$ for lower part of the web frame.

Q_u : Shear force, in kN, taken as:

$$Q_u = S\,[c_u\ \ell_{vw}\,(P_u + P_l) - h_u\ P_u]$$

where a cross tie is fitted in a centre or wing cargo tank and $\ell_{vw\text{-}ct}$ is greater than 0.7 ℓ_{vw}, then ℓ_{vw} in the above formula is to be taken as $\ell_{vw\text{-}ct}$.

Q_l : Shear force, in kN, taken as the greater of the following:

- $S\,[c_l\ \ell_{vw}(P_u + P_l) - h_l\ P_l]$
- $c_w\ S\ c_l\ \ell_{vw}(P_u + P_l)$
- $1.2\ Q_u$

where a cross tie is fitted in a centre or wing cargo tank and $\ell_{vw\text{-}ct}$ is greater than 0.7 ℓ_{vw}, then ℓ_{vw} in the above formula is to be taken as $\ell_{vw\text{-}ct}$.

P_u : Design pressure given in Table 1 for the design load set being considered, calculated at mid-height of upper bracket of the vertical web frame, h_u located at mid tank, in kN/m^2.

P_l : Design pressure given in Table 1 for the design load set being considered, calculated at mid-height of lower bracket of the vertical web frame, h_l located at mid tank, in kN/m^2.

ℓ_{vw} : Length of the vertical web frame, in m, between the flange of the deck transverse and the inner bottom, see Figure 3.

$\ell_{vw\text{-}ct}$: Length of the vertical web frame, in m, between the flange of the deck transverse and mid-depth of the cross tie, where fitted.

h_u : Effective length of upper bracket of the vertical web frame, in m, as shown in Figure 3.

h_l : Effective length of lower bracket of the vertical web frame, in m, as shown in Figure 3.

c_u : Coefficient defined in Table 6.

c_l : Coefficient defined in Table 6.

c_w : Coefficient taken as:

- c_w = 0.57 for ships with a centreline longitudinal bulkhead,
- c_w = 0.50 for ships with two longitudinal bulkheads.

Table 6 : Values of c_u and c_l for vertical web frame on longitudinal bulkhead

Structural configuration		c_u	c_l
Ships with a centreline longitudinal bulkhead		0.17	0.28
Ships with two longitudinal bulkheads	Q_u or Q_l based on $\ell_{vw\text{-}ct}$		
	Q_u or Q_l based on ℓ_{vw}	0.075	0.18

1.7.5 Shear area over the length of the vertical web frame

The shear area over the length of the vertical web frame on the longitudinal bulkhead is to comply with the following. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

a) The required shear area for the upper part is to be maintained over the upper 0.2 ℓ_{shr}.

b) The required shear area for the lower part is to be maintained over the lower 0.2 ℓ_{shr}.

c) Where Q_u and Q_l are determined based on $\ell_{vw\text{-}ct}$, the required shear area for the lower part is also to be maintained below the cross tie.

d) For ships without cross ties in the wing or centre cargo tanks, the required shear area between the upper and lower parts is to be reduced linearly towards 50% of the required shear area for the lower part at mid-span.

e) For ships with cross ties in the wing or centre cargo tanks, the required shear area along the span is to be tapered linearly between the upper and lower parts.

where:

ℓ_{shr} : Effective shear span of the vertical web frame, in m.

$\ell_{shr} = \ell_{vw} - h_u - h_l$ where Q_u and Q_l are determined based on ℓ_{vw}.

$\ell_{shr} = \ell_{vw-ct} - h_u$ where Q_u and Q_l are determined based on $\ell_{vw\text{-}ct}$.

ℓ_{vw}, $\ell_{vw\text{-}ct}$, h_u, h_l, Q_u, Q_l : Parameters defined in [1.7.4].

1.8 Horizontal stringers on transverse bulkheads

1.8.1 Web depth

The web depth of horizontal stringers on transverse bulkhead is not to be less than:

- 0.28 $\ell_{bdg\text{-}hs}$ for horizontal stringers in wing cargo tanks of ships with two longitudinal bulkheads.
- 0.20 $\ell_{bdg\text{-}hs}$ for horizontal stringers in centre tanks of ships with two longitudinal bulkheads, but the web depth of horizontal stringers in centre tank is not to be less than required depth for a horizontal stringer in wing cargo tanks.
- 0.20 $\ell_{bdg\text{-}hs}$ for horizontal stringers of ships with a centreline longitudinal bulkhead.
- The web height required in [1.1.6].

where:

$\ell_{bdg\text{-}hs}$: Effective bending span, in m, defined in [1.8.2].

1.8.2 Net section modulus

The net section modulus, Z_{n50} in cm^3, of the horizontal stringer over the end 0.2 $\ell_{bdg\text{-}hs}$ is not to be less than:

$$Z_{n50} = \frac{850M}{C_{s-pr}\ R_{eH}}$$

where:

M : Design bending moment, in kNm.

$$M = c\ P\ S\ \ell_{bdg-hs}^2$$

P : Design pressure given in Table 1 for the design load set being considered, calculated at mid-point of effective bending span, $\ell_{bdg\text{-}hs}$ and at mid-point of the spacing, S of the horizontal stringer, in kN/m^2.

$\ell_{bdg\text{-}hs}$: Effective bending span of the horizontal stringer, in m, but is not to be taken as less than 50% of the breadth of the tank at the location being considered, see Figure 3.

c : Coefficient taken as:

- c = 0.073 for horizontal stringers in cargo tanks of ships with a centreline bulkhead.
- c = 0.083 for horizontal stringers in wing cargo tanks of ships with two longitudinal bulkheads.
- c = 0.063 for horizontal stringers in the centre tank of ships with two longitudinal bulkheads.

1.8.3 Section modulus over the length of horizontal stringers

The required section modulus at mid effective bending span is to be taken as 70% of that required at the ends, intermediate values are to be obtained by linear interpolation. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

1.8.4 Net shear area

The net shear area, $A_{shr\text{-}n50}$ in cm^2, of the horizontal stringer over the end 0.2 ℓ_{shr} is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\ \tau_{eH}}$$

where:

Q : Design shear force, in kN.

$$Q = 0.5P\ S_{hs}\ \ell_{shr}$$

P : Design pressure given in Table 1 for the design load set being considered, calculated at mid-point of effective bending span, $\ell_{bdg\text{-}hs}$ and at mid-point of the spacing, S of the horizontal stringer, in kN/m².

S_{hs} : Spacing, in m, defined in [1.8.2].

ℓ_{shr} : Effective shear span of the horizontal stringer, in m.

1.8.5 Shear area at mid effective shear span

The required shear area at mid effective shear span is to be taken as 50% of that required in the ends, intermediate values are to be obtained by linear interpolation. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

1.9 Cross ties

1.9.1 Maximum applied design axial load

The maximum applied design axial load on cross ties, W_{ct} is to be less than or equal to the permissible load, $W_{ct\text{-}perm}$ as given by:

$$W_{ct} \le W_{ct-perm}$$

where:

W_{ct} : Applied axial load, in kN.

$$W_{ct} = P\, b_{ct}\, S$$

$W_{ct\text{-}perm}$: Permissible load, in kN.

$$W_{ct-perm} = 0.12\, A_{ct-n50}\, \eta_{all}\, \sigma_{cr}$$

P : Maximum design pressure for all the applicable design load sets being considered given in Table 1, calculated at centre of the area supported by the cross tie located at mid tank, in kN/m².

b_{ct} : Span, in m, taken as:

- Cross tie fitted in centre cargo tank: $b_{ct} = 0.5\, \ell_{bdg\text{-}vw}$
- Cross ties fitted in wing cargo tanks:
  - $b_{ct} = 0.5\, \ell_{bdg\text{-}vw}$ for design cargo pressure from the centre cargo tank.
  - $b_{ct} = 0.5\, \ell_{bdg\text{-}st}$ for design sea pressure.

$\ell_{bdg\text{-}vw}$: Effective bending span, in m, defined in [1.5.2].

$\ell_{bdg\text{-}st}$: Effective bending span, in m, defined in [1.5.2].

η_{all} : Allowable buckling utilisation factor as defined in Pt 1, Ch 8, Sec 1, [3.3].

σ_{cr} : Critical buckling stress in compression of the cross tie, in N/mm², as calculated using the net sectional properties in accordance with Pt 1, Ch 8, Sec 5, [3.1.1].

$A_{ct\text{-}n50}$: Net cross sectional area of the cross tie, in cm².

1.9.2 Welded connections

Special attention is to be paid to the adequacy of the welded connections for the transmission of the forces, and also to the stiffening arrangements, in order to provide effective means for transmission of the compressive forces into the webs.

Particular attention is to be paid to the welding at the toes of all end brackets of the cross ties.

1.9.3 Horizontal stiffeners

Horizontal stiffeners are to be located in line with, and attached to, the longitudinals at the ends of the cross ties.

2 VERTICALLY CORRUGATED BULKHEADS

2.1 Application

2.1.1

In addition to the requirements of Pt 1, Ch 6, Sec 4, [1], vertically corrugated bulkheads of oil tankers are also to comply with the requirements of [2.2].

2.2 Scantling requirements

2.2.1 Net plate thickness over the height

The net plate thicknesses as required by [2.2.3] and [2.2.4] are to be maintained for two thirds of the corrugation length, ℓ_{cg} from the lower end. Above that, the net plate thickness may be reduced by 20% from the net thickness required in [2.2.3] for the mid part of the corrugation provided that the net section modulus of the upper end of the corrugation complies with [2.2.4].

2.2.2 Net web plating thickness over the height

The net web plating thickness of the lower 15% of the corrugation, t_w in mm, is to be taken as the greatest value calculated for all applicable design load sets, as given in Pt 1, Ch 6, Sec 2, [2], and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool.

$$t_w = \frac{1000|Q_{cg}|}{d_{cg}\ C_{t-cg}\ \tau_{eH}}$$

where:

Q_{cg} : Design shear force imposed on the web plating at the lower end of the corrugation, in kN.

$$Q_{cg} = \frac{s_{cg}\ \ell_{cg}|3P_l + P_u|}{8000}$$

P_l : Design pressure given in Table 1 for the design load set being considered, calculated at the lower end of the corrugation, in kN/m^2.

P_u : Design pressures given in Table 1 for the design load set being considered, calculated at the upper end of the corrugation, in kN/m^2.

d_{cg} : Depth of corrugation, in mm, see Figure 4.

C_{t-cg} : Permissible shear stress coefficient:

C_{t-cg} = 0.75 for acceptance criteria set AC-S.

C_{t-cg} = 0.90 for acceptance criteria set AC-SD.

2.2.3 Net thicknesses of the flanges over the height

The net thicknesses of the flanges of corrugated bulkheads, t_f in mm, for two thirds of the corrugation length from the lower end are to be taken as the greatest value calculated for all applicable design load sets, as given in Pt 1, Ch 6, Sec 2, [2], and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool.

$$t_f = \frac{6.57\, b_{f-cg} \sqrt{\sigma_{bdg-max}}}{C_f} 10^{-3}$$

where:

$\sigma_{bdg-max}$: Maximum value of the vertical bending stresses in N/mm^2 in the flange. The bending stress is to be calculated at the lower end and at the mid span of the corrugation length.

$$\sigma_{bdg-max} = \frac{M_{cg}}{Z_{cg-act}} 10^3$$

M_{cg} : Vertical bending moment, in kNm, as defined in [2.2.4].

$Z_{cg\text{-}act}$: Actual net section modulus at the lower end and at the mid length of the corrugation, in cm^3.

$b_{f\text{-}cg}$: Breadth of flange plating, in mm. See Figure 4.

$b_{w\text{-}cg}$: Breadth of web plating, in mm. See Figure 4.

C_f : Coefficient taken as:

$$C_f = 7.65 - 0.26\left(\frac{b_{w-cg}}{b_{f-cg}}\right)^2$$

2.2.4 Net section modulus over the height

The net section modulus at the lower and upper ends and at the mid length of the corrugation (ℓ_{cg} / 2) of a unit corrugation, Z_{cg} are to be taken as the greatest value calculated for all applicable design load sets, as given in Pt 1, Ch 6, Sec 2, [2] and given by the following.

$$Z_{cg} = \frac{1000\ M_{cg}}{C_{s-cg}\ R_{eH}}$$

where:

M_{cg} : Vertical bending moment in kNm.

$$M_{cg} = \frac{C_i |P| s_{cg}\ \ell_0^2}{12000}$$

P : Averaged pressure in kN/m^2.

$$P = \frac{P_u + P_l}{2}$$

P_l, P_u : Design pressure given in Table 1 for the design load set being considered, calculated at the lower and upper ends of the corrugation, respectively, in kN/m^2:

- For transverse corrugated bulkheads, the pressures are to be calculated at a section located at b_{tk} / 2 from the longitudinal bulkheads of each tank.
- For longitudinal corrugated bulkheads, the pressures are to be calculated at the ends of the tank, i.e. the intersection of the forward and aft transverse bulkheads and the longitudinal bulkhead.

b_{tk} : Maximum breadth of tank under consideration measured at the bulkhead, in m.

ℓ_o : Effective bending span of the corrugation, in m, measured from the mid depth of the lower stool to the mid depth of the upper stool. Where no lower or upper stool is fitted, ℓ_{cg} is to be measured to lower or upper end. See Figure 4.

C_i : Bending moment coefficient given in Table 7.

$C_{s\text{-}cg}$: Permissible bending stress coefficient at the mid-length of the corrugation length, ℓ_{cg}:

$C_{s\text{-}cg} = c_e$ but not to be taken as greater than 0.75 for acceptance criteria set AC-S.

$C_{s\text{-}cg} = c_e$ but not to be taken as greater than 0.90 for acceptance criteria set AC-SD.

At the lower and upper ends of the corrugation length, ℓ_{cg}:

$C_{s\text{-}cg}$ = 0.75 for acceptance criteria set AC-S.

$C_{s\text{-}cg}$ = 0.90 for acceptance criteria set AC-SD.

c_e : Coefficient taken as:

$$c_e = \frac{2.25}{\beta} - \frac{1.25}{\beta^2} \quad \text{for } \beta \geq 1.25$$

$$c_e = 1.0 \quad \text{for } \beta < 1.25$$

β : Coefficient taken as:

$$\beta = \frac{b_{f-cg}}{t_f}\sqrt{\frac{R_{eH}}{E}}$$

$b_{f\text{-}cg}$: Breadth of flange plating, in mm, see Figure 4.

t_f : Net thickness of the corrugation flange, in mm.

Table 7 : Values of C_i

Bulkhead	At lower end of ℓ_{cg}	At mid-length of ℓ_{cg}	At upper end of ℓ_{cg}
Transverse bulkhead	C_1	C_{m1}	0.65 C_{m1}
Longitudinal bulkhead	C_3	C_{m3}	0.65 C_{m3}

where:

C_1 : Coefficient taken as:

$$C_1 = a_1 + b_1\sqrt{\frac{A_{dt}}{b_{dk}}} \quad \text{but taken not less than 0.60.}$$

$$C_1 = a_1 - b_1\sqrt{\frac{A_{dt}}{b_{dk}}} \quad \text{for transverse bulkhead with no lower stool, but taken less than 0.55.}$$

a_1 : Coefficient taken as:

$$a_1 = 0.95 - \frac{0.41}{R_{bt}}$$

$a_1 = 1.0$ for transverse bulkhead with no lower stool.

b_1 : Coefficient taken as:

$$b_1 = -0.20 + \frac{0.078}{R_{bt}}$$

$b_1 = 0.13$ for transverse bulkhead with no lower stool.

C_{m1} : Coefficient taken as:

$$C_{m1} = a_{m1} + b_{m1}\sqrt{\frac{A_{dt}}{b_{dk}}} \quad \text{but not taken less than 0.55.}$$

$$C_{m1} = a_{m1} - b_{m1}\sqrt{\frac{A_{dt}}{b_{dk}}} \quad \text{for transverse bulkhead with no lower stool, but not taken less than 0.60.}$$

a_{m1} : Coefficient taken as:

$$a_{m1} = 0.63 + \frac{0.25}{R_{bt}}$$

$a_{m1} = 0.85$ for transverse bulkhead with no lower stool.

b_{m1} : Coefficient taken as:

$$b_{m1} = -0.25 - \frac{0.11}{R_{bt}}$$

$b_{m1} = 0.34$ for transverse bulkhead with no lower stool.

C_3 : Coefficient taken as:

$$C_3 = a_3 + b_3 \sqrt{\frac{A_{dl}}{\ell_{dk}}}$$ but not taken less than 0.60.

$$C_3 = a_3 - b_3 \sqrt{\frac{A_{dl}}{\ell_{dk}}}$$ for longitudinal bulkhead with no lower stool, but not taken less than 0.55.

a_3 : Coefficient taken as:

$$a_3 = 0.86 - \frac{0.35}{R_{bl}}$$

$a_3 = 1.0$ for longitudinal bulkhead with no lower stool.

b_3 : Coefficient taken as:

$$b_3 = -0.17 + \frac{0.10}{R_{bl}}$$

$b_3 = 0.13$ for longitudinal bulkhead with no lower stool.

C_{m3} : Coefficient taken as:

$$C_{m3} = a_{m3} + b_{m3} \sqrt{\frac{A_{dl}}{\ell_{dk}}}$$ but not taken less than 0.55.

$$C_{m3} = a_{m3} - b_{m3} \sqrt{\frac{A_{dl}}{\ell_{dk}}}$$ for longitudinal bulkhead with no lower stool, but not taken less than 0.60.

a_{m3} : Coefficient taken as:

$$a_{m3} = 0.32 + \frac{0.24}{R_{bl}}$$

$a_{m3} = 0.85$ for longitudinal bulkhead with no lower stool.

b_{m3} : Coefficient taken as:

$$b_{m3} = -0.12 - \frac{0.10}{R_{bl}}$$

$b_{m3} = 0.19$ for longitudinal bulkhead with no lower stool.

R_{bt} : Coefficient taken as:

$$R_{bt} = \frac{A_{bt}}{b_{ib}}\left(1 + \frac{\ell_{ib}}{b_{ib}}\right)\left(1 + \frac{b_{av-t}}{h_{st}}\right)$$ for transverse bulkheads.

R_{bl} : Coefficient taken as:

$$R_{bl} = \frac{A_{bl}}{l_{ib}}\left(1 + \frac{\ell_{ib}}{b_{ib}}\right)\left(1 + \frac{b_{av-l}}{h_{sl}}\right)$$ for longitudinal bulkheads.

A_{dt} : Cross sectional area enclosed by the moulded lines of the transverse bulkhead upper stool, in m^2.

$A_{dt} = 0$ if no upper stool is fitted.

A_{dl} : Cross sectional area enclosed by the moulded lines of the longitudinal bulkhead upper stool, in m^2.

$A_{dl} = 0$ if no upper stool is fitted.

A_{bt} : Cross sectional area enclosed by the moulded lines of the transverse bulkhead lower stool, in m^2.

A_{bl} : Cross sectional area enclosed by the moulded lines of the longitudinal bulkhead lower stool, in m^2.

$b_{av\text{-}t}$: Average width of transverse bulkhead lower stool, in m. See Figure 4.

$b_{av\text{-}l}$: Average width of longitudinal bulkhead lower stool, in m. See Figure 4.

h_{st} : Height of transverse bulkhead lower stool, in m. See Figure 4.

h_{sl} : Height of longitudinal bulkhead lower stool, in m. See Figure 4.

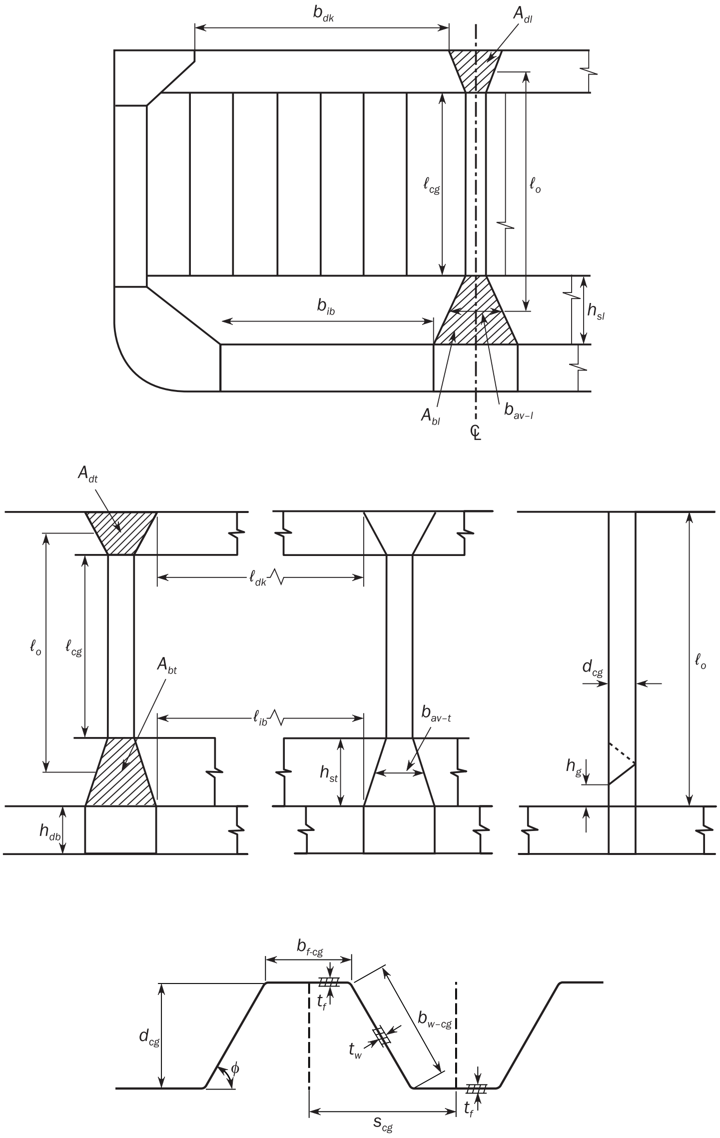
b_{ib} : Breadth of cargo tank at the inner bottom level between hopper tanks, or between the hopper tank and centreline lower stool, in m. See Figure 4.

b_{dk} : Breadth of cargo tank at the deck level between upper wing tanks, or between the upper wing tank and centreline deck box or between the corrugation flanges if no upper stool is fitted, in m. See Figure 4.

ℓ_{ib} : Length of cargo tank at the inner bottom level between transverse lower stools, in m. See Figure 4.

ℓ_{dk} : Length of cargo tank at the deck level between transverse upper stools or between the corrugation flanges if no upper stool is fitted, in m. See Figure 4.

Figure 4 : Definition of parameters for corrugated bulkhead
(Tankers with longitudinal bulkhead at centreline)



SECTION 4
HULL OUTFITTING

1 SUPPORTING STRUCTURES FOR COMPONENTS USED IN EMERGENCY TOWING ARRANGEMENTS

1.1 General

1.1.1

Emergency towing arrangements are to be fitted at both the bow and stern of every tanker with a deadweight of 20,000 tonnes or more, as required by SOLAS.

1.1.2

The design and construction of the towing arrangements is to be approved by the Flag Administration.

1.2 Documents to be submitted

1.2.1

Plans showing details of the supporting structure for the emergency towing arrangement, including the connection to the deck, are to be provided for approval. Information on emergency towing arrangement showing sufficient detail to enable the position and direction of load actions to be ascertained is to be submitted for reference.

1.3 Structural arrangement

1.3.1 Continuity of strength

The structural arrangement is to provide continuity of strength.

1.3.2 Stress concentrations

The structural arrangement of the ship's structure in way of the emergency towing equipment is to be such that, abrupt changes of shape or section are to be avoided in order to minimise stress concentrations. Sharp corners and notches are to be avoided, especially in high stress areas.

1.4 Minimum thickness requirements

1.4.1 Deck plating

The deck in way of strong-points and fairleads is to have a minimum gross thickness of 15 mm.

1.5 Loads

1.5.1 Safe working loads

Safe working load of emergency towing arrangements is not to be taken less than:

- 1,000 kN for tankers having a deadweight greater than or equal to 20,000 t, but less than 50,000 t.
- 2,000 kN for tankers having a deadweight greater than or equal to 50,000 t.

The position and direction of load actions to be ascertained is to be submitted for reference.

1.5.2 Load case

The design load for the connection of the strong-point and fittings to the deck and its supporting structure is to be taken as twice the safe working load. Information on lines of action of the applied design load provided in emergency towing arrangement plan is to be taken into account.

1.6 Scantling requirements

1.6.1 General

The scantlings of the support structure are to be dimensioned to ensure that for the load cases specified in [1.5.2], the calculated stresses in the support structure do not exceed the permissible stress levels specified in [1.6.3].

The capacity of the structure to resist buckling failure is also to be assured.

1.6.2 Calculation procedure

These requirements are to be assessed using a simplified engineering analysis based on elastic beam theory, two dimensional grillage or finite element analysis using gross scantlings.

1.6.3 Permissible stresses

For the design load given in [1.5.2], the shear stresses and normal stresses, including bending stresses induced in the supporting structure and welds, in way of strong-points and fairleads, are not to be exceed the permissible values given below based on the gross thickness of the structure:

- Normal stress, 1.00 R_{eH}.
- Shear stress, 0.58 R_{eH}.

2 MISCELLANEOUS DECK ATTACHMENTS

2.1 Cargo manifolds

2.1.1 Cargo manifold support

The design of the cargo manifold support is to be such as to distribute the loads imposed on the pipework into the ship structure in seagoing or in harbour operations during loading and unloading. To achieve this, the connection of the cargo manifold support to the deck is to be arranged to align with stiffening members of the main hull structure or stiffening is to be fitted in order to avoid the creation of hard points. Attention is to be paid to the detail design of the structure forming the deck attachment in order to minimise the effects of change of section. The arrangement of such details and their approval is considered on a case-by-case basis by the Society.

3 GUARD RAILS AND BULWARKS

3.1 General

3.1.1

Generally, open guard rails are to be fitted on the upper deck. Plate bulwarks, with a 230 mm high continuous opening, at the lower edge, may be accepted provided the arrangement allows for the acceptable handling of spillage on deck and minimises the possibility for accumulation of volatile gas.

3.1.2

Deck spills are to be prevented from spreading to the accommodation and service areas and from discharge into the sea by a permanent continuous coaming with a minimum height of 100 mm surrounding the cargo deck. Along the sides at the aft end of the cargo deck of oil tankers, the coaming is to have a minimum height of 300 mm extending a minimum of 4.5 m forward from each corner. At the aft end of the cargo deck, the coaming is to have a minimum height of 300 mm and is to extend from side to side of the ship.

3.1.3

Scupper plugs of mechanical type are to be provided. Means of draining or removing oil or oily water within the coaming are also to be provided.

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